Tetrachloroethylene: Development of a Biologic Standard for the Industrial Worker by Breath Analysis

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16. Abstracts

The development of a biologic standard for exposure of industrial workers to tetrachloroethylene (PCE) (127184), based on breath analysis, was carried out in a comprehensive study using human volunteers. Particular emphasis was placed on: 1) the subject's health, including measurements of pulmonary, cardiovascular, and central nervous system functions during repeated, controlled exposures to PCE vapor; and 2) the relationship of exposure magnitude to PCE body burden, as demonstrated by the measurement of PCE or its metabolites in blood, urine and breath. A baseline is presente for additional studies which are needed to assure a healthful working environment wherever this chemical is utilized. The observations made and the data collected are provided, and a recommendation is presented for a biologic threshold-limit-value for tetrachloroethylene utilizing breath analysis decay curves. It is concluded that: 1) repeated daily exposure to PCE results in a tachyphylactic response regarding subjectiv feelings and odor detection, rendering these parameters unreliable as measures of ~~[illegible]~~ exposure concentration; 2) considerable individual differences exist in response to to PCE vapor exposure; 3) EEG analysis indicates preliminary signs of narcosis in most subjects exposed to 100 ppm PCE for 7½ hours; 4) CNS response is probably due to PCE; 5) postexposure breath analysis is an excellent method to estimate magnitude of body burden; and 6) physical exercise increases body burden.

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TETRACHLOROETHYLENE:

DEVELOPMENT OF A BIOLOGIC STANDARD

FOR THE INDUSTRIAL WORKER

BY BREATH ANALYSIS

99-72-84 (74-6)

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TETRACHLOROETHYLENE

TETRACHLOROETHYLENE

A comprehensive study has been carried out with human volunteer subjects on the effects of repeated controlled exposures to the vapor of tetrachloroethylene ($CCl_2 = CCl_2$, perchloroethylene, PCE). Particular emphasis was placed on two areas; (1) the subject's health, including measurements of pulmonary, cardiovascular and central nervous system functions, and (2) the relationship of exposure magnitude to PCE body burden, as demonstrated by the measurement of PCE or its metabolites in blood, urine and breath. This study affords a baseline for additional studies which are needed to assure a healthful working environment wherever this chemical is utilized. This report includes the observations made and the data collected during these studies, and a recommendation for a "biologic threshold limit value" for this compound utilizing breath analysis decay curves. Because the 1971 TLV for industrial air was included in the exposure levels studied, a preliminary estimate of the magnitude of the TLV's safety factor is made in the conclusion to the report.

EXPERIMENTAL

This study was divided into two sections; the first was carried out with male subjects and the second with females. The subjects represented a cross section of the Caucasian, middle class, working population of the Milwaukee metropolitan area. They were recruited for this study by a private employment agency. Each subject that completed a section of the study received $2.50 per hour spent at the laboratory, plus overtime, with a 3 hr minimum on Saturday mornings. After the objectives of the study and the nature of the procedures to be used were fully explained to them, all subjects signed an informed consent form, a copy of which is attached as APPENDIX I.

Subjects, Males:

Ten healthy males volunteered as subjects for this section of the study. Their ages ranged from 19 to 33 years, height from 175 to 186 cm, and weight from 65 to 86 kg. None was obese. The ten subjects were divided into three groups for 7-1/2, 3 or 1 hrs of daily exposure. Four volunteered for the 7-1/2 hr (Group I), three for the 3 hr (Group II), and three for the 1 hr (Group III) exposure. Most of the subjects had no other wage-earning job during the time of the study, and none experienced any exposure to PCE outside of the laboratory.

Subjects, Females:

Nine healthy females volunteered as subjects under similar circumstances as the males. Because we were one subject short of the optimal, we reduced the number in Group III to two subjects. During the second exposure day and the following night of week 2 (see Exposure Schedule, Table I), a severe blizzard paralyzed Milwaukee transportation making it impossible to continue the study the following day. Therefore, it was decided to begin the 5 days/week schedule again the following week; however, three subjects could not participate because of prior commitments. They were replaced by three new volunteers. Finally, a Group II subject became ill with influenza during the interim between studies, so that the study during week 3 was carried out with a total of eight subjects, four exposed for 7-1/2 hrs per day (Group I), two for 3 hrs per day (Group II) and two for 1 hr per day (Group III). The eleven females who volunteered for this study ranged in age from 19 to 43 years; their weights ranged from 52 to 68 kg, and heights from 158 to 170 cm. None of the subjects was obese. All were housewives or students and none was exposed to PCE outside of the laboratory.

All subjects, including males, were cautioned to either abstain from the use of drugs and/or alcohol, or to limit their use to very moderate amounts. Subjects who were smokers were not allowed to smoke during their stay in the environmental control chamber. Subjects who underwent behavioral testing (Groups I and II) were asked to refrain from consuming any caffeine prior to the end of each day's study (1 hr post-exposure).

Exposure Chamber:

All exposures to the vapor of PCE were conducted in a controlled environment chamber (room) 20 x 20 x 8 ft in size, which contained a 5 x 4 x 8 ft toilet facility and a 5 x 4 x 6-1/2 ft commercial audiometric booth. Both the toilet facility and the audiometric booth were ventilated with air from the chamber. Air flow through the chamber was approximately 1500 cu ft/min, and approximately 25% of this flow was exhausted. A slight negative pressure was maintained in the chamber at all times. Air temperature was 72 - 74°F, while relative humidity ranged between 45 -55%. The PCE was introduced by sweeping the concentrated vapor from a warm flask with a stream of air into the chamber's circulating air. A reciprocal dual-piston pump maintained a steady flow of liquid PCE into the flask.

Analysis of Exposure Chamber Atmosphere:

The tetrachloroethylene (inhibited with 0.5% ethanol, Eastman Kodak Company, 2418) used in these studies was shown by infrared analysis to be > 99% pure. The concentration of PCE in the chamber atmosphere was continuously recorded by an infrared spectrometer (MIRAN I, Wilks Scientific Corporation) equipped with a 20-m path-length gas cell which was continuously flushed with air drawn from the chamber through a 1/4 inch diameter polyethylene tubing. The absorbance at 10.9 μ was measured through a path-length of 5.25 m. The infrared signal to the recorder was monitored each second by an on-line PDP-12 (Digital Equipment Corp.) computer, which displayed the mean vapor concentration, as compared to standards, for each 30-second time interval of exposure and calculated the daily time-weighted average exposures. Calibration standards of PCE in purified air were prepared in saran bags and analyzed before and hourly during each daily exposure.

A second independent chamber monitoring system using the gas chromatograph (GC) as the measuring instrument was used for back-up of the infrared system. The GC system was equipped with an automatic

sampling device that swept a sample of the chamber atmosphere into the carrier gas (N_2) of the chromatograph every three minutes. The Varian Aerograph Model 2700, Moduline® GC was fitted with a stainless steel column, 14 x 1/8 inch, packed with Porapak Q, 60/80 mesh. The column was preconditioned at 200 °C for 24 hrs prior to its use. Throughout the study, the column was baked at 180 °C when it was not in use. The operating conditions of the GC were: carrier gas flow rate of 35 ml/min, column temperature 180 °C, injection port 150 °C, and detector approximately 250 °C. Peak heights of chamber atmosphere samples were compared to peak heights of calibration standards prepared in saran bags and swept through the system from the chamber. The calibration standards for the two systems were prepared independently by separate individuals and the measured concentrations of PCE in the chamber atmosphere had to agree before subjects were allowed to enter the chamber. The two systems were cross-checked frequently during daily exposure to assure that the concentration in the chamber was correct.

Exposure Schedule:

The exposure concentration schedules chosen for both males and females are shown in Table I. The numbers are the desired concentration of PCE vapor in air listed as parts per million (ppm, volume/volume). Both male and female subjects were exposed during their first full week of exposure to 100 ppm PCE, the present TLV, at a steady or non-fluctuating

state. Males were additionally exposed five consecutive days to a fluctuating concentration of from 50 to 150 ppm PCE with a time-weighted average of 100 ppm, for four consecutive days to 20 ppm, and for five consecutive days to 150 ppm. Appropriate zero exposure days took place before and after the PCE exposures, and for the male subjects on the first day of the second week of exposure. A graph demonstrating the planned fluctuation during week 4 is shown in Figure 1.

The daily schedule of activities varied within each week but was constant for the five full weeks of daily exposure. Daily exposure of Group I (7-1/2 hrs) and Group III (1 hr) subjects began at 9:00 A M , after the daily pre-exposure sampling and tests were carried out. Group II (3 hrs) subjects began their exposure at 10:00 A M , just after the Group III subjects exited the chamber, and it ended at 1:00 P M , after which they ate their lunches. Group I subjects ate their lunches in the chamber, exiting the chamber at 4:30 P M. The daily activities carried out during the exposures are shown in Figure 2. Male subjects exercised daily on bicycle ergometers. Groups I and II exercised for two successive 6-minute periods at 350 and 750 KPM at 5 hrs and 1 hr, respectively, after start of exposure. Group III subjects exercised for 5 minutes at 350 KPM midway through their exposure. Additional information regarding time schedules will be found where appropriate in the various sections which follow.

Health Care:

Each subject was given a comprehensive medical examination prior to the study and after the last exposure day of the study. These examinations included a complete history and physical examination with the following laboratory studies: complete blood count, complete panel of clinical chemistries and a 12-lead electrocardiogram (EKG). In addition, a pregnancy test (PREGNOSIS - Roche) was carried out on samples of urine from each female subject. A complete blood count and the survey panel of clinical chemistries was repeated at least once per week during the weekly exposures. Prior to each day's exposure, the subjects were given a brief medical examination which included blood pressure, temperature, subjective signs or symptoms, and urinalysis (Combistix®). During the time that they were in the environmental chamber, each subject's EKG (lead II) was continuously monitored by telemetry, and recorded at hourly intervals. The subjects were under continual surveillance by medical personnel while they were in the study.

Twenty-four hour urine collections were begun daily as each subject entered the chamber. Urobilinogen determinations were carried out (male subjects only) on fresh 24-hour urine specimens using the method of Watson, et al. as modified by Henry, et al. in Henry[1]. A Coleman Model 6/2-A Junior® IIA spectrophotometer was used to determine linear absorbance at 562 m μ. The PSP dye standard was adjusted in concentration

to give an optical density of 0.384 at 562 mμ on a Beckman DB spectrophotometer, using water as a blank. Results were reported in Ehrlich units per 24 hrs. Determinations of urinary creatinine by Autoanalyzer®, based on the Folin and Wu method in Hawk, et al.[2], were used as an index to the validity of the 24-hr urine collections.

Breath Sample Collection and Analysis:

Alveolar breath samples were obtained daily from each subject prior to entry into the environmental chamber (pre-exposure): 1, 5, 10, 15, 30 min; 1, 2, 3 hr. The last two samples were collected in duplicate. A 16, 21, and 23 hr post-exposure sample (usually identical to the pre-exposure sample) for Groups I, II, and III, respectively, was also collected. Pre-exposure samples and samples obtained 1 min to 1 hr post-exposure were collected in saran bags after breath-holding by the subject for 30 seconds. The remaining samples were collected in 35 ml glass tubes fitted at each end with screw caps containing saran liners. One of the caps had a pre-drilled hole through which an aliquot of the alveolar breath sample could be withdrawn. The subject flushed the tube twice, then after holding the third breath for 30 seconds, exhaled and capped the tube while finishing the exhalation.

Fifteen minutes after the end of the exposure on the fifth day of week 4 (100 ppm, fluctuating) a second alveolar breath sample was collected

from each male subject in a 4-liter saran bag. This breath sample was slow-scanned in a Beckman® IR-10 infrared spectrometer with a 10-m gas cell.

A Varian Aerograph Model 2700 gas chromatograph equipped with a hydrogen flame ionization detector was used to determine PCE in the breath samples. All samples were analyzed for PCE within 24 hours of sampling. The GC was fitted with a stainless steel column, 36 x 1/8 in., packed with 25% Apiezon L on Chromosorb W, AW, 45/60 mesh. The column was preconditioned at 200°C overnight prior to use. The operating conditions of the GC were as follows: carrier gas (helium) flow rate of 40/ml min; column temperature, 105°C; injection port, 210°C; and detector 250°C. Standards at five concentrations (ppm) to bracket the unknown levels were prepared with purified air as diluent. A single injection was made from saran bag samples while duplicate injections were made from samples collected in glass tubes. The concentration of PCE in unknowns was obtained by direct comparison of peak heights to the standards. The minimal amount of the PCE detectable in breath by this method was 0.05 ppm with an accuracy of $\pm$0.1 ppm.

Blood Sample Collection and Analysis:

During the six week study with male subjects, blood samples for PCE analysis were obtained from each subject on Monday and Friday with

the following exceptions: week 1, Friday only; week 3, Tuesday and Friday; and week 6, Monday only. The female subjects gave blood samples on Friday of week 1, Monday of week 2, Monday and Friday of week 3 and Monday of week 4. Venous blood was obtained from an antecubital vein at the following times: pre-exposure, just prior to chamber exit for males and just after chamber exit for females, and 15 minutes post-exposure.

Two ml of blood was introduced into a 4-ml aluminum-capped, glass vial containing 2 ml pure hexane. The mixture was shaken for about 30 seconds to extract the PCE. Longer agitation (1-1/2 hours) did not improve the efficiency of the extraction. The emulsion was separated into two phases by means of centrifugation, usually for 3 minutes. The top hexane layer was analyzed for PCE with a Varian Aerograph Model 2700, Moduline® GC equipped with a tritium foil electron capture detector. The GC was fitted with a stainless steel column, 24 x 1/8 in. packed with Porapak Q, 60/80 mesh. The column was preconditioned at 230°C overnight prior to its use. Throughout the analysis for PCE in blood, the column was baked at 200°C when it was not in use. Comparable results were also achieved with a 25% Apiezon L column mentioned in the breath analysis section. The operating conditions of the GC were:

carrier gas (N_2) flow rate of 30 ml/min , column temperature 185°C, injection port 230°C, and detector 210°C. A calibration curve (peak height versus concentration), prepared daily, was constructed with the following concentrations (ppm PCE in hexane): 0.10, 0.25, 0.50, 1.00, 2.00, 3.00, 5.00 and 10.00. Samples were injected in duplicate and the concentration of PCE in blood was obtained directly from the calibration curve. The detectable limit of PCE in blood by this method was 1 ppb, while the accuracy reported here was ± 0.05 ppm. A control sample was included throughout the analysis for PCE in blood. The concentration of PCE in controls was found to be less than 0.05 ppm.

Urine Sample Collection and Analysis:

As recorded under the section on Clinical Testing, subjects collected 24-hr urines beginning at the start of each exposure day. The collections were made in graduated plastic jars which were placed in iced foam buckets. Each morning following the previous day's exposure, the urinalysis sample was added to the 24-hr collection and the total was recorded. Samples were frozen for subsequent analyses after an aliquot had been withdrawn for urobilinogen determination. Samples representing the highest exposures of both males and females were analyzed for trichloroethanol (TCEt) and trichloroacetic acid (TCA), suggested metabolites of tetrachloroethylene. For the TCEt analysis, one ml of urine was

added to a 4-ml screw-capped vial containing 1 ml of β-glucuronidase (500 units) in 0.15 M phosphate buffer. The mixture was incubated for 1 hour at 37°C; approximately 0.5 g NaCl was added for salting purposes, and the mixture was shaken briefly with 1 ml of hexane. The hexane layer was analyzed for TCEt with a GC equipped with a tritium foil electron capture detector. The GC contained a 6 ft x 1/8 in stainless steel column packed with 25% Apiezon L on Chromosorb W, 45/60 mesh. Column temperature was set at 140°C. A standard curve was prepared with TCEt added to control urine. The detectable limit for TCEt by this method was 0.5 μg/ml.

Analysis for TCA was made directly on undiluted urine using a GC equipped with a hydrogen flame ionization detector. Conditions used were similar to those used for TCEt except that the column temperature was reduced to 105°C. A standard curve was prepared from control urine spiked with TCA. The detection limit was 0.01 mg/ml.

Creatinine determinations were made on undiluted samples, or samples diluted to the most convenient concentration, by the method referred to in the section on Clinical Testing.

Cardio-pulmonary Function Studies:

Measurements designed to evaluate functional integrity of pulmonary airways, alveolar-capillary gas exchange, and regulation of pulmonary

ventilation and heart rate were made on Group I male subjects (#118, 163, 164 and 165) only between the 5th and 7th hours the subjects were in the chamber. These measurements were made on six different occasions in the following sequence: (1) at 0 ppm on day 4 of week 1, (2) at 100 ppm (steady) on day 4 of week 2, (3) at 20 ppm on day 4 of week 3, (4) at 100 ppm (fluctuating) on day 4 of week 4, (5) at 150 ppm on day 4 of week 5, and (6) at 0 ppm on day 2 of week 6. The testing protocol was standardized over all testing sessions.

Functional integrity of airways was assessed by having the subject perform a forced maximum expiratory maneuver. The subject was seated, erect, and breathing through a mouthpiece connected with wide bore tubing to a Fliesch flow-transducer. The transducer was connected to a Vertek pneumotachograph which sent analog data to the analog-to-digital converter of a PDP-12 computer. Appropriate software was utilized to calculate values for vital capacity (FVC), percent of VC expired in 1 second (FEV 1), peak expiratory flow rate (PEFR), and flow rate at 50% of FVC (MMEF). This maneuver was performed at least three times, with the data from the two "best" maneuvers being saved on magnetic tape. The mean of the two values was taken as indicative of the function for each specific condition.

Alveolar-capillary gas exchange was assessed by the single breath carbon monoxide diffusion technique ($D_L CO$).[3] Measurements

were made twice on each subject at rest and once during the sixth minute of two levels of moderate exercise on a bicycle ergometer. The first exercise level was set to elicit a heart rate of approximately 100 beats/min (350 KPM) while the second elicited a heart rate of approximately 150 beats/min (750 KPM). Computerized systems as noted above were used to calculate inspired, residual, and total lung volume and $D_L CO$. Neon was used as the inert gas to measure residual volume. Neon and CO concentrations in the collected alveolar sample were analyzed using a Quintron® Thermo-conductivity Chromatograph.

Pulmonary ventilation, Pa_{CO_2}, arterial pH, PA_{O_2}, and metabolic rate were measured directly or calculated for resting and two conditions of exercise (5th-6th minute). These parameters were used to assess the effect of PCE exposure on mechanisms regulating breathing. Ventilation was measured using a Parkinson-Cowan gas meter whose output was fed to a Hewlitt-Packard recorder. While ventilation was being measured, 50 ml of the mixed expired air was collected in a glass syringe. This sample was analyzed for CO_2 and O_2 concentration using a Quintron chromatograph. Ventilation and CO_2 and O_2 concentration were used to calculate metabolic rate and PA_{O_2}. For sampling of blood, a twenty-one gauge needle was placed in a superficial dorsal hand vein. The needle was attached to a tubing-stopcock arrangement which during non-sampling periods was filled with heparinized saline. For 5 minutes prior to sampling, the entire

hand was heated to approximately 42°C. This procedure sufficiently "arterializes" the blood so that P_{CO_2} and pH are virtually identical to arterial.[4] The blood was analyzed within 15 minutes for P_{CO_2} and pH with the Radiometer® and electrode arrangement.

Heart rate was measured using the Biotel® 170 ECG patient telemetry system developed by Spacelabs, Inc. (Chatsworth, California). Heart rate was measured during the 30-second interval preceeding initiation of the exercise and over the final 30-second interval of each exercise period (350 and 750 KPM).

Neurological Studies:

Within 5 min of entry into the environmental chamber, and within 10 min prior to exit, each subject performed a modified Romberg and heel-to-toe equilibrium test which was videotaped for later inspection if necessary. The test consisted of standing upon each leg singly with arms at the side for a minimum of 3 sec, and walking heel-to-toe in a straight line for approximately 5 ft. This was first done with the eyes open and then repeated with eyes shut.

During weeks 2 through 5 of the exposure of male subjects, electroencephalograms (EEG) and visual evoked response (VER) measurements were made on Group I subjects on days 1, 3, and 5. During the first and sixth weeks, measurements were made one day, 5 and 1, respectively.

Measurements were made on female, Group I, subjects on days 1, 3, and 5 of the study. On each measurement day, four recordings were made, one during the first hour of exposure and three between the fifth and seventh hours of exposure. A modified 10-20 international electrode arrangement was used for EEG recordings. One electrode was placed 2 to 2.5 cm above the inion, and the VER was recorded from this electrode with the left ear as the reference. The details of our recording arrangements have been presented in a previous publication.[5]

The EEG and VER were both analyzed initially by visual examination. In addition, the amplitude of the 3rd, 4th and 5th waves of the VER complex were measured (mm ruler). A neuropharmacologist and a practicing neurologist from The Medical College of Wisconsin reviewed the EEG records. Our objective was to ascertain whether changes occurred within a day, during a week at each PCE level, and from one concentration to another.

Behavioral Testing:

A series of behavioral tests was performed by the seven male subjects in Groups I and II. One of the series was an alertness test given on days 1, 3, and 5 of each week, that was also performed by the female subjects. It began 2-1/4 hours after the start of an exposure of Group I, and 1-1/4 hours after "zero time" of Group II. No training was

required for this test. On days 2 and 4 of each week, the remaining tests in the series were performed by males beginning at 3 and 2 hrs after "zero time" for Groups I and II, respectively. The subjects were trained to near a performance plateau before these tests were used during exposures.

For each of the behavioral tests, the subjects sat in comfortable chairs at individual carrels assigned to them for the duration of the study. The subjects were not permitted to talk or have access to watches, food, soft drinks, radios, etc., during the tests. All instructional commands were made from outside of the chamber via an intercom system. The tests are described below in the order in which they were performed.

Alertness Test. This test was also called the "clock" test because the subjects watched a black clock face from which all numerals and hands were removed except the sweep second hand. The test, administered and graded by a PDP-12 computer, consisted of a primary and a secondary task. For the primary task, the subject pressed a hand-held micro-switch as rapidly as possible whenever he observed a "stop and start" of the sweep second hand. During the 90 min test, only 30 of these signals were presented. The clock stoppages were for 0.23 seconds or 0.13 seconds, each occurring randomly 50% of the time. For the secondary task, the subject

pressed the hand-held switch whenever a tone was heard through the headphones he was wearing. These auditory signals were presented randomly for one second, 3 to 6 times per test. At the completion of the test, the computer printed the results of signal duration, time of occurrence, reaction time or miss for each signal, percent correct for the day, and the average reaction times for clock stoppages and for tones.

Ten and Thirty Second Time Estimation Test. Each subject, upon verbal signal (ready, begin) depressed a hand-held, silent, push-button micro-switch for an interval of time he estimated to be 10 seconds. This was repeated two additional times, and then three 30-second estimates were made. The micro-switches were connected to the PDP-12 Digital computer which measured the time intervals. This test took approximately 3 min to perform.

Marquette Time Estimation Test. This test consisted of a series of nine tone stimuli followed by nine light stimuli of approximately 1, 3, and 5 seconds duration presented in a random sequence but always with three stimuli of each time interval. At the termination of each stimulus, the subject depressed the push-button for that interval of time he estimated to be equal in length to the original auditory or light stimulus. A detailed description of the test and the instrumentation used to carry it out has been described by Stewart, et al.[6] This test took approximately 7 min to perform.

Coordination Test. This test was the Flanagan Aptitude Classification Test, 7A, Coordination, published by Science Research Associates, Inc. 259 East Erie Street, Chicago, Illinois. This test asked the subject to rapidly follow a spiral pathway with a pencil. The subject was allowed 40 seconds to complete each of 6 spirals. The first 2 were considered practice and the last 4 were scored and totaled. The total score depended upon the longest distance attained in each spiral minus the number of times the sides of the spiral pathway were touched with the pencil. This test took approximately 5 min to perform.

Arithmetic Test. This test, which measured the subject's ability to work with numbers, was divided into two parts. The first part, lasting 5 min, consisted of simple addition and subtraction problems while the second part, lasting 3 min, consisted of multiplication and division. The maximum score attainable if all answers were correct was 125; however, no subjects completed the test in the allotted time. In order to minimize memorization of answers, ten permutations of problem order were used.

Inspection Test. This test was a measure of the subject's ability to spot the number 3 in rows of random numbers on an 8-1/2 x 11 inch page. The subject was asked to scan each row, beginning at the top of the page, and slash out with a red pencil each "3" encountered. The subject was

given 2 min to strike out as many as possible. No subjects ever finished the entire page. A subject's score was the total number of "3's" struck. Six different pages with random numbers were utilized so that no subject received an identical number sheet on consecutive test days.

Additional Studies:

Combination Effect of Ethanol and PCE. In an effort to elicit the "degreasers' flush" experienced by subjects exposed to the combination of ethanol and trichloroethylene,[7] two Group I male subjects each drank 1 qt of beer 6-1/2 hours into the run on day 3 of week 5 (150 ppm). Eyes were checked for nystagmus, skin for "flushing", and blood was analyzed for PCE and ethanol concentrations for the hour following the beer drinking.

Subjective Responses. All subjects were asked to complete a subjective response form which included entries immediately upon entering the controlled exposure chamber, one-half hour after entry and at hourly intervals until three hours post-exposure. Subjects were instructed to note by the adjectives "mild", "moderate" and "strong" any abnormal feelings. Noted on the forms were: headache, nausea, dizziness, abdominal pain, chest pain, eye, nose or throat irritation, other and odor. All subjects were informed at the beginning of the study that they would be exposed to various vapor concentrations of PCE; however, they were unaware of the sequence of exposures (see Table I for sequence of exposures).

Effect of Exercise on Blood and Breath PCE Levels:

Blood samples of male subjects undergoing cardio-pulmonary function studies which included two 6-minute levels of exercise (see previous section) were analyzed for PCE concentration by the previously described methodology. Each week of weeks 3 through 6 during these studies a resting blood sample taken prior to exercise and a blood sample obtained at the end of the study period were analyzed. During week 5 (150 ppm) these subjects also gave additional pre and post exercise blood samples taken from the arm while it was extended outside the chamber through a porthole. Analysis of these samples for PCE gave a check on the "contamination" problem which might have occurred by taking blood samples in the chamber. In addition, a volunteer male faculty member entered the controlled environment chamber for 30 min on days 3, 4, and 5 of week 4 (100 ppm fluctuating, actual was 150 ppm). During the first day of this sequence this person remained sedentary while in the chamber, on the second and third days he exercised on a bicycle ergometer at rates of approximately 350 KPM. Blood and breath samples were obtained and analyzed for PCE pre-exposure and at 0, 15, 30 min, 1 and 2 hours post exposure.

Study of PCE Stability in Breath Containers. Breath containers, either saran bags, glass tubes (see section on breath analysis) or plastic soft drink type bottles (Dow), were flushed with chamber air while the concentration

of PCE in the controlled environment chamber was held steady at approximately 40 ppm. Ten glass tubes, each of 5 saran bags, and 5 plastic bottles were analyzed for PCE concentration by the GC method immediately after filling and 72 hours later. Additionally, 10 glass tubes were mailed back to the laboratory from approximately 50 miles distant, and analyzed, along with 10 glass tubes kept in the laboratory and the 5 saran bags, 144 hours after filling.

RESULTS

Analysis of Exposure Chamber Atmosphere:

It was possible to expose the subjects to PCE vapor with excellent precision. The time-weighted average (TWA) concentrations of PCE vapor to which subjects were exposed are listed in Table II (also noted are subject absences and any deviations from the protocol). These data were obtained from the computerized infrared method for chamber monitoring, where the recorder pen position was monitored each second, averaged each 30 seconds and these averages utilized in determining the TWA of each exposure. A "best-fit" equation, based on the standards analyzed, was selected daily for optimum accuracy. The greatest percentage deviation in the TWA from any day's objective occurred on day 2, week 3,

males, when each group was exposed to a 10% greater PCE concentration than was the objective (22 vs 20 ppm). On all other days, the planned TWA exposure concentration was met within 5% and usually it was within 1%. During the week of fluctuating exposure, week 4, males, the maximum and minimum concentrations of PCE in the chamber each day were as follows: day 1, 166 and 44; day 2, 166 and 42; day 3, 157 and 39; day 4, 153 and 42; and day 5, 167 and 43.

Health Care:

Pre and post-exposure comprehensive medical examinations revealed that all subjects were in excellent health before and after these studies. The attached forms (Appendix II - History, Appendix III - Physical Examination) were used, and have been retained in each subject's personal file. Of the following blood clinical chemistries: glucose, calcium, PBI, total protein, albumin, phosphorus, creatinine, alkaline phosphatase, SGOT, SGPT, total bilirubin, total cholesterol and urea nitrogen, there were 18/234 out-of-normal adult values prior to exposure for all subjects, and 14/234 out-of-normal when the last blood sample was obtained at least four days after the last exposure to PCE. Each "abnormal" value was rechecked to assure that it did not reflect a significant disease state. There were no trends or bunching in any post-exposure out-of-normal range values. Hematology values, including WBC with differential count, RBC, hemoglobin,

hematocrit, calculated RBC indices, and platelets revealed 18/234 out-of-normal adult values prior to exposure for all subjects, and 22/234 post-exposure. Most of the out-of-normal range hematology values occurred in the calculated RBC indices, where they contributed 52% of all abnormal values. Again, there were no trends or bunching of the post-exposure out-of-normal range values. All female subjects accepted for the study had negative pregnancy tests before and after the study. The 12-lead EKG tracings were normal. During the weekly exposures of male subjects, the following clinical chemistries were omitted from the panel listed previously: calcium, PBI, phosphorus, creatinine, cholesterol and SGPT; while uric acid was added. There were no trends or bunching of abnormal values during the PCE exposure weeks.

A study of urinary creatinine excretion values revealed that four of the ten male subjects probably failed to collect all of their 24-hour urine specimens on many of the exposure days. Table III lists the mean and the S.D. of grams excreted/24 hr for a minimum of 20 collections from each subject. Subjects 163 and 165 (Group I), 168 (Group II) and 171 (Group III) had mean values below 1 gram creatinine excreted/24 hr, indicating incomplete collections. Urobilinogen values were abnormal ($>$ 10 Erhlich units per 24 hours) for only one subject, #169, Group III.

His abnormal values were 12.9 on day 4 of week 1, 16.6 on day 1 of week 2, and 14.4 on day 2 of week 2. Creatinine values on all three of these days were above his average for the study. He had no further abnormal values during the remainder of the study.

Daily medical examinations elecited two situations wherein a subject was not fit healthwise to be exposed. One occurred in a male subject who reported with "flu" symptoms on a Monday morning. The other occurred in a female subject who was exposed on Monday and Tuesday of week 2 (blizzard week) and returned on Monday morning of week 3 with "flu" symptoms. Her case of influenza lasted for four days, whereafter she was not returned to the study.

Brief questioning of the subjects prior to each day's exposure revealed that approximately half of the male subjects consumed alcohol the previous evening. However, there were only isolated cases of excessive use.

Breath Analysis:

Tables IV through XV list the mean (±S. D.) concentrations of PCE found in the breath of male subjects after daily exposure to this solvent. With the exception of the first value for the week, the pre-exposure value listed is identical to the last post-exposure value listed. Breath PCE concentrations obtained from the female subjects during the full week of exposure to PCE are listed in Tables XVI through XVIII. Five, 10 and 20 min

post exposure samples were not obtained from the female subjects, as had been the case with the males. In order to obtain logical mean values, individual values that were less than one-half of the mean value for the other subjects on a given day, and that obviously represented leaking containers, were rejected. For the saran bag values, $<0.4\%$ were rejected. In the case of the glass tubes that were used for collecting duplicate 2 and 3 hr post-exposure samples, the highest value of the duplicates was always used. Of these sample data, 8% of the values were discarded in calculating the means.

Infrared scans of breaths from all male subjects, obtained 15 minutes post-exposure on day 5 of week 4 (100 ppm PCE, fluctuating), revealed no extraneous absorbance bands, other than those attributable to PCE, when compared to a control breath scan.

Analysis of Blood for PCE:

Tables XIX, XX and XXI list the mean values in ppm PCE (v/v) found in the blood of male subjects during this study, and Table XXII lists mean values for the female subjects. Technical difficulties made results unavailable on male subjects at 15 minutes post, week 2, day 5. The results from the first part of the study with female subjects (week 2, day 1) were also unavailable, due to the blizzard.

Analysis of Urine for Metabolites:

Table XXIII lists the results obtained from the analysis of selected urine samples for trichloroacetic acid (TCA) and trichloroethanol (TCEt).

After the last day of exposure of the male subjects to 150 ppm of PCE, a trace of TCA was found in the urine of one subject. This was probably the most concentrated of the urine samples. No TCEt was found from this day's 24-hr urine collections; neither was any TCA or TCEt found in the previous day's collection. Two female subjects excreted traces of TCA after their last day of exposure to 100 ppm PCE, but none after the third day. Additionally, there was no TCEt detectable after the last day of exposure to PCE at 100 ppm.

Cardio-Pulmonary Function Studies:

Presented in Tables XXIV and XXV are the data obtained on four male subjects (mean & SEM) to evaluate the effect of 7-1/2 hours of daily PCE exposure on certain aspects of pulmonary and cardiac function. Considering the data obtained at rest and during work, it is apparent that exposure to tetrachloroethylene did not have a major, general effect on any of the parameters studied. However, certain trends seemed to develop during exposure at the highest concentration of PCE (week 5, day 4). For example: (1) resting and one level of exercise D_L CO/V_A, and $P_{A_{O_2}}$ at both exercise levels, were lowest on this day while, (2) resting and exercise heart rate and resting and low exercise arterial pH were highest on this day. Although most of these changes were slight and statistically insignificant, they do suggest direction for future studies.

There was a high degree of within day reproducibility of certain of the parameters studied during resting conditions. The standard error of the average difference between paired samples ranged between 0.5 to 3.3% for lung volumes, expiratory flow rates, lung diffusion, and the blood parameters ($P > 0.5$).

Neurological Studies:

The modified Romberg and heel-to-toe equilibrium test performed by each subject just after entry and just prior to exit of the chamber revealed no impairment of equilibrium in any subject.

Electrode positionings for the EEG and VER studies are listed in Table XXVI, and copies of composites of selected EEG recordings are shown in Figures 3-22. Exposure to PCE resulted in a major change in the EEG of 3 of 4 male and 4 of 5 female subjects. In most subjects the change was characterized by a reduction to over-all wave amplitude and frequency. This change was most strikingly evident in occipital leads in which alpha wave activity (8-10 hertz, 10-50 μv amplitude) was generally replaced by delta or theta wave activity (3-5 hertz, 10-100 μv amplitude). In essence the altered pattern is quite similar to that seen in a healthy adult during drowsiness, light sleep and the first stages of anesthesia. As detailed below, there was inter-subject variability in the onset of this change. There was minimal adaptation to this effect of PCE and in all the subjects the change was still evident during 0 ppm conditions after the final day of PCE exposure.

Male Subject #118. This subject's EEG did not change appreciably from control until the third week of exposure to PCE (week 4). Of specific interest is the data obtained on the final day of the third week. After 10 minutes exposure the EEG was quite comparable to the EEG during 0 ppm conditions (Figures 3 and 4). However, after 4 hours and 30 minutes exposure, delta wave activity was evident in all channels (Figure 4). Finally, at 5 hours and 30 minutes (Figure 5), there was occasional asymmetry between the two parietal-occipital leads. EEG frequencies in the delta range and bilateral asymmetry were evident on this subject throughout the weeks 4 and 5 of the study.

Male Subject #163. This subject's EEG was markedly changed from normal after only 10 minutes of the first day of exposure to PCE (Figures 6 and 7). With continued exposure on that day there was a slight return to his normal EEG pattern (Figures 7 and 8). During several additional exposures his EEG was similarly abnormal (Figure 8). Bilateral asymmetry and wave frequencies in the delta range were observed frequently during the exposures.

Male Subject #164. As shown in Figures 9 and 10, after 30 minutes on the first day of exposure to PCE, this subject's EEG was very near normal. However, after 5 hours and 22 minutes of exposure on that day, the delta wave pattern was very prominent. On the majority of exposure

days the EEG was similarly quite normal during the first hour of exposure, but the records during the fifth to seventh hours of exposure were characterized by bilateral asymmetry and high amplitude, low frequency waves (Figures 11 and 12).

Female Subjects #116 and #192. Because of the extenuating circumstances, five days separated the first two days from the full 5 days of exposure of females to PCE. On both days 1 during these first two weeks, the EEG of these two subjects was quite similar after 10-20 minutes exposure to the EEG during 0 ppm conditions (Figures 13-18). However, after 5 hours exposure to PCE, the EEG wave frequency and over-all amplitude decreased relative to 0 ppm conditions in both subjects. On the remaining days of exposure when the EEG was recorded, wave frequency and over-all amplitude was similarly altered from normal but to a lesser extent than on day 1 of each week.

Female Subject #193. This subject was exposed to PCE for only two days, and the only EEG recordings were made on day 1 after 5-7 hours exposure (Figure 20). These records differed from the 0 ppm day (Figure 19) as demonstrated by a marked slowing in EEG wave frequency.

Female Subject #198. No records were obtained on this subject during 0 ppm conditions prior to PCE exposure. On the first day of PCE exposure, the EEG did not change between 30 minutes and 5-7 hours exposure.

However, on both the third and fifth days of exposure, there was a marked slowing of the EEG wave frequency between 30 minutes and 5-7 hours exposure (Figures 21 and 22).

There was no general alteration in VER wave amplitude, latency or configuration that could be attributed to exposure to PCE. Analysis of the data by both visual examination (Figures 23-28) and by actual measurement of wave amplitude and latency led to this conclusion. The most notable alterations in the VER's were slight changes in wave configuration during PCE exposure in female subjects #116 and #192, (Figures 27 and 28).

Behavioral Testing:

Both male and female subjects, Groups I and II, performed the alertness test; however, the results from the Group II female subjects were not usable due to subject absences. The paired t-test was used to determine significance of the data. Percent of correct responses and average reaction times were compared on PCE exposure days versus the mean of two zero exposure days. Results are listed in Table XXVII. There were two significant (0.05 level) differences; both occurred in male subjects. The Group I (7-1/2 hour exposure) male subjects reacted more rapidly on day 4 during the week of exposure to 150 ppm PCE, and the Group II (3 hour exposure) had a lower percent correct on day 2 during the week of exposure to 20 ppm PCE. Both of these "significant" changes were probably spurious.

Flanagan coordination tests, arithmetic tests, inspection tests and time tests were performed by Group I (7-1/2 hour exposure) and Group II (3 hour exposure) male subjects on days 1, 3, and 5 of each week. Ten training sessions were conducted for each of these behavioral tests before the first zero chamber concentration session (session 11) was conducted. Graphs to depict the mean scores plus one standard deviation were developed for each group from the results of each individual session and for the combined results from sessions at 0, 100 steady, 100 fluctuating and 150 ppm of PCE.

Figures 29 to 38 show in graphical form the scores obtained for the various tests performed by the subjects of Group I versus the testing sessions. Figures 39 to 48 show the combined scores obtained by the same subjects versus the concentration of PCE expressed in ppm. Figures 49 to 68 show the comparable data for the subjects of Group II.

For a determination of the significance of the results obtained, paired t-tests were used to compare the control (from three 0 ppm exposures) values versus those obtained for each subject at each PCE vapor concentration. Table XXVIII shows the results of these statistical comparisons for Group I and Table XXIX for Group II.

The t-values for Group I data show that there was a statistically significant difference in the results of the 10-second time estimation tests at 20 ppm and at 100 ppm fluctuating vapor concentration. However, this difference was not significant at 100 ppm non-fluctuating and at

150 ppm suggesting that this variation was spurious in nature and not related to the PCE exposure.

The t-value for the coordination test for Group I subjects exposed at 150 ppm was statistically significant, and therefore may delineate the toxicity threshold of PCE as detected by this particular test.

No deleterious effect of PCE exposure was detected by this battery of tests for the subjects in Group II.

Combination Effect of Ethanol and PCE:

The two subjects who each consumed a quart of beer on day 3 of their 7-1/2 hour exposure to 150 ppm PCE experienced no "flushing", as does occur with exposure to trichloroethylene. The beer also had no measurable effect upon the concentration of PCE in the blood up to 1 hour after consumption, as shown in Table XXX. Although many of the subjects admitted to the social use of alcohol in the evenings during this study, no case of "flushing" was reported.

Subjective Responses:

The subjective response forms were reviewed on an individual basis at the end of the study. An objective evaluation of the responses, exclusive of odor, was prepared, but no attempt was made to evaluate the severity of the feelings. In addition, the "other" responses "stuffy nose" and "sleepy" were not recorded because they did not occur often enough to conclude that more than one subject out of each group was

recording this response, even though all may have had these feelings occasionally. The objective evaluation is presented in tabular form in Table XXXI. In evaluating the results shown in this table, it must be remembered that the first two exposure days for males occurred on Thursday and Friday of week 1 and were 0 ppm PCE. There was another 0 ppm day on Monday of week 3 and two on Monday and Tuesday of the last week, week 6. The first exposure day that included PCE was on Monday of week 2, and all subjects noted the odor of 100 ppm PCE immediately upon entering the chamber. Likewise, the female subjects all noted the odor of 100 ppm PCE on their first day of PCE exposure. The two 0 ppm PCE exposure days for females occurred on Friday of week 1 and Monday of week 4.

In Table XXXI the term "number of exposure days" was obtained by summing the number of subjective response forms obtained from those subjects who were exposed to each concentration of PCE. The total is not always equivalent to the product of the number of subjects in the group multiplied by the number of days at that concentration, for occasionally a subject was absent or forgot to return the form.

Effect of Exercise on Blood and Breath PCE Levels:

Table XXXII demonstrates the effects of exercise on the concentration of PCE in the blood of male subjects being exposed to various levels of PCE.

The ratio (E/R) of the PCE blood concentration after exercise as compared to the level at rest before exercise is given in the last column. The results of duplicate sampling of blood while the arm was extended outside the chamber atmosphere through a port and while in the chamber atmosphere are listed in Table XXXIII. The results of analyzing the blood of a faculty member who volunteered for repeat daily 30-minute exposures with and without controlled exercise are shown in Table XXXIV while the results of PCE analysis of his breath are shown in Table XXXV.

Stability of PCE in Breath Containers:

Three types of breath containers were filled with air containing 37 ppm PCE. The saran bag containers were used as controls, and were reassayed, while individual glass tubes and plastic bottles were assayed at each specific time period after filling. Table XXXVI lists the results obtained from this study. The plastic bottles were the poorest containers after 72 hours, while the glass tubes that did not leak seemed to be the best containers at 72 and 144 hours. Mailing the glass tubes had no detrimental effect. The saran bags "lost" approximately 10% of the PCE after 72 hours and 30% after 144 hours.

DISCUSSION

The major purpose for carrying out this study with tetrachloroethylene (PCE) was to obtain baseline data from human subjects under specified conditions of vapor exposure. These conditions are emphasized here because any variations from these conditions could lead to different results. In addition, there is the possibility that uncontrolled conditions in this study unknowingly influenced the results, or could influence other repeat studies. The controlled conditions of this study included the following: healthy adult Caucasian males, who were unrestricted as to diet with the exception of caffeine, who consumed zero to moderate amounts of alcohol and medications, who each breathed air contaminated with PCE vapor for a specified period of time 5 days per week for 5 weeks, who while breathing this contaminated air were sedentary except for short periods of exercise each day and who were in comfortable conditions of temperature and relative humidity while breathing this contaminated air. There were no restrictions, other than those cited, placed on the subjects while they were absent from the laboratory. In the study with females, besides the gender, the only other basic conditions which changed were the elimination of the brief period of daily exercise, and the exposure period to PCE was reduced to one week. Although the females were not

subjected to the cognitive task testing battery and the cardiopulmonary function testing, these tests very probably did not influence the results of any other tests. These basic conditions must be taken into account in the application of the results of these studies to any other PCE exposures, be they exposures in an industrial plant using PCE or the exposure of volunteer humans.

In general, subject attendance for these studies was excellent; however, they were paid only for hours in attendance, which was a motivating factor. Influenza was prevalent in the community during the time of the study with female subjects, which influenced the higher ratio of absences per total exposure days of females.

Table II demonstrates the excellent control obtained for actual concentrations of PCE to which all subjects were exposed. The dual, complementary chamber monitoring systems provided this reliable control, which allows one to have complete confidence in the relationship of exposure to reaction.

Extraordinary provisions for health care were made, including comprehensive medical examinations by physicians, clinical chemistries and hematology studies. No subject exposed to PCE was judged by the attending physicians to have demonstrated any deleterious signs or symptoms which

could be unequivocably related to the PCE exposures. One subject (#164), a male, who in the estimation of the investigators was especially reliable and honest, did experience an exceptional number of headaches, occasional nausea, dizziness, etc. However, this subject also experienced these same subjective feelings to some degree on the days of zero exposure to PCE. This subject probably experienced these subjective responses partly because of apprehension, and partly because of PCE exposure.

Table XXXI summarizes the subjective responses of all subjects. In reviewing the table, it is obvious that there is no dose-response relationship detectable in any of the three male groups exposed to several concentrations of PCE. The highest ratio of responses per exposure day occurred when the 7-1/2 hour males were exposed to 100 ppm PCE. This was the first PCE exposure week. The 1 hour males also showed their highest ratio this first week, while the 3 hour subjects showed minimal responses throughout the study. The number of responses on the first day of the week are shown on the table in brackets. It is of interest that 10 of the 14 responses to the PCE exposure of Group I males were recorded the first day. Of the total of 43 responses recorded by the males while being exposed to PCE, 22 or slightly over 50% were recorded the first day of exposure to a particular PCE concentration. This reaction was not as great in females where 7 of the 18 responses were on the first day. However,

it does corroborate the finding of Stewart, et al.[8], that individuals chronically exposed develop a tolerance to the compound. In addition, the results of this study indicate that subjective responses were also elicited to an almost equal degree on 0 ppm exposure days. Stewart, et al.[8], did not carry out studies that included such 0 ppm days, and allowed for the possibility that their observations may have been typical 0 ppm responses. In the present study, it is concluded that untoward subjective complaints did not increase to any significant degree in either males or females when exposed to several concentrations of PCE when compared to 0 ppm PCE concentrations.

The current study also concurs with Stewart's report that a certain percentage of the population may be more susceptible from a subjective response standpoint to PCE. One male 7-1/2 hour subject referred to earlier (#164) accounted for a disproportionate number of responses in this study, both on 0 ppm PCE exposure days (8 of 11 total responses from his group) and on actual PCE exposure days (20 of 26). When this subject's responses are subtracted from the total for his group, it is obvious that the remaining 3 subjects noted very few untoward subjective responses. Even at the highest exposure concentration (150 ppm PCE), the 3 subjects recorded a total of only one such complaint during the 5 days of exposure. The subject who experienced the disproportionate number of subjective responses,

as can be surmised from the earlier discussion, experienced almost all of them on the first exposure day to a particular concentration, which was almost always on Monday, and experienced none by the last day of the week, even though the magnitude of exposure was identical to the first.

The number of headaches experienced during their stay in the chamber is shown in parentheses in the table. In Group II, Males, all recorded responses during actual exposure to PCE were headaches, while one-half of the Group I, Males, and only 2 of 9 Group III, Males, responses were headaches. Therefore, there was no conclusive picture regarding type of response, except that headaches predominated and that the remainder of the responses were spread rather evenly over the remaining categories.

(8)

Contrary to the Stewart, et al., report, the male subjects in the current study did not feel a need for more than their normal amount of sleep when queried on Saturday regarding sleep needs during the week of exposure to 100 ppm PCE (week 2). Only one of the ten subjects felt an increased need for sleep. Occasionally the subjects indicated a "tired" feeling on their subjective response forms, but the few entries did not correspond to dose levels, and seemed to be a result of occasional boredom in the chamber.

All subjects could detect the odor of PCE at concentrations of 20, 100 and 150 ppm on the first day of exposure immediately upon entering

the chamber. Thereafter, each subject's ability to detect the odor became quite individualistic, with some apparently retaining this ability to detect the odor during the entire exposure period, particularly at 150 ppm, and a very few indicating no odor after the first few hours on the first day. In general, the subjects responded similarly to those studied previously by Stewart,et al.,[8] " . . . their ability to perceive the odor progressively diminished during the course of the week . . .", and even during each day. In general, however, the males who were exposed to a fluctuating PCE concentration from 50 to 150 ppm on 5 days of week 4 did not note the fact that the concentration increased by increments of 50 ppm when this occurred. Occasionally during this week a subject would note a mild odor after not smelling any for several hours, but this happened so seldom that it can be concluded that 50 ppm incremented increases in concentrations of PCE vapor would not normally be detected in a work place.

Breath samples were collected in saran bags up to one hour post-exposure. These were all analyzed the same day they were collected. As revealed in the study of breath containers, PCE stored in saran bags decreased in PCE concentration at 72 hours to 90% of the initial amount and to 70% at 144 hours (see Table XXXVI). Only 4 out of over 1,000 saran bag samples analyzed during the human studies indicated leakage out

of the bag. The glass tubes used for the 2 and 3-hour breath samples contained many leakers, but the container study confirmed that the non-leakers retained the original PCE concentration at 72 hours post-filling. During the studies, duplicate glass tubes were filled by the subjects, and these were analyzed within 24 hours.

The results of the PCE breath analyses confirmed that this chemical is excreted in the breath for long periods post-exposure.[8, 9] A study of the results in Tables IV through XV show that readily measurable concentrations of PCE appeared in the breath of subjects on a Monday morning following the last previous exposure on Friday. A daily carryover, as shown by Stewart, et al. in their earlier studies, is particularly evident during days 2 and 3 of the 100 ppm exposure (week 2) of male subjects. However, the following days' breath concentrations (days 4 and 5) indicated an equilibrium situation. Reviewing the breath analysis data for the following weeks of exposure revealed that an equilibrium was attained by day 3 of each week. Therefore, each group's breath analysis decay curves (BADCs) were prepared from all values on days 3, 4, and 5 of that week. The BADCs for the three concentrations of steady-state PCE to which the male subjects were exposed are shown in Figures 69, 70 and 71. Means and ranges are plotted on semi-log paper.

It is easily seen when comparing the daily breath levels of the female subjects to males that the breath levels of PCE from female subjects were consistently lower than those from males under comparable conditions. Figure 72 demonstrates the BADCs for the female subjects. As noted earlier, one of the basic differences in conditions between the two studies besides sex was the brief exercise of the males. Although the results are not directly comparable, the data from Table XXXV obtained from one male faculty member where PCE breath concentrations were analyzed after 30 minutes of exposure to 150 ppm PCE with and without exercise, indicate the rather great effect exercise had on the breath PCE concentration. Figure 73 better demonstrates the difference in BADCs of one subject due to exercise. It is probable that the exercise of the male subjects caused a part of the increased PCE breath excretion, which when added to the males greater vital capacity caused the visible difference between the BADCs of the two groups.

Comparison of the tables listing blood PCE concentrations for males and females similarly exposed do not reveal the differences between the groups as shown by the breath decay curves. However, Tables XXXII and XXXIV reveal the significant impact that exercise had on the blood PCE concentration in the male subjects.

The BADCs for the two sexes demonstrate the excellence of this method for determining the magnitude of a person's past exposure. A sedentary male worker who has been in an atmosphere of PCE for 7-1/2 hours should not have a PCE breath level of over 10 ppm at 16.5 hours post-exposure if the TLV of 100 ppm remains as a desirable level for PCE. This breath level should be no greater than 6 ppm at 16.5 hours post-exposure for a female sedentary worker. For 3 hours of exposure time, the breath levels at 21 hours post-exposure should be no greater than 5 and 1 ppm for males and females, respectively. Twenty-three hours post-exposure values for 1 hour of exposure would be 1.4 and 0.8 ppm.

The analysis for PCE in blood was not found to be of great value in determining the magnitude of PCE exposure. Although, as shown in Tables XIX, XX and XXI, there is a positive relationship between blood concentration and exposure magnitude, the problems of sampling, the difficulty of the analysis, and the lack of precision make it a second choice for biological monitoring.

Of special interest is the fact that we were unable to demonstrate measurable levels of any PCE metabolites in the urine of these subjects. Only one male subject of four excreted a detectable amount of trichloroacetic

acid (TCA) during the 2 days these subjects' urines were assayed during the week of exposures to 150 ppm PCE, and only two of four females showed detectable levels during 100 ppm exposures. No trichloroethanol (TCEt) was detected.[10] These results are in general agreement with Daniel who found very little conversion of PCE to TCA in rats using Cl-labelled PCE, and no conversion to TCEt.[36] Yllner, studying mice after PCE vapor exposure, found a considerable conversion to TCA, but none to TCEt.[11] Kylin, Sumegi and Yllner reported fatty degeneration of the liver of mice exposed to 200 ppm PCE for 4 hours/day for 8 weeks.[12] Daniel found no liver injury in his rats.[10] The work of Ikeda, Nagano and Okado confirms this difference in the effect of PCE on liver lipids of mice and rats.[13] It would appear from our studies that man handles PCE much like the rat and not like the mouse, where liver injury may be due to TCA or related metabolites.[14] Papers by Ogata, et al. and Ikeda, et al.[15] both claim a low conversion of PCE to TCA by humans, and subsequent excretion in the urine. However, both used methodology for TCA which is not highly specific at the low level reported.

The cardio-pulmonary studies in males revealed no deleterious effects of PCE exposures up to and including 100 ppm, and only "suggested" changes during exposure to 150 ppm for 5 days. The data in Tables XXIV

and XXV indicate that PCE exposure, as in this study, had no major effect on these organ systems. The lung volume and expiratory flow rate data suggest normalcy of lung elastic recoil and airway diameter during exposure. The constant D_L/V_A throughout the study demonstrates that alveolar-capillary membranes and pulmonary ventilation/perfusion ratios were unaffected by PCE exposure. The pulmonary ventilation, Pa_{CO_2}, and PA_{O_2} data indicate that mechanisms regulating ventilation were unaffected. Regulation of heart rate also appears normal throughout the study. Finally, mechanisms regulating arterial blood acid-base status were not affected by these exposures to PCE.

Neurological studies revealed no effect of the PCE exposures on the equilibrium test performed by all subjects or on the VER testing carried out on Group I subjects only. However, altered EEG patterns indicate that the PCE exposures affected some area of the central nervous system. The EEG changes induced by PCE exposure are indicative of cortical depression.[16] This change is consistent with the previously established anesthetic properties of PCE.[17] Anesthetics are thought to induce CNS depression by suppressing the influence of the reticular activating system. This suppression did not appear to extend to specific sensory and other cortical centers as other functions studies (VER, Romberg, arithmetic test, etc.) were unaffected by PCE exposure.

The persistance of the altered EEG through the final 0 ppm day is troublesome. This may represent a residual effect of PCE exposure, presumably transient. Alternatively, it could mean that the changes observed were unrelated to PCE. The latter explanation seems highly unlikely. Five of the seven subjects' EEGs were altered on the first day of exposure and it seems improbable that any single extraneous factor or combination of factors would be experienced so uniformly. Detection of the odor of PCE can be eliminated as a possible extraneous factor because in several previous studies vapor odor has not induced similar changes.

The battery of behavioral tests did not reveal any consistent effect of the PCE at several exposure levels. The significantly lower coordination test scores of Group I males at 150 ppm exposure as revealed by the paired t-test indicate that this may be a deleterious magnitude of PCE exposure.

CONCLUSIONS

Rowe, et al,[18] first suggested "that for daily exposures of seven to eight hours' duration the vapor concentration of tetrachloroethylene in the breathing atmosphere should not exceed 200 ppm and the average of representative samples taken over the seven to eight hour exposure should not exceed 100 ppm". Stewart, et al.,[8,9] confirmed this finding with more extensive behavioral studies and repeat exposures. The studies reported here further confirm the previous work and add a more sophisticated dimension of EEG studies to the neurological data base.

Based upon these studies, the following conclusions are advanced:

1. Repeated daily exposures to PCE result in a tachyphylactic type of response regarding subjective feelings and odor detection. Therefore, both of these parameters are unreliable measures of exposure concentration.

2. There is considerable individual difference in subjective response to PCE vapor exposures.

3. EEG analyses indicate that the preliminary signs of narcosis are present in most subjects exposed to 100 ppm PCE for 7-1/2 hours per day.

4. Impairment of coordination may occur at 150 ppm exposure for 7-1/2 hours.

5. Because there is very little metabolism of PCE by humans, the CNS response is probably due to the PCE itself.

6. Analysis of the chemical in the post-exposure expired breath provides an excellent tool for estimating the magnitude of the body burden of PCE.

7. Physical activity (exercise) during exposure to PCE dramatically increases the body burden of the chemical. Therefore, the time-weighted average concentration to which a male or female human is exposed may not reflect the true body burden attained by that individual.

8. Post-exposure levels of the chemical in the breath are an accurate reflection of the body burden and thus provide a "biologic threshold limit value" for worker exposure to this chemical.

Based upon the above conclusions, it is suggested that the data developed in this study could be used to construct BADCs whose upper limit of 95% confidence would define the "biologic threshold limit value" for workers in industry. The data from males exposed for 7-1/2 hours on days 3, 4, and 5 of week 2 to a steady PCE concentration of 100 ppm was computerized, and a preliminary equation and BADC developed. It is demonstrated in Figure 74. The means of 1 and 16-1/2 hr values from days 3, 4, and 5 during the fluctuating PCE concentration of 100 ppm are added to show how well they fall within the confidence limits of this BADC.

The final objective of this study was to ascertain the magnitude of the safety factor in the TLV of 100 ppm. From the data developed it is apparent that the TLV of 100 ppm contains no safety factor for those persons who seem to be peculiarly susceptible, both subjectively and neurologically, to the vapor of PCE. Excluding this portion of the population, additional studies on EEG changes are necessary to define their relevance to safety during exposures to this chemical at its TLV.

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TABLE I

EXPOSURE SCHEDULE FOR
TETRACHLOROETHYLENE

MALES

DAY	1 (M)	2 (TU)	3 (W)	4 (TH)	5 (F)
WEEK 1	-	-	-	0	0
WEEK 2	100	100	100	100	100
WEEK 3	0	20	20	20	20
WEEK 4	100f *	100f	100f	100f	100f
WEEK 5	150	150	150	150	150
WEEK 6	0	0	-	-	-

FEMALES

WEEK 1	-	- (snowstorm)	-	-	0
WEEK 2	100	(100)	-	-	-
WEEK 3	100	100	100	100	100
WEEK 4	0	-	-	-	-

* f = fluctuating from 50 to 150 ppm with a time-weighted average of 100 ppm; all other concentrations to be steady.

TABLE II

DAILY CONCENTRATION (TWA IN PPM) OF TETRACHLOROETHYLENE IN CHAMBER

MALES

Week	Group	Day 1 TWA	±SD	Day 2 TWA	±SD	Day 3 TWA	±SD	Day 4 TWA	±SD	Day 5 TWA	±SD
WEEK 2	I	100	3	100	2	100	2	100	3	100	3
(100 ppm	II	100	3	99	3	100	3	100	3	99	3
non-fluct.)	III	101	3	101	2	101	2	100[a]	2	101	2
WEEK 3	I	0[b]		22[c]	2	20	1	20	1	20	2
(20 ppm	II	0		22	1	20	1	20	1	19	2
non-fluct.)	III	0		22	1	21	2	21	1	19	1
WEEK 4	I	100	39	101	41	98	41	101	38	100	39
(100 ppm	II	99	39	104[b]	45	98	41	102	40	100	37
fluctuating)	III	101	35	101	37	99	41	96	43	100	40
WEEK 5	I	150	5	149	8	149[b]	7	150	6	150[d]	4
(150 ppm	II	150	4	152	6	149	4	150	4	150	3
non-fluct.)	III	150	2	144	4	147	5	151	3	149	7

FEMALES

WEEK 2	I	103[b]	5	101[b]	4	NO EXPOSURE					
(100 ppm	II	105	4	101	5	NO EXPOSURE					
non-fluct.)	III	102	5	101	6	NO EXPOSURE					
WEEK 3	I	101	4	101	4	100	2	100	3	100	3
(100 ppm	II	102	3	99	3	100	3	98[b]	1	101	3
non-fluct.)	III	98	3	104	3	101	2	101	2	99	1

[a] 1 subject = 98 ± 2

[b] 1 subject absent

[c] 1 Group I subject transferred to Group II, this day only

[d] 2 subjects; 7 hrs. only

TABLE III

AVERAGE 24-HOUR URINARY CREATININE EXCRETION VALUES

Subject #	Group	# of Collections	Mean Value grams/24-hr	S.D. grams/24-hr
118	I	21	1.64	0.39
163	I	21	0.89	0.33
164	I	20	1.45	0.27
165	I	22	0.78	0.16
166	II	21	1.29	0.26
167	II	20	1.66	0.33
168	II	20	0.58	0.29
169	III	22	1.54	0.25
170	III	22	1.43	0.29
171	III	22	1.91	0.32

TABLE IV

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 7-1/2 HOURS TO 100 PPM PCE

Four Male Subjects
Week 2

	DAY				
	1	2	3	4	5
	Means and Standard Deviations in PPM				
PRE-EXPOSURE	0	2.92 ±0.26	6.36 ±0.34	7.69 ±1.23	9.01 ±0.38
POST-EXPOSURE					
1 minute	40.91 ±6.6	35.64 ±2.9	47.56 ±2.45	46.45 ±2.18	43.43 ±4.35
5 minutes		33.66 ±3.1	43.29 ±2.76	42.76 ±1.65	41.98 ±4.40
10 minutes		30.86 ±2.9	38.87 ±4.38	39.21 ±2.45	37.84 ±2.39
15 minutes	30.12 ±6.1	28.55 ±2.0	35.98 ±2.91	31.89 ±7.78	37.00 ±3.22
20 minutes		24.50 ±1.1	33.31 ±2.94	30.19 ±3.64	33.88 ±2.50
30 minutes	26.87 ±1.5	22.11 ±2.9	30.94 ±1.66	31.25 ±2.31	29.05 ±3.52
1 hour	22.89 ±2.5	20.96 ±1.3	24.39 ±0.86	27.98 ±2.98	24.01 ±2.17
2 hours	10.41 ±1.7	15.74 ±3.5	14.82 ±0.18	16.66 ±2.68	14.30 ±4.46
3 hours	5.96 ±1.4	12.12 ±0.6	13.26 ±3.40	13.61 ±2.72	13.76 ±3.71
16-1/2 hours	2.92 ±0.26	6.36 ±0.34	7.69 ±1.23	9.01 ±0.38	9.48 ±0.46

TABLE V

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 3 HOURS TO 100 PPM PCE

Three Male Subjects
Week 2

	DAY 1	2	3	4	5
		Means and Standard Deviations in PPM			
PRE-EXPOSURE	0	1.30 ±0.27	2.72 ±0.62	3.67 ±0.57	3.86 ±0.60
POST-EXPOSURE					
1 minute	30.32 ±5.12	24.13 ±2.58	28.76 ±1.34	25.29 ±0.69	26.97 ±0.65
5 minutes		23.07 ±0.92	26.83 ±1.47	22.69 ±1.52	25.71 ±2.35
10 minutes		20.71 ±0.09	24.06 ±2.02	21.74 ±0.68	20.65 ±2.00
15 minutes	22.10 ±3.78	19.56 ±0.86	21.37 ±3.45	20.17 ±2.55	19.15 ±5.59
20 minutes		17.59 ±0.70	20.95 ±1.67	18.46 ±0.14	20.26 ±3.01
30 minutes	18.99 ±3.94	16.19 ±0.46	19.30 ±2.68	18.51 ±1.25	18.67 ±3.42
1 hour	12.30 ±4.59	12.97 ±0.54	14.83 ±3.31	15.14 ±1.38	15.82 ±2.85
2 hours	6.20 ±0.36	6.06 ±1.25	9.45 ±2.03	5.95 ±1.55	7.91 ±2.03
3 hours	3.68 ±0.61	5.72 ±1.23	6.30 ±0.74	6.17 ±1.86	7.54 ±0.50
21 hours	1.30 ±0.27	2.72 ±0.62	3.67 ±0.57	3.86 ±0.60	3.99 ±0.70

TABLE VI

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 1 HOUR TO 100 PPM PCE

Three Male Subjects
Week 2

	DAY				
	1	2	3	4	5
	Means and Standard Deviations in PPM				
PRE-EXPOSURE	0	0.51	0.82 ±0.20	1.11 ±0.10	1.20 ±0.17
POST-EXPOSURE					
1 minute	23.38 ±4.59	20.44 ±0.11	24.15 ±2.27	21.43 ±2.92	22.09 ±2.21
5 minutes		20.16 ±3.72	21.94 ±2.29	18.51 ±2.60	20.45 ±3.35
10 minutes		17.35 ±3.30	18.27 ±2.79	16.35 ±3.23	16.40 ±0.42
15 minutes	14.65 ±4.05	14.68 ±2.97	16.90 ±3.24	14.29 ±1.77	15.00 ±1.45
20 minutes		13.42 ±2.43	14.17 ±2.41	12.89 ±2.36	14.66 ±1.71
30 minutes	12.00 ±2.64	11.61 ±2.51	12.62 ±2.04	12.13 ±2.57	12.06 ±1.60
1 hour	8.88 ±1.36	8.85 ±1.32	10.03 ±1.35	9.52 ±2.06	9.70 ±1.90
2 hours	3.26 ±1.17	4.28 ±0.89	4.38 ±0.80	2.67 ±0.73	4.04 ±1.35
3 hours	2.70 ±1.09	3.64 ±1.15	3.45 ±0.96	2.95 ±0.99	3.31 ±0.83
23 hours	0.51	0.82 ±0.20	1.11 ±0.10	1.20 ±0.17	1.44 ±0.11

TABLE VII

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 7-1/2 HOURS TO 20 PPM PCE

Four Male Subjects
Week 3

	DAY			
	2	3	4	5
	Mean and Standard Deviations in PPM			
PRE-EXPOSURE	4.31 ±0.56	3.42 ±0.52	3.63 ±0.26	3.61 ±0.23
POST-EXPOSURE				
1 minute	10.18 ±0.83	8.21 ±0.21	6.37 ±1.00	9.14 ±1.00
5 minutes	9.06 ±1.32	7.89 ±0.32	8.03 ±1.36	8.95 ±0.55
10 minutes	8.74 ±0.74	7.24 ±0.56	8.81 ±0.29	8.66 ±0.54
15 minutes	8.42 ±0.28	7.09 ±0.43	8.45 ±0.55	7.95 ±0.54
20 minutes	8.22 ±0.70	6.41 ±0.43	7.80 ±0.36	6.93 ±0.75
30 minutes	7.76 ±1.12	6.01 ±0.57	7.08 ±0.23	6.20 ±0.73
1 hour	6.47 ±0.66	5.17 ±0.39	6.13 ±0.39	5.87 ±0.39
2 hours	5.47 ±1.43	5.32 ±1.18	5.08 ±1.00	5.95 ±0.92
3 hours	4.04 ±1.26	4.31 ±1.36	4.91 ±0.83	4.49 ±1.04
16-1/2 hours	3.42 ±0.52	3.63 ±0.26	3.61 ±0.23	3.62 ±0.11

TABLE VIII

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE) AFTER EXPOSURE FOR 3 HOURS TO 20 PPM PCE

Three Male Subjects
Week 3

	DAY			
	2	3	4	5
	Mean and Standard Deviations in PPM			
PRE-EXPOSURE	1.36 ±0.48	1.30 ±0.36	1.22 ±0.12	1.31 ±0.18
POST-EXPOSURE				
1 minute	7.07 ±0.05	4.08 ±0.90	5.48 ±1.03	6.15 ±0.12
5 minutes	6.28 ±0.28	4.80 ±0.27	4.39 ±0.80	5.67 ±0.32
10 minutes	5.94 ±0.32	4.27 ±0.43	3.44 ±0.33	5.39 ±0.37
15 minutes	5.48 ±0.26	4.08 ±0.34	3.04 ±0.23	5.10 ±0.39
20 minutes	4.76 ±0.18	3.72 ±0.21	3.10 ±0.57	4.55 ±0.28
30 minutes	4.82 ±0.17	3.45 ±0.19	2.78 ±0.44	4.24 ±0.32
1 hour	3.78 ±0.20	3.12 ±0.11	2.64 ±0.27	3.45 ±0.32
2 hours	1.77 ±0.46	2.09 ±0.13	2.41 ±0.23	2.49 ±0.45
3 hours	1.80 ±0.64	2.20 ±0.58	2.40 ±0.16	1.74 ±0.52
21 hours	1.30 ±0.36	1.22 ±0.12	1.31 ±0.18	1.31 ±0.19

TABLE IX

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE) AFTER EXPOSURE FOR 1 HOUR TO 20 PPM PCE

Three Male Subjects
Week 3

	DAY			
	2	3	4	5
	Mean and Standard Deviations in PPM			
PRE-EXPOSURE	0.51 ±0.09	0.45 ±0.04	0.61 ±0.16	0.65 ±0.18
POST-EXPOSURE				
1 minute	5.53 ±0.67	4.10 ±0.58	4.42 ±0.51	4.58 ±0.82
5 minutes	4.82 ±0.32	3.55 ±0.11	3.73 ±0.55	4.13 ±0.51
10 minutes	4.23 ±0.65	3.27 ±0.18	3.49 ±0.42	3.19 ±0.32
15 minutes	3.94 ±0.23	2.78 ±0.21	2.91 ±0.05	2.98 ±0.55
20 minutes	3.54 ±0.26	2.40 ±0.11	2.75 ±0.12	2.69 ±0.41
30 minutes	3.06 ±0.17	2.04 ±0.46	2.22 ±0.62	1.73 ±0.36
1 hour	2.50 ±0.12	1.85 ±0.36	2.04 ±0.30	2.12 ±0.21
2 hours	1.39 ±0.22	1.35 ±0.29	1.13 ±0.05	1.18
3 hours	0.83 ±0.35	1.24 ±0.26	0.73 ±0.12	0.96 ±0.45
23 hours	0.45 ±0.04	0.61 ±0.16	0.65 ±0.18	0.55 ±0.09

TABLE X

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE) AFTER EXPOSURE FOR 7-1/2 HOURS TO 100 PPM* PCE

Four Male Subjects
Week 4

	DAY 1	2	3	4	5
	Mean and Standard Deviations in PPM				
PRE-EXPOSURE	2.90 ±0.94	5.76 ±0.45	6.37 ±0.27	7.76 ±0.75	7.96 ±0.76
POST-EXPOSURE					
1 minute	36.43 ±4.01	35.24 ±1.52	37.18 ±4.17	37.55 ±2.92	38.77 ±2.16
5 minutes	33.74 ±1.63	30.51 ±3.13	34.38 ±2.65	31.66 ±4.35	35.82 ±4.09
10 minutes	30.10 ±3.36	29.43 ±1.41	32.33 ±1.65	30.52 ±3.35	32.55 ±2.61
15 minutes	27.43 ±2.53	27.76 ±1.31	30.17 ±2.11	29.85 ±3.53	31.63 ±2.22
20 minutes	27.79 ±2.90	23.92 ±2.42	29.31 ±2.66	27.10 ±3.92	29.59 ±2.63
30 minutes	22.90 ±0.71	23.33 ±2.31	27.05 ±1.67	25.67 ±2.19	26.12 ±2.52
1 hour	17.48 ±0.74	19.49 ±2.07	22.42 ±1.54	21.48 ±0.66	24.49 ±2.43
2 hours	12.41 ±1.49	12.64 ±1.83	11.28 ±3.75	13.42 ±0.47	12.67 ±6.33
3 hours	10.26 ±2.64	11.95 ±2.37	11.10 ±3.57	10.56 ±0.71	12.92 ±7.15
16-1/2 hours	5.76 ±0.45	6.37 ±0.27	7.76 ±0.75	7.96 ±0.76	9.76 ±1.00

*Fluctuating from 50 to 150 PPM

TABLE XI

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 3 HOURS TO 100 PPM* PCE

Three Male Subjects
Week 4

	DAY 1	2	3	4	5
		Means and Standard Deviations in PPM			
PRE-EXPOSURE	0.99 ±0.32	1.00 ±0.32	2.63 ±0.98	3.33 ±0.74	3.07 ±0.29
POST-EXPOSURE					
1 minute	NO DATA OBTAINED	26.55 ±6.15	26.16 ±4.21	24.22 ±3.87	26.11 ±2.66
5 minutes		25.29 ±4.37	22.24 ±4.11	22.89 ±5.61	24.67 ±2.34
10 minutes		21.72 ±4.78	20.68 ±3.72	22.16 ±2.30	20.81 ±3.13
15 minutes		20.18 ±4.77	18.85 ±4.06	20.49 ±2.83	21.18 ±3.10
20 minutes		19.02 ±3.42	16.31 ±4.64	19.03 ±4.38	17.44 ±1.70
30 minutes		16.99 ±4.09	16.44 ±3.78	17.23 ±3.25	16.70 ±2.32
1 hour		14.58 ±5.59	12.33 ±1.98	13.77 ±1.70	12.71 ±2.60
2 hours		8.18	6.48	5.22 ±1.65	7.24 ±3.91
3 hours		4.89 ±1.33	3.30 ±1.98	4.41 ±0.64	5.61 ±3.38
21 hours	1.00 ±0.32	2.63 ±0.98	3.33 ±0.74	3.07 ±0.29	3.98 ±0.57

*Fluctuating from 50 to 150 PPM

TABLE XII

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 1 HOUR TO 100 PPM* PCE

Three Male Subjects
Week 4

	DAY 1	2	3	4	5
	Means and Standard Deviations in PPM				
PRE-EXPOSURE	0.51 ±0.17	0.79 ±0.19	1.00 ±0.19	1.20 ±0.26	1.12 ±0.18
POST-EXPOSURE					
1 minute	18.98 ±3.50	22.20 ±3.02	20.81 ±1.64	20.36 ±2.60	20.31 ±1.56
5 minutes	15.84 ±2.64	17.76 ±0.34	18.53 ±3.28	17.90 ±2.99	17.82 ±2.38
10 minutes	13.55 ±2.50	15.96 ±2.45	14.74 ±2.55	16.57 ±2.95	15.95 ±2.18
15 minutes	11.95 ±1.54	14.09 ±1.65	13.70 ±2.94	14.30 ±2.32	13.58 ±2.38
20 minutes	10.86 ±2.24	13.10 ±1.47	12.13 ±2.12	12.44 ±2.20	11.03 ±2.53
30 minutes	10.00 ±1.55	11.07 ±0.48	10.11 ±1.77	10.64 ±2.08	11.15 ±2.90
1 hour	6.92 ±1.33	9.60 ±0.97	8.42 ±0.90	8.85 ±1.03	7.41 ±0.29
2 hours	3.71 ±0.75	3.53 ±0.74	2.97	3.10 ±1.40	3.06 ±1.87
3 hours	2.22 ±0.21	2.98 ±0.14	2.70	1.62 ±0.56	2.34 ±1.07
23 hours	0.79 ±0.17	1.00 ±0.19	1.20 ±0.26	1.12 ±0.18	1.53 ±0.20

*Fluctuating from 50 to 150 PPM

TABLE XIII

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 7-1/2 HOURS TO 150 PPM PCE

Four Male Subjects
Week 5

	DAY				
	1	2	3	4	5
	Means and Standard Deviations in PPM				
PRE-EXPOSURE	7.09 ±1.41	10.71 ±0.61	13.46 ±1.19	10.83 ±2.67	11.64 ±1.32
POST-EXPOSURE					
1 minute	63.10 ±2.80	59.49 ±8.02	55.50 ±9.90	50.21 ±6.65	55.98 ±4.79
5 minutes	50.34 ±6.26	58.57 ±6.16	40.00 ±3.50	47.00 ±4.36	53.59 ±5.49
10 minutes	52.38 ±2.42	51.39 ±2.21	43.67 ±4.37	43.80 ±5.09	47.81 ±5.23
15 minutes	48.13 ±1.51	48.61 ±3.07	44.67 ±5.58	41.39 ±5.80	46.81 ±5.05
20 minutes	43.37 ±4.39	45.83 ±3.42	40.17 ±2.84	41.39 ±5.15	40.74 ±3.02
30 minutes	40.48 ±3.26	43.06 ±2.68	37.67 ±1.26	39.46 ±5.04	37.25 ±3.40
1 hour	33.50 ±2.25	35.85 ±4.80	32.67 ±2.36	32.29 ±5.80	30.78 ±2.75
2 hours	23.49 ±2.26	23.56 ±4.28	No Sample	21.53 ±2.42	21.67 ±4.96
3 hours	20.01 ±3.40	21.69 ±1.51	No Sample	18.24 ±4.16	22.76 ±3.08
16-1/2 hours	10.71 ±0.61	13.46 ±1.19	10.83 ±2.67	13.36 ±0.76	11.64 ±1.32
64-1/2 hours					8.88 ±0.82

TABLE XIV

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
AFTER EXPOSURE FOR 3 HOURS TO 150 PPM PCE

Three Male Subjects
Week 5

	DAY 1	2	3	4	5
	Means and Standard Deviations in PPM				
PRE-EXPOSURE	2.38 ±0.08	4.47 ±0.13	5.35 ±0.18	6.55 ±1.03	5.19 ±0.42
POST-EXPOSURE					
1 minute	51.55 ±7.14	41.87 ±7.99	38.67 ±2.02	41.68 ±4.92	48.41 ±7.60
5 minutes	42.04 ±7.73	38.29 ±7.69	40.50 ±4.58	34.83 ±4.98	40.44 ±3.66
10 minutes	43.99 ±8.10	33.47 ±6.56	33.50 ±3.50	32.75 ±4.03	38.05 ±4.23
15 minutes	38.83 ±9.35	32.10 ±5.23	31.00 ±2.18	30.07 ±1.86	35.86 ±5.64
20 minutes	36.31 ±9.03	31.13 ±5.23	29.50 ±2.78	28.59 ±4.09	32.47 ±3.66
30 minutes	32.76 ±6.75	27.55 ±4.22	26.83 ±4.04	26.50 ±5.38	31.48 ±6.20
1 hour	23.25 ±3.44	21.21 ±4.24	18.83 ±2.75	21.14 ±5.08	23.91 ±2.82
2 hours	13.06 ±2.90	9.18 ±1.69	13.68 ±2.29	10.62 ±2.61	12.47 ±0.86
3 hours	6.82 ±2.55	8.51 ±4.15	7.90 ±6.57	9.37 ±3.66	12.47 ±0.51
21 hours	4.47 ±0.13	5.35 ±0.18	6.55 ±1.03	5.19 ±0.42	6.72 ±0.54
69 hours					3.34 ±0.26

TABLE XV

BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE) AFTER EXPOSURE FOR 1 HOUR TO 150 PPM PCE

Three Male Subjects
Week 5

	DAY 1	2	3	4	5
	Means and Standard Deviations in PPM				
PRE-EXPOSURE	1.12 ±0.17	1.69 ±0.16	1.53 ±0.20	2.38 ±0.51	5.19 ±0.42
POST-EXPOSURE					
1 minute	32.47 ±7.98	34.71 ±7.17	27.67 ±3.79	32.45 ±4.58	31.98 ±5.42
5 minutes	28.09 ±5.21	30.99 ±7.45	28.33 ±3.62	27.99 ±4.41	27.74 ±5.08
10 minutes	25.12 ±4.93	26.58 ±6.40	23.83 ±2.75	26.49 ±2.23	24.11 ±4.87
15 minutes	23.12 ±5.37	22.04 ±4.57	20.83 ±3.82	20.55 ±4.09	21.71 ±4.40
20 minutes	20.20 ±4.39	20.80 ±4.22	18.00 ±0.50	19.65 ±3.57	19.25 ±3.47
30 minutes	17.40 ±2.98	17.77 ±3.67	15.83 ±2.26	16.67 ±3.14	15.38 ±2.66
1 hour	13.18 ±3.49	12.54 ±1.04	12.33 ±0.76	14.29 ±2.36	12.67 ±1.36
2 hours	5.22 ±0.28	4.88 ±2.42	4.74	5.09 ±0.13	6.38 ±1.01
3 hours	4.25 ±0.54	No Sample	5.53 ±1.12	4.39	
23 hours	1.69 ±0.16	1.53 ±0.20	2.38 ±0.51	5.19 ±0.42	1.92 ±0.08
71 hours					0.95 ±0.28

TABLE XVI

TETRACHLOROETHYLENE BREATH DATA IN PPM (MEAN ±SD)

Group I: 4 Female Subjects

Chamber Concentration: 100 ppm

Exposure Time: 7½ Hours

	Baseline (16½ hr. post)	1 Min. Post	15 Min. Post	30 Min. Post	1 Hour Post	2 Hour Post	3 Hour Post
Week 3, Day 1	0.51 ±0.07	30.07 ±3.10	22.04 ±1.44	17.42 ±0.83	14.56 ±0.63	6.70 ±1.87	6.95
Week 3, Day 2	2.01 ±0.53	29.10 ±0.42	21.44 ±0.82	18.21 ±0.71	15.99 ±0.42	9.93 ±3.39	6.31 ±0.52
Week 3, Day 3	3.92 ±0.73	26.00 ±3.38	19.57 ±2.57	16.76 ±1.53	14.95 ±1.59	7.85 ±2.14	7.74 ±4.62
Week 3, Day 4	2.99 ±0.66	28.52 ±3.39	21.48 ±2.78	17.18 ±3.00	15.25 ±1.03	8.84 ±0.62	8.07 ±1.25
Week 3, Day 5	4.01 ±0.89	26.18 ±2.87	20.24 ±3.57	17.45 ±1.90	15.40 ±0.61	8.90 ±1.95	7.48 ±1.49
Week 3, Day 6	5.89 ±1.27						
Week 4, Day 1	2.94 ±0.59 (64 hours post)						

TABLE XVII

TETRACHLOROETHYLENE BREATH DATA IN PPM (MEAN ± SD)

Group II: 2 Female Subjects

Chamber Concentration: 100 ppm

Exposure Time: 3 Hours

	Baseline (21 Hr. Post)	1 Min. Post	15 Min. Post	30 Min. Post	1 Hour Post	2 Hour Post	3 Hour Post
Week 3, Day 1	0.60 ±0.70	18.26 ±0.17	13.37 ±0.33	10.28 ±0.51	8.36 ±0.67	3.56 ±1.17	2.73
Week 3, Day 2	0.75 ±0.23	16.03 ±0.14	11.09	8.47	6.96 ±0.43	3.82 ±0.15	3.18
Week 3, Day 3	1.33 ±0.22	15.58	10.69 ±0.25	8.97 ±0.13	6.62 ±0.64	4.29	3.15
Week 3, Day 4	1.07	21.43	10.62	9.46	7.14	3.89	N.A.
Week 3, Day 5	1.06 ± .49	16.43 ±0.83	11.59 ±0.21	9.68 ±1.24	7.33 ±0.83	3.44	3.44
Week 3, Day 6	N.A.						
Week 3, Day 6	0.61 (69 hours post)						

TABLE XVIII

TETRACHLOROETHYLENE BREATH DATA IN PPM (MEAN ± SD)

Group III: 2 Female Subjects

Chamber Concentration: 100 ppm

Exposure Time: 1 Hour

	Baseline (22 Hour Post)	1 Min. Post	15 Min. Post	30 Min. Post	1 Hour Post	2 Hour Post	3 Hour Post
Week 3, Day 1	0.23 ± .20	17.78 ± 1.85	9.43 ± 0.51	6.68	4.30	1.62 ± .29	1.24
Week 3, Day 2	0.41	17.14 ± 4.56	8.42 ± 0.93	5.65 ± .86	4.03	2.55 ± 0.76	1.65 ± 0.08
Week 3, Day 3	0.48 ± .23	13.04 ± 2.31	6.80 ± 0.39	5.07	3.53 ± 0.13	1.76 ± 0.05	1.18 ± 0.25
Week 3, Day 4	0.40 ± 0.15	11.20 ± 0.54	7.63 ± 0.13	5.79	4.15 ± 0.68	1.65 ± 0.49	1.59 ± 0.41
Week 3, Day 5	0.41 ± 0.08	14.96 ± 2.49	7.04	5.28	3.52 ± 0.41	1.78 ± 0.08	0.98 ± 0.52
Week 3, Day 6	0.86 ± 0.17						
Week 4, Day 1	0.37 (70 hours post)						

TABLE XIX

Tetrachloroethylene (PCE) Concentrations in Blood at Various Exposure Vapor Levels

GROUP I EXPOSURE TIME 7-1/2 HOURS NUMBER OF SUBJECTS: 4 Males

Exposure Week	Exposure Day	Concentration of PCE in Chamber in ppm	Mean Concentration of PCE in Blood in ppm: Pre-exp. Base Line	Right Before Leaving Chamber	15 minutes Post Exposure
1	5	0	0	0	0
2	1	100	0	0.62	0.90
2	5	100	0.17	1.12	--
3	2	20	0.20	0.71	0.38
3	5	20	0.16	0.66	0.80
4	1	100F*	0.18	2.98	2.33
4	5	100F*	0.15	2.53	2.98
5	1	150	0.65	4.88	4.53
5	5	150	0.83	2.90	2.05
6	1	0	0.86	0.67	0.74

* Fluctuating

TABLE XX

Tetrachloroethylene (PCE) Concentrations in Blood at Various Exposure Vapor Levels

GROUP II EXPOSURE TIME 3 HOURS NUMBER OF SUBJECTS: 3 Males

Exposure Week	Exposure Day	Concentration of PCE in Chamber in ppm	Mean Concentration of PCE in Blood in ppm: Pre-exp. Base Line	Right Before Leaving Chamber	15 minutes Post Exposure
1	5	0	0	0	0
2	1	100	0	0.52	1.10
2	5	100	0.10	1.10	--
3	2	20	0.07	0.37	0.35
3	5	20	0.09	0.64	0.55
4	1	100F*	0.08	2.38	1.50
4	5	100F*	0.05	2.95	1.55
5	1	150	0.14	2.84	2.82
5	5	150	0.44	2.00	2.55
6	1	0	0.31	0.20	0.35

* Fluctuating

TABLE XXI

Tetrachloroethylene (PCE) Concentrations in Blood at Various Exposure Vapor Levels

GROUP III EXPOSURE TIME 1 HOUR NUMBER OF SUBJECTS: 3 Males

Exposure Week	Exposure Day	Concentration of PCE in Chamber in ppm	Mean Concentration of PCE in Blood in ppm: Pre-exp. Base Line	Right Before Leaving Chamber	15 minutes Post Exposure
1	5	0	0	0	0
2	1	100	0	0.21	0.29
2	5	100	0.05	0.92	--
3	2	20	0.11	0.24	0.11
3	5	20	0.05	0.48	0.33
4	1	100F*	0.01	1.58	0.99
4	5	100F*	0.01	1.58	1.03
5	1	150	0.08	3.05	2.40
5	5	150	0.08	2.07	1.93
6	1	0	0.13	0.13	0.15

* Fluctuating

TABLE XXII

TETRACHLOROETHYLENE (PCE) CONCENTRATIONS IN BLOOD OF FEMALE SUBJECTS

EXPOSURE CONCENTRATION: 100 ppm (WEEK 3)

MEANS AND STANDARD DEVIATIONS IN PPM

Exposure Groups			Pre-Exposure*		Immed. Post Exp.		15 min. Post Exp.	
			Day 1	Day 5	Day 1	Day 5	Day 1	Day 5
Gp I	4 Subj.	$7\frac{1}{2}$ hrs.	0	0.30±0.04	1.33±0.03	1.22±0.22	0.95±0.23	0.96±0.15
Gp II	2 Subj.	3 hrs.	0	< 0.05	1.27±0.04	1.05**	0.84±0.04	0.77±0.06
Gp III	2 Subj.	1 hr.	0	< 0.05	1.07±0.01	0.50±0.03	0.57±0.10	0.50**

* On day 1, week 4, the tetrachloroethylene in blood for all subjects was determined and was found to be < 0.05 ppm in all cases.

** Sample from one subject only.

TABLE XXIII

ANALYSIS OF URINE FOR TRICHLOROACETIC ACID (TCA)
AND TRICHLOROETHANOL (TCEt)

Exposure				No.	Urine	TCA		TCEt	
Group	Week	Day	ppm PCE		Volume, ml.	mg/ml.	total, mg.	mg/ml.	total, mg.
Males, I	5	4	150	118	1450	< 0.001	< 2	< 0.001	< 2
				163	550	< 0.001	< 1	< 0.001	< 1
				164	1150	< 0.001	< 2	< 0.001	< 2
				165	350	< 0.001	< 1	< 0.001	< 1
Males, I	5	5	150	118	300	0.008	2.4	< 0.001	< 1
				163	550	< 0.001	< 1	< 0.001	< 1
				164	1050	< 0.001	< 2	< 0.001	< 2
				165	450	< 0.001	< 1	< 0.001	< 1
Females, I	3	3	100	116	1600	< 0.001	< 2		
				192	1850	< 0.001	< 2		
				198	1830	< 0.001	< 2		
				201	1100	< 0.001	< 2		
Females, I	3	5	100	116	2230	< 0.001	< 3	< 0.001	< 3
				192	2100	0.001	2.1	< 0.001	< 3
				198	2190	0.001	2.2	< 0.001	< 3
				201	790	< 0.001	< 1	< 0.001	< 1

TABLE XXIV

MEAN AND SEM OF PARAMETERS MEASURED AT REST ON FOUR MALE SUBJECTS TO EVALUATE THE EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE ON PULMONARY AND CARDIAC FUNCTION

Day & Condition		FVC 1-BTPS	FEV_1 % of FVC	PEFR 1/sec	MMEF 1/sec	$\dot{V}_E$ 1/min	Pa_{CO_2} mmHg	PA_{O_2} mmHg	pHa	D_LCO/V_A ml/min/mmHg 1-STPD	HR Beats/ Min.
Week 1, Day 4	$\bar{X}$	5.78	80.7	11.8	4.76	7.56	38.4	101.9	7.391	6.6	71
0 ppm	SEM	0.33	2.5	0.7	0.5	0.5	0.4	0.5	0.009	0.4	6.7
Week 2, Day 4	$\bar{X}$	5.84	79.6	11.3	4.64	7.67	40.0	100.7	7.375	6.7	64
100 ppm	SEM	0.32	3.3	0.5	0.6	0.7	0.6	0.9	0.007	0.2	6.7
Week 3, Day 4	$\bar{X}$	5.56	81.4	11.1	4.78	7.73	41.3	104.9	7.367	N.A.	62
20 ppm	SEM	0.35	3.1	0.4	0.5	0.3	1.2	1.7	0.006		3.8
Week 4, Day 4	$\bar{X}$	5.98	76.5	11.4	4.1	8.4	40.8	103.6	7.378	6.6	67
100 ppm	SEM	0.26	3.2	0.5	0.6	0.5	1.3	1.3	0.006	0.2	4.5
Week 5, Day 4	$\bar{X}$	5.73	81.2	11.1	4.6	8.2	39.0	N.A.	7.405	5.9	73
150 ppm	SEM	0.25	3.6	0.6	0.6	0.4	0.6		0.012	0.4	4.6
Week 6, Day 2	$\bar{X}$	5.66	79.1	11.1	4.3	7.22	39.1	101.6	7.374	6.7	66
0 ppm	SEM	0.27	1.9	0.2	0.5	0.2	0.2	1.8	0.007	3.3	7.5

FVC	Maximum volume of air exhaled after a maximum inspiration, in liters at body temperature and pressure, saturated.
FEV_1	Percent of FVC exhaled in one second.
PEFR	Maximum rate of air flow during FVC maneuver.
MMEF	Maximum rate of air flow at mid-point of FVC.
$\dot{V}_E$	Volume of air exhaled from lungs each minute
Pa_{CO_2}	Partial pressure of CO_2 in arterial blood.
PA_{O_2}	Calculated partial pressure of O_2 in the lungs.
pHa	Reflects the acid-base status of arterial blood.
D_LCO/VA	Capability of CO to move from the lungs to the blood per unit lung volume, at standard temperature and pressure, dry.
HR	Number of heart beats per minute.
N.A.	Not available.

TABLE XXV

MEAN AND SEM OF PARAMETERS MEASURED ON FOUR SUBJECTS DURING TWO LEVELS OF EXERCISE TO EVALUATE THE EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE ON PULMONARY AND CARDIAC FUNCTION

Day & Condition	$\dot{V}_{O_2}$ l/min STPD	$\dot{V}_E$ l/min BTPS	Pa_{CO_2} mmHg	PA_{O_2} mmHg	pHa	D_LCO/V_A ml/min/mmHg l-STPD	HR Beats/ min.
			350 KPM				
wk 1, day 4	1.16	30.3	38.7	107.4	7.363	7.5	112
0 ppm	0.06	1.7	2.2	2.4	0.01	0.2	3.8
wk 2, day 4	1.10	33.7	38.5	102.1	7.359	7.6	110.7
100 ppm	0.05	3.3	1.5	2.8	0.003	0.2	9.3
wk 3, day 4	1.29	34.7	41.6	100.9	7.340	N.A.	115.3
20 ppm	0.18	3.0	0.7	7.6	0.008		1.8
wk 4, day 4	1.20	33.7	41.7	104.4	7.353	7.7	113.8
100 ppm	0.04	2.3	1.8	1.7	0.014	0.2	6.3
wk 5, day 4	1.45	34.6	40.8	95.0	7.379	7.4	115.5
150 ppm	0.11	2.9	0.8	3.7	0.006	0.3	6.0
wk 6, day 2	1.34	34.0	39.5	101.6	7.347	7.5	110.0
0 ppm	0.13	2.4	1.4	0.3	0.006	0.1	4.4
			750 KPM				
wk 1, day 4	1.75	47.8	37.6	111.2	7.339	8.7	141
0 ppm	0.59	2.9	1.2	1.3	0.006	0.2	6.6
wk 2, day 4	1.93	54.8	39.0	106.7	7.335	8.4	147
100 ppm	0.12	4.0	1.4	3.0	0.015	0.2	3.0
wk 3, day 4	2.13	63.6	38.7	109.0	7.326	N.A.	149
20 ppm	0.19	4.0	1.0	2.1	0.010		9.1
wk 4, day 4	1.97	57.3	39.8	108.8	7.343	8.7	144
100 ppm	0.07	4.3	1.2	1.4	0.008	0.2	7.1
wk 5, day 4	2.21	61.8	39.5	104.2	7.347	8.6	148
150 ppm	0.11	4.9	1.3	1.4	0.007	0.3	5.5
wk 6, day 2	2.10	58.3	37.8	107.0	7.341	8.3	143
0 ppm	0.15	3.3	1.1	1.4	0.004	0.3	6.7

Abbreviations are as indicated in Table XXIV.

$\dot{V}_{O_2}$ = Oxygen utilization per minute.

TABLE XXVI

ELECTRODE POSITIONING FOR EEG RECORDINGS

Numerical Designation	Position
1-9	Right frontal to right parietal
3-11	Left frontal to left parietal
11-14	Left parietal to left occipital
9-13	Right parietal to right occipital
9-5	Right parietal to right temporal
11-7	Left parietal to left temporal
16-A_2	Inion to left ear

TABLE XXVII

EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE (PCE) ON PERFORMANCE OF ALERTNESS TEST

Paired t-test Comparison of Performance on PCE vs. Mean of Two Zero Exposure Days

MALES

		Week 3, 20 ppm				Week 2, 100 ppm				(Fluctuating) Week 4, 100 ppm				Week 5, 150 ppm			
		Day 2		Day 4		Day 2		Day 4		Day 2		Day 4		Day 2		Day 4	
		t	df	t	df	t	df	t	df	t	df	t	df	t	df	t	df
Group I 7-1/2 hr.	Percent Correct	.303	3	-.630	3	-1.492	3	-.538	3	.662	3	2.10	3	-.095	3	1.428	3
	Average Reaction Time	0.000	3	1.769	2	.449	3	.891	2	-1.153	2	-1.084	3	-.852	3	2.949*	3
Group II 3 hr.	Percent Correct	3.288*	2	.441	2	-.124	2	.247	2	2.375	1	1.664	2	1.509	2	1.125	2
	Average Reaction Time	-1.355	2	.282	2	-1.850	2	-.552	2	-1.438	1	-1.068	2	-1.867	2	-.933	2

FEMALES

		Week 3, 100 ppm			
		Day 2		Day 4	
		t	df	t	df
Group I 7-1/2 hr.	Percent Correct	-.391	3	.514	3
	Average Reaction Time	-.268	3	-1.939	3

* $P < 0.05$

TABLE XXVIII

Paired t Test Values for Comparison of Control
with
Exposure Test Performance
for
$7\frac{1}{2}$ hour/day Exposed Groups

		TETRACHLOROETHYLENE CONCENTRATION, PPM							
		20		100		100 fluctuating		150	
Test		t	df	t	df	t	df	t	df
Marquette:	E/S	-1.00	3	-1.11	3	-0.82	3	-1.43	3
Sound	|E-S|	-1.18	3	-1.43	3	-0.96	3	-1.26	3
Stimulus	R x T	0.98	2	0.60	3	0.46	3	0.12	3
Light	E/S	1.85	3	0.68	3	-0.03	3	-0.51	3
Stimulus	|E-S|	-1.14	3	-1.16	3	-0.50	3	0.99	3
	R x T	0.18	3	0.83	3	0.35	3	0.32	3
10 Second Estimations		-7.97**	3	-2.20	3	-3.33*	3	-2.82	3
30 Second Estimations		-0.67	3	-1.76	3	-1.09	3	0.16	3
Coordination Test		0.35	3	1.72	3	0.79	3	4.19*	3
Inspection Test		0.72	3	1.30	3	0.90	3	0.60	3
Arithmetic Test		-1.08	3	-0.24	3	0.62	3	-0.02	3

* $P < 0.05$
** $P < 0.01$

TABLE XXIX

Paired t Test Values for Comparison of Control
with
Exposure Test Performance
for
3 hour/day Exposed Groups

		TETRACHLOROETHYLENE CONCENTRATION, PPM							
		20		100		100 fluctuating		150	
	Test	t	df	t	df	t	df	t	df
Marquette:	E/S	0.42	2	0.30	2	0.31	2	0.73	2
Sound Stimulus	|E-S|	-0.80	2	-0.33	2	-0.23	2	-1.52	2
	R x T	1.18	2	-1.45	2	-0.08	2	0.10	2
Light Stimulus	E/S	-0.18	2	-0.84	2	-0.72	2	-0.37	2
	|E-S|	-1.22	2	-1.29	2	-0.38	2	-0.06	2
	R x T	1.24	2	1.59	2	2.21	2	0.02	2
10 Second Estimations		-0.44	2	-0.44	2	-0.31	2	-0.20	2
30 Second Estimations		-1.49	2	-3.21	2	-0.83	2	-0.99	2
Coordination Test		0.61	2	1.81	2	1.78	2	1.02	2
Inspection Test		1.12	2	0.82	2	0.80	2	-0.71	2
Arithmetic Test		1.16	2	2.40	2	0.80	2	0.93	2

TABLE XXX

THE EFFECT OF ETHYL ALCOHOL (BEER*) ON THE BLOOD LEVEL OF TETRACHLOROETHYLENE (PCE) OF SUBJECTS EXPOSED TO THE VAPOR OF PCE

Subject No.	Concentration of PCE in Chamber in ppm	Concentration of PCE in Blood in ppm			Concentration of Ethyl Alcohol in Blood in mg %		
		Start 0 hours	30 minutes	60 minutes	Start 0 hours	30 minutes	60 minutes
118	150	3.90	3.30	3.60	0	2	10
163 (control)	150	4.10	4.05	4.10	0	0	0
165	150	4.10	4.10	4.10	0	2	10

*Except subject No. 163 as control, subjects No. 118 and 165 were given 1 quart of Schlitz beer at 3:30 p.m. after they were being exposed with PCE vapor for 6-1/2 hours.

TABLE XXXI

NUMBER OF SUBJECTIVE RESPONSES* TO TETRACHLOROETHYLENE (PCE)

MALES

ppm PCE	0	20	100s	100f	150	total during exp. to PCE
days, # of	5	4	5	5	5	19
Gp I - 7½ hr.						
# subjects	4	4	4	4	4	
# exp. days	19	15	19	20	18	72
# responses	11(7)**	3[0]+	14[10]	4[3]	5[1]	26(13)
Gp II - 3 hr.						
# subjects	3	3	3	3	3	
# exp. days	14	12	15	11	13	51
# responses	2(1)	3[1]	1[0]	2[1]	2[1]	8(8)
Gp III - 1 hr.						
# subjects	3	3	3	3	3	
# exp. days	15	12	15	14	12	53
# responses	0	1[1]	6[4]	0	2[0]	9(2)

FEMALES

ppm PCE	0	100s
days, # of	2	6
Gp I - 7½ hr.		
# subjects	4	4
# exp. days	7	22
# responses	8(2)	4(0)[1]
Gp II - 3 hr.		
# subjects	3	3
# exp. days	3	9
# responses	3(2)	12(8)[5]
Gp III - 1 hr.		
# subjects	2	2
# exp. days	4	11
# responses	1(1)	2(2)[1]

*
** Excluding odor responses
\+ Numbers in parentheses represent headache responses
Numbers in brackets represent responses on first day of exposure to this concentration

TABLE XXXII

THE EFFECT OF EXERCISE ON THE BLOOD CONCENTRATION OF TETRACHLOROETHYLENE (PCE)

4 Male Subjects

Date	Concentration of PCE in Chamber in ppm	Subject No.	Concentration of PCE in Blood in ppm		Time Lapse in Minutes	Ratio of E/R
			At Rest (R)	End of Exercise* (E)		
Wk 3, Day 4	20	118	0.86	0.32	--	0.37
	20	163	0.47	0.36	--	0.77
	20	164	0.57	0.56	--	1.00
	20	165	0.44	0.40	--	0.91
Wk 4, Day 4	100F**	118	2.95	4.10	61	1.30
	100F**	163	3.05	4.10	60	1.30
	100F**	164	2.15	2.65	91	1.30
	100F**	165	1.30	4.00	17	3.00
Wk 5, Day 4	150	118	3.60	6.40	46	1.78
	150	163	4.35	7.00	50	1.61
	150	164	4.20	5.75	82	1.37
	150	165	5.00	6.40	32	1.28
Wk 6, Day 2	0	118	0.66	0.55	32	0.83
	0	163	0.49	0.25	57	0.51
	0	164	0.55	--	--	--
	0	165	0.50	0.46	29	0.92

*The exercise was carried out after the subjects had been exposed to PCE for 6 to 7 hours. The exercise period was 12 minutes; see Cardio-pulmonary Function Section for details.

**Fluctuating concentration from 50 to 150 ppm PCE.

TABLE XXXIII

A COMPARISON OF SAMPLING OF BLOOD OUT OF VERSUS IN THE CHAMBER

PCE Concentration in the Blood in ppm

Subject No.	Sampling out of Chamber			Sampling in the Chamber		
	At Rest	End of Exercise	Time Lapse in Minutes	At Rest	End of Exercise	Time Lapse in Minutes
118	4.20	7.20	50	3.60	6.40	46
163	4.35	7.20	40	4.35	7.00	50
164	4.25	6.40	95	4.20	5.75	82
165	4.50	6.60	65	5.00	6.40	32
Average	4.33	6.85		4.29	6.39	

TABLE XXXIV

THE EFFECT OF EXERCISE ON THE BLOOD CONCENTRATION OF TETRACHLOROETHYLENE (PCE)

1 Male Subject

Chamber Concentration: 150 ppm PCE

Exposure Length: 30 minutes

Concentration of Blood PCE in ppm

Sample	11-7-73 Without Exercise	11-8-73 With $\frac{1}{2}$ hr. Exercise	11-9-73 With $\frac{1}{2}$ hr. Exercise
Pre-Exposure	0.05	0.05	0.30
0 min. post	1.90	3.00	3.20
15 min. post	1.20	2.45	2.55
30 min. post	0.75	2.00	2.20
60 min. post	0.48	1.50	1.65
120 min. post	0.27	0.83	0.95
180 min. post			0.75
240 min. post			0.46
300 min. post			0.40

TABLE XXXV

THE EFFECT OF EXERCISE ON THE BREATH CONCENTRATION OF TETRACHLOROETHYLENE (PCE)
1 Male Subject

Chamber Concentration: 150 ppm PCE

Exposure Length: 30 minutes

	Concentration of Breath PCE in ppm		
Sample	11-7-73 Without Exercise	11-8-73 With ½ hr. Exercise	11-9-73 With ½ hr. Exercise
Pre-Exposure	2.68	2.27	5.41
0 min. post	23.42	47.35	42.85
15 min. post	22.60	28.23	27.00
30 min. post	8.48	20.94	21.43
60 min. post	5.80	14.11	16.28
120 min. post	3.57	10.02	11.14
180 min. post			9.43
240 min. post			8.83
300 min. post			8.07

TABLE XXXVI

TETRACHLOROETHYLENE STABILITY IN BREATH CONTAINERS

	NO. OF HOURS AFTER FILLING CONTAINERS								
	0			72			144		
Container	Saran Bag	Glass Tube	Plastic Bottle	Saran Bag	Glass Tube	Plastic Bottle	Saran Bag	Glass Tube	Glass Tube*
No. Filled	5	10	5	5	10	5	5	10	10
No. Valid	5	8	5	4	7	2	4	9	6
Mean Concentration in PPM	37.0	32.7	36.7	32.8	37.2	21.6	26.0	29.2	29.0
± SD	1.7	1.6	1.5	2.2	3.0	1.0	1.6	4.0	2.7
SEM	0.7	0.6	0.7	1.1	1.1	0.7	0.8	1.4	1.1
High	39.0	35.0	39.0	35.1	42.2	22.2	27.8	35.7	33.9
Low	34.5	29.9	35.0	29.9	34.1	20.9	24.0	25.2	26.3
% of Saran Bag at 0 Hr.	100	88	99	89	101	58	70	79	78

* Mailed

FIGURE 1

DAILY FLUCTUATION OF PCE VAPOR CONCENTRATION IN THE CHAMBER
MALES, WEEK 4

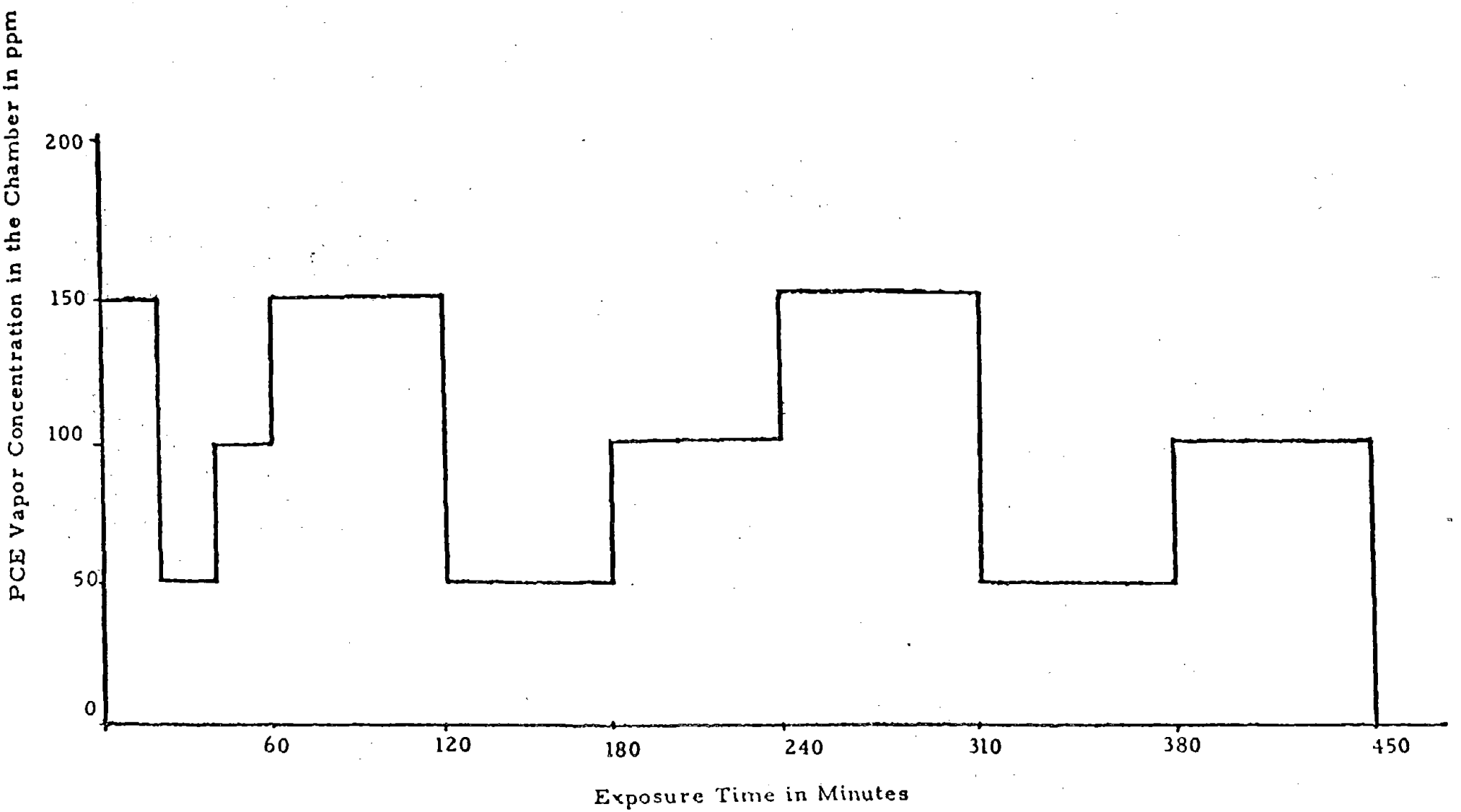
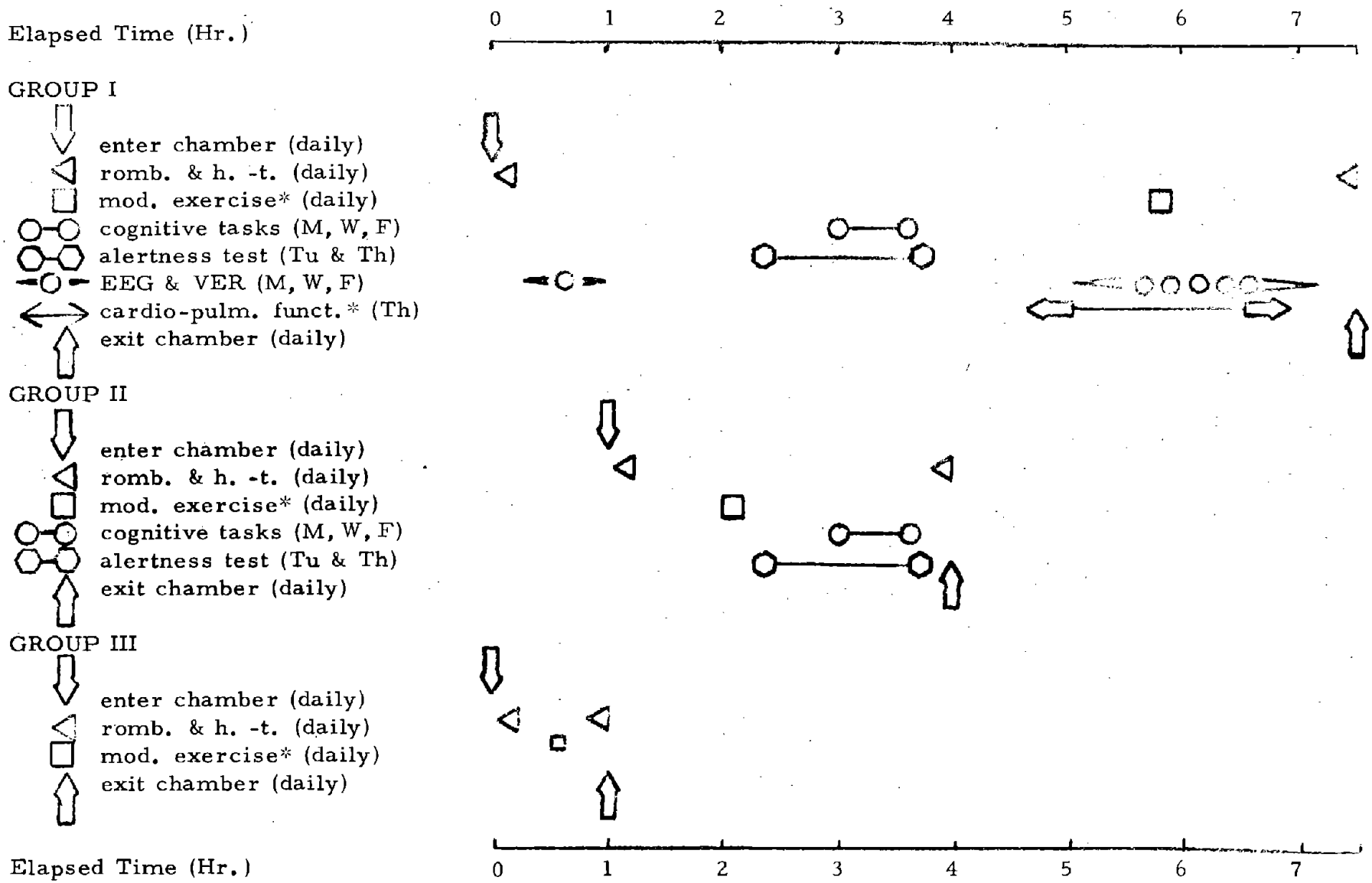


FIGURE 2

TETRACHLOROETHYLENE EXPOSURES - DAILY SCHEDULE



* Male subjects only

FIGURE 3

SPONTANEOUS EEG OF SUBJECT 118 ON DAY 5, WEEK 1 AFTER 10 MINUTES (LEFT) AND 6 HOURS 10 MINUTES (RIGHT) EXPOSURE DURING 0 PPM CONDITIONS

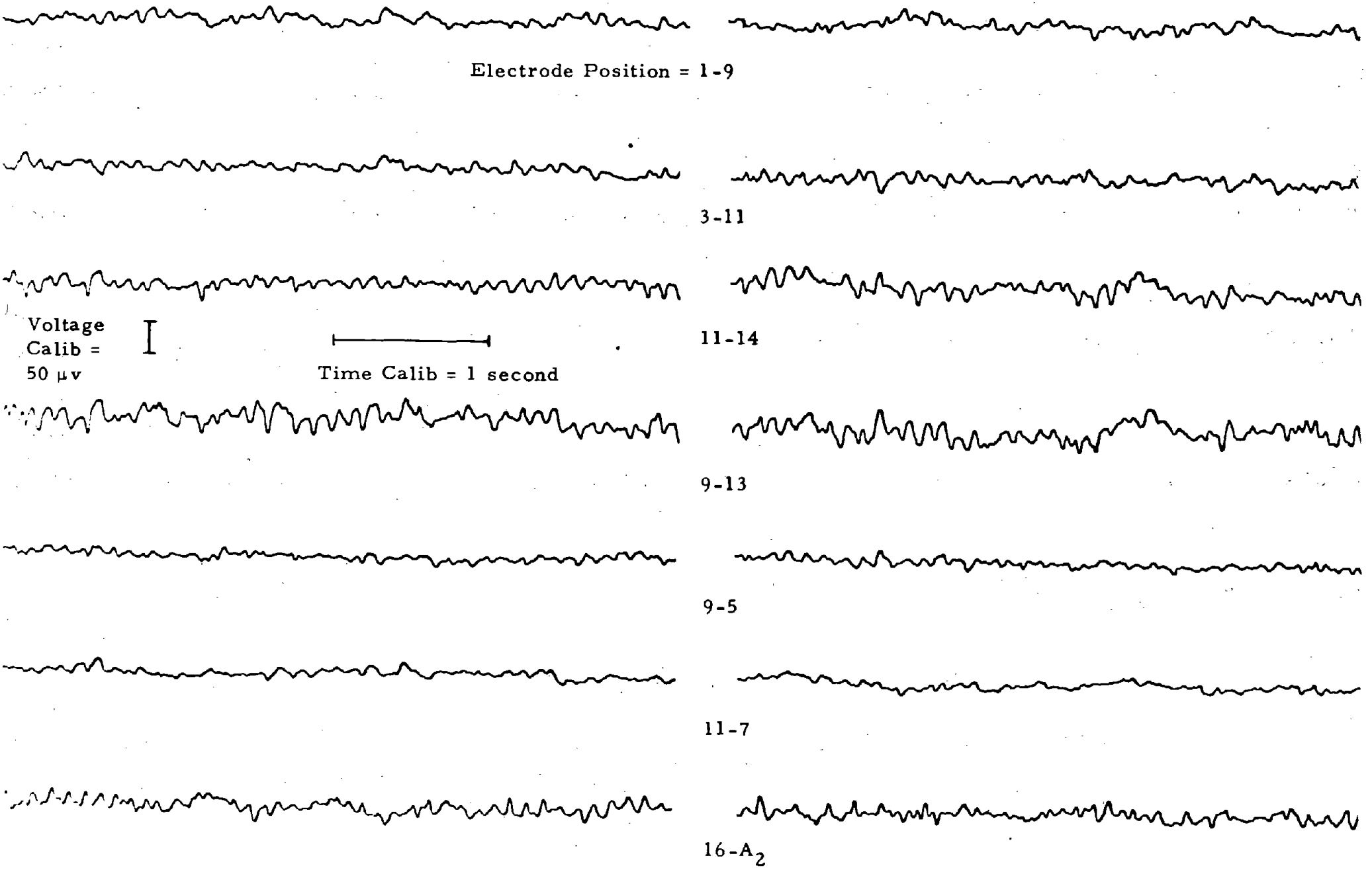


FIGURE 4

SPONTANEOUS EEG OF SUBJECT 118 ON DAY 5, WEEK 4 AFTER 10 MINUTES (LEFT) AND 4 HOURS 30 MINUTES (RIGHT) EXPOSURE DURING 100 PPM (FLUCTUATING) CONDITIONS

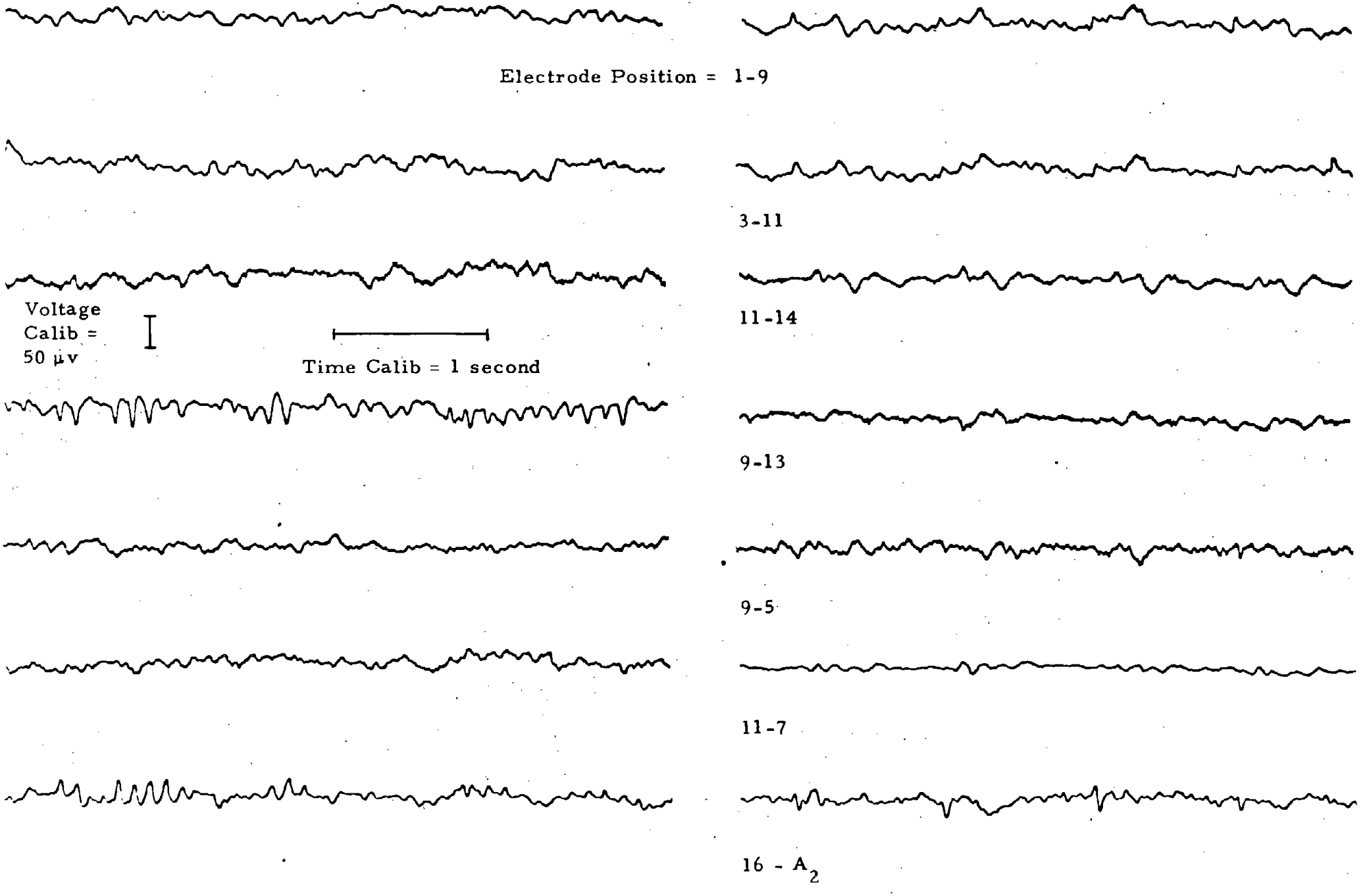


FIGURE 5

SPONTANEOUS EEG OF SUBJECT 118 ON DAY 5, WEEK 4 AFTER 5 HOURS 30 MINUTES (LEFT) AND 5 HOURS 30 MINUTES 20 SECONDS (RIGHT) EXPOSURE DURING 100 PPM (FLUCTUATING) CONDITIONS

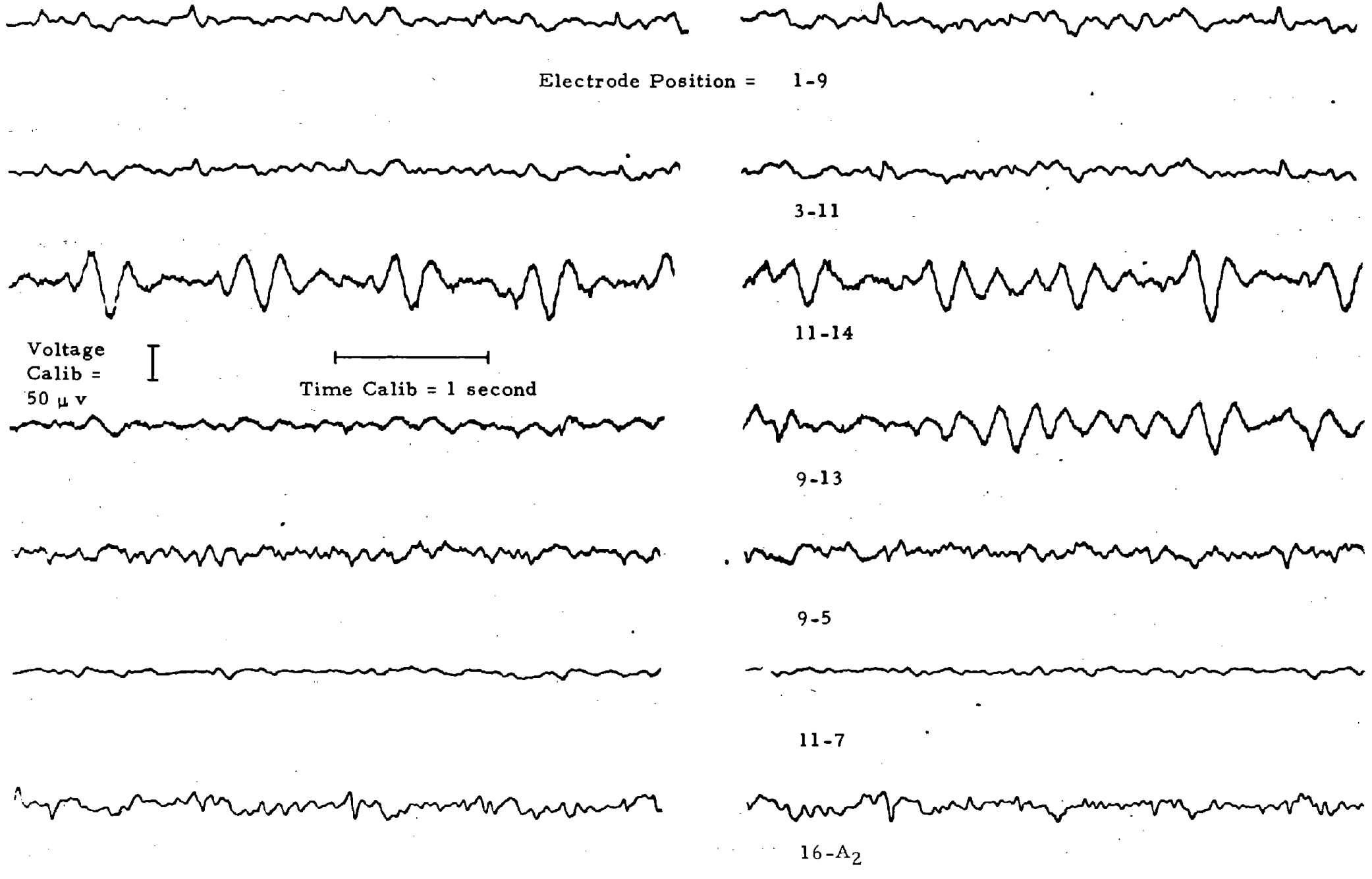


FIGURE 6

SPONTANEOUS EEG OF SUBJECT 163 ON DAY 5, WEEK 1, AFTER 40 MINUTES (LEFT) AND 6 HOURS 45 MINUTES (RIGHT) EXPOSURE DURING 0 PPM CONDITIONS

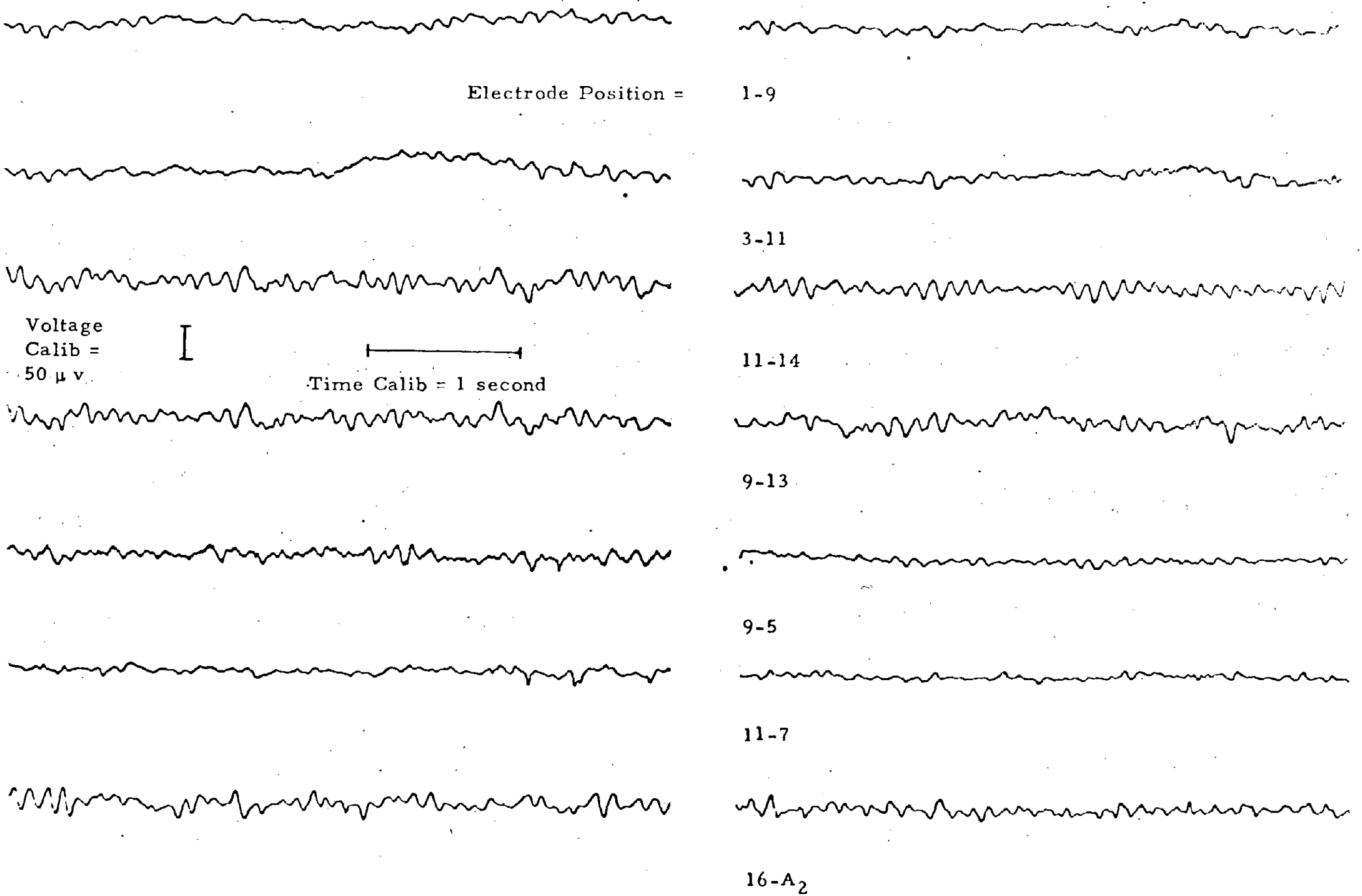


FIGURE 7
SPONTANEOUS EEG OF SUBJECT 163 ON DAY 1, WEEK 2 AFTER 10 MINUTES (LEFT) AND 5 HOURS 13 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

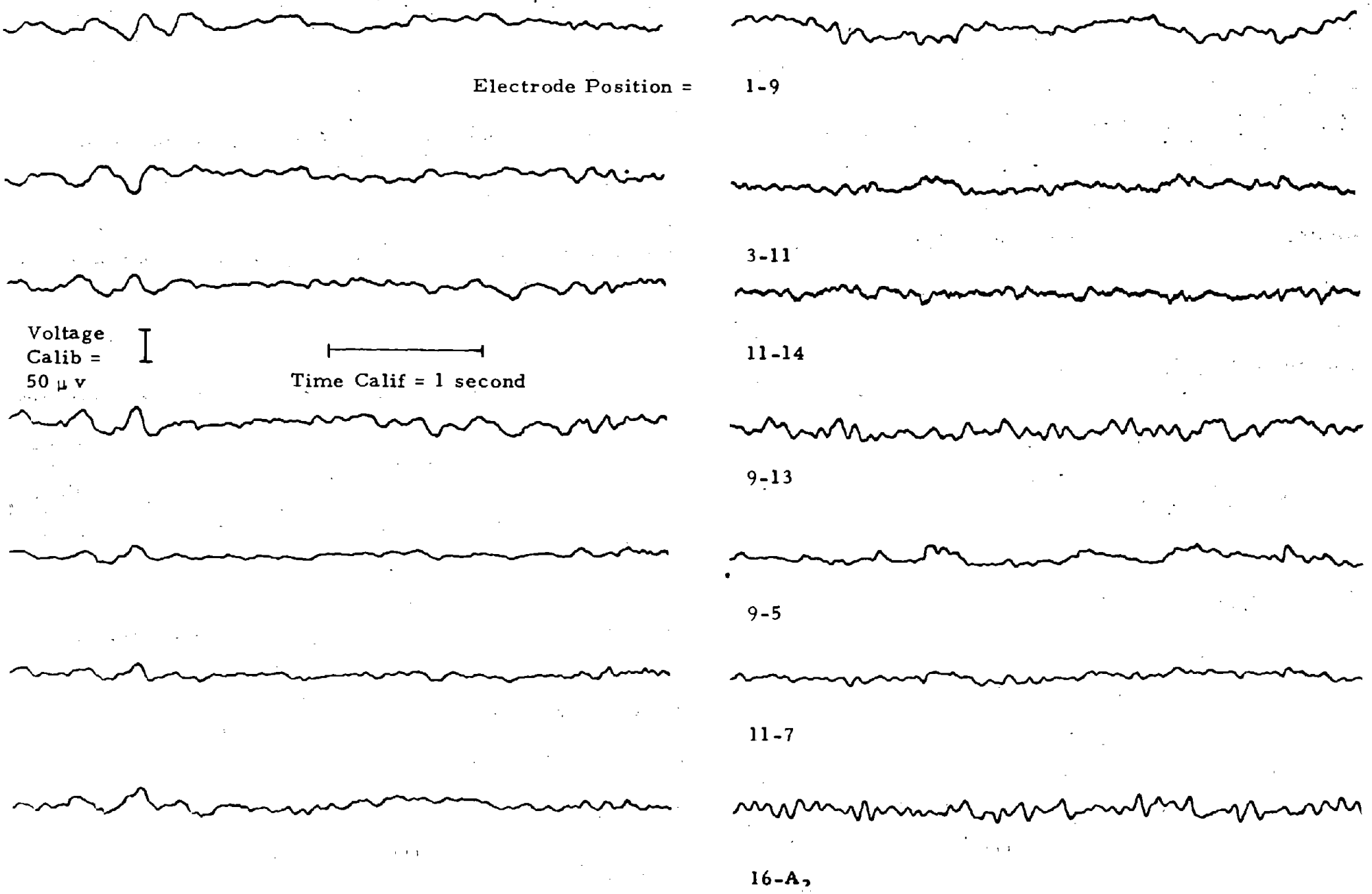


FIGURE 8

SPONTANEOUS EEG OF SUBJECT 163 ON DAY 5, WEEK 5 AFTER 50 MINUTES (LEFT) AND 5 HOURS 5 MINUTES (RIGHT) EXPOSURE DURING 150 PPM CONDITIONS

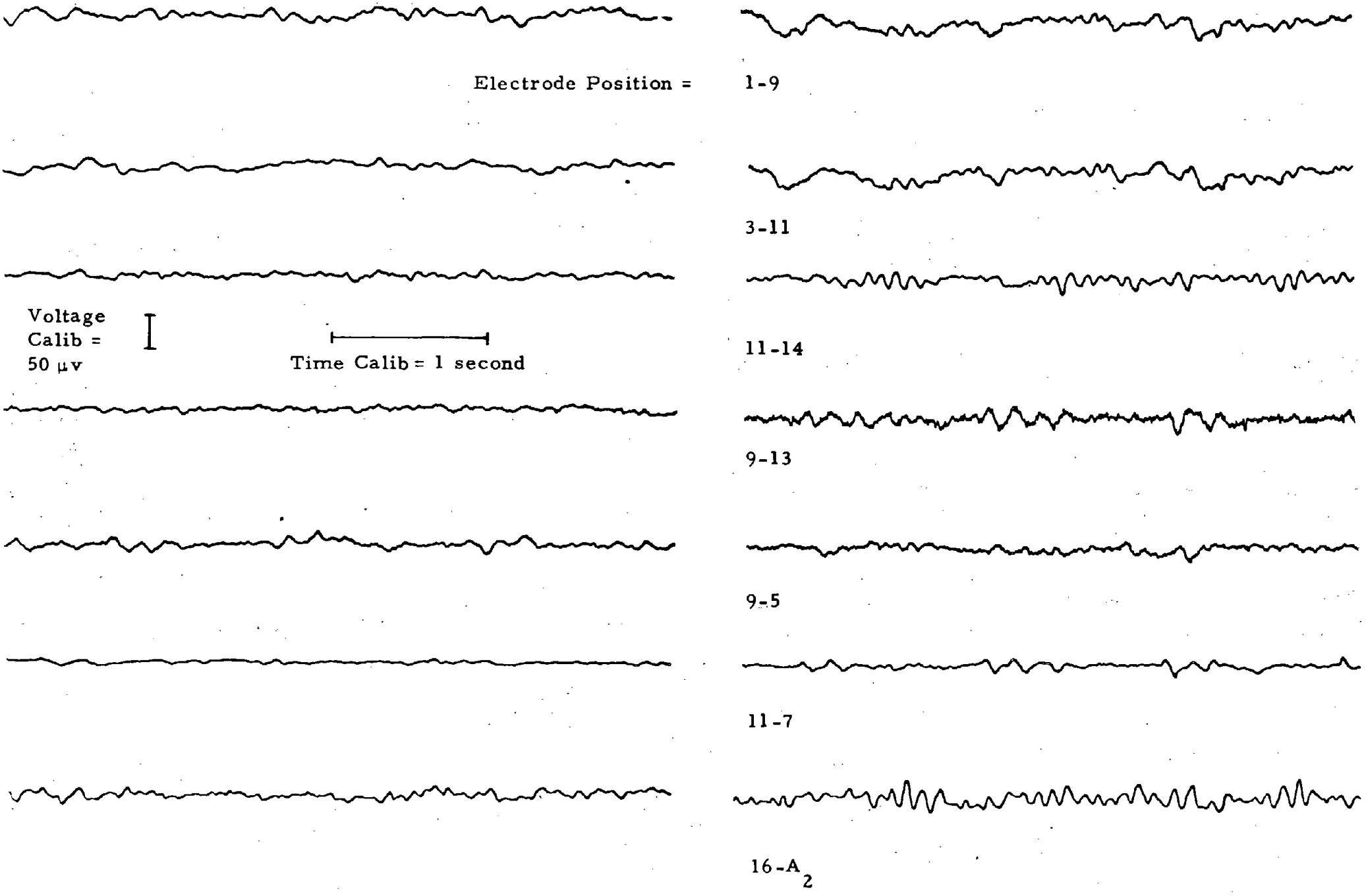


FIGURE 9

SPONTANEOUS EEG OF SUBJECT 164 ON DAY 5, WEEK 1, AFTER 45 MINUTES (LEFT) AND 5 HOURS 25 MINUTES (RIGHT) EXPOSURE DURING 0 PPM CONDITIONS

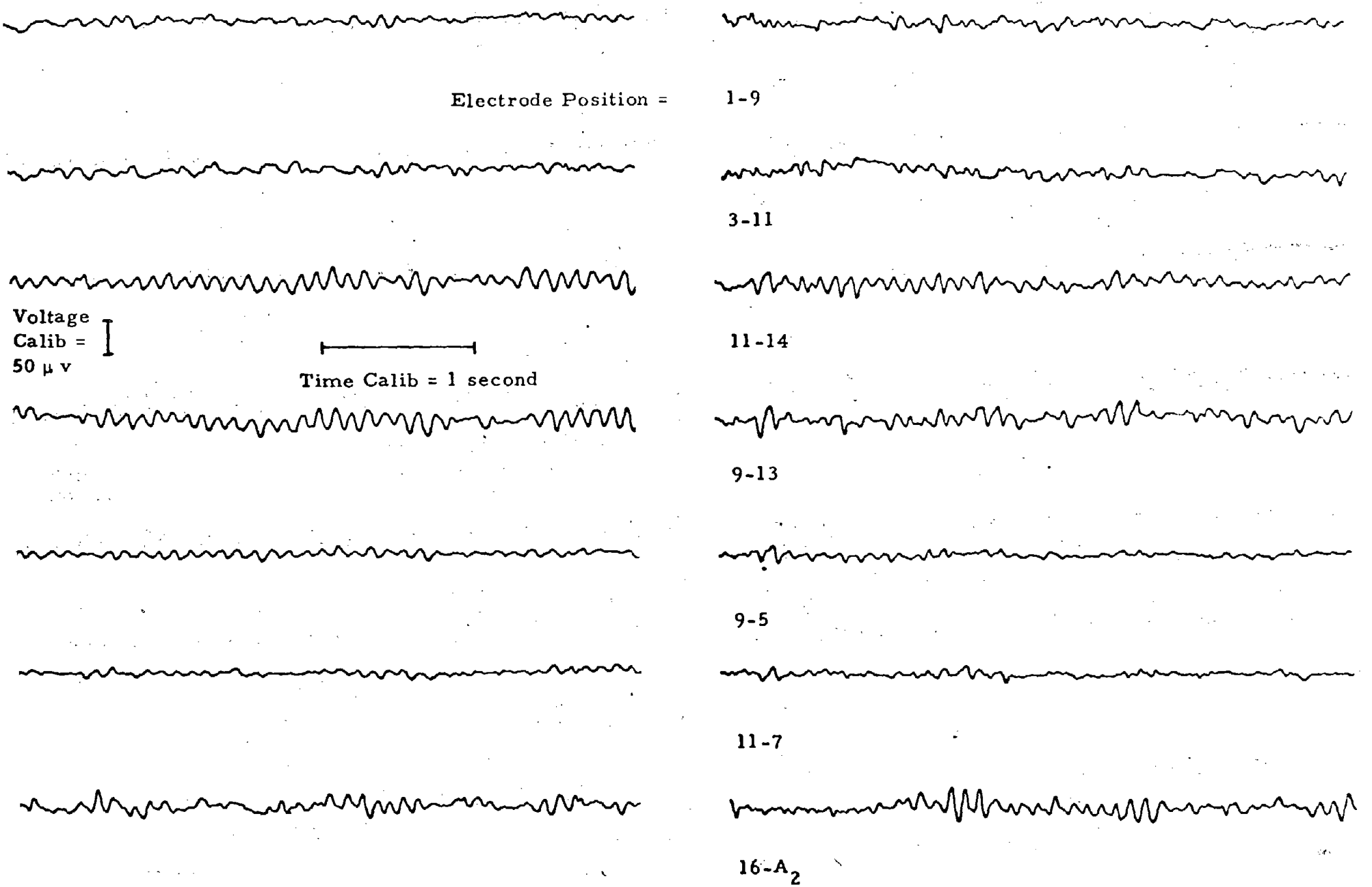


FIGURE 10
SPONTANEOUS EEG OF SUBJECT 164 ON DAY 1, WEEK 2 AFTER 30 MINUTES
(LEFT) AND 5 HOURS 22 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

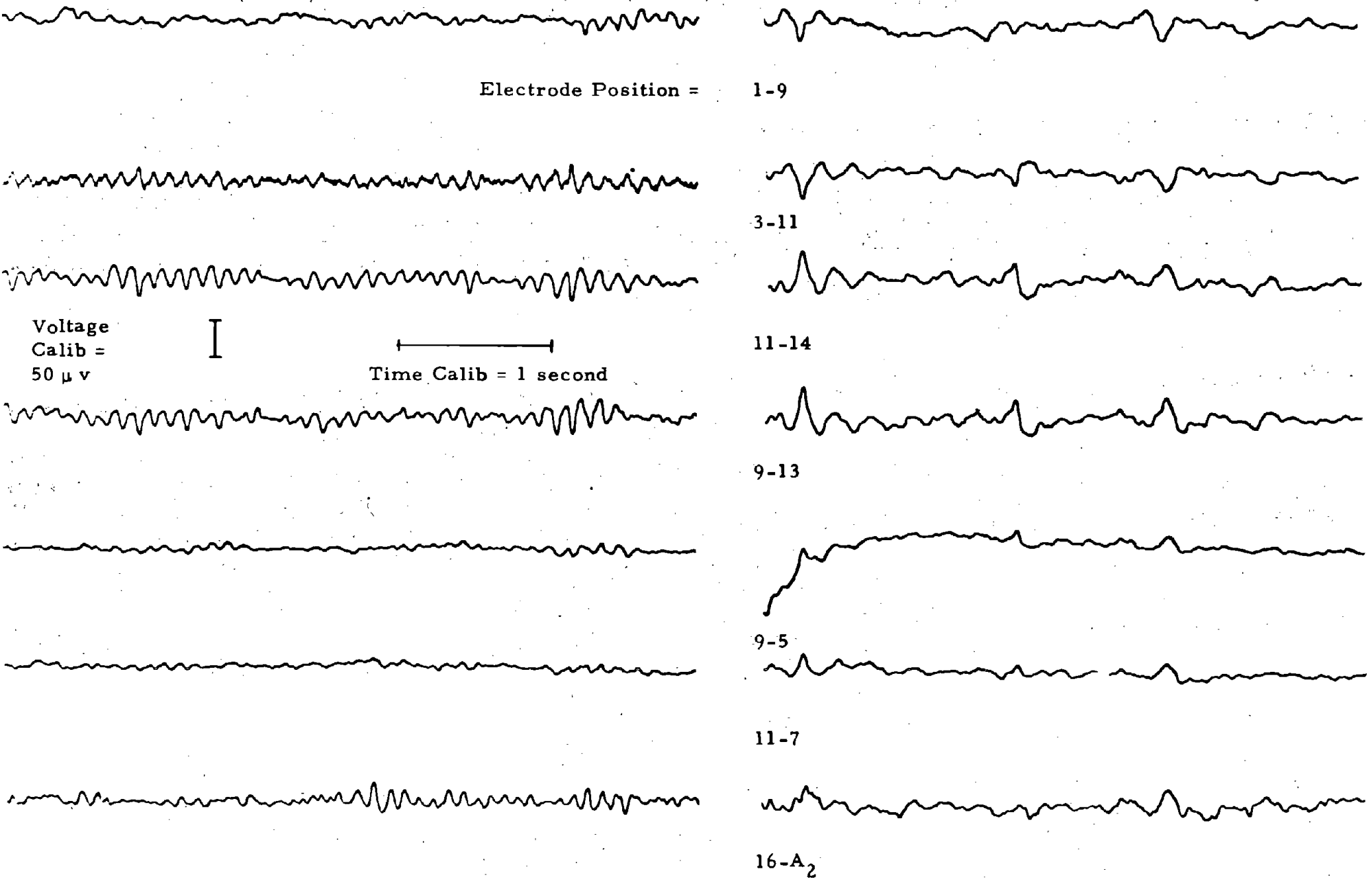


FIGURE 11
SPONTANEOUS EEG OF SUBJECT 164 ON DAY 1, WEEK 4 AFTER 30 MINUTES
(LEFT) AND 5 HOURS 20 MINUTES (RIGHT) EXPOSURE DURING 100 PPM (FLUCTUATING) CONDITIONS

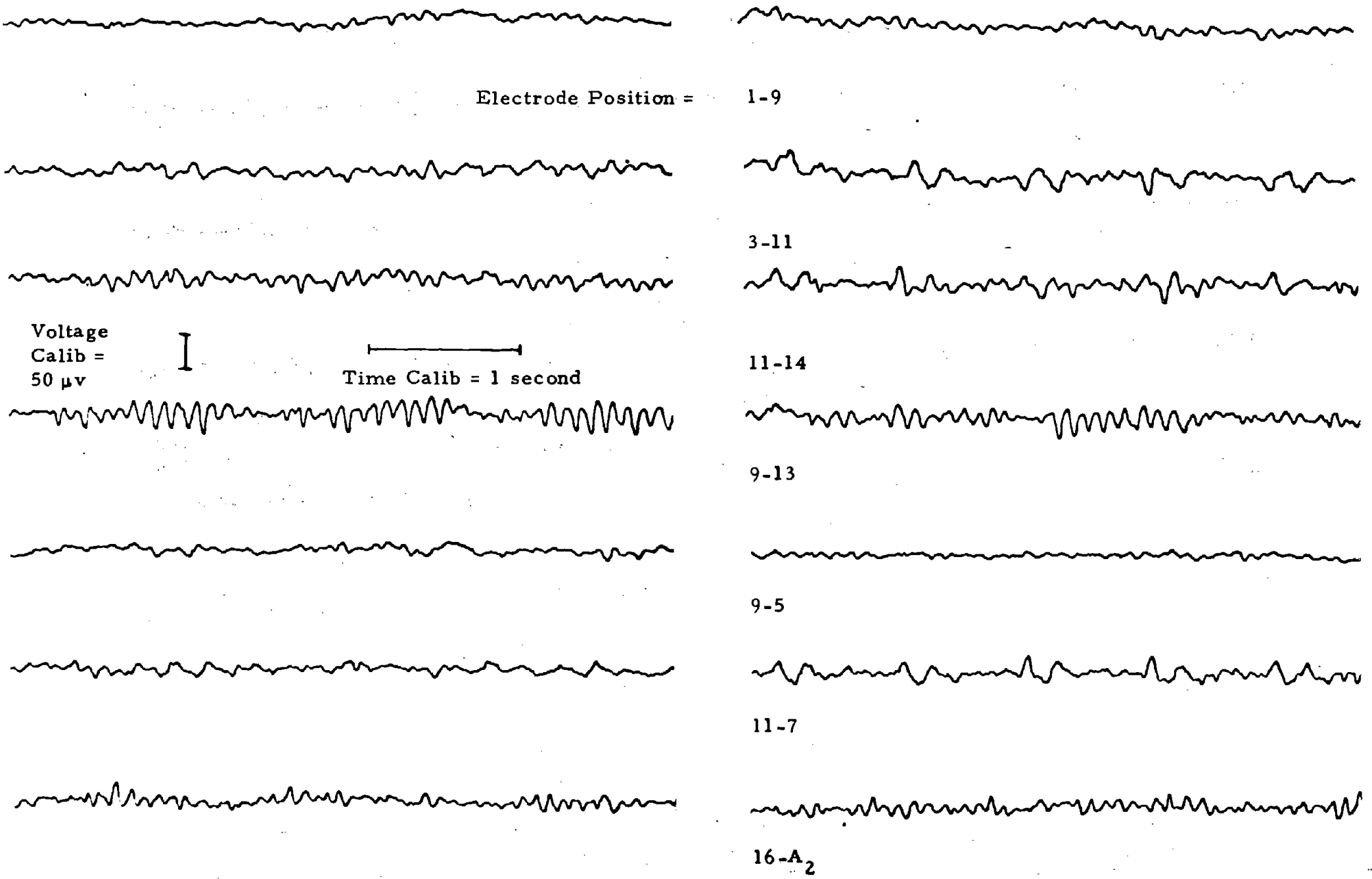


FIGURE 12
SPONTANEOUS EEG OF SUBJECT 164 ON DAY 1, WEEK 4 AFTER 7 HOURS AND 10 MINUTES EXPOSURE DURING 100 PPM (FLUCTUATING) CONDITIONS

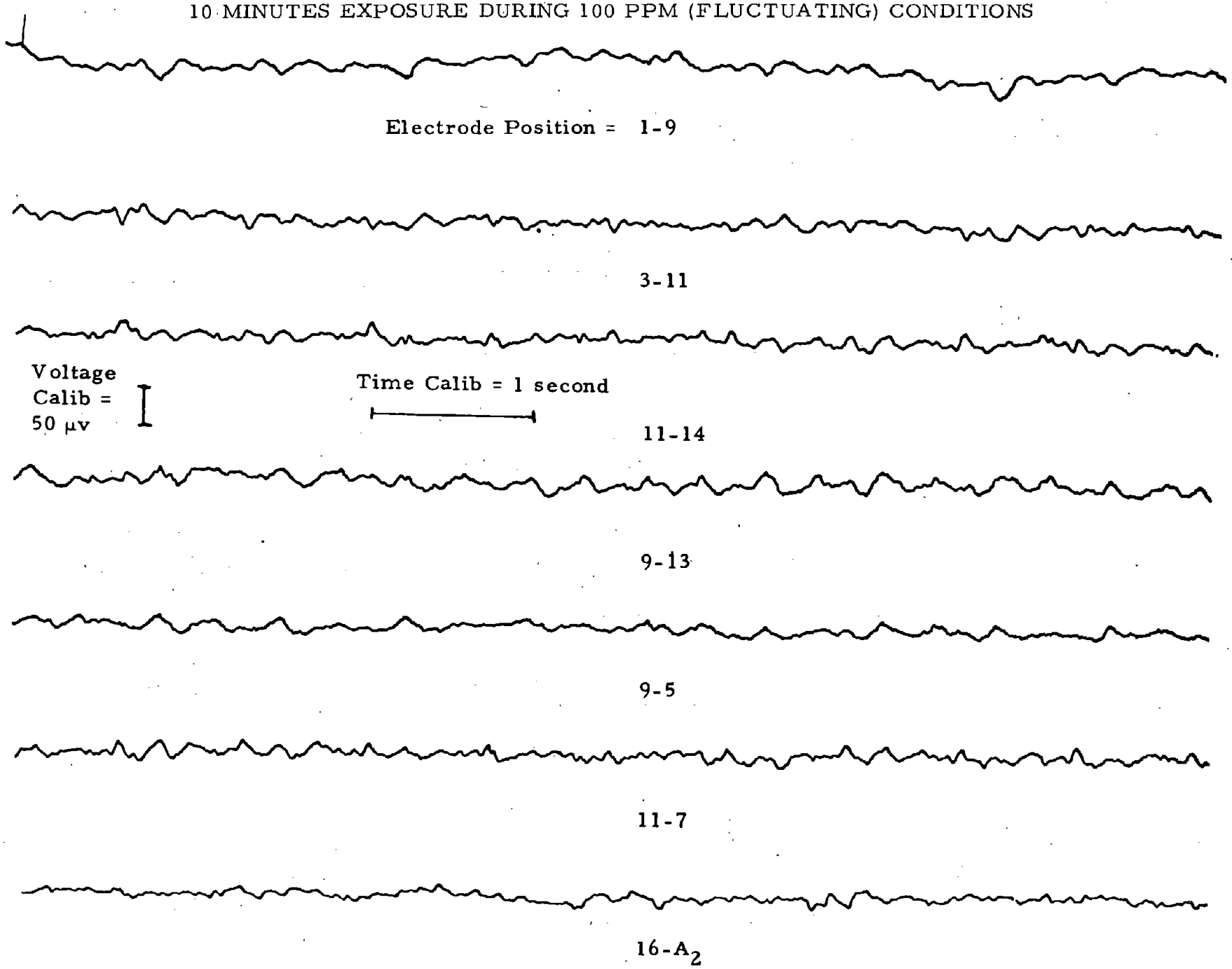


FIGURE 13
SPONTANEOUS EEG OF SUBJECT 116 ON DAY 5, WEEK 1 AFTER 10 MINUTES EXPOSURE DURING 0 PPM CONDITIONS

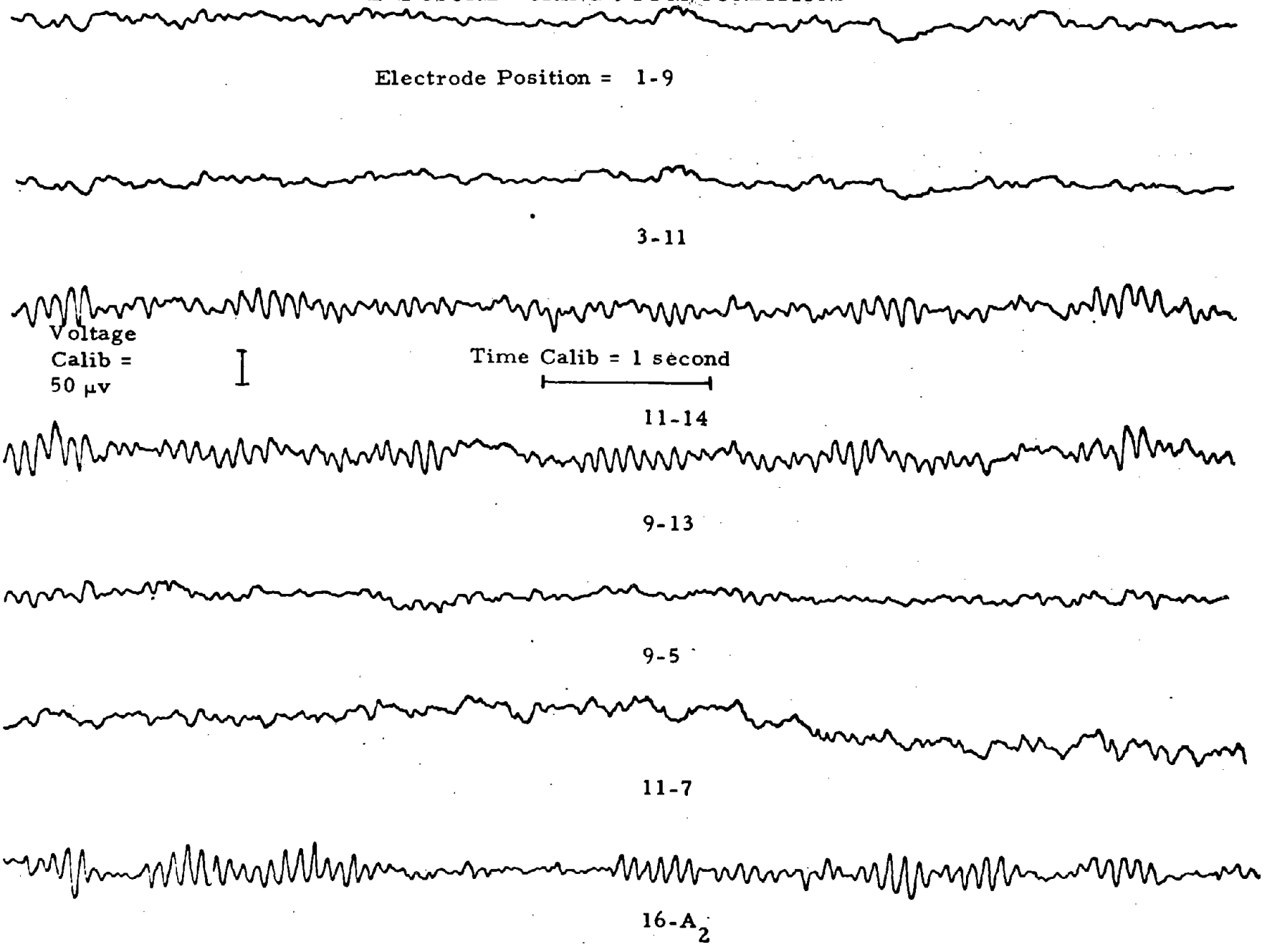


FIGURE 14

SPONTANEOUS EEG OF SUBJECT 116 ON DAY 1, WEEK 2 AFTER 10 MINUTES (LEFT) AND 6 HOURS 35 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

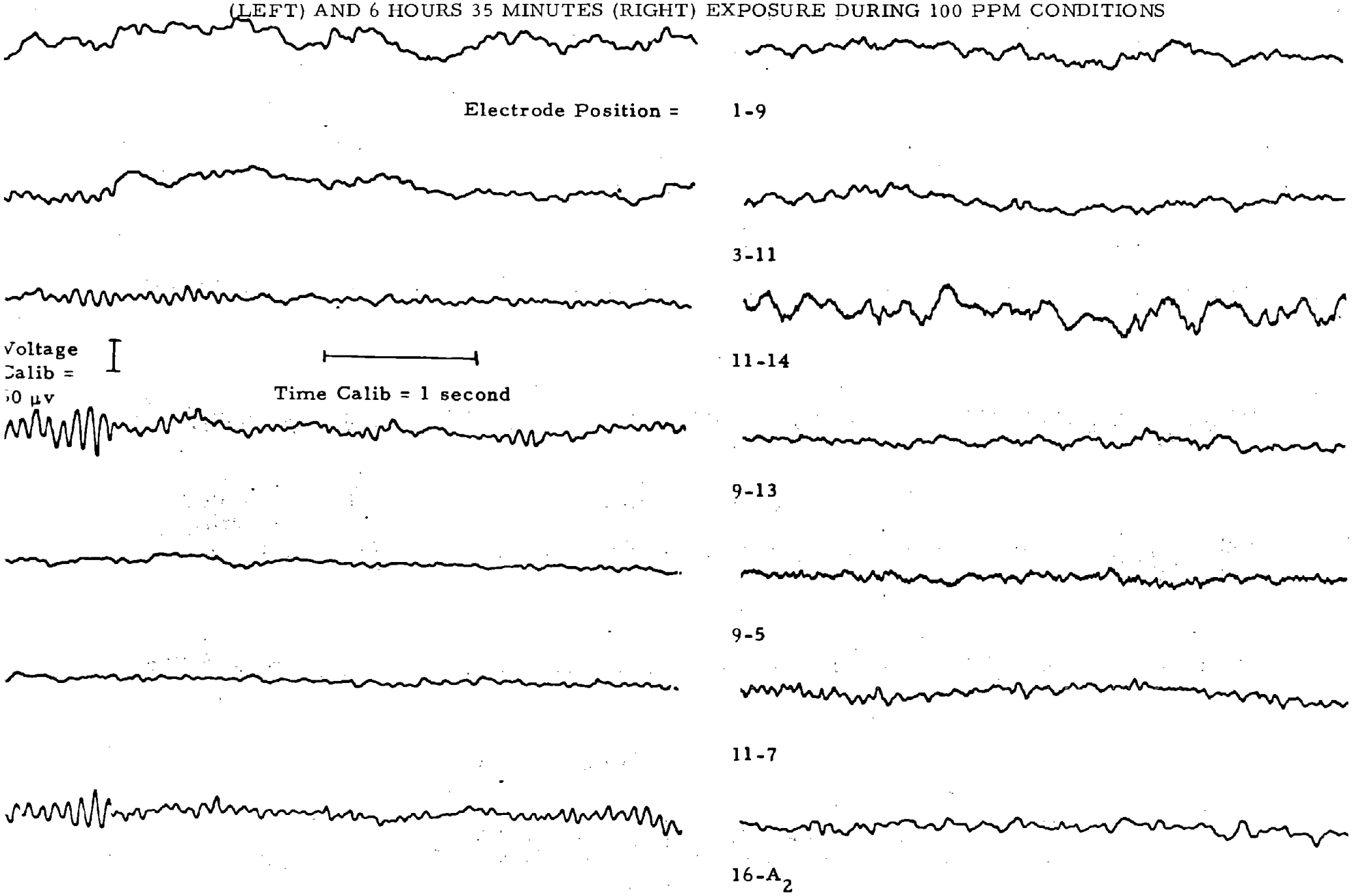


FIGURE 15
SPONTANEOUS EEG OF SUBJECT 116 ON DAY 1, WEEK 3 AFTER 10 MINUTES (LEFT) AND 4 HOURS 55 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

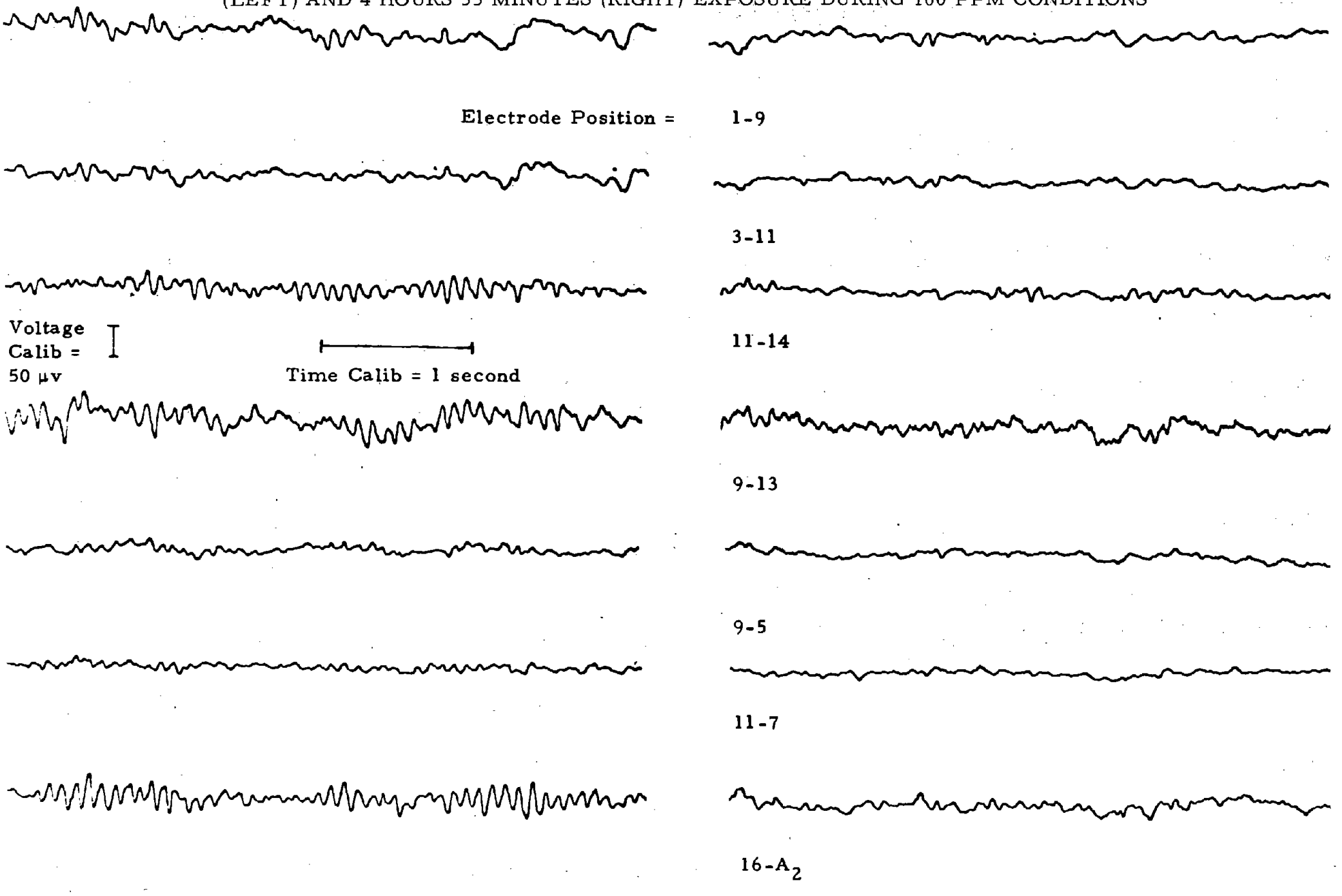


FIGURE 16
SPONTANEOUS EEG OF SUBJECT 192 ON DAY 5, WEEK 1 AFTER 20 MINUTES
(LEFT) AND 5 HOURS 5 MINUTES (RIGHT) EXPOSURE DURING 0 PPM CONDITIONS

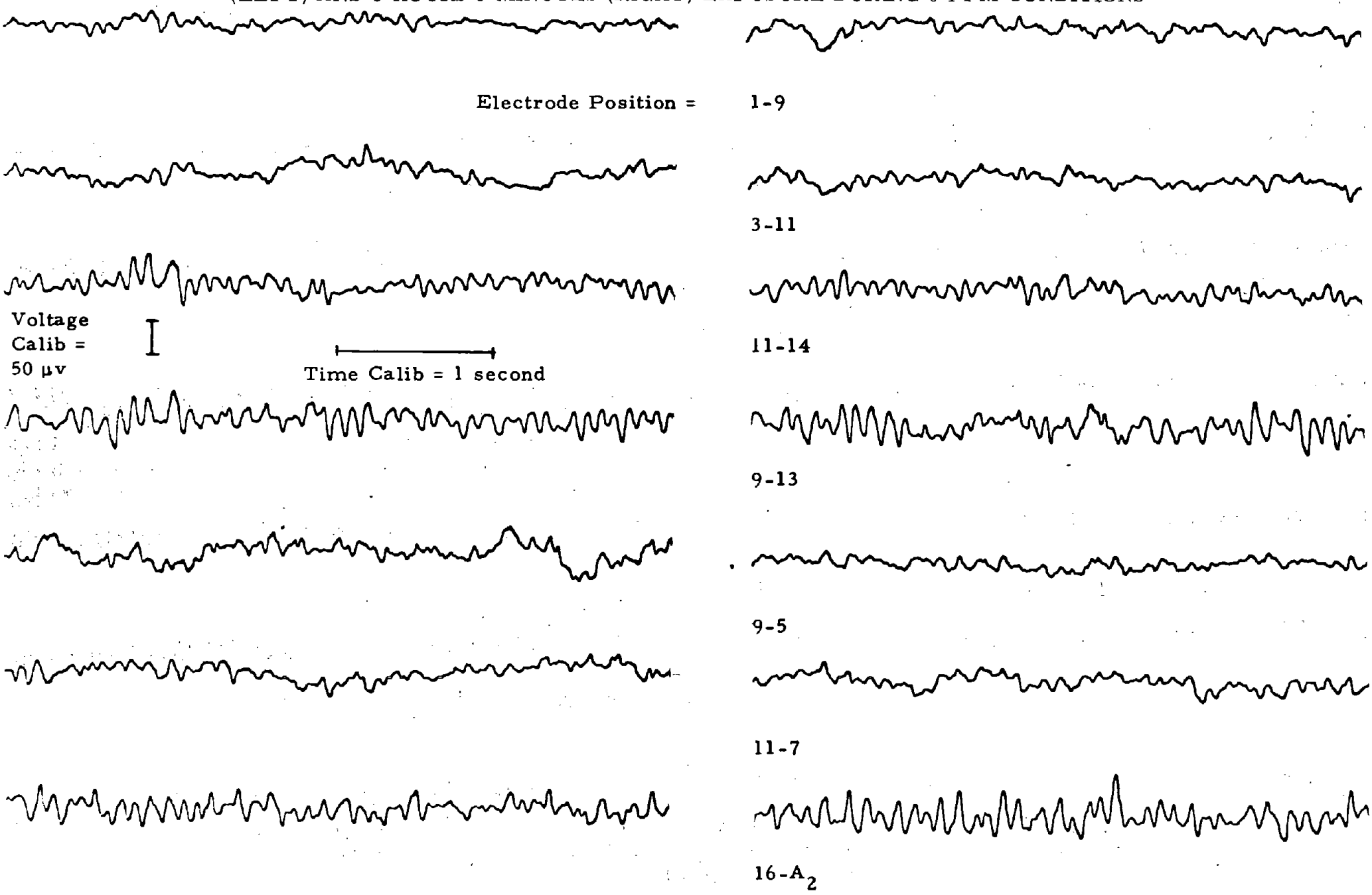


FIGURE 17

SPONTANEOUS EEG OF SUBJECT 192 ON DAY 1, WEEK 2 AFTER 20 MINUTES (LEFT) AND 5 HOURS 30 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

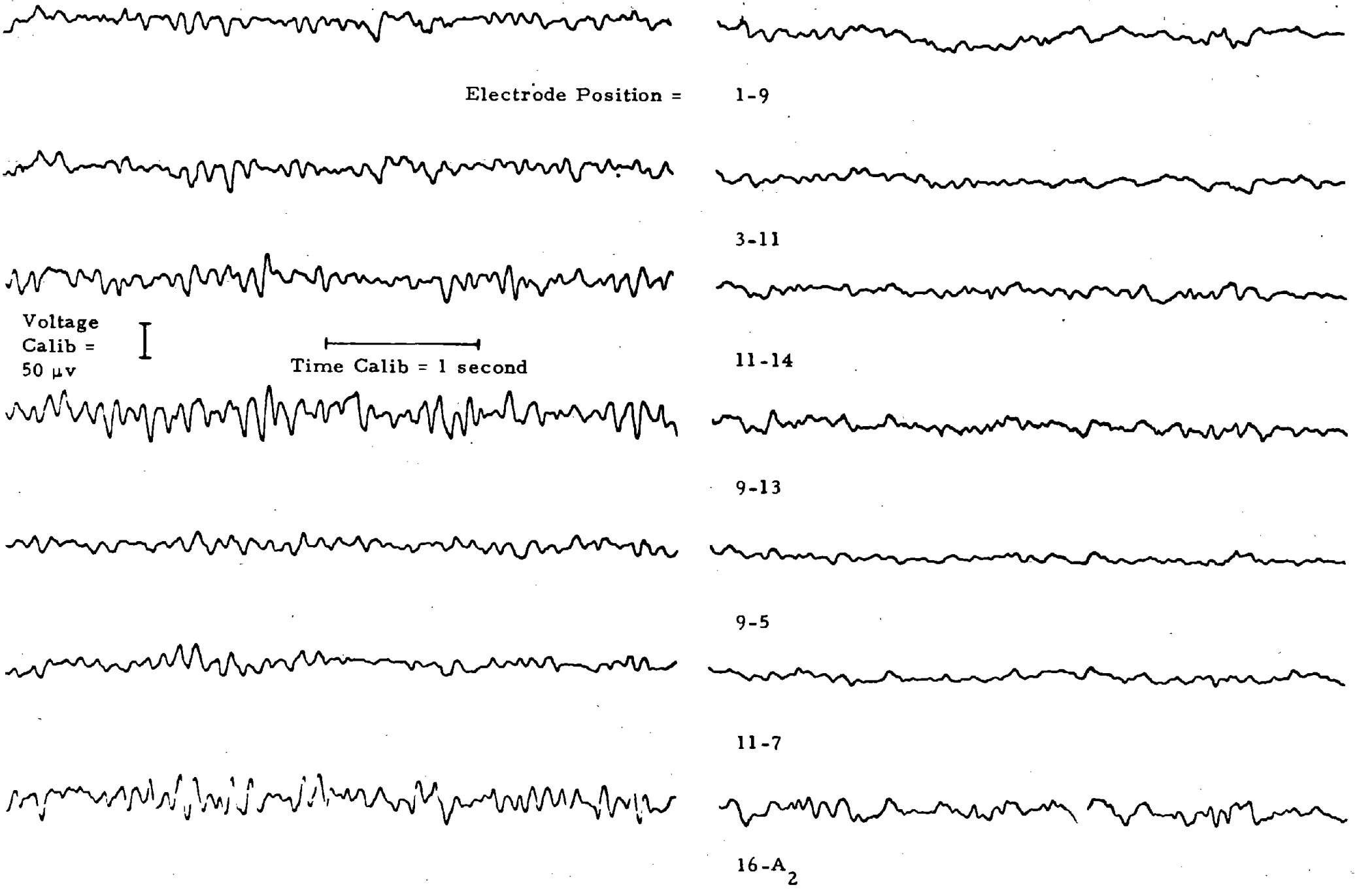


FIGURE 18

SPONTANEOUS EEG OF SUBJECT 192 ON DAY 1, WEEK 3 AFTER 20 MINUTES (LEFT) AND 5 HOURS 5 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

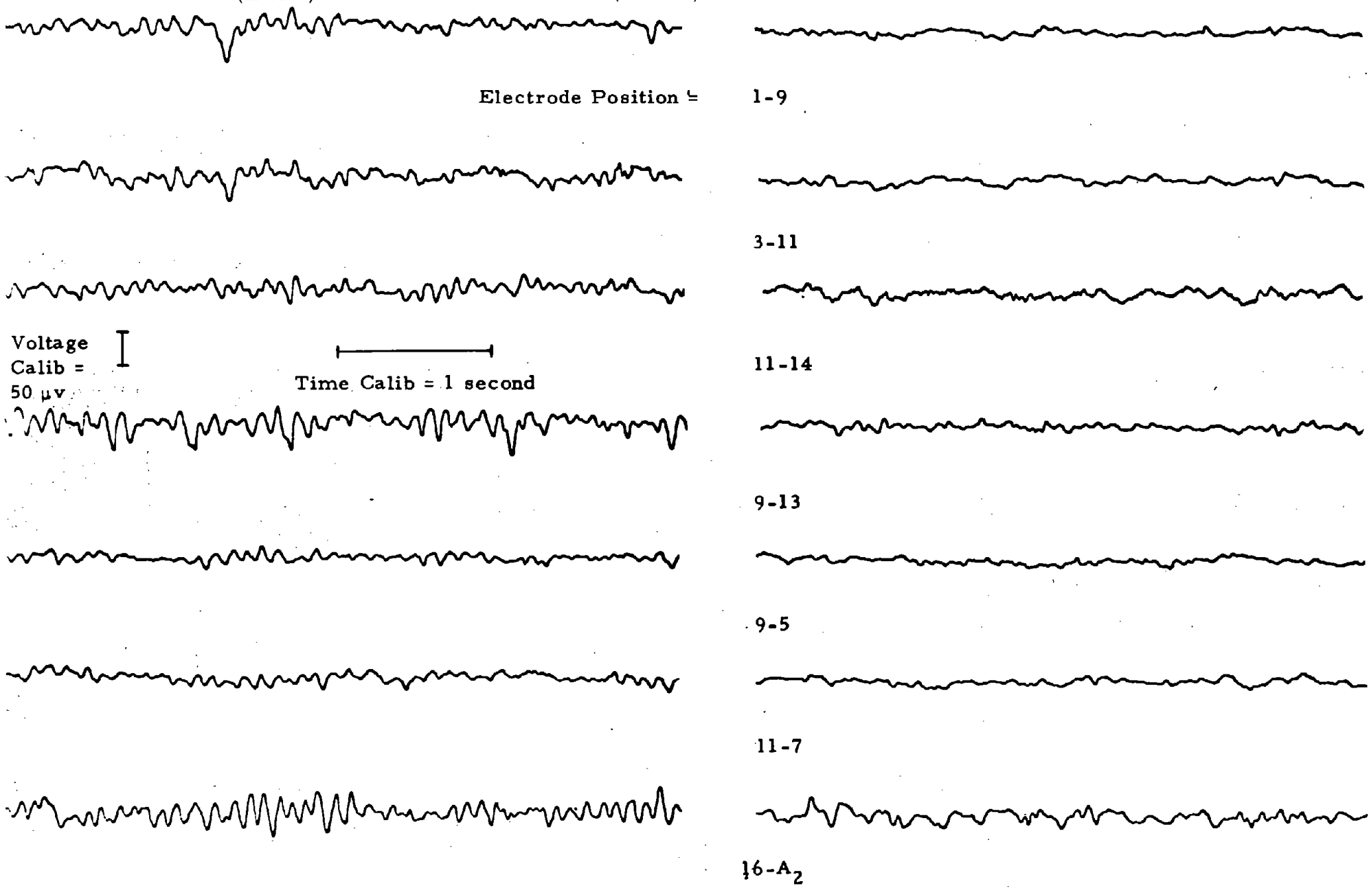


FIGURE 19
SPONTANEOUS EEG OF SUBJECT 193 ON DAY 5, WEEK 1 AFTER 30 MINUTES (LEFT) AND 6 HOURS 10 MINUTES (RIGHT) EXPOSURE DURING 0 PPM CONDITIONS

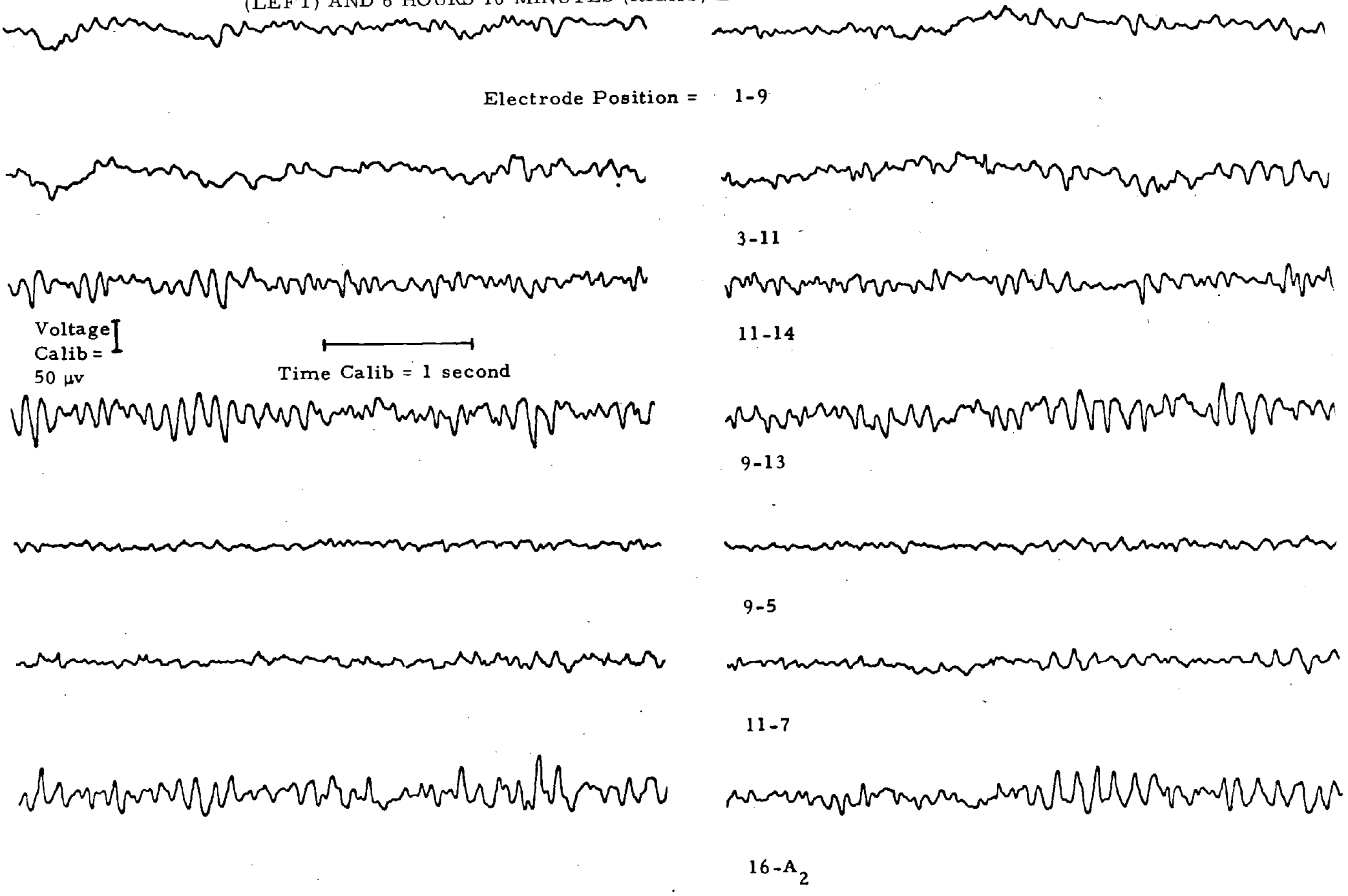


FIGURE 20
SPONTANEOUS EEG OF SUBJECT 193 ON DAY 1, WEEK 2 AFTER 6 HOURS
25 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

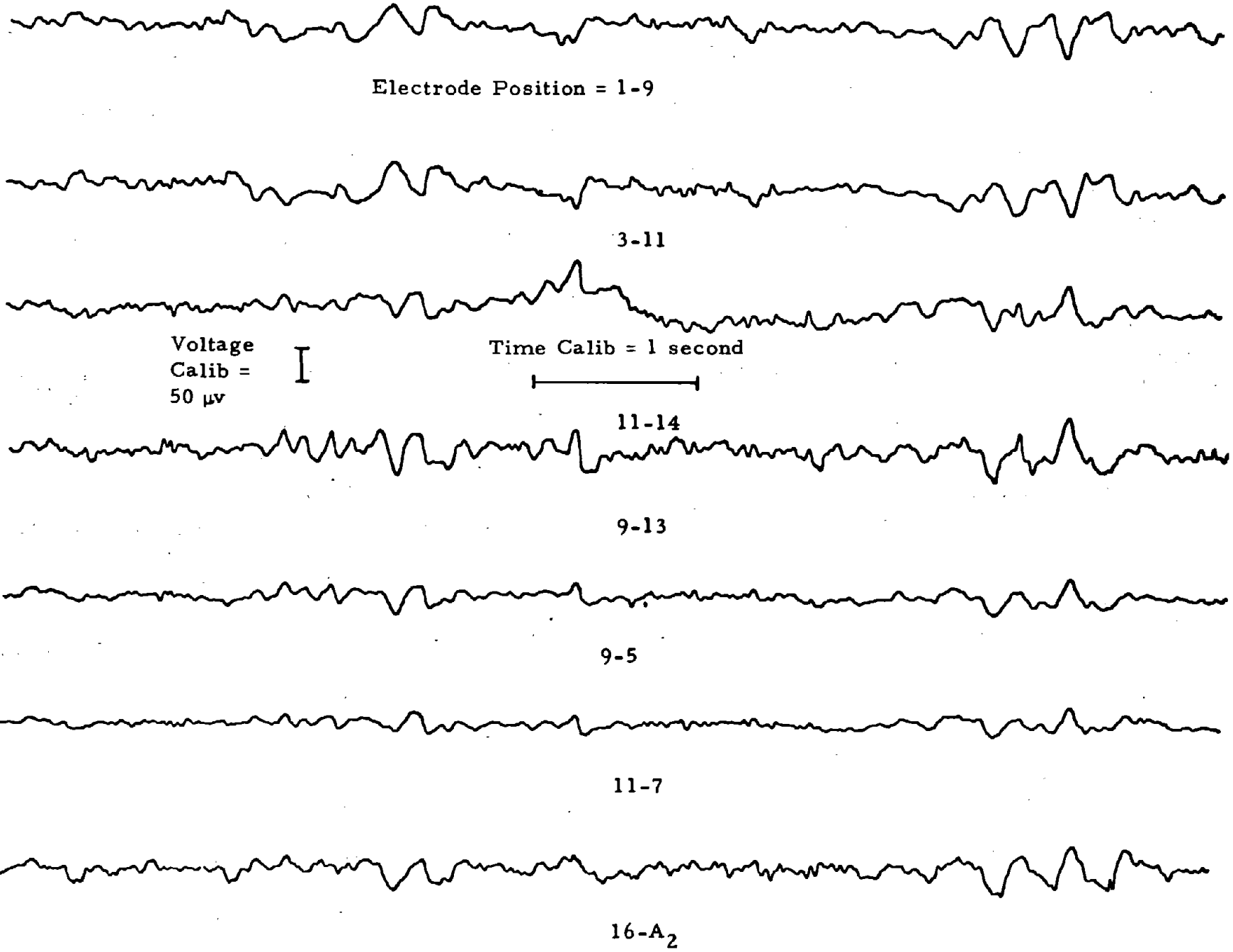


FIGURE 21
SPONTANEOUS EEG OF SUBJECT 198 ON DAY 1, WEEK 3 AFTER 30 MINUTES (LEFT) AND 5 HOURS 15 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

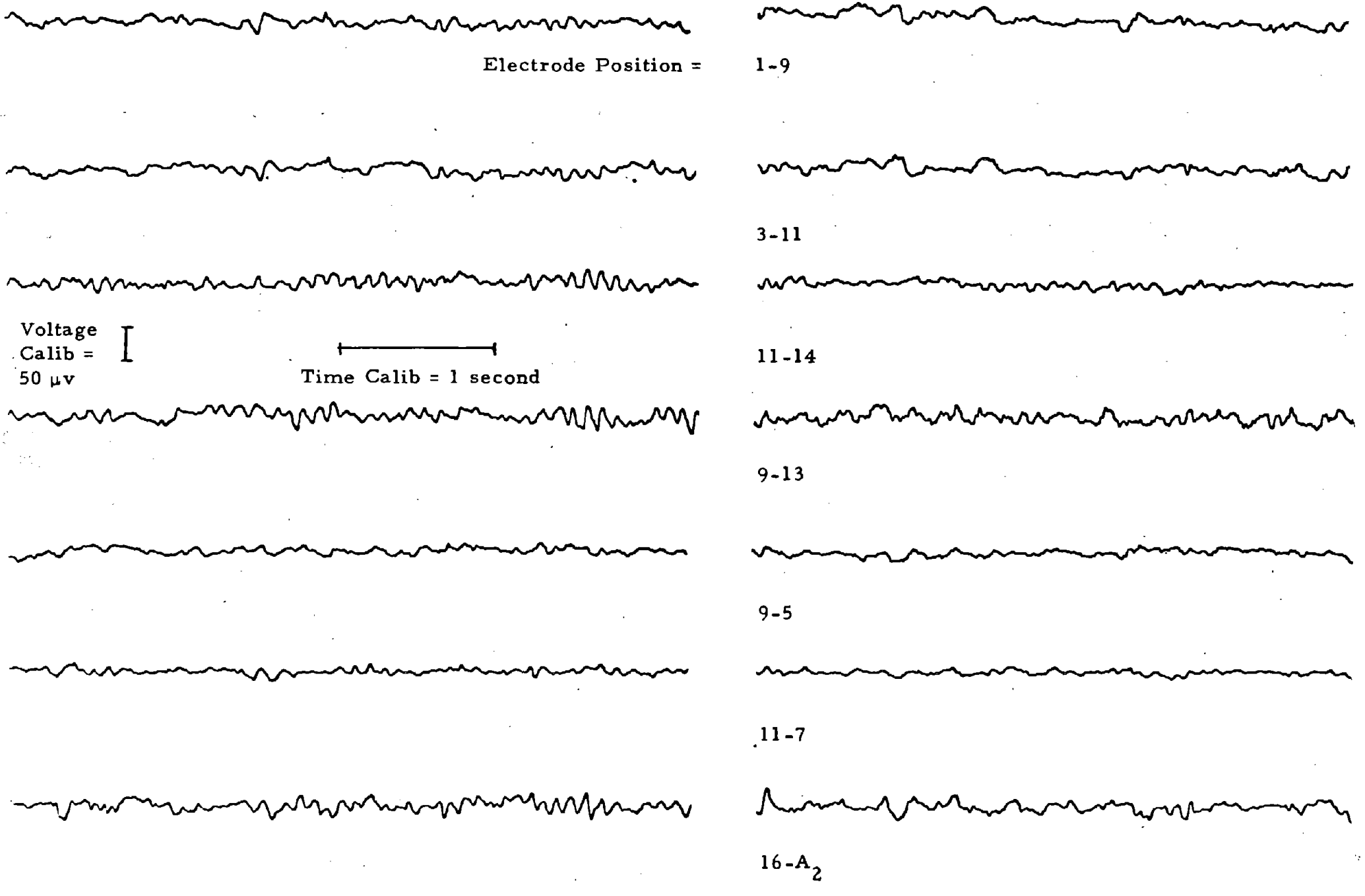


FIGURE 22
SPONTANEOUS EEG OF SUBJECT 198 ON DAY 3, WEEK 3 AFTER 30 MINUTES
(LEFT) AND 6 HOURS 10 MINUTES (RIGHT) EXPOSURE DURING 100 PPM CONDITIONS

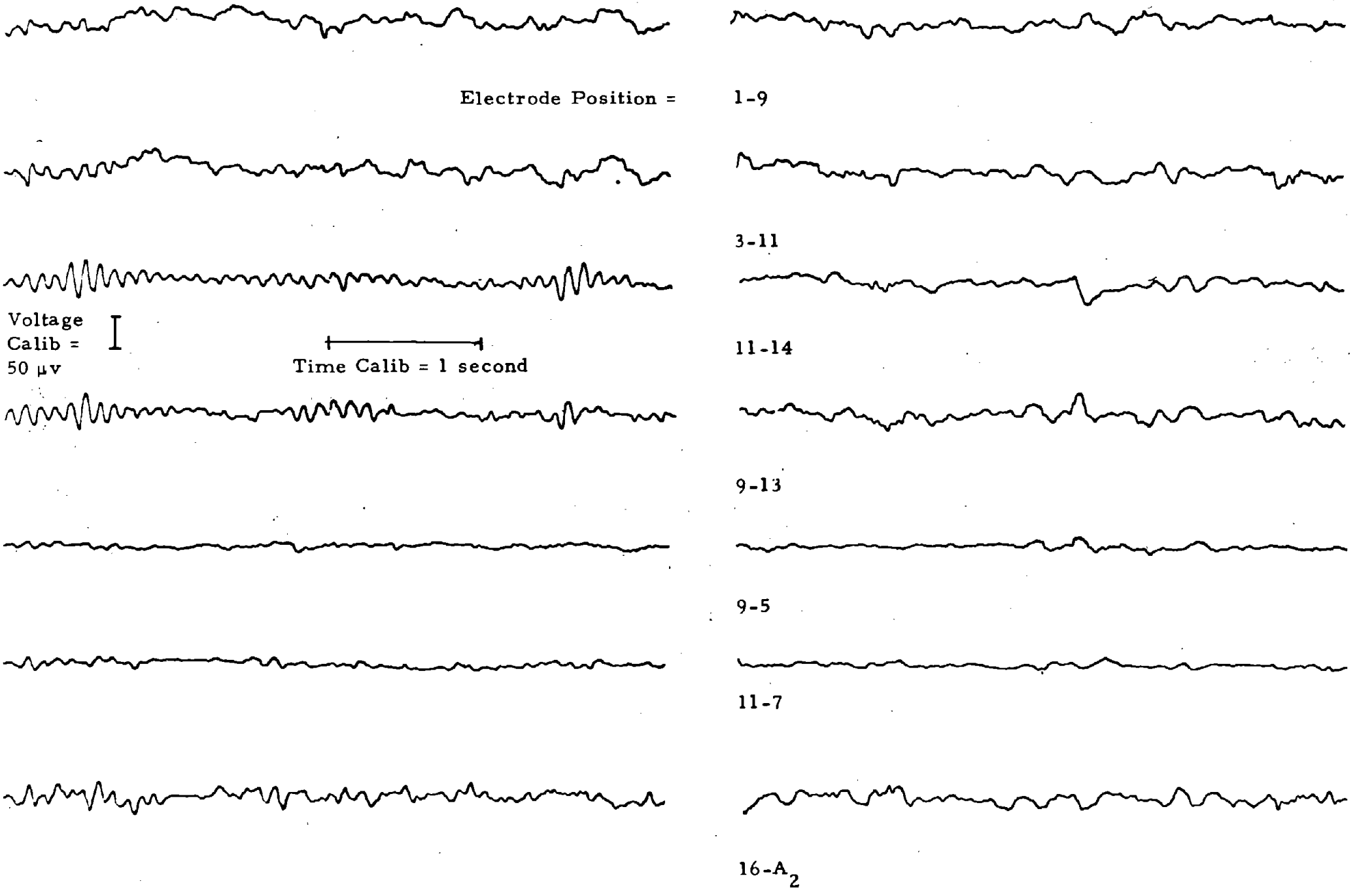
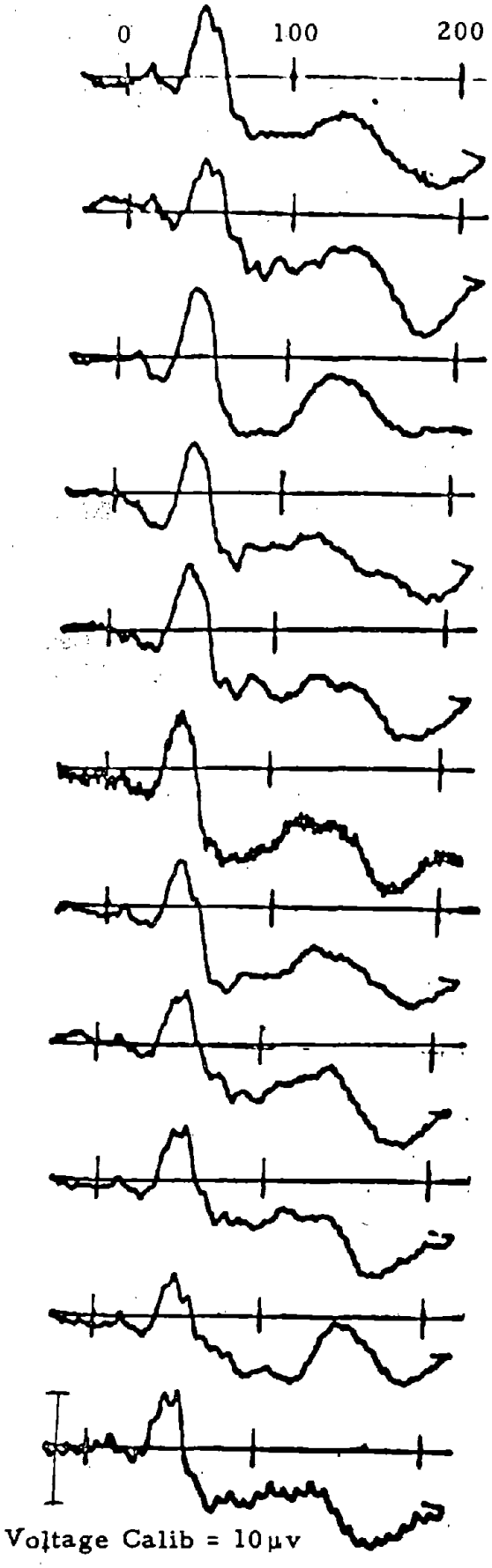
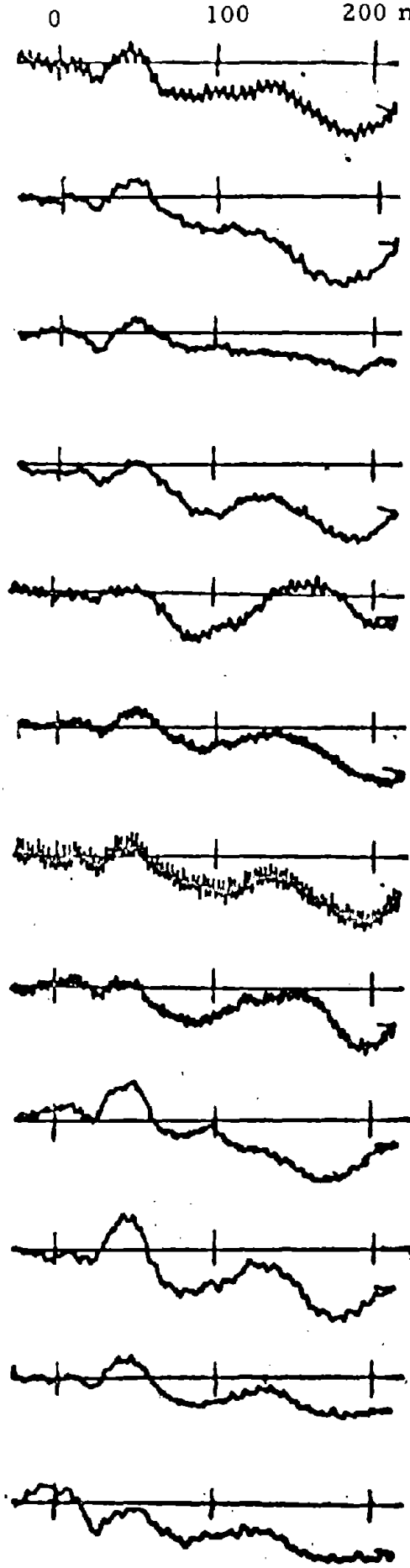


FIGURE 23 - SELECTED VER's OF SUBJECT 118



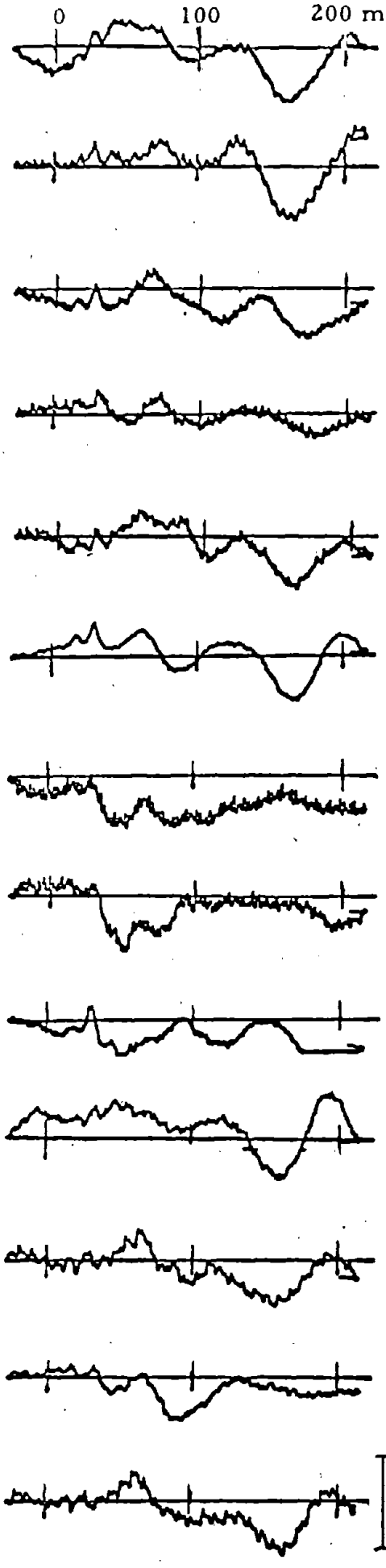
Date	Exposure Duration	Condition
10/19/73	10 minutes	0 PPM
10/19/73	5 hrs. 10 minutes	0 PPM
10/19/73	5 hrs. 50 minutes	0 PPM
10/22/73	10 minutes	First Day 100 PPM
10/22/73	5 hrs. 5 minutes	"
10/22/73	5 hrs. 50 minutes	"
10/22/73	6 hrs. 50 minutes	"
11/12/73	10 minutes	First Day 150 PPM
11/12/73	4 hrs. 50 minutes	"
11/12/73	5 hrs. 30 minutes	"
11/12/73	6 hrs. 40 minutes	"

FIGURE 24 - SELECTED VER's OF SUBJECT 163



Date	Exposure Duration	Condition
10/19/73	30 minutes	0 PPM
10/19/73	5 hrs. 15 minutes	0 PPM
10/19/73	6 hrs.	0 PPM
10/19/73	6 hrs. 45 minutes	0 PPM
10/22/73	15 minutes	First Day 100 PPM
10/22/73	5 hrs. 13 minutes	"
10/22/73	5 hrs. 55 minutes	"
10/22/73	6 hrs. 58 minutes	"
11/12/73	20 minutes	First Day 150 PPM
11/12/73	5 hrs.	"
11/12/73	5 hrs. 40 minutes	"
11/12/73	6 hrs. 50 minutes	"

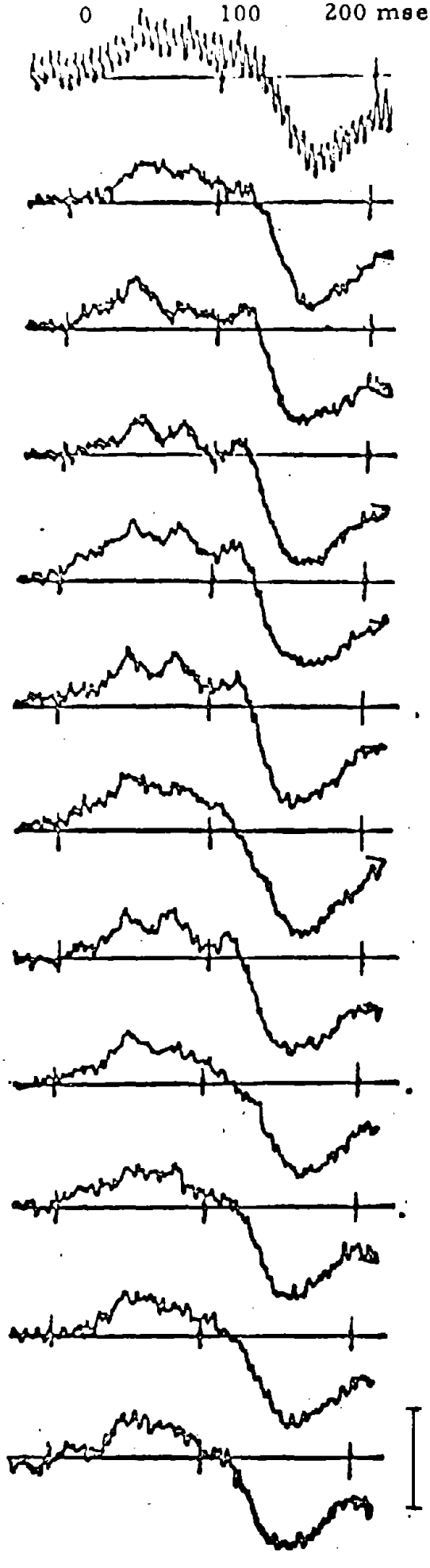
FIGURE 25 - SELECTED VER's OF SUBJECT 164



Date	Exposure Duration	Condition
10/19/73	50 minutes	0 PPM
10/19/73	5 hrs. 30 minutes	0 PPM
10/19/73	6 hrs. 5 minutes	0 PPM
10/19/73	6 hrs. 95 minutes	0 PPM
10/19/73	7 hrs. 5 minutes	0 PPM
10/22/73	10 minutes	First Day 100 PPM
10/22/73	5 hrs. 22 minutes	"
10/22/73	6 hrs. 4 minutes	"
10/22/73	7 hrs. 5 minutes	"
11/12/73	30 minutes	First Day 150 PPM
11/12/73	5 hrs. 10 minutes	"
11/12/73	5 hrs. 50 minutes	"
11/12/73	7 hrs.	"

Voltage Calib = 10 μv

FIGURE 26 - SELECTED VER's OF SUBJECT 165



Date	Exposure Duration	Condition
10/19/73	15 minutes	0 PPM
10/19/73	5 hrs. 10 minutes	0 PPM
10/19/73	5 hrs. 30 minutes	0 PPM
10/19/73	6 hrs. 50 minutes	0 PPM
10/22/73	25 minutes	First Day 100 PPM
10/22/73	5 hrs. 28 minutes	"
10/22/73	6 hrs. 12 minutes	"
10/22/73	7 hrs. 11 minutes	"
11/12/73	40 minutes	First Day 150 PPM
11/12/73	5 hrs. 20 minutes	"
11/12/73	6 hrs.	"
11/12/73	7 hrs. 10 minutes	"

Voltage Calib = 10 μv

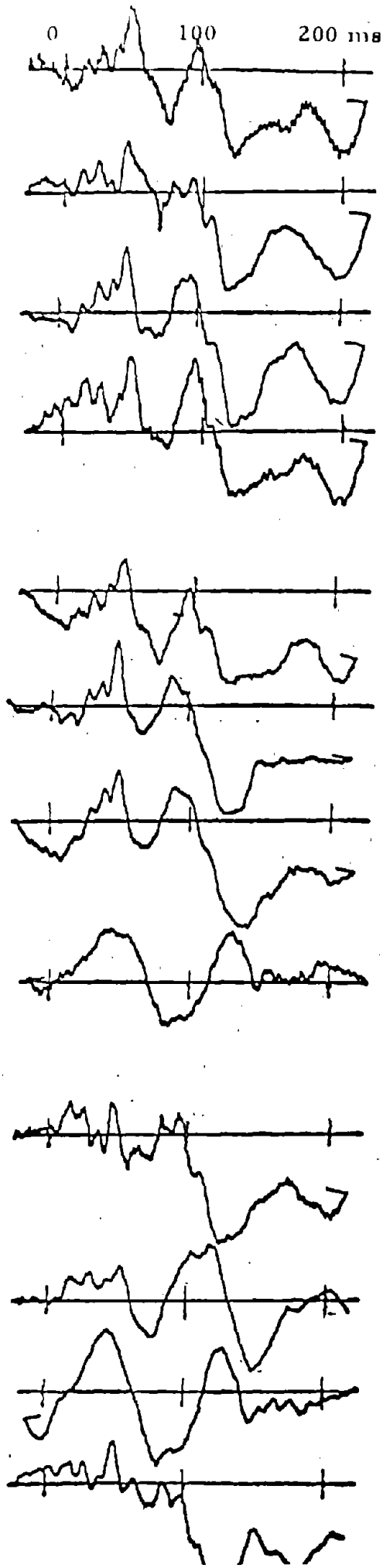


FIGURE 27 - SELECTED VER's OF # 116

Date	Exposure Duration	Condition
2/1/74	10 minutes	0 PPM
2/1/74	4 hrs. 50 minutes	0 PPM
2/1/74	5 hrs. 40 minutes	0 PPM
2/1/74	6 hrs. 35 minutes	0 PPM
2/4/74	10 minutes	First Day 100 PPM
2/4/74	5 hrs. 10 minutes	"
2/4/74	5 hrs. 55 minutes	"
2/4/74	6 hrs. 35 minutes	"
2/11/74	10 minutes	100 PPM
2/11/74	4 hrs. 55 minutes	"
2/11/74	5 hrs. 38 minutes	"
2/11/74	6 hrs. 20 minutes	"

Voltage Calib = 10 μ v

FIGURE 28 - SELECTED VER's OF SUBJECT #192

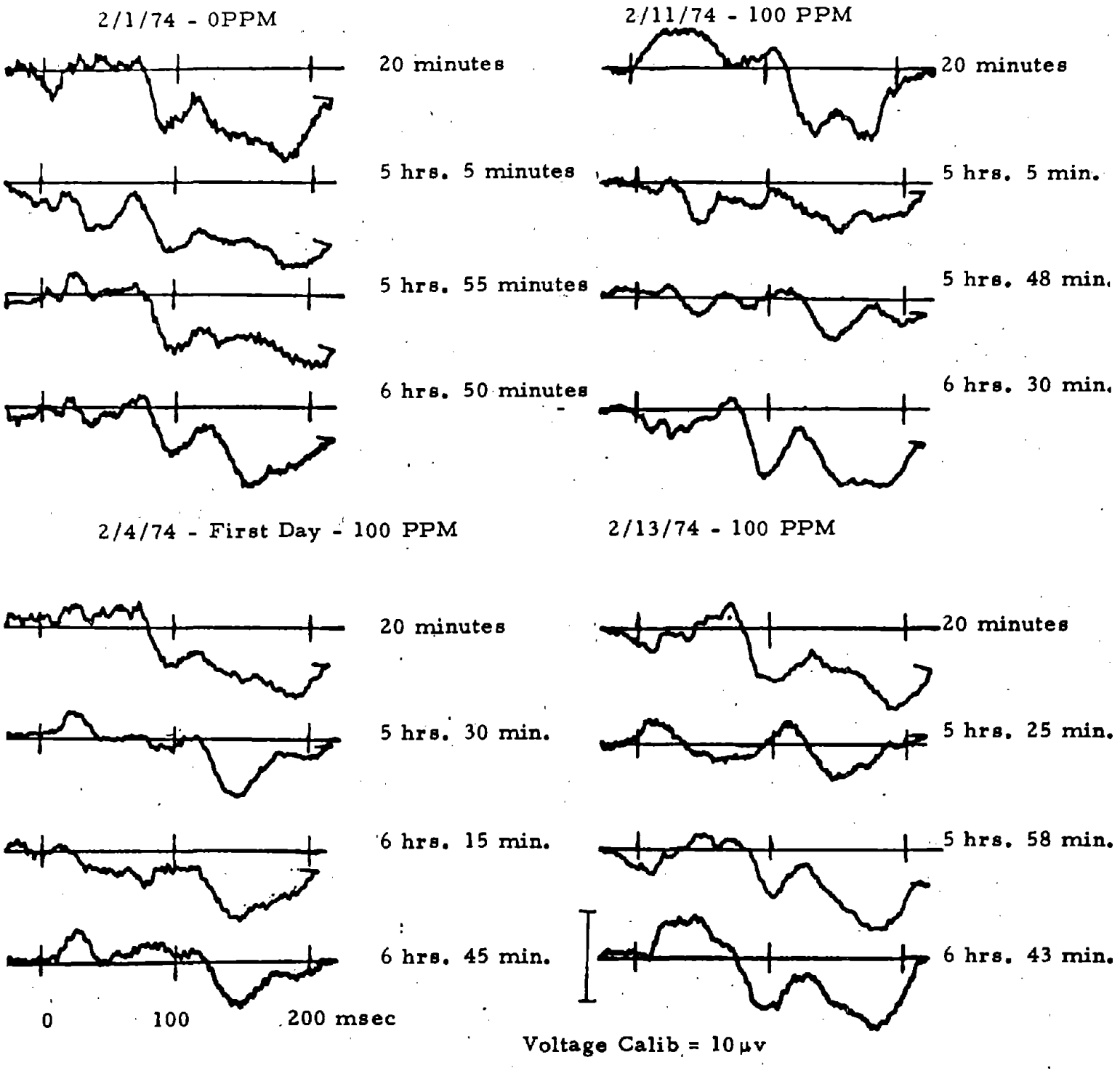


FIGURE 29

The Effect of Training and Exposure to Tetrachloroethylene on Time Estimations - $7\frac{1}{2}$ Hour Exposure

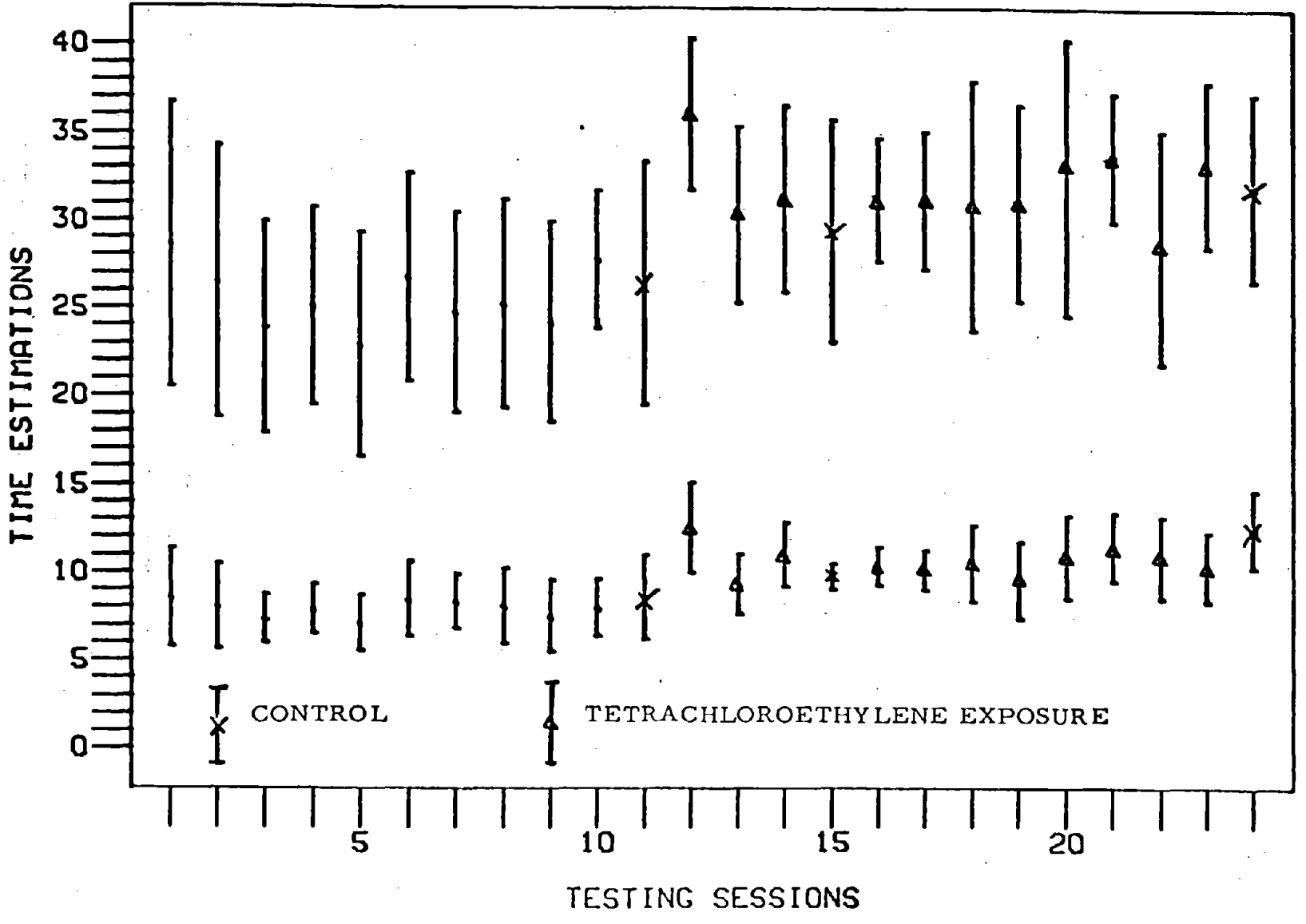


FIGURE 30

The Effect of Training and Exposure to Tetrachloroethylene on The Marquette Test - $7\frac{1}{2}$ Hour Exposure

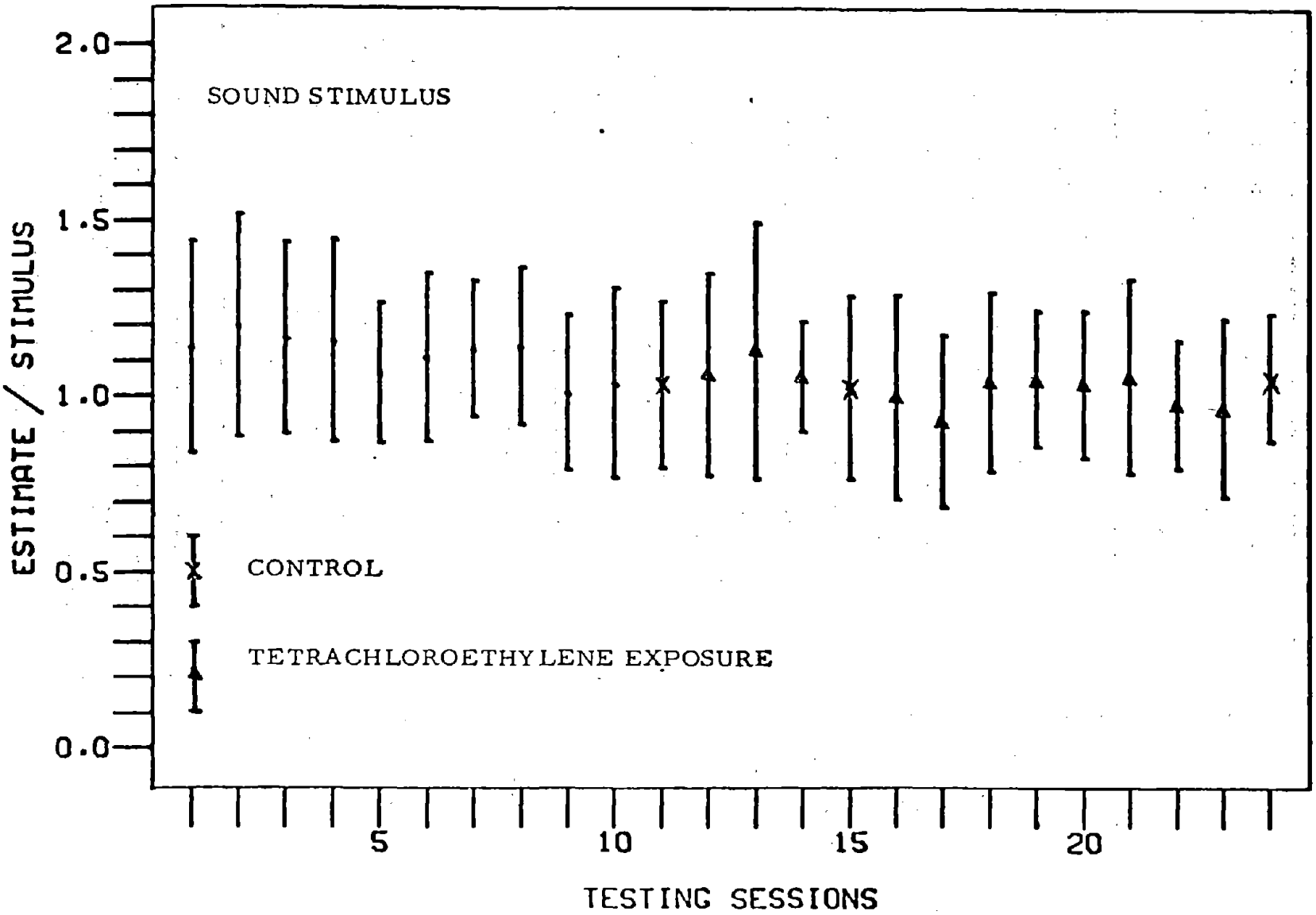


FIGURE 31

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

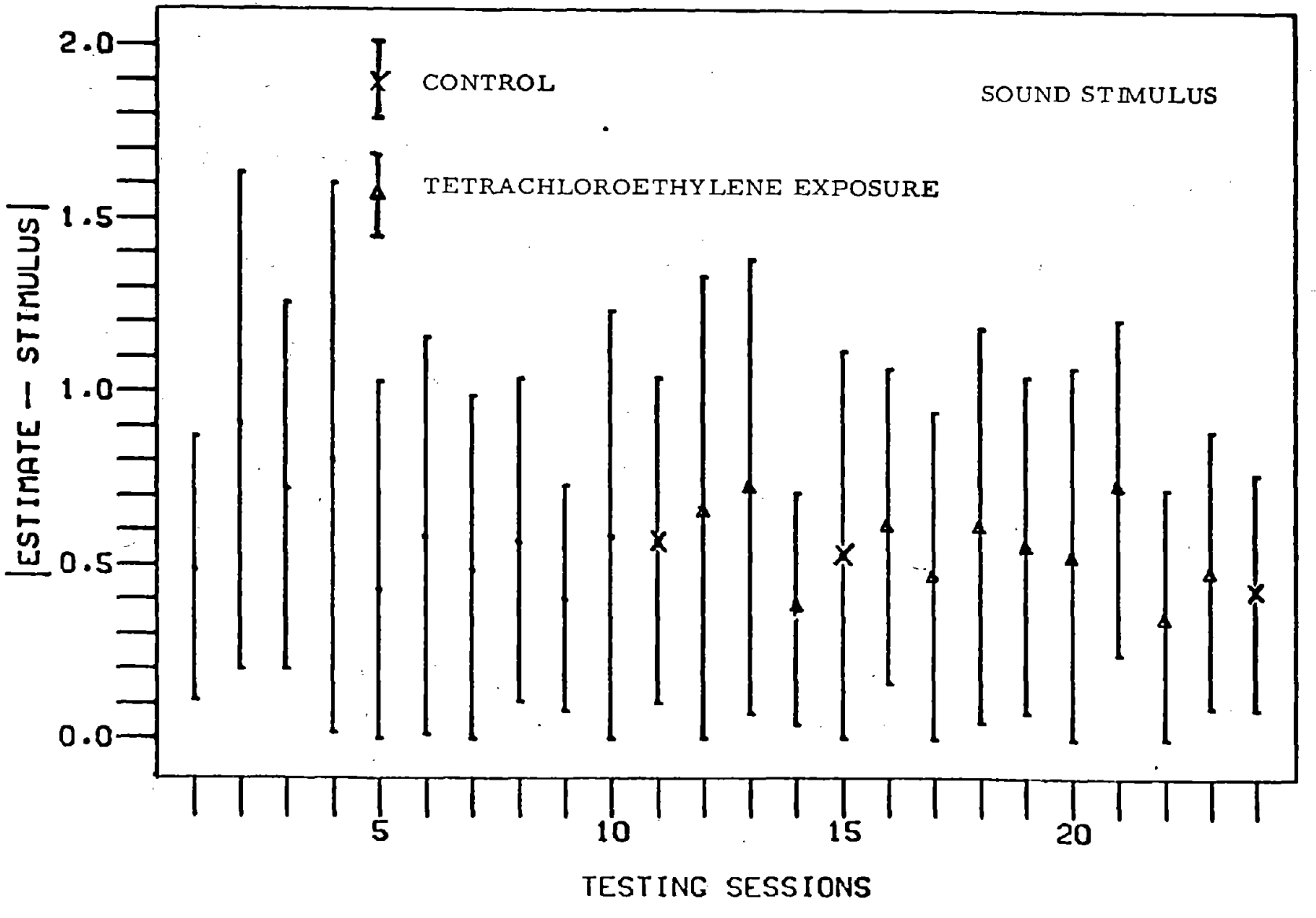


FIGURE 32

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

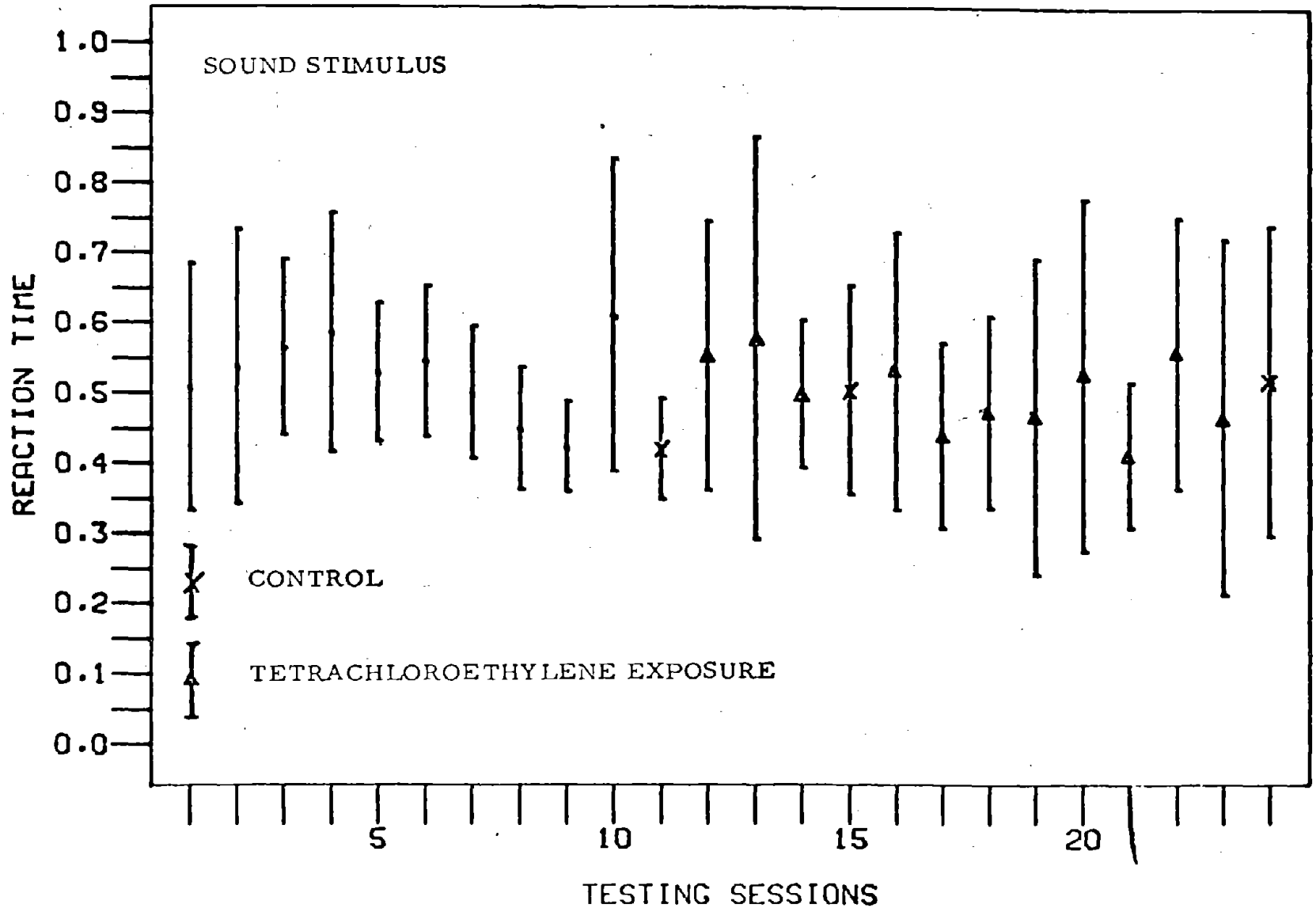


FIGURE 33

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

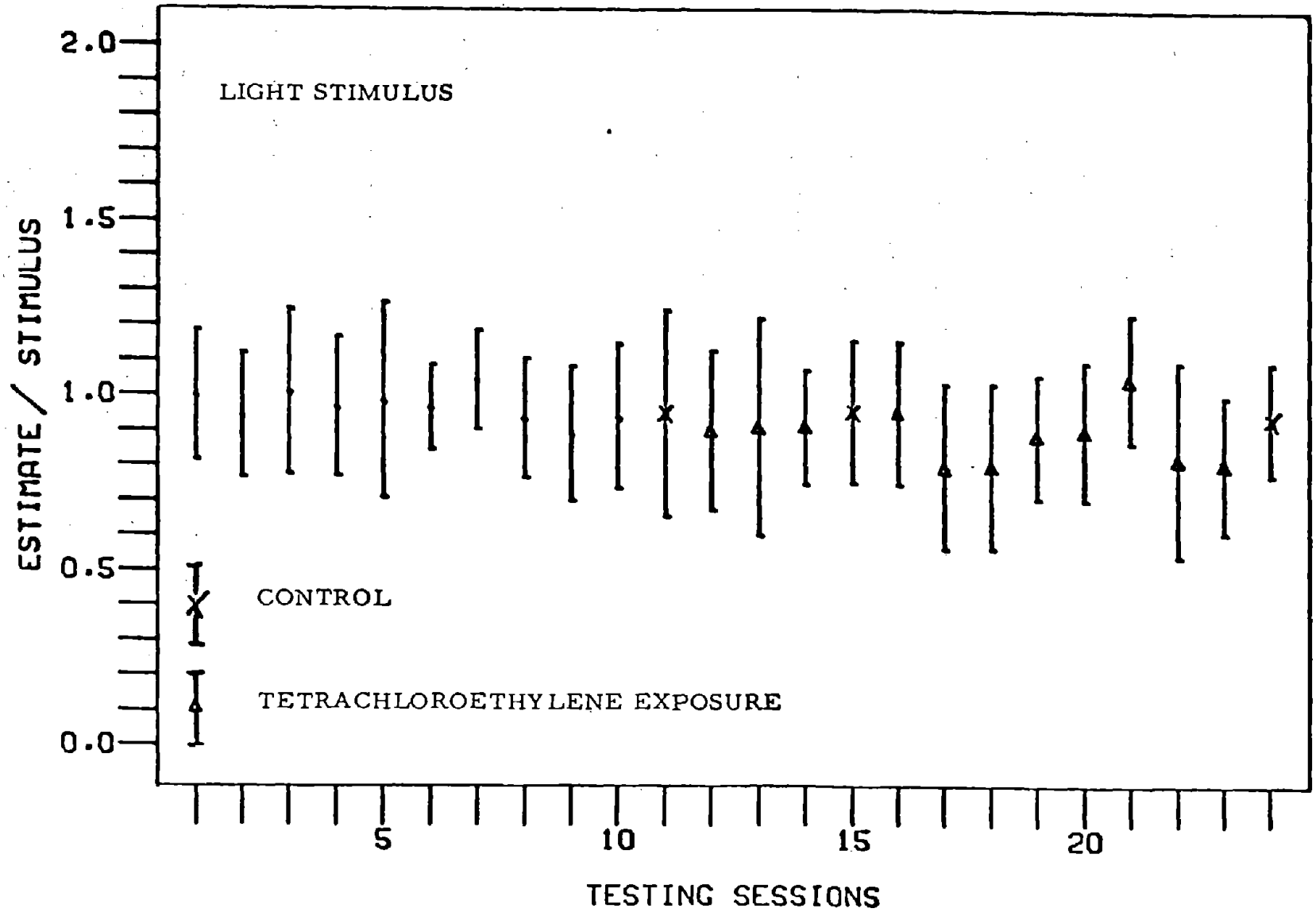


FIGURE 34

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

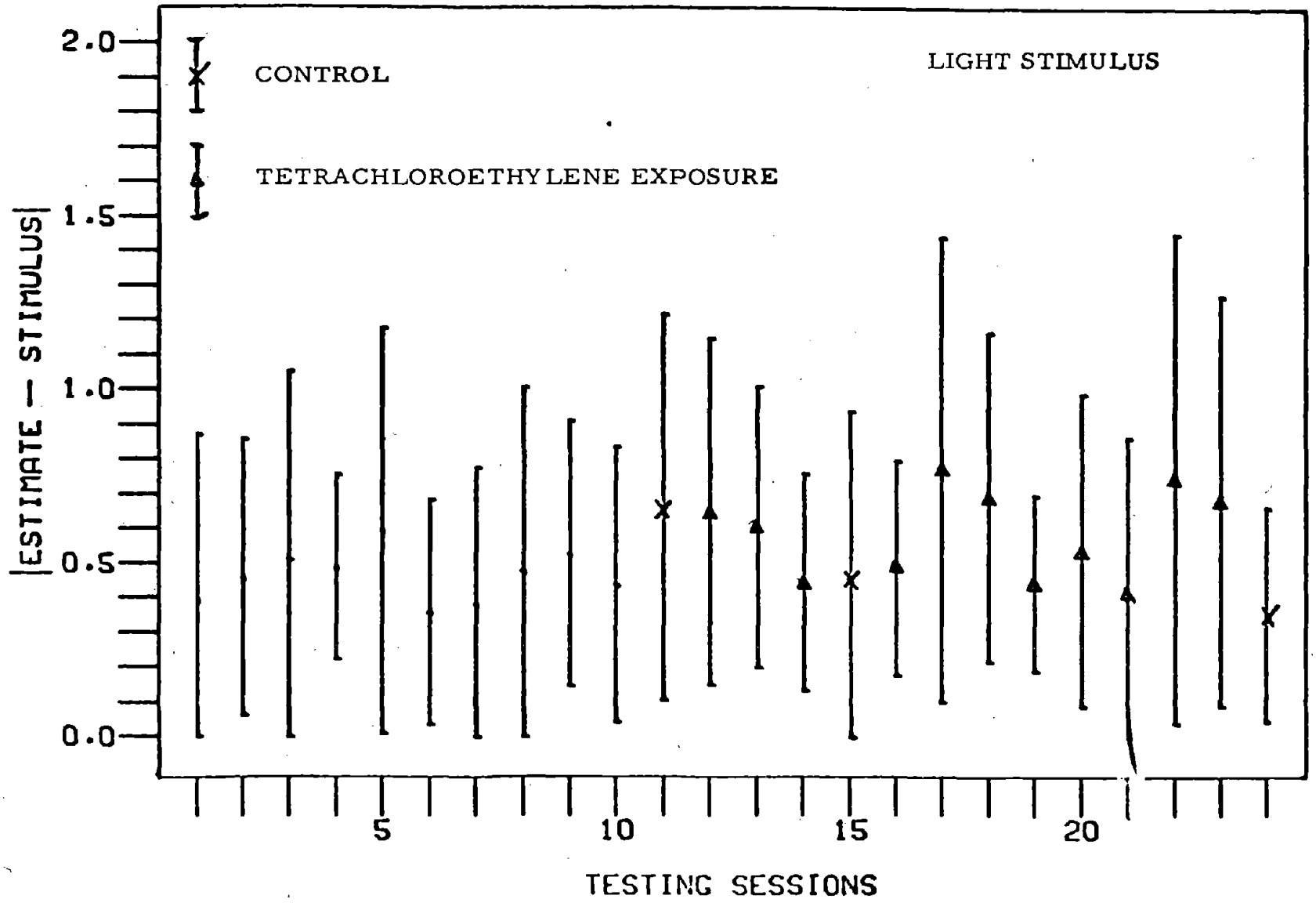


FIGURE 35

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

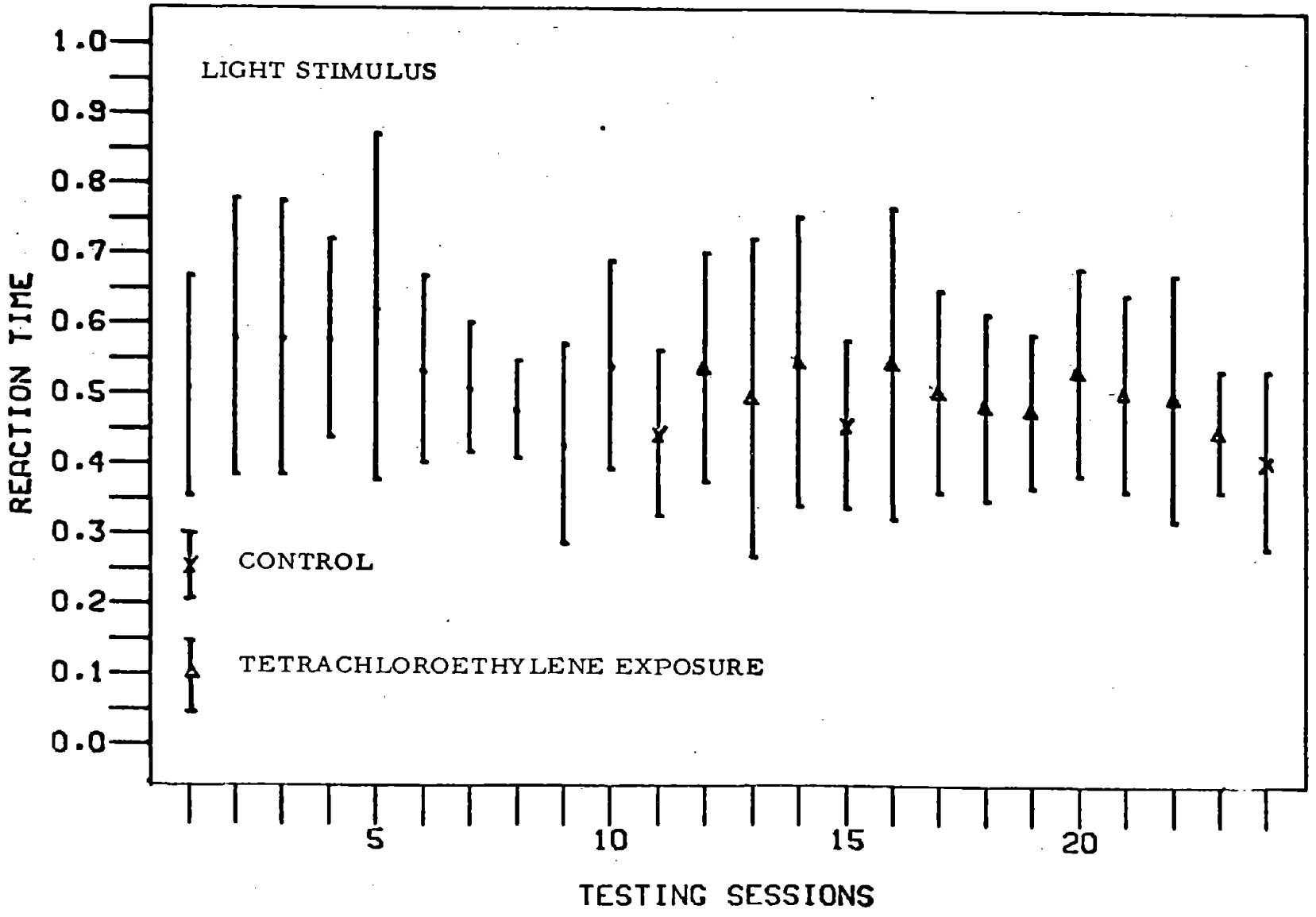


FIGURE 36

The Effect of Training and Exposure to Tetrachloroethylene on The Coordination Test - $7\frac{1}{2}$ Hour Exposure

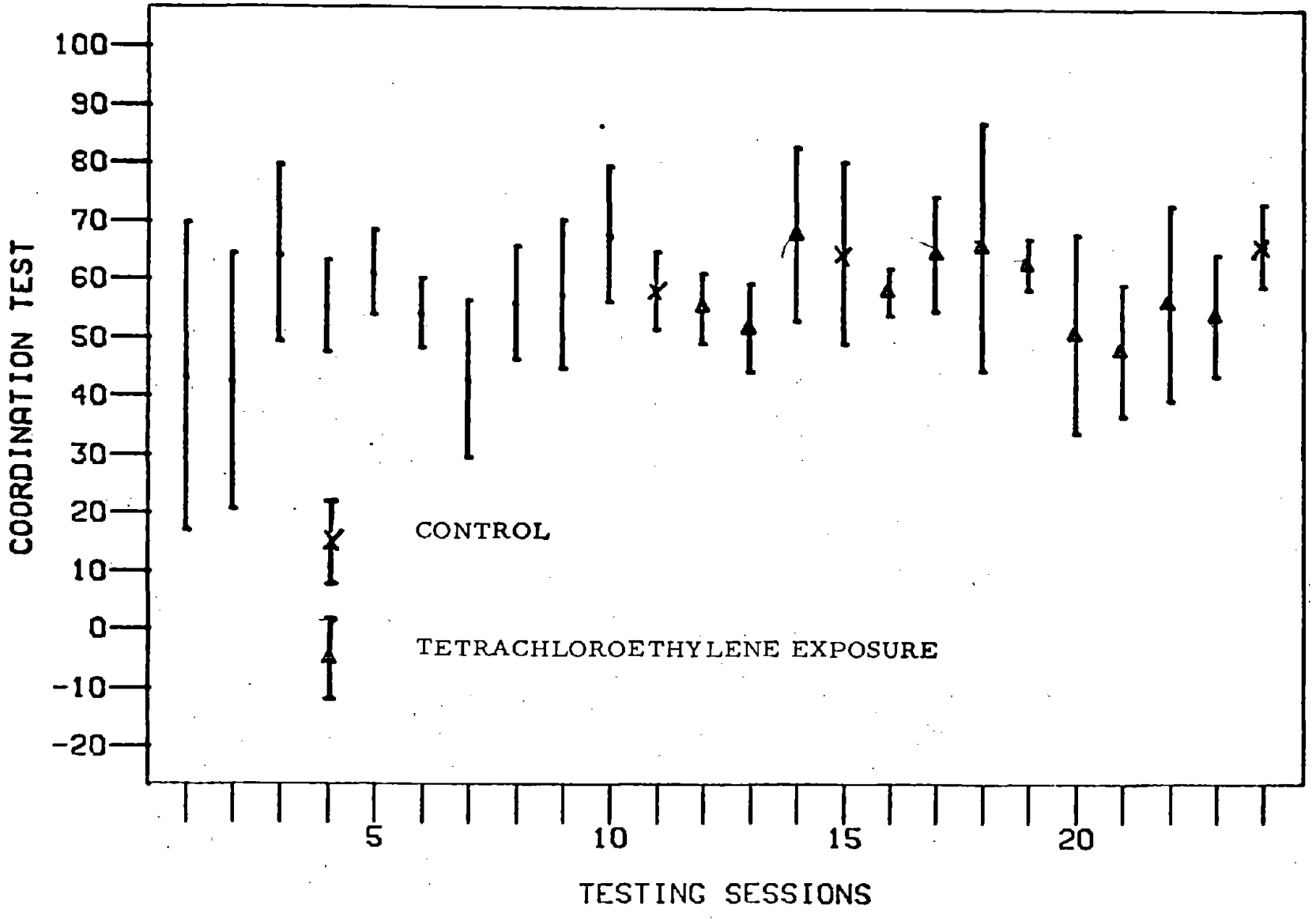


FIGURE 37

The Effect of Training and Exposure to Tetrachloroethylene on
The Arithmetic Test - $7\frac{1}{2}$ Hour Exposure

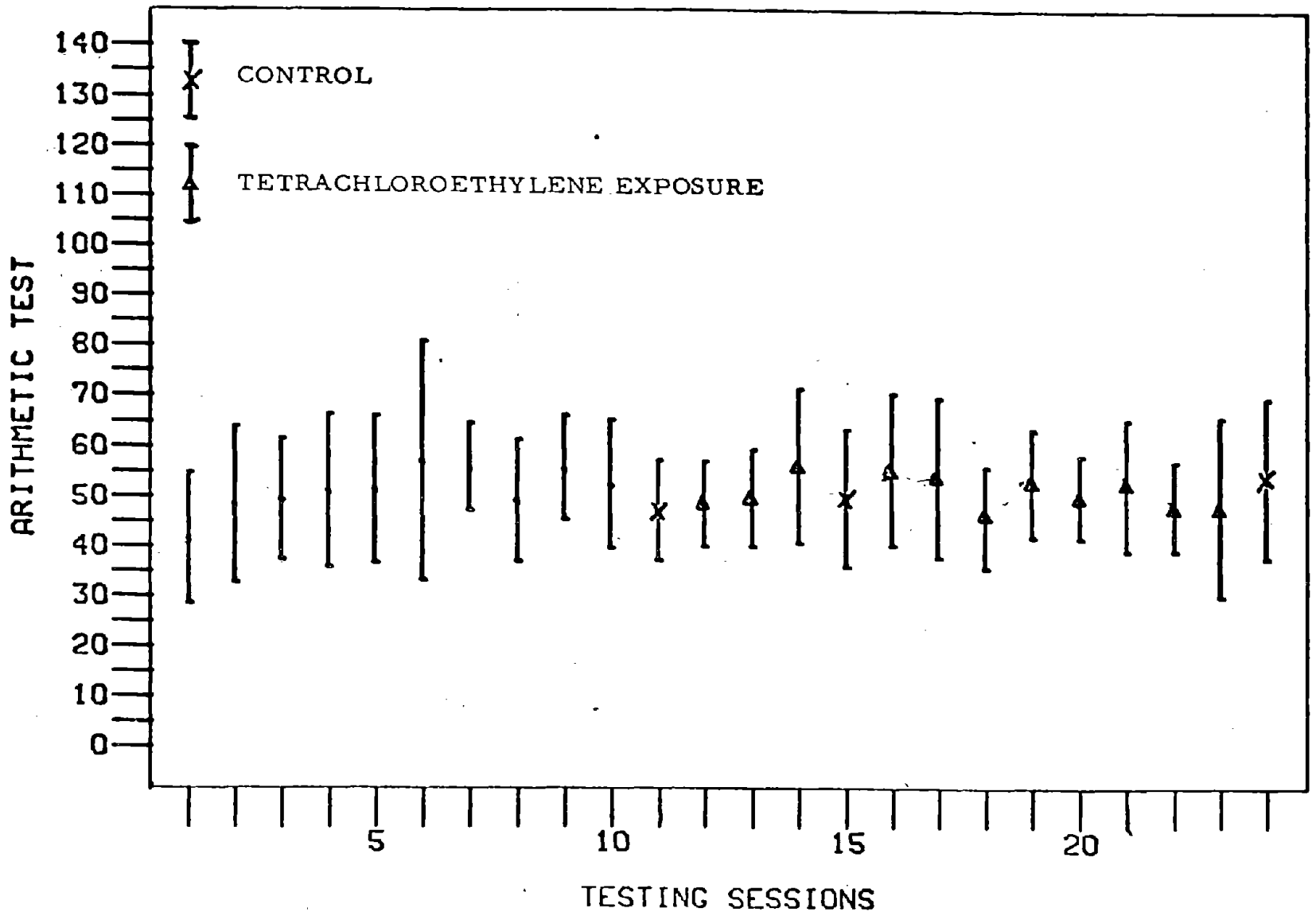


FIGURE 38

The Effect of Training and Exposure to Tetrachloroethylene on The Inspection Test - $7\frac{1}{2}$ Hour Exposure

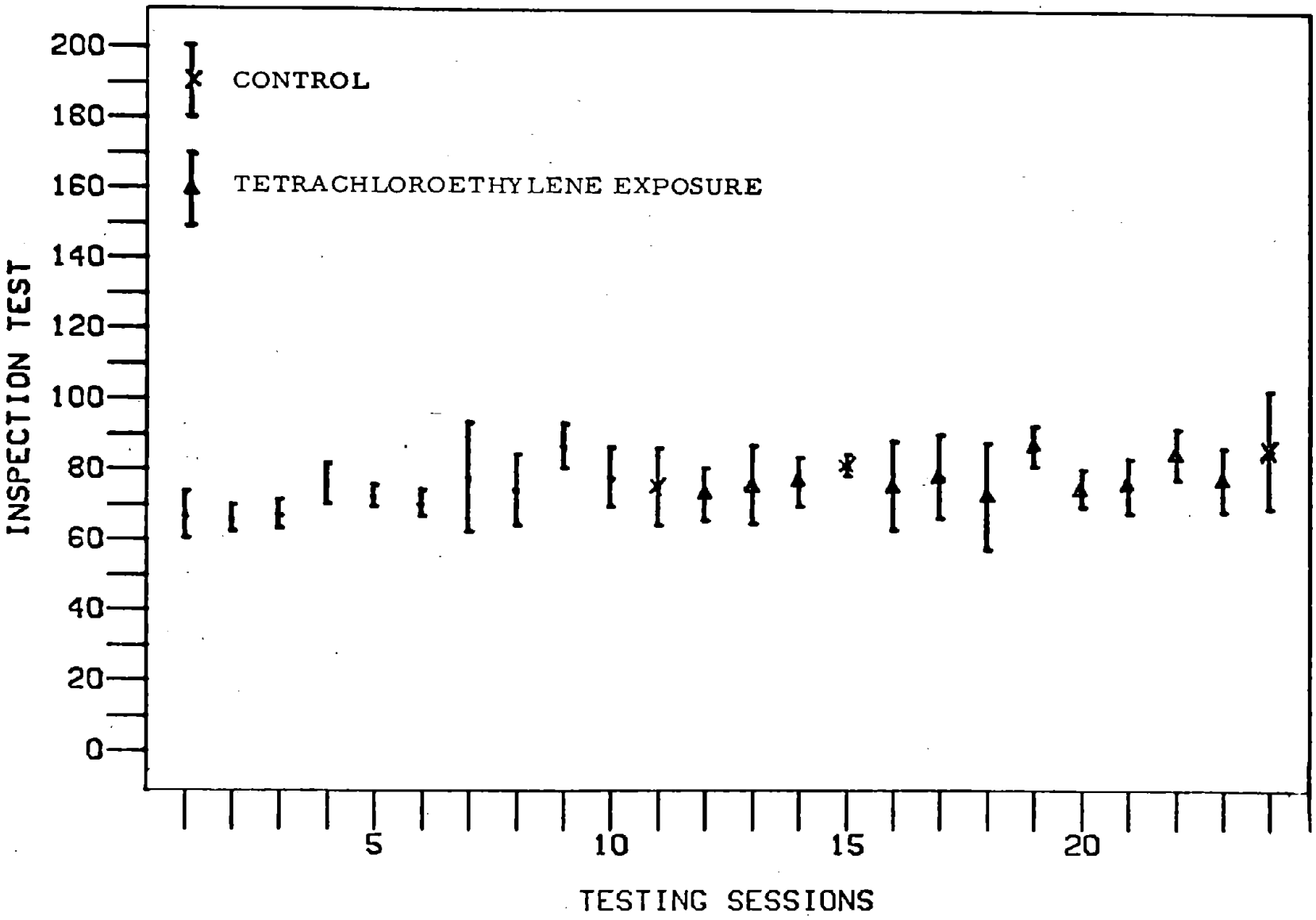


FIGURE 39

THE EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE ON TIME ESTIMATIONS
7-1/2 HOUR EXPOSURE

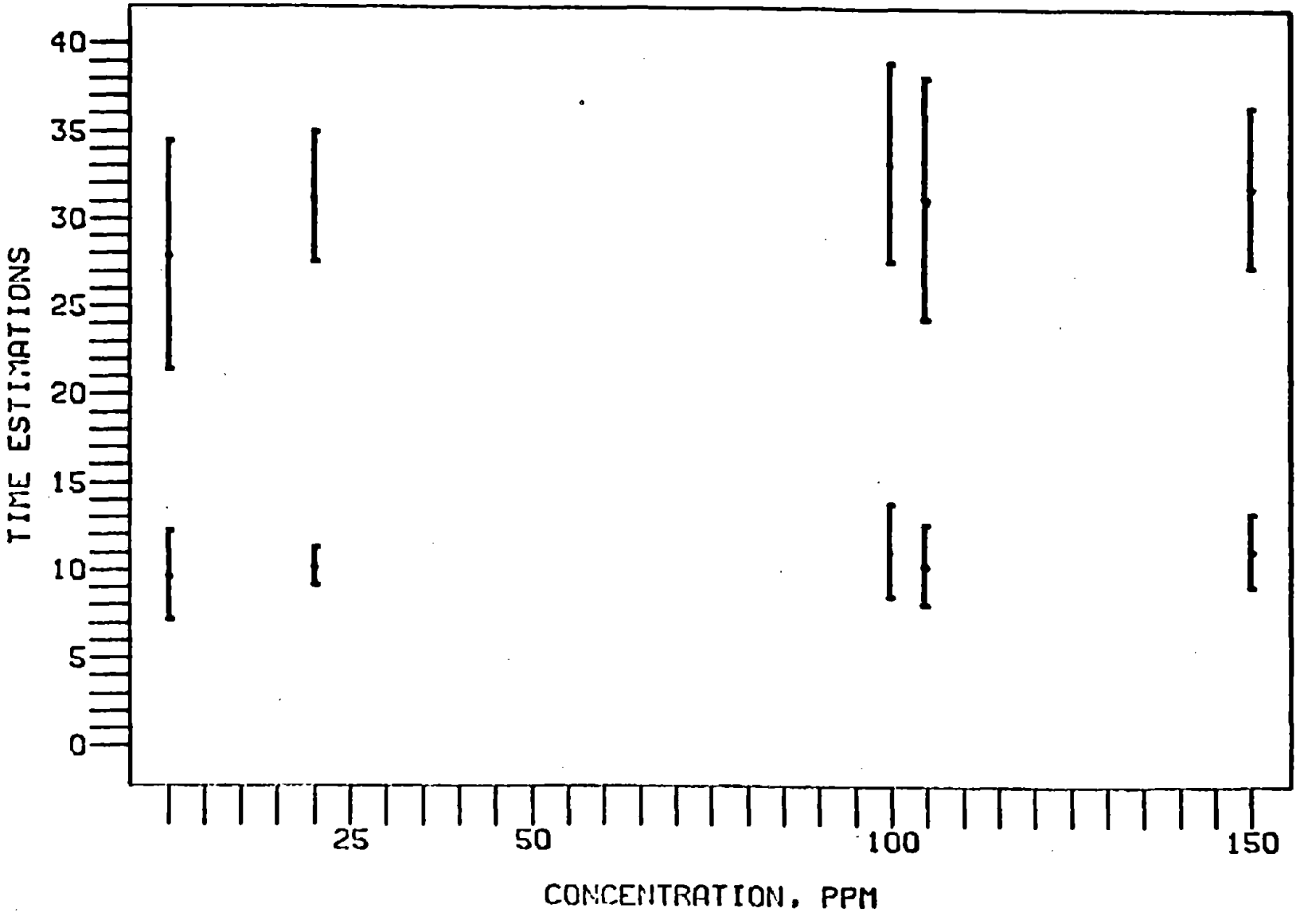


FIGURE 40

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 7½ Hour Exposure

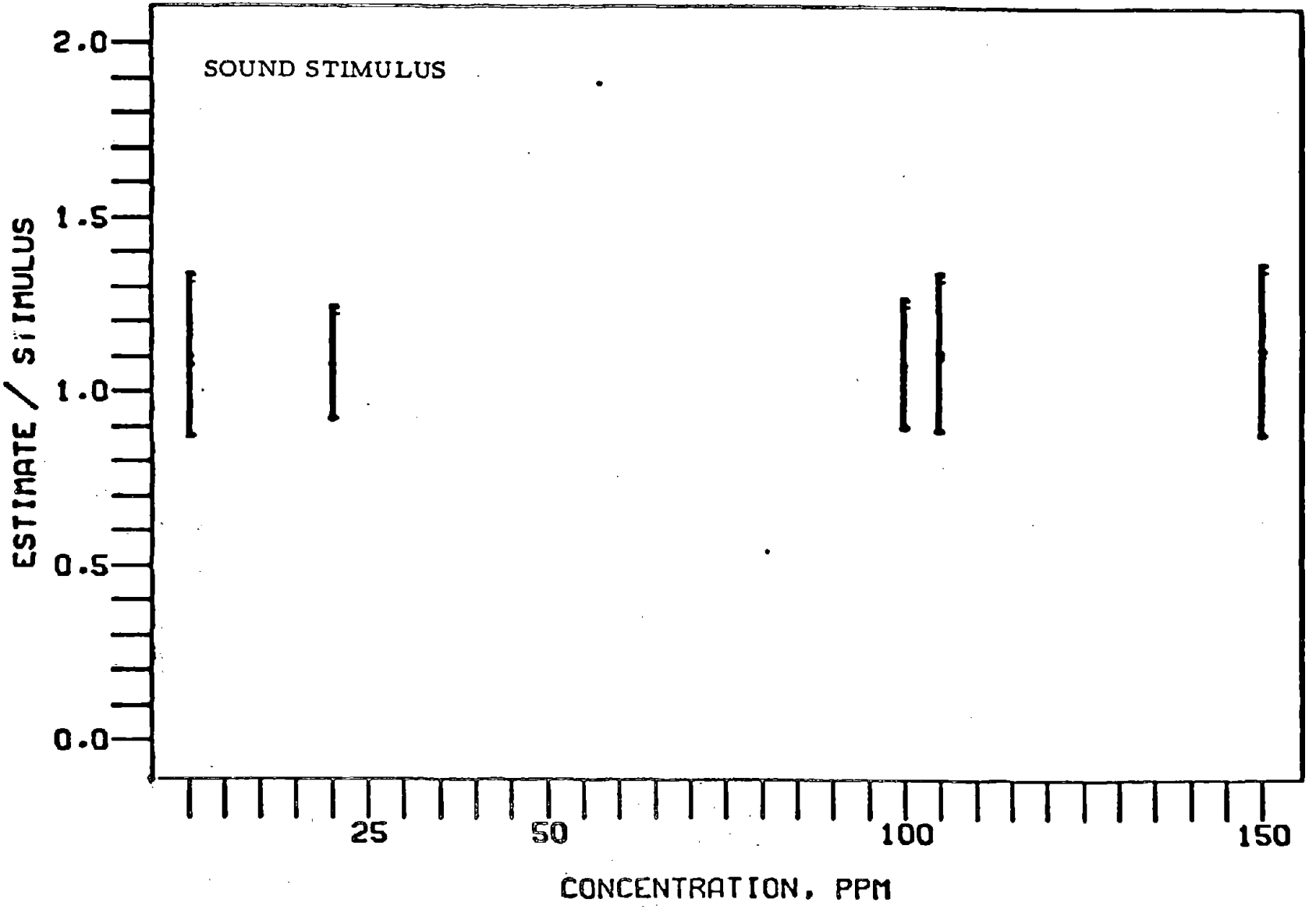


FIGURE 41

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

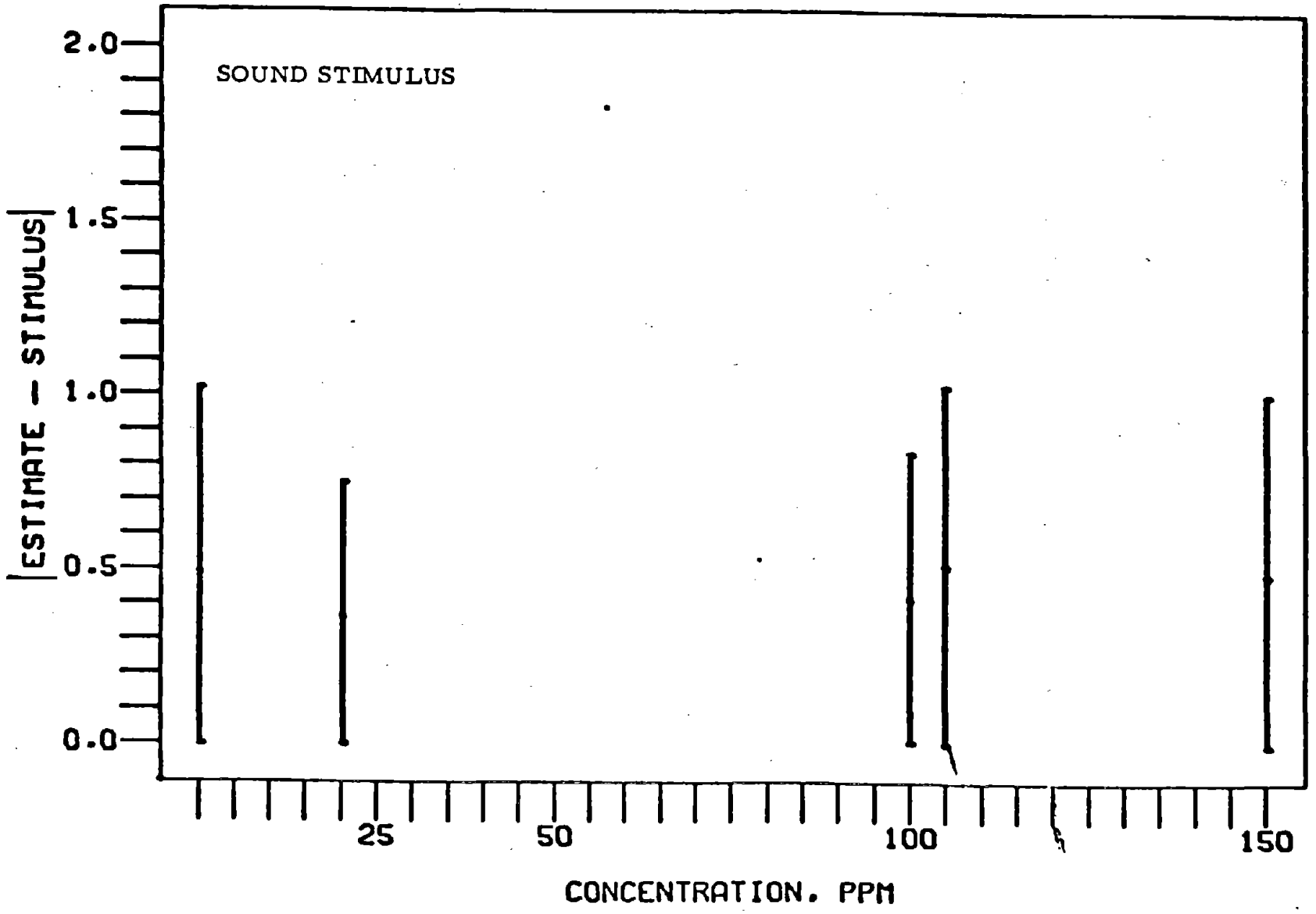


FIGURE 42

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

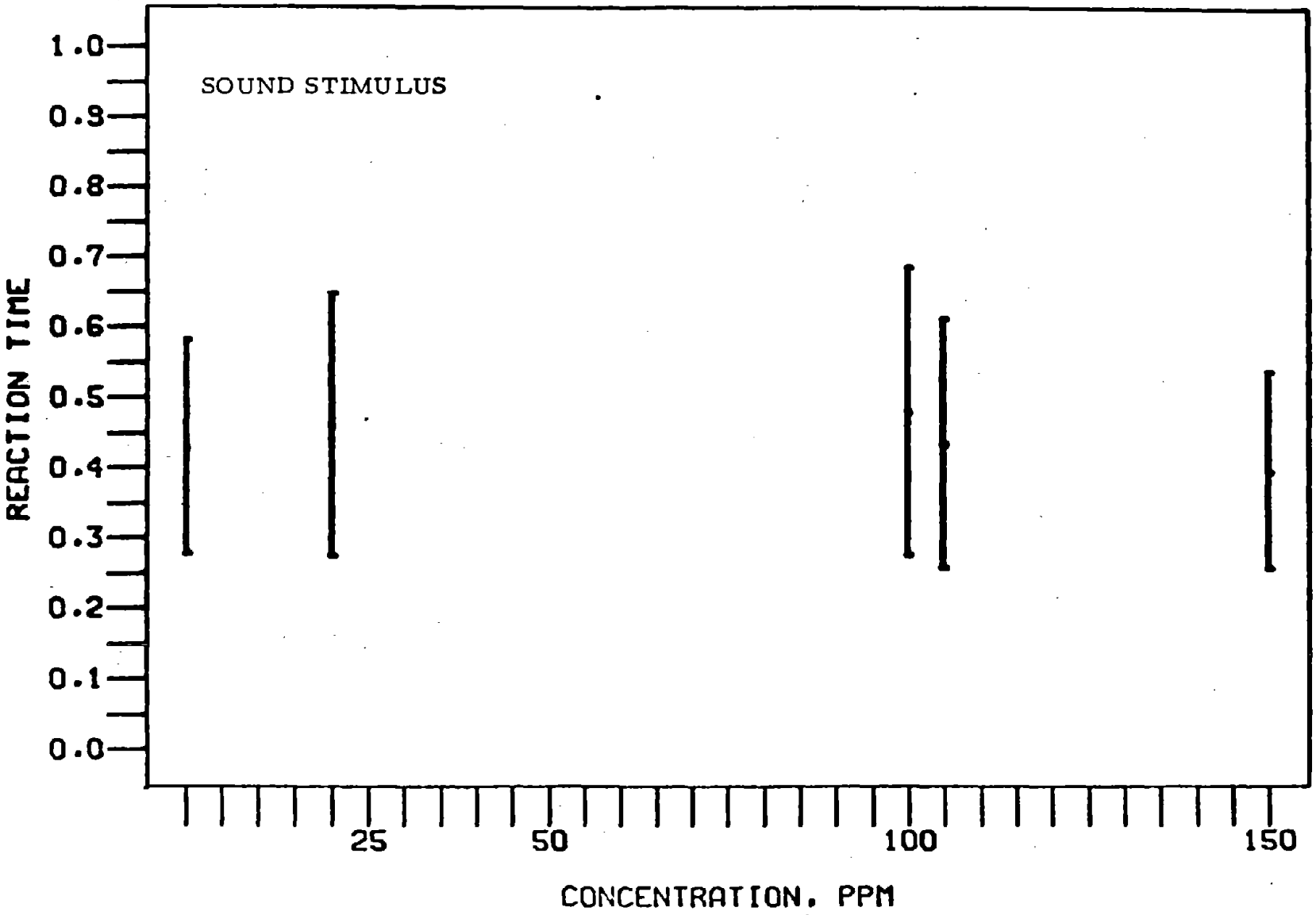


FIGURE 43

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

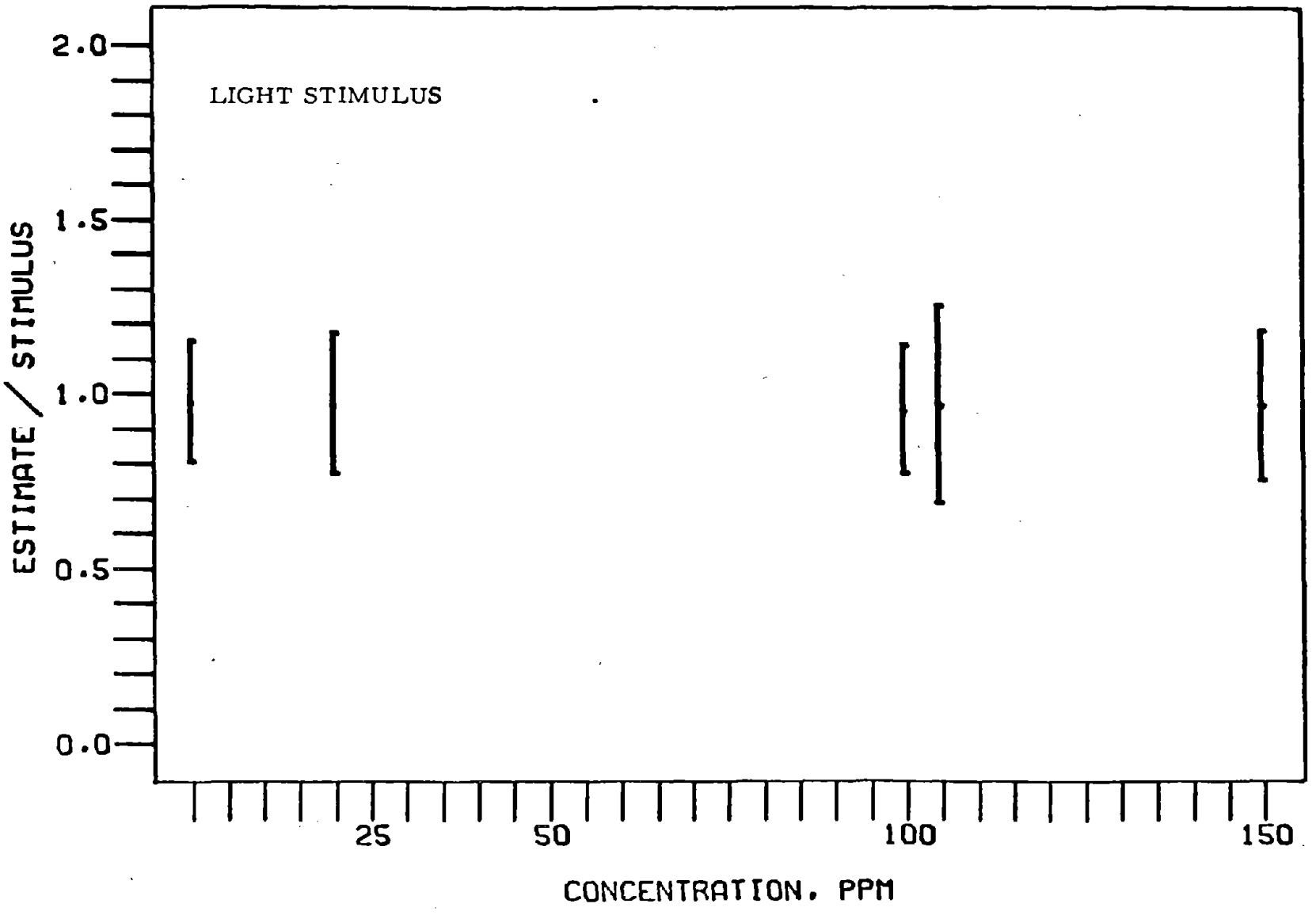


FIGURE 44

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

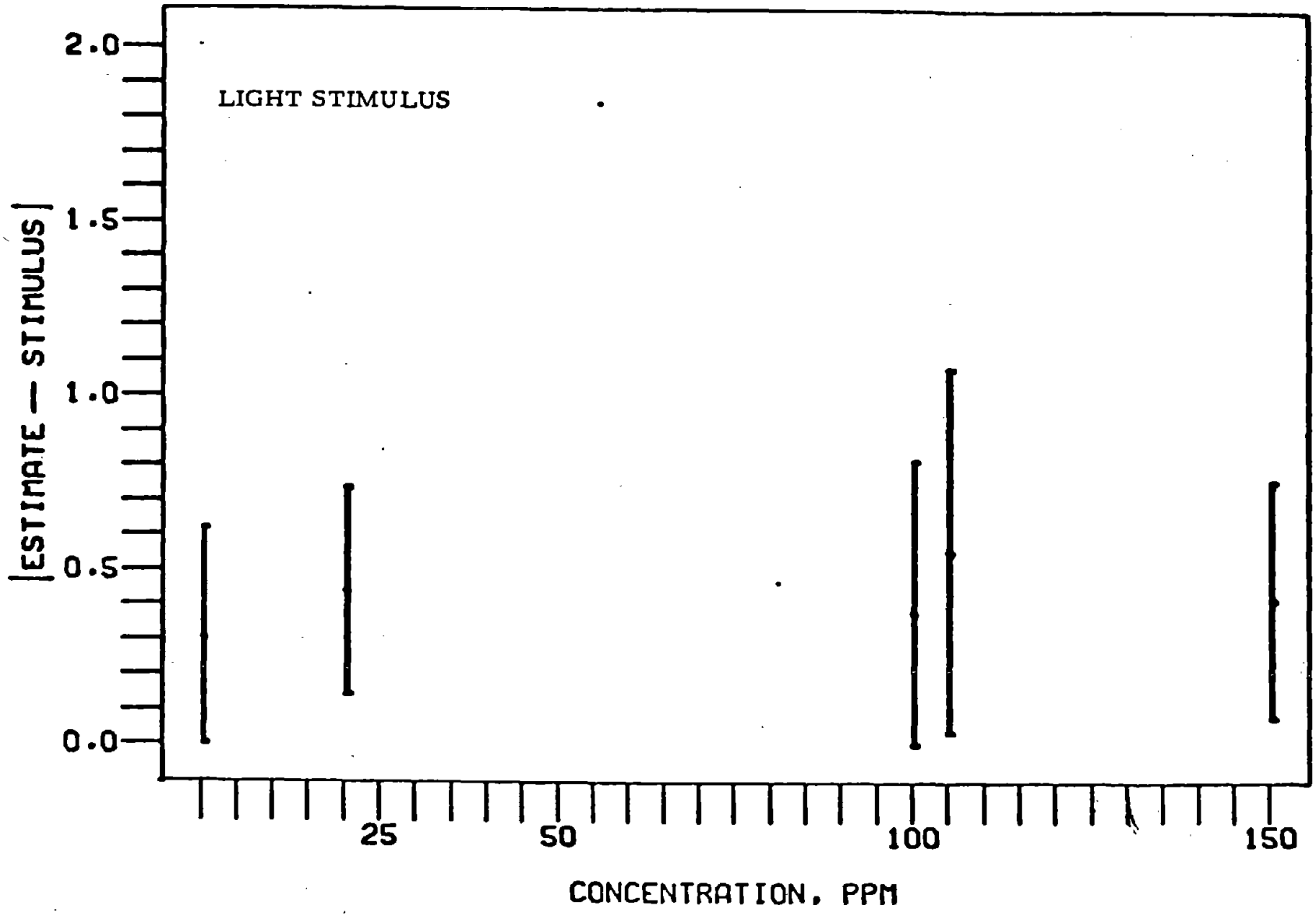


FIGURE 45

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - $7\frac{1}{2}$ Hour Exposure

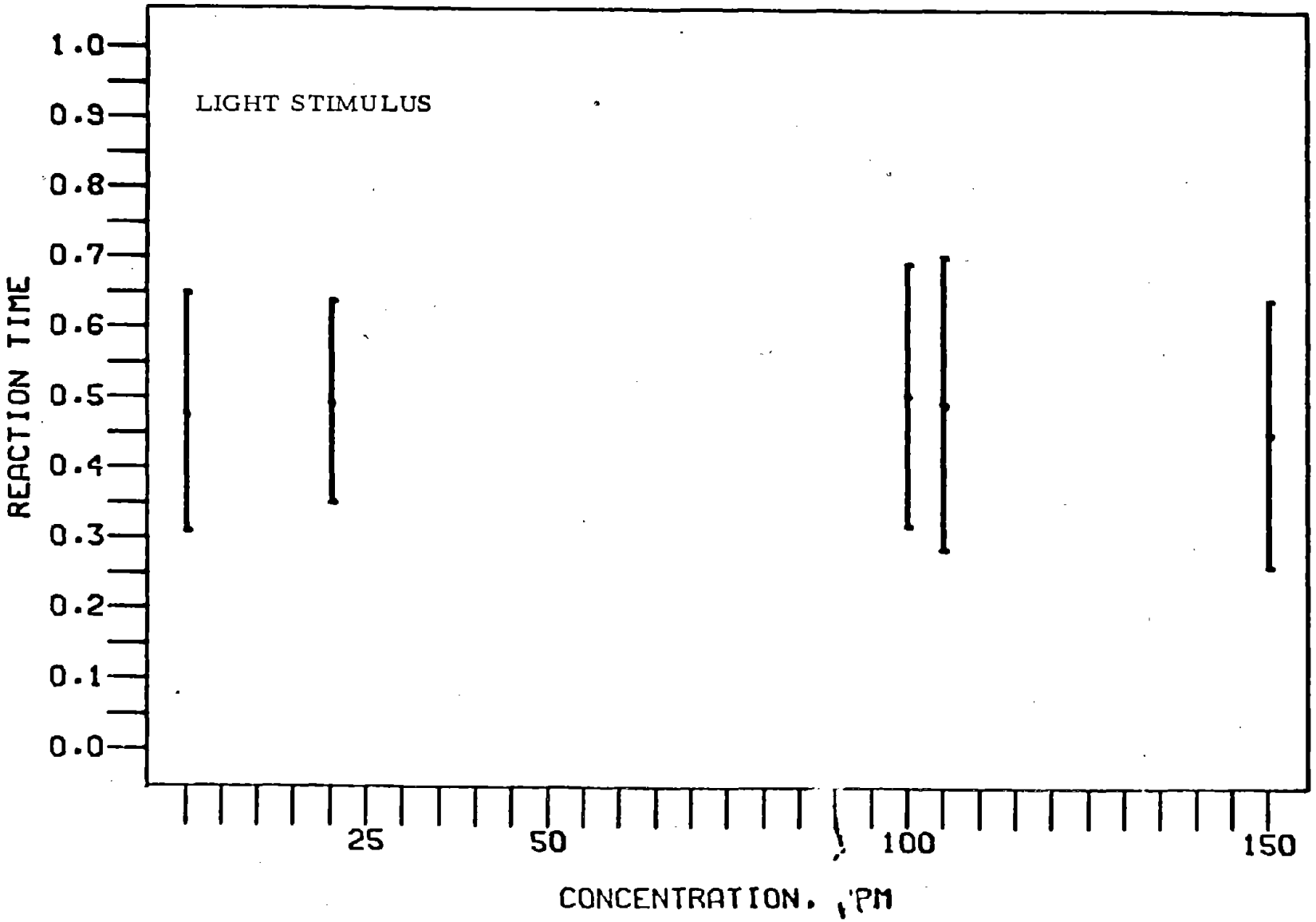


FIGURE 46
THE EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE ON
THE COORDINATION TEST
7-1/2 HOUR EXPOSURE

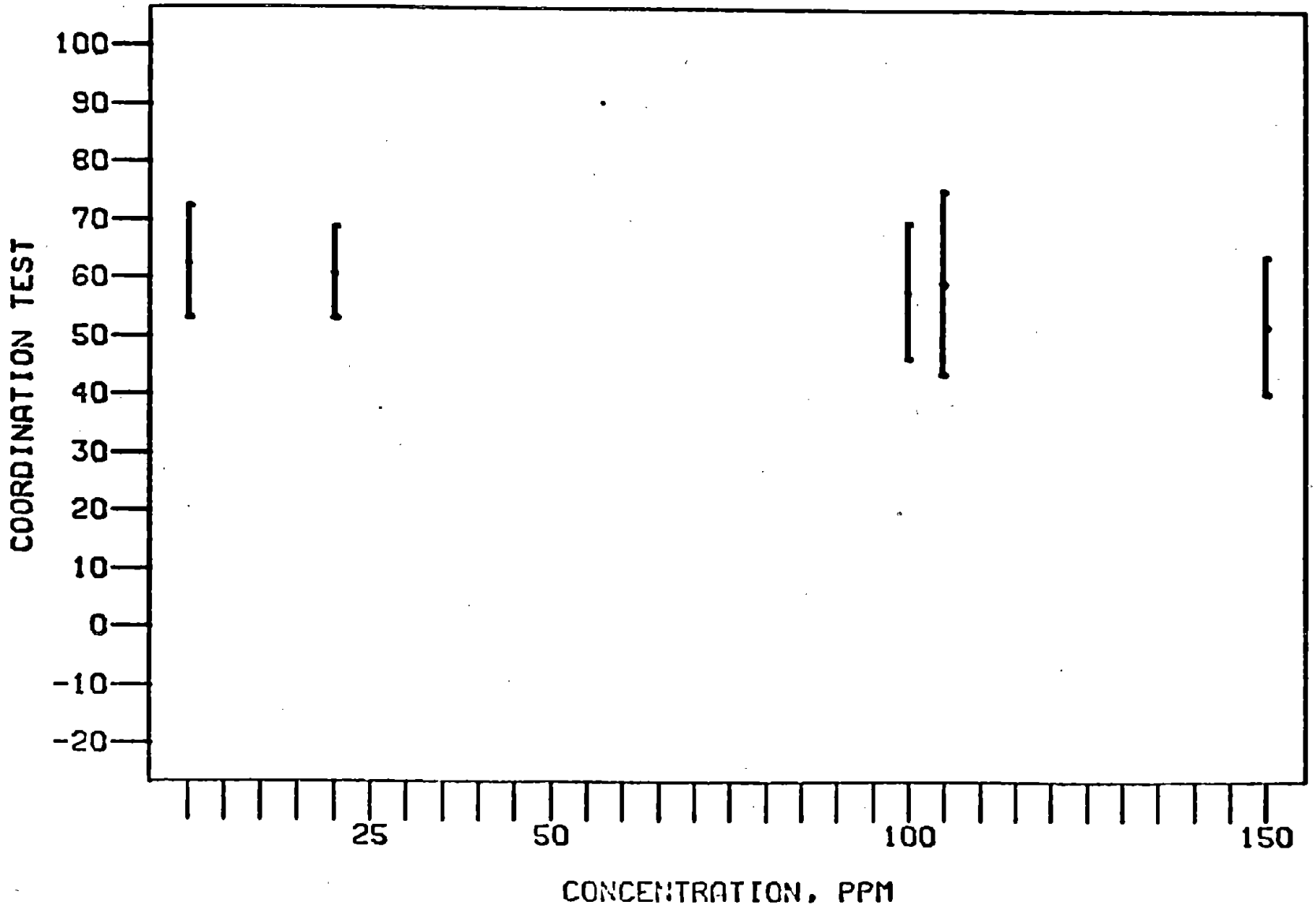


FIGURE 47
THE EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE ON
THE INSPECTION TEST
7-1/2 HOUR EXPOSURE

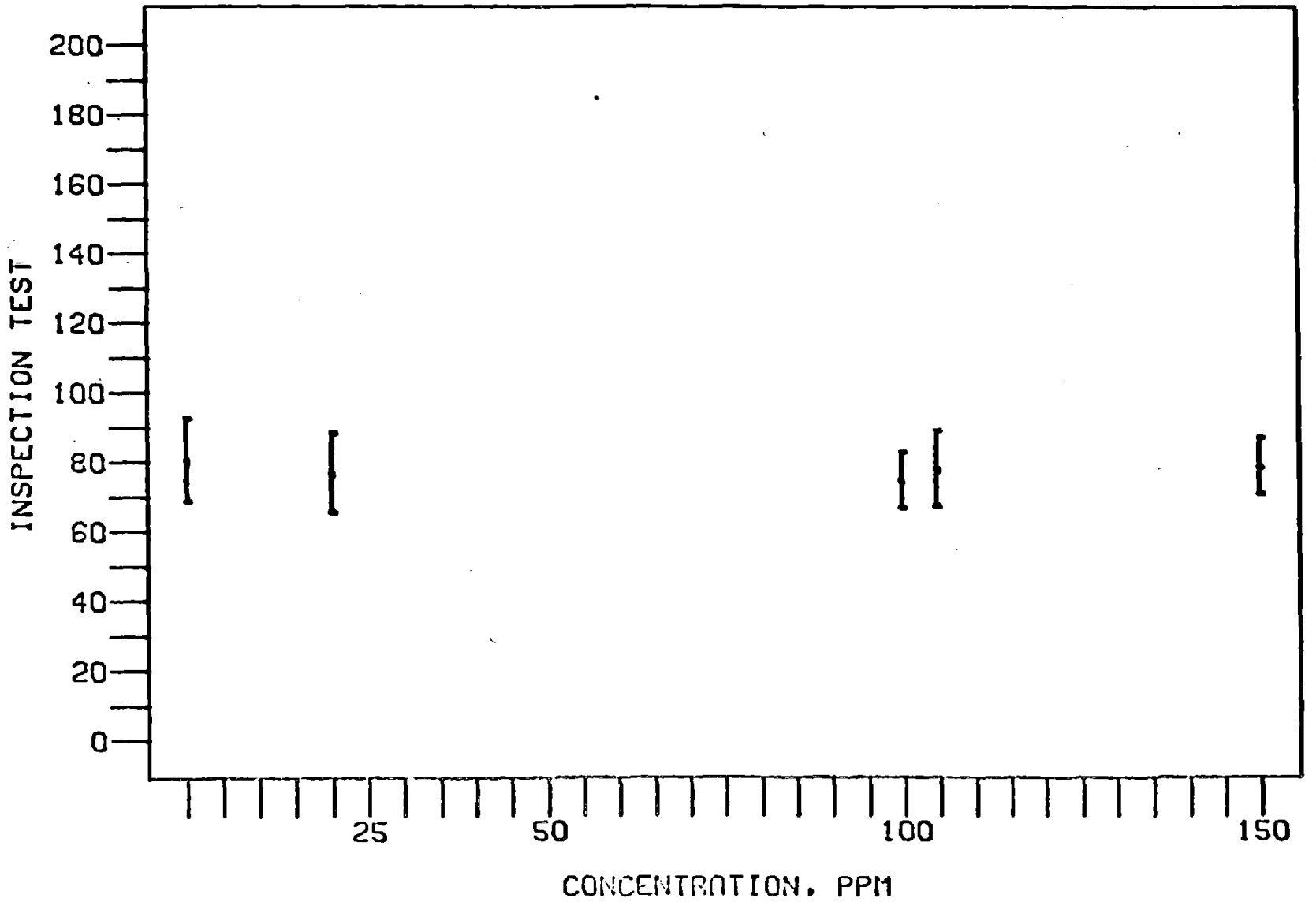


FIGURE 48
THE EFFECT OF EXPOSURE TO TETRACHLOROETHYLENE ON
THE ARITHMETIC TEST
7-1/2 HOUR EXPOSURE

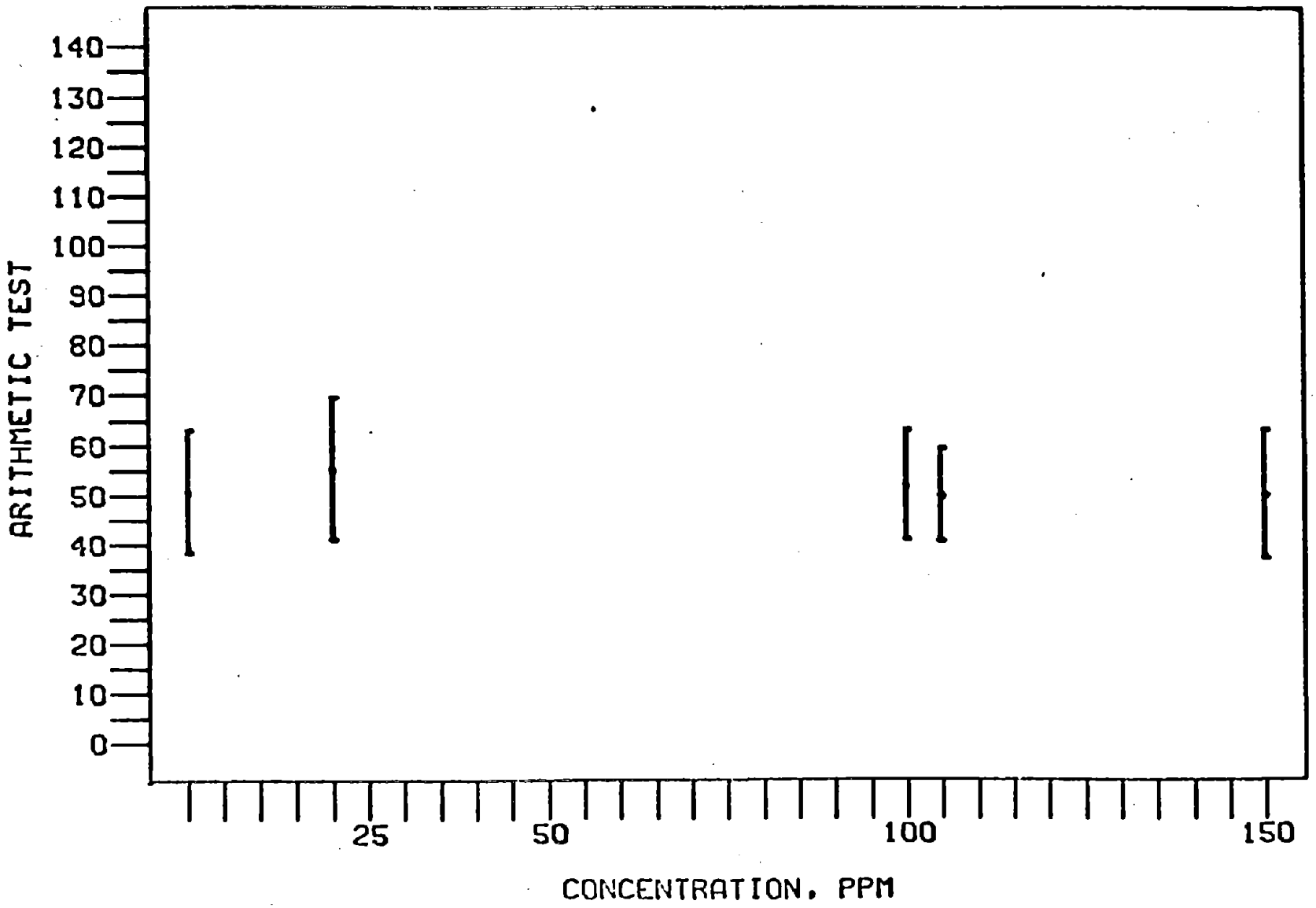


FIGURE 49

The Effect of Training and Exposure to Tetrachloroethylene on Time Estimations - 3 Hour Exposure

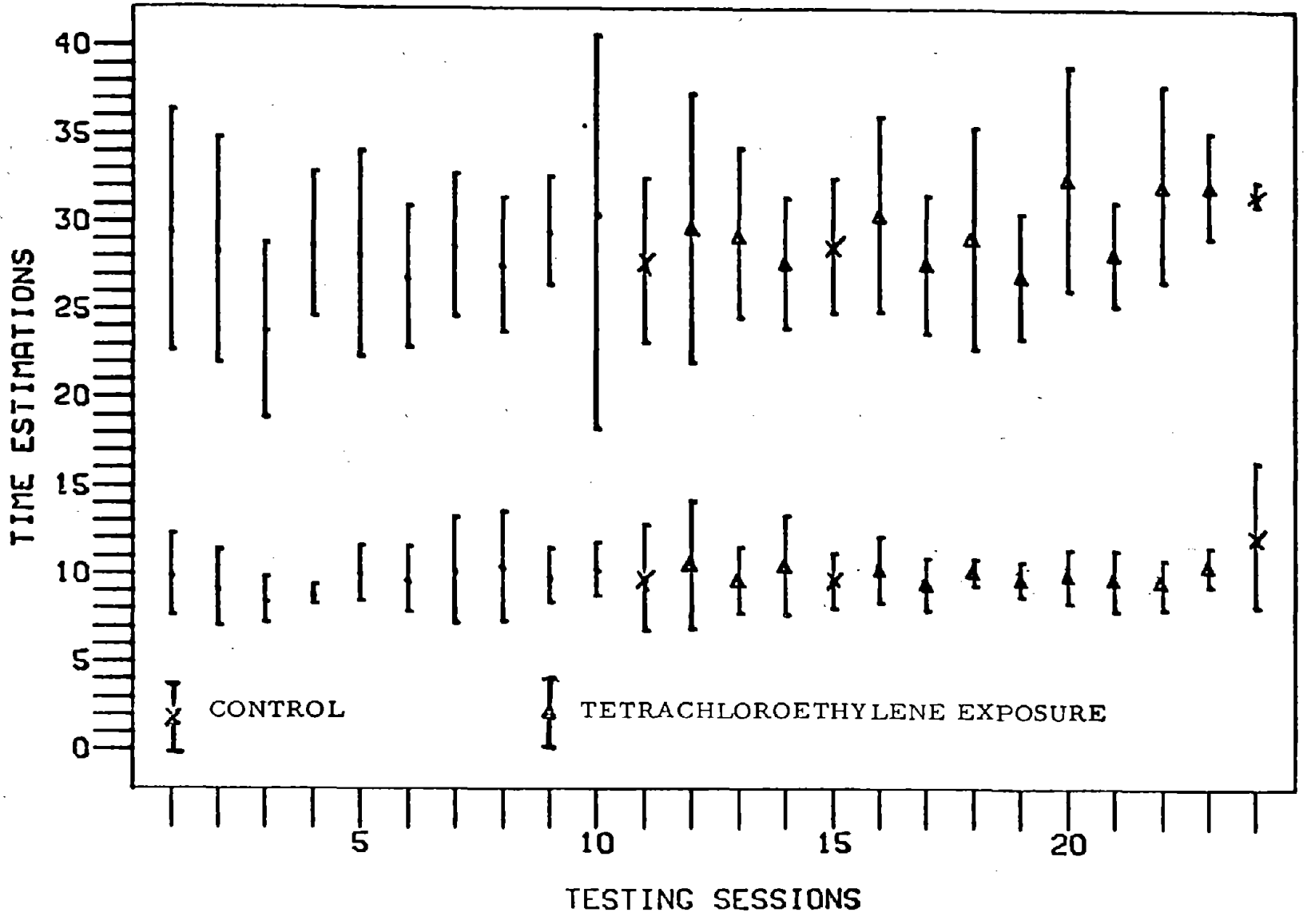


FIGURE 50

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

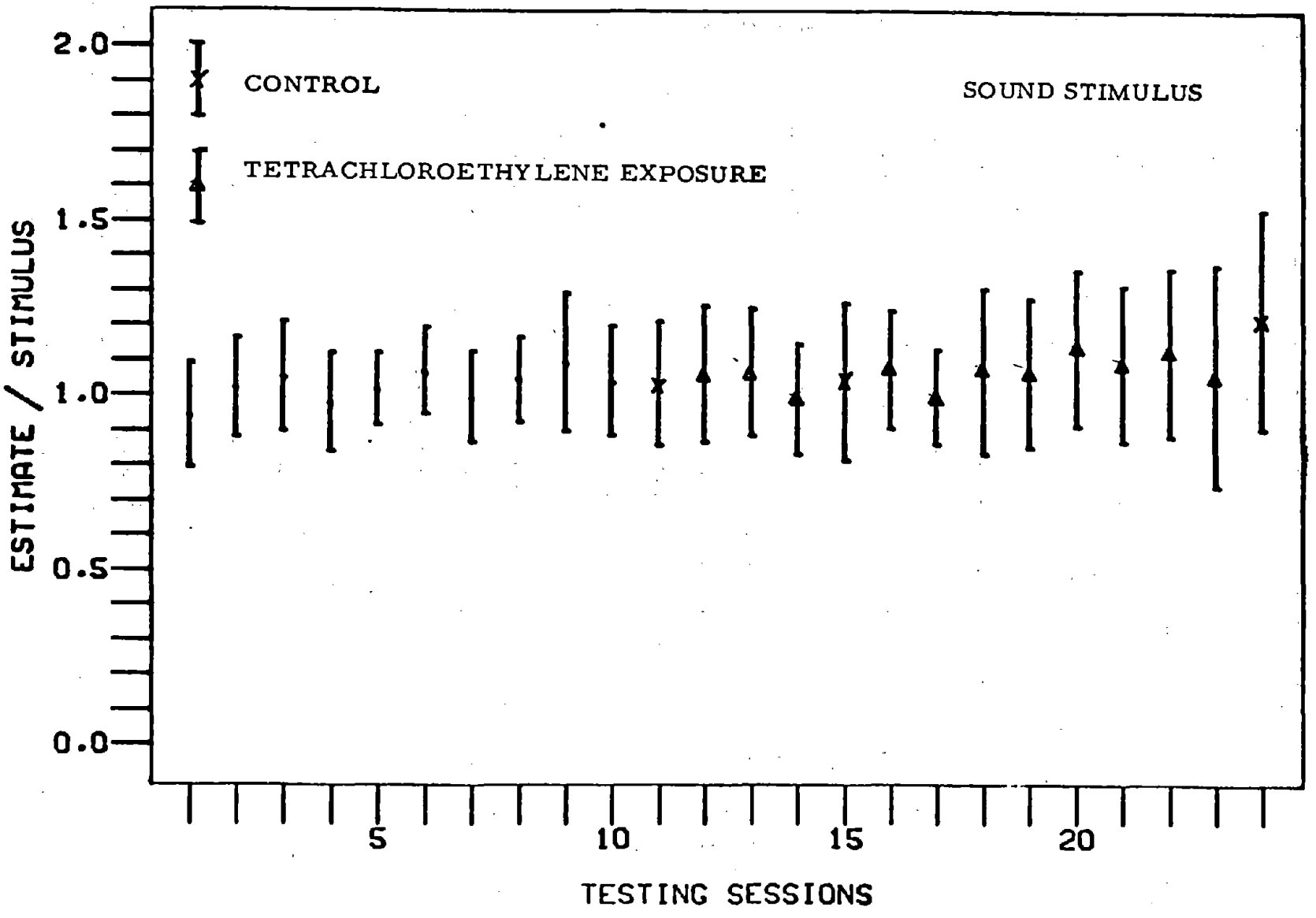


FIGURE 51

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

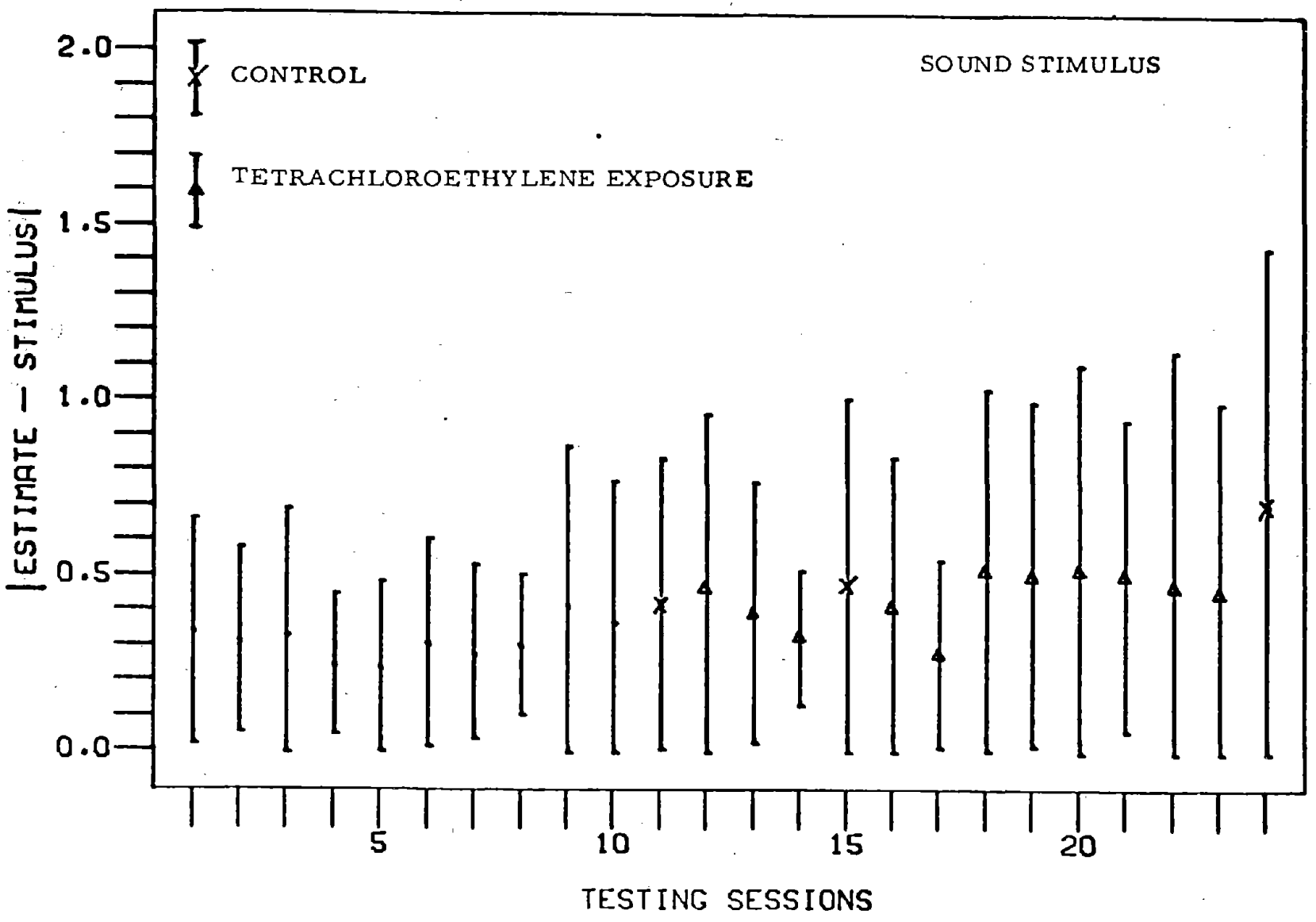


FIGURE 52

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

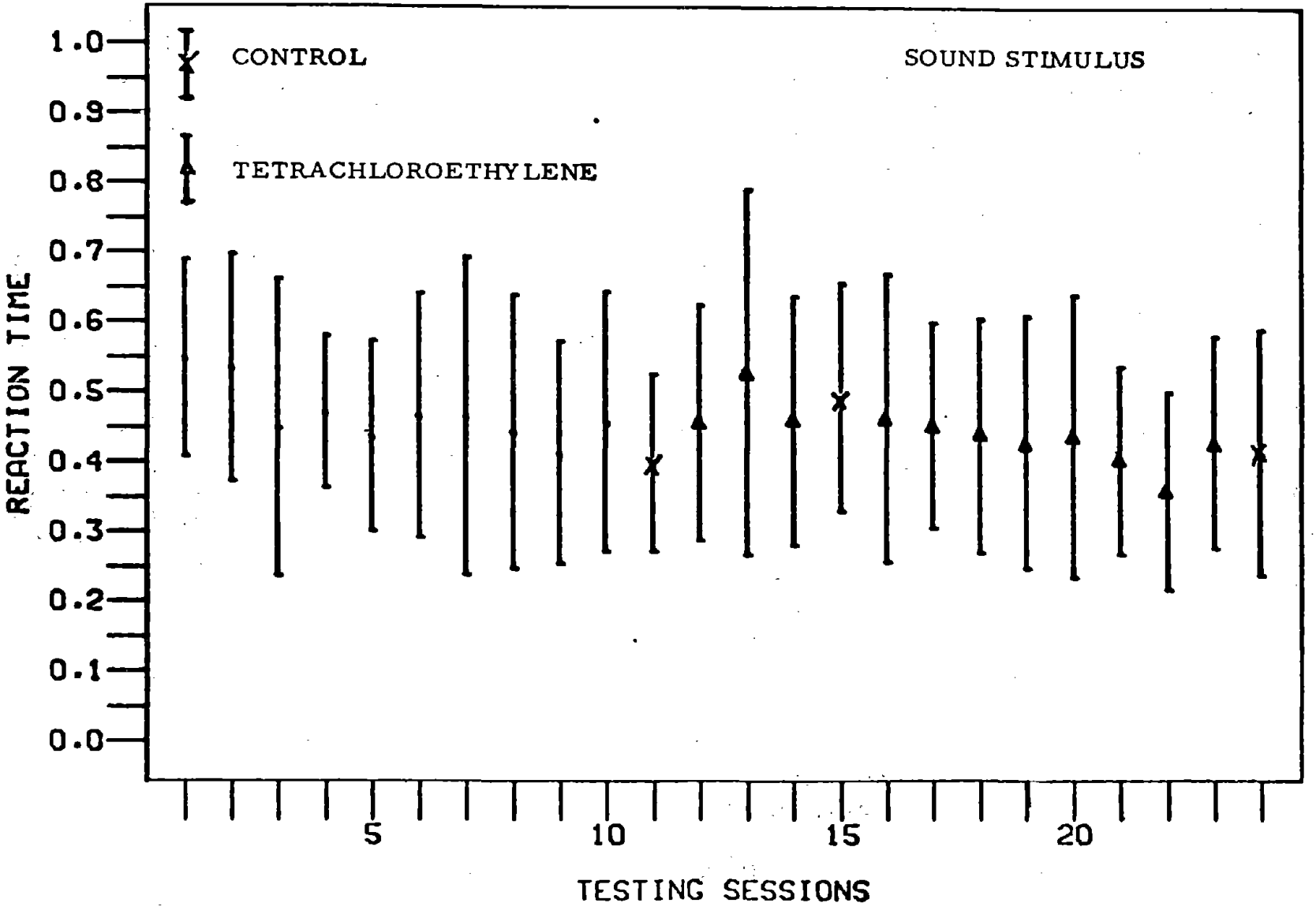


FIGURE 53

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

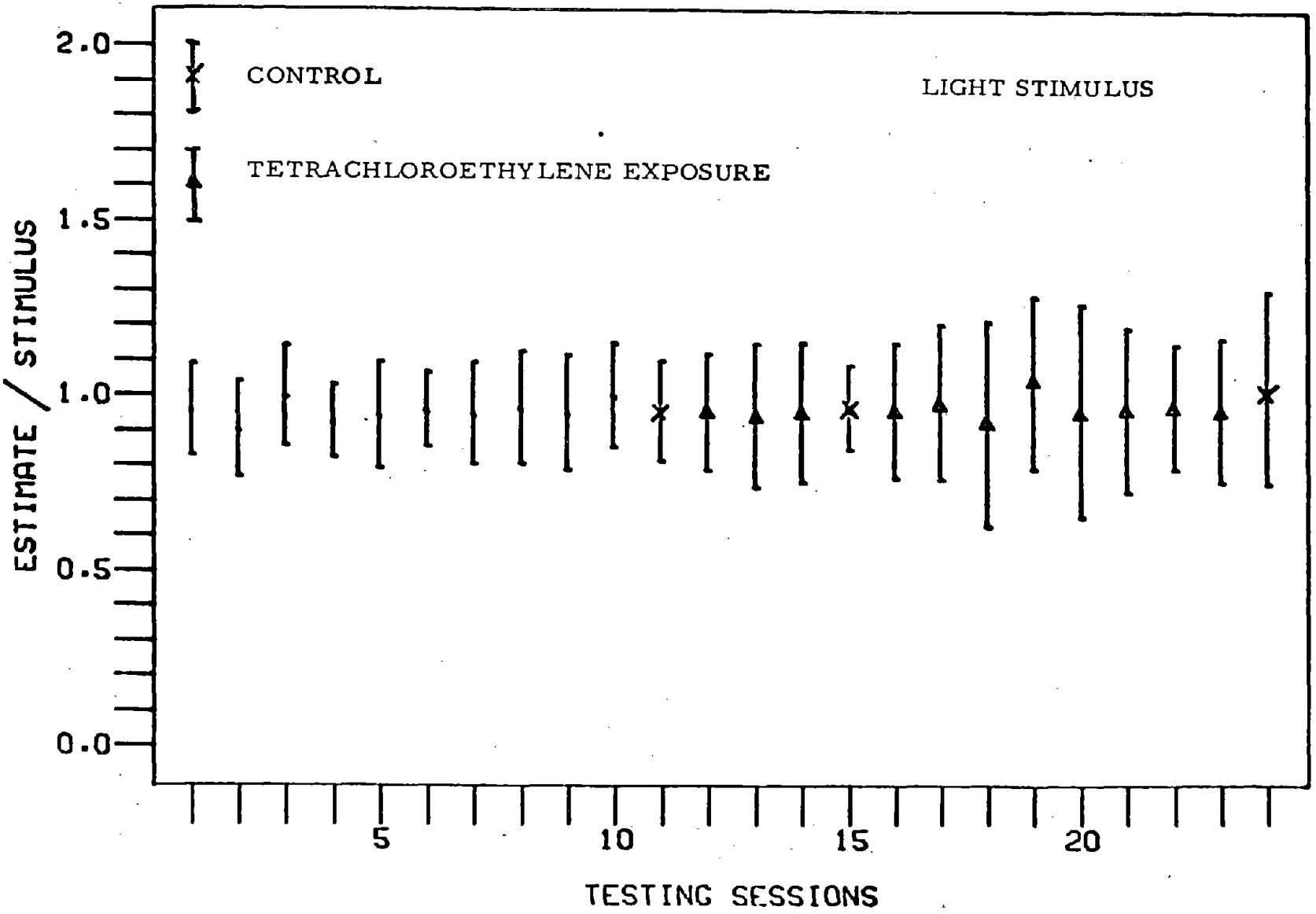


FIGURE 54

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

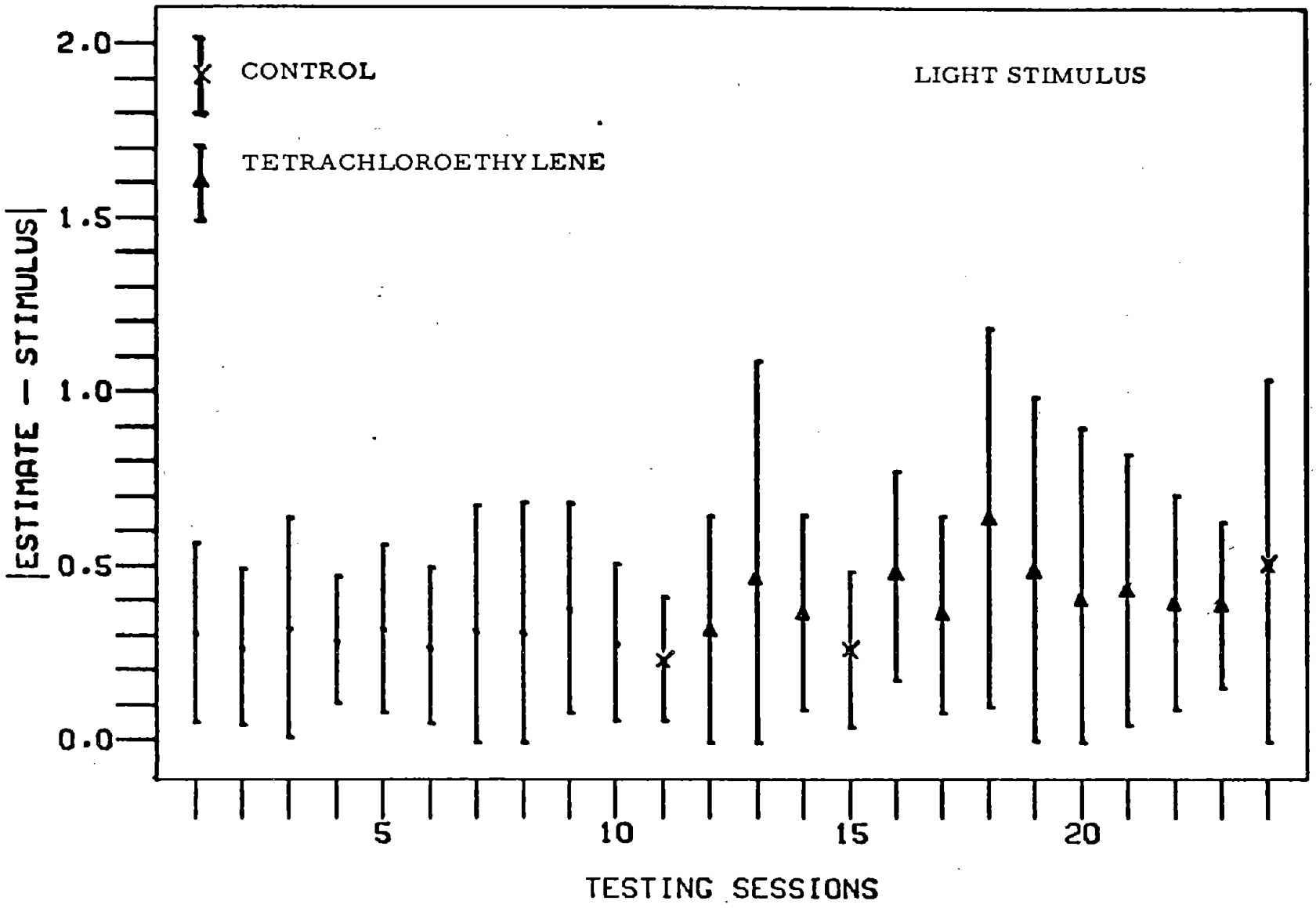


FIGURE 55

The Effect of Training and Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

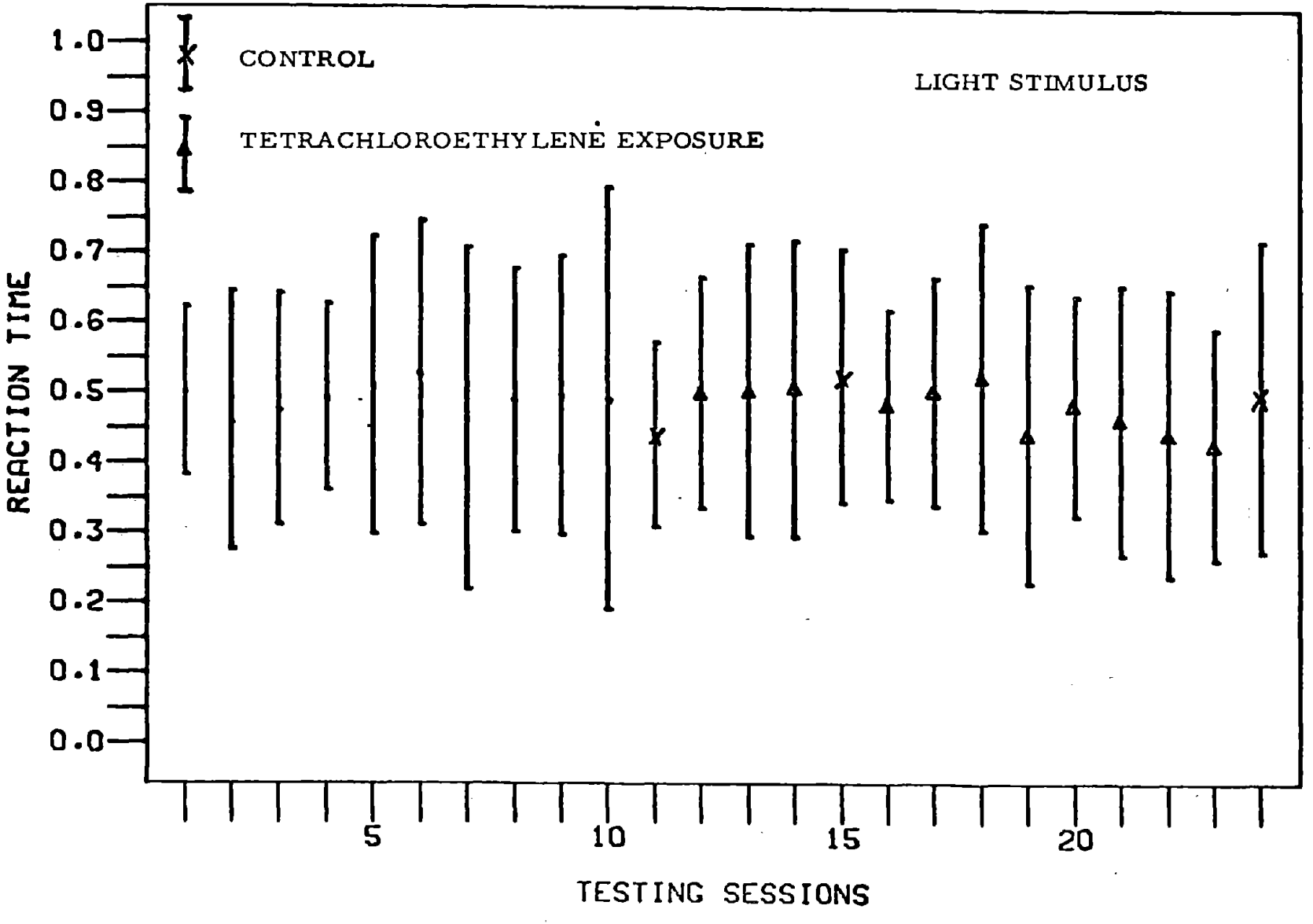


FIGURE 56

The Effect of Training and Exposure to Tetrachloroethylene on
The Coordination Test - 3 Hour Exposure

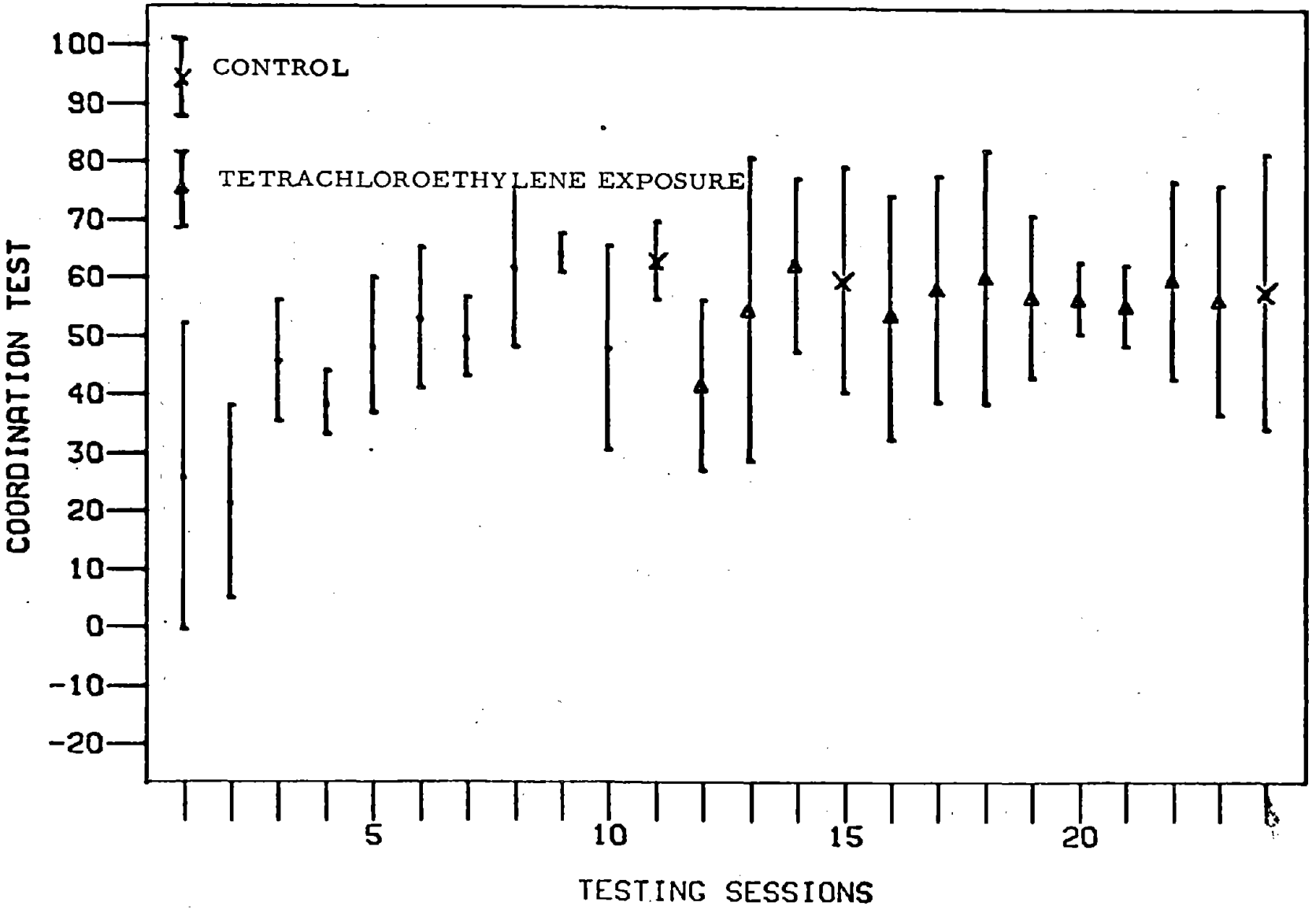


FIGURE 57

The Effect of Training and Exposure to Tetrachloroethylene on
The Arithmetic Test - 3 Hour Exposure

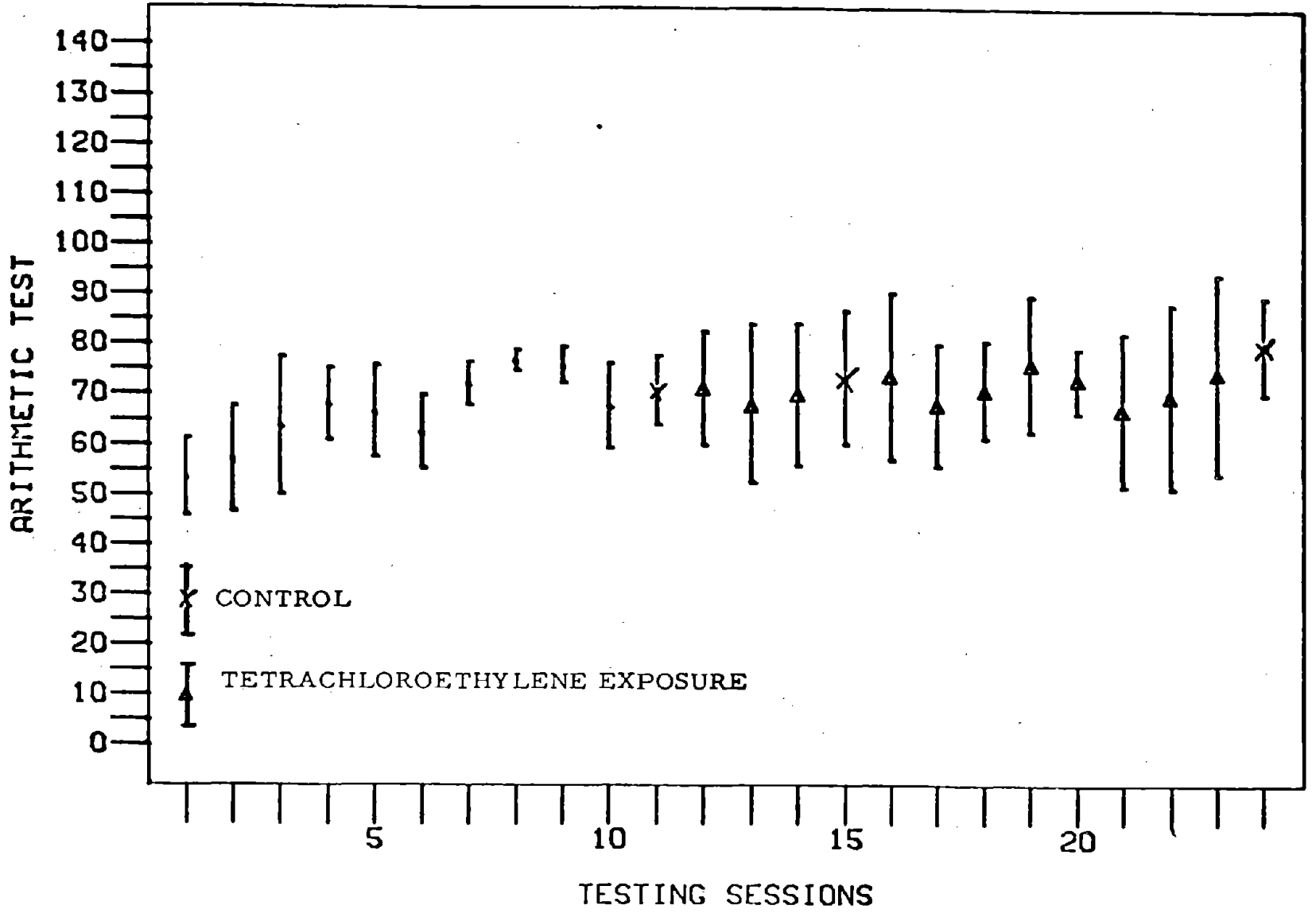


FIGURE 58

The Effect of Training and Exposure to Tetrachloroethylene on
The Inspection Test - 3 Hour Exposure

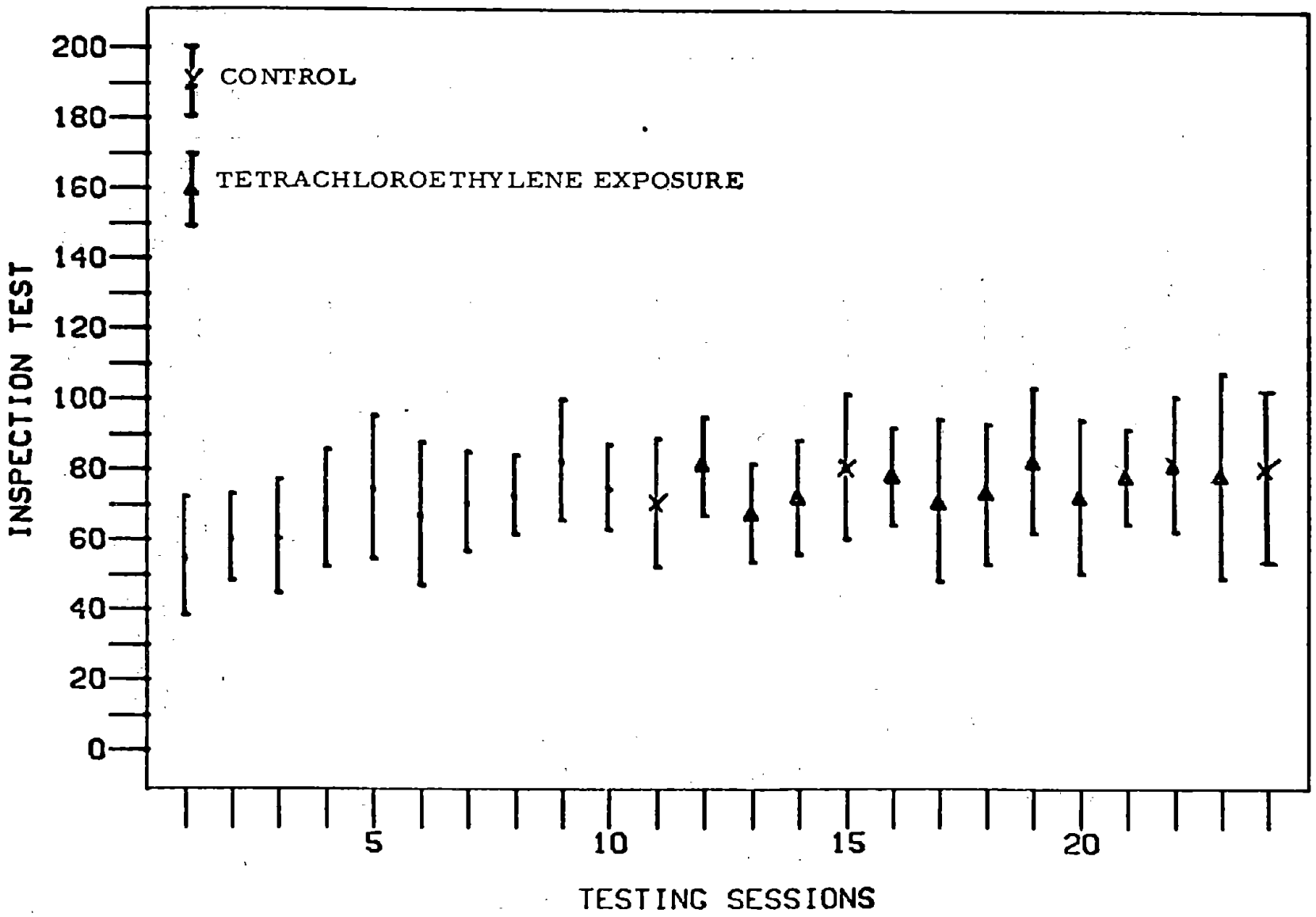


FIGURE 59

The Effect of Exposure to Tetrachloroethylene on
Time Estimations - 3 Hour Exposure

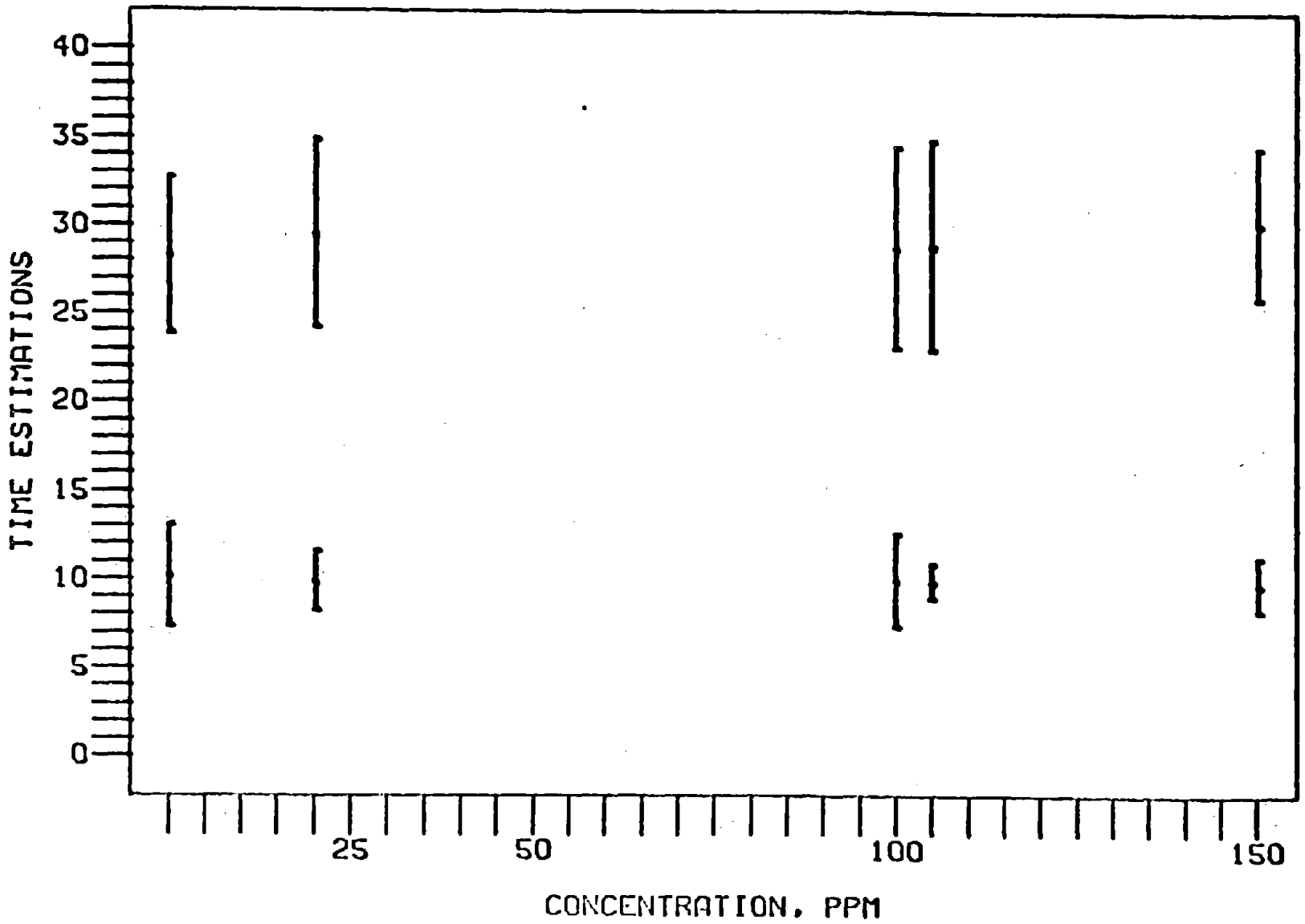


FIGURE 60

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

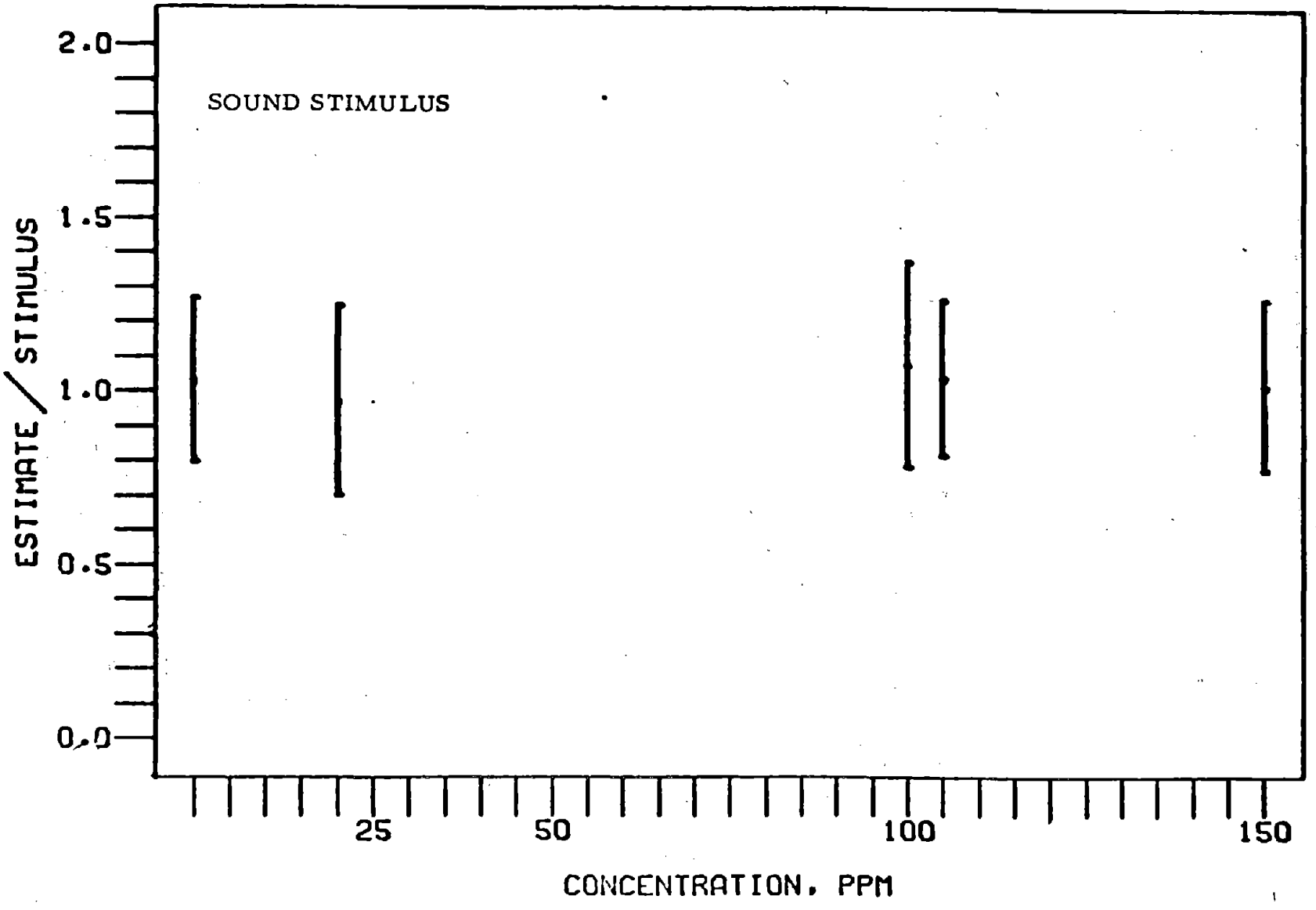


FIGURE 61

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

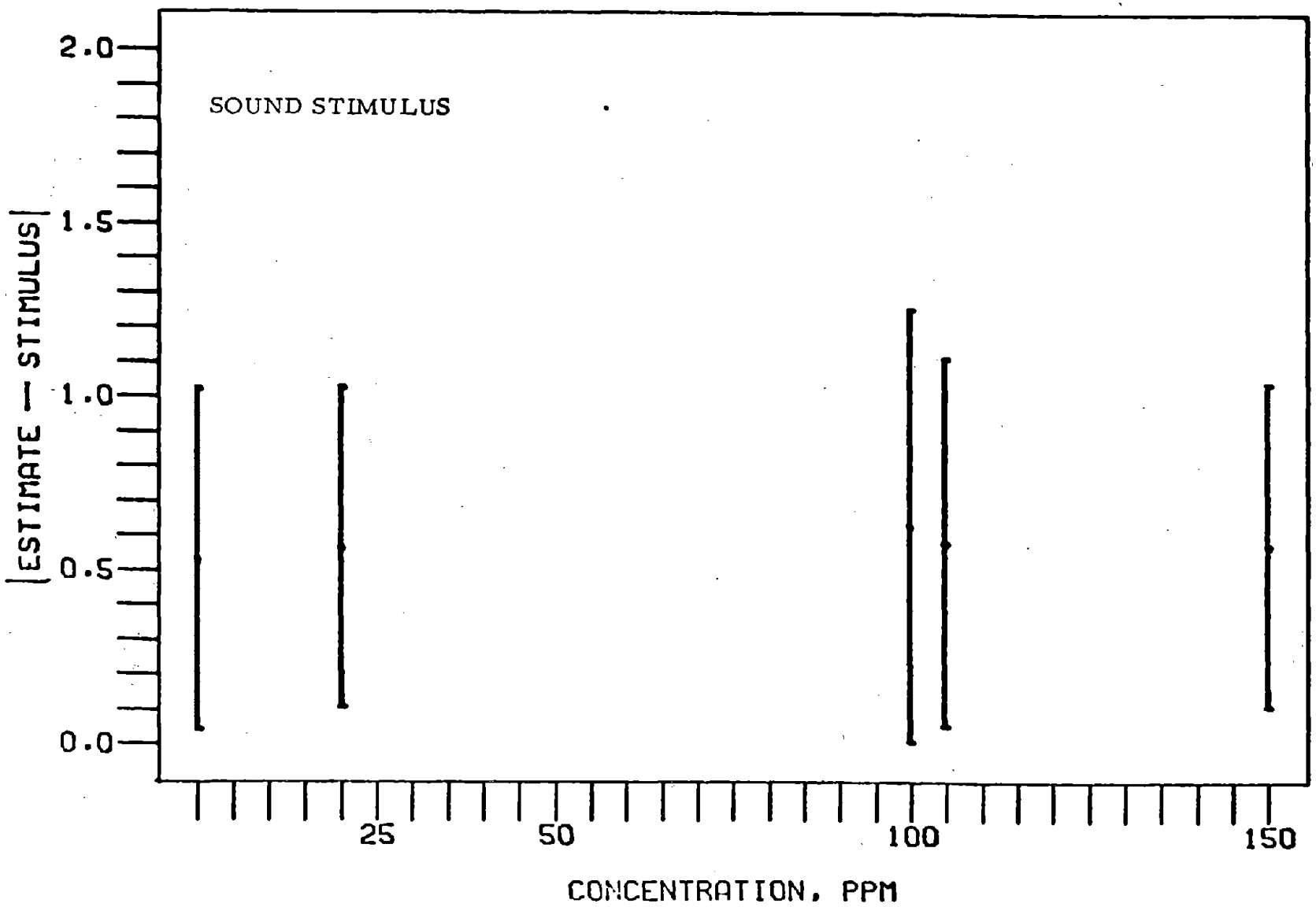


FIGURE 62

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

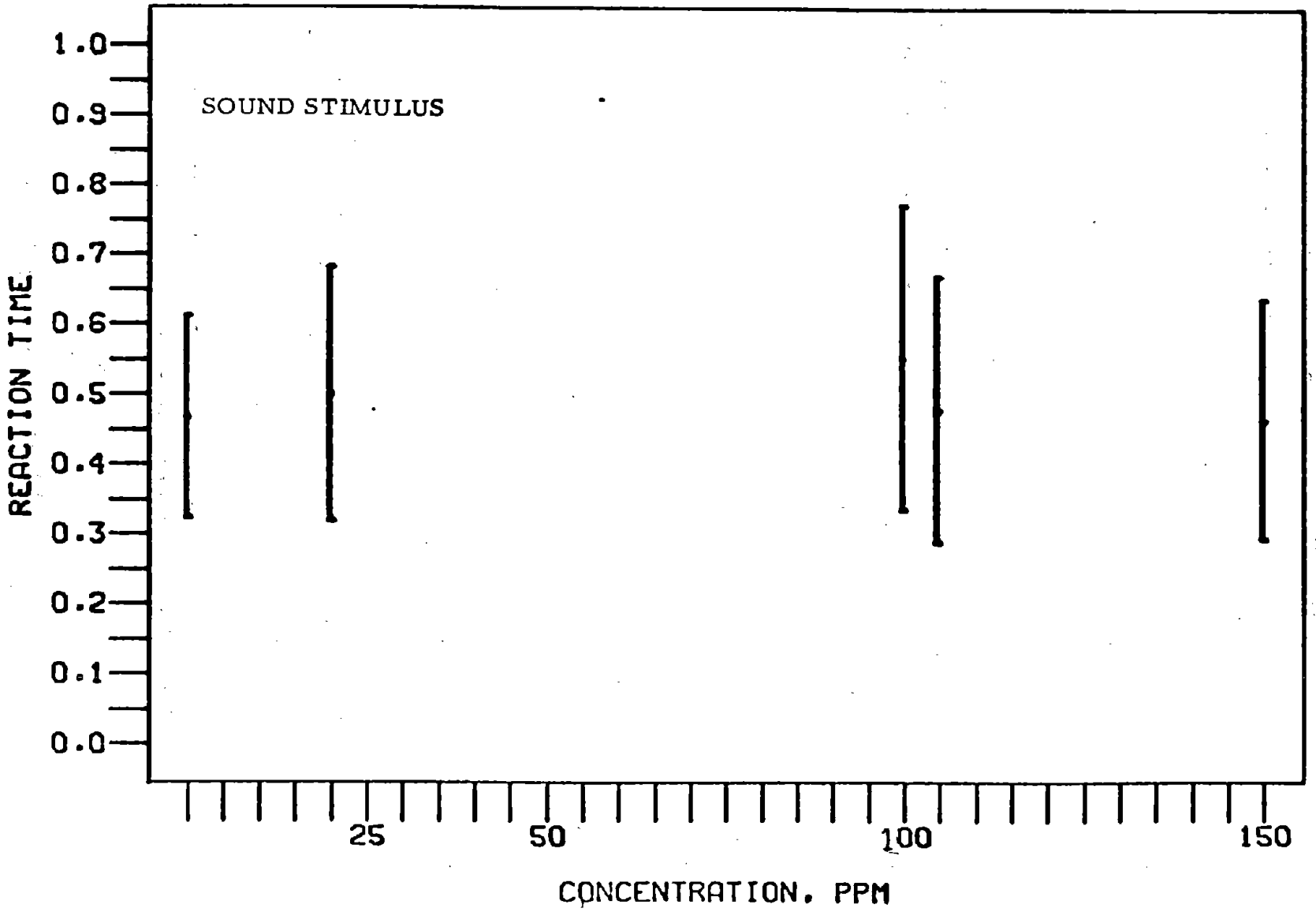


FIGURE 63

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

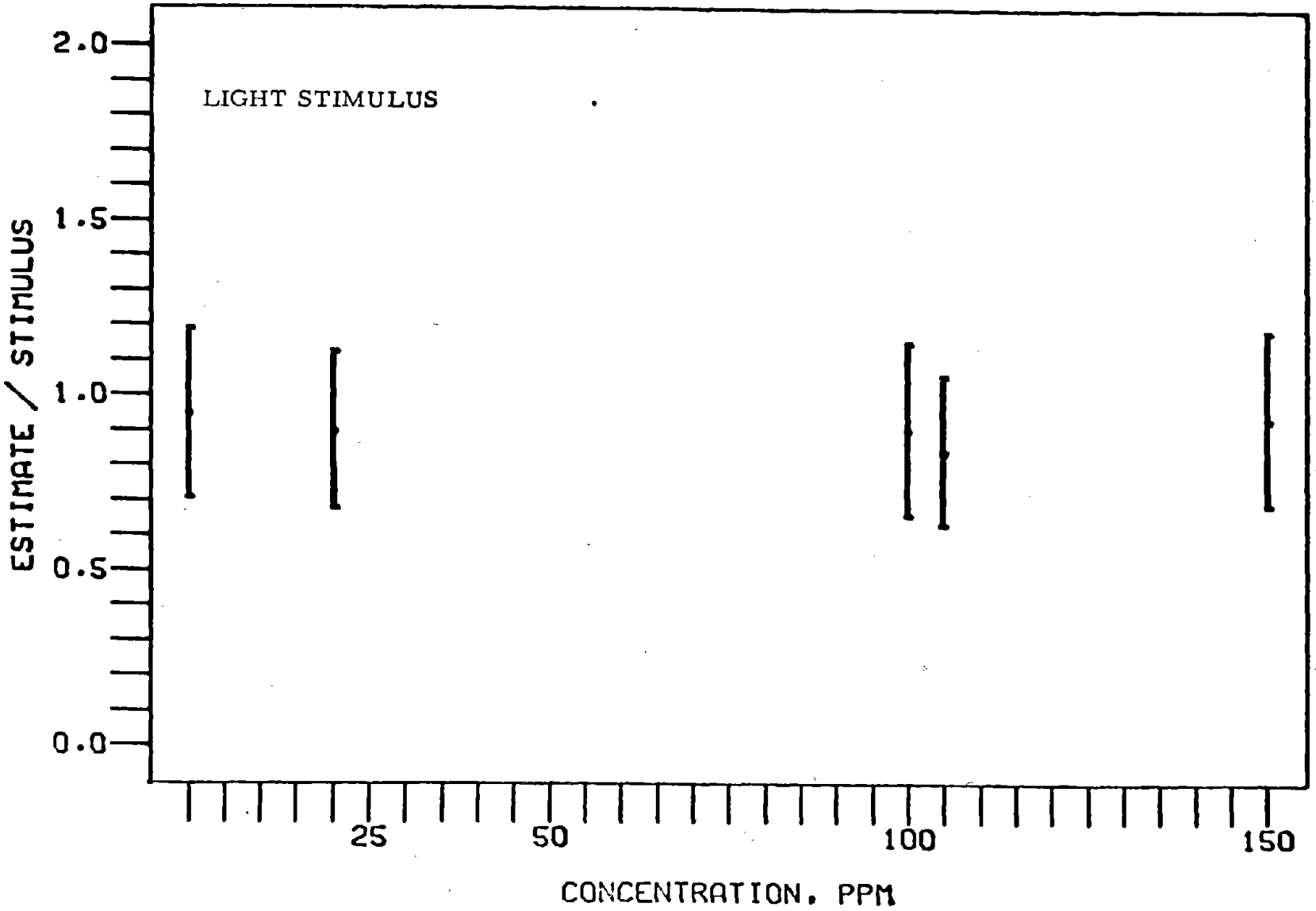


FIGURE 64

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

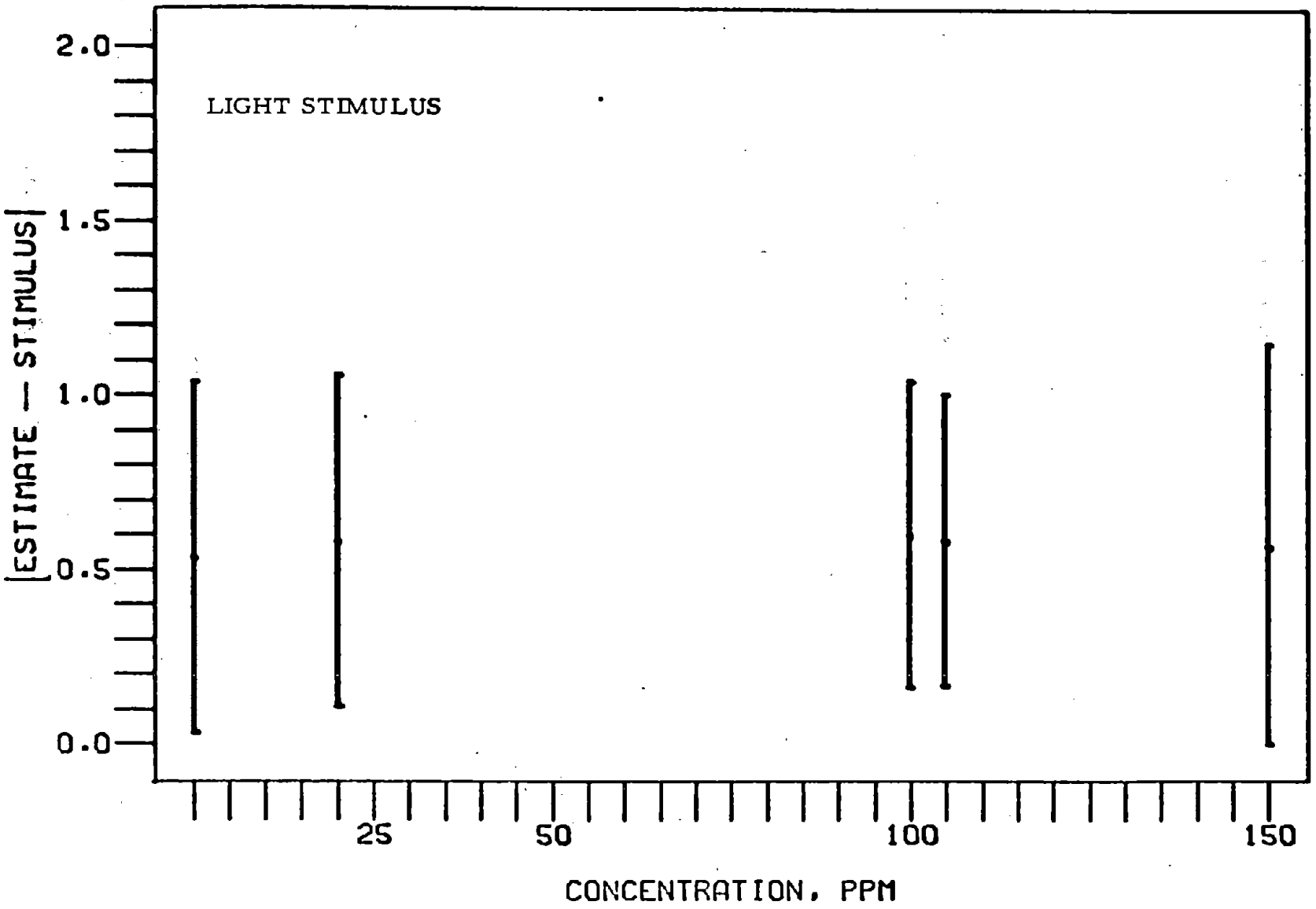


FIGURE 65

The Effect of Exposure to Tetrachloroethylene on
The Marquette Test - 3 Hour Exposure

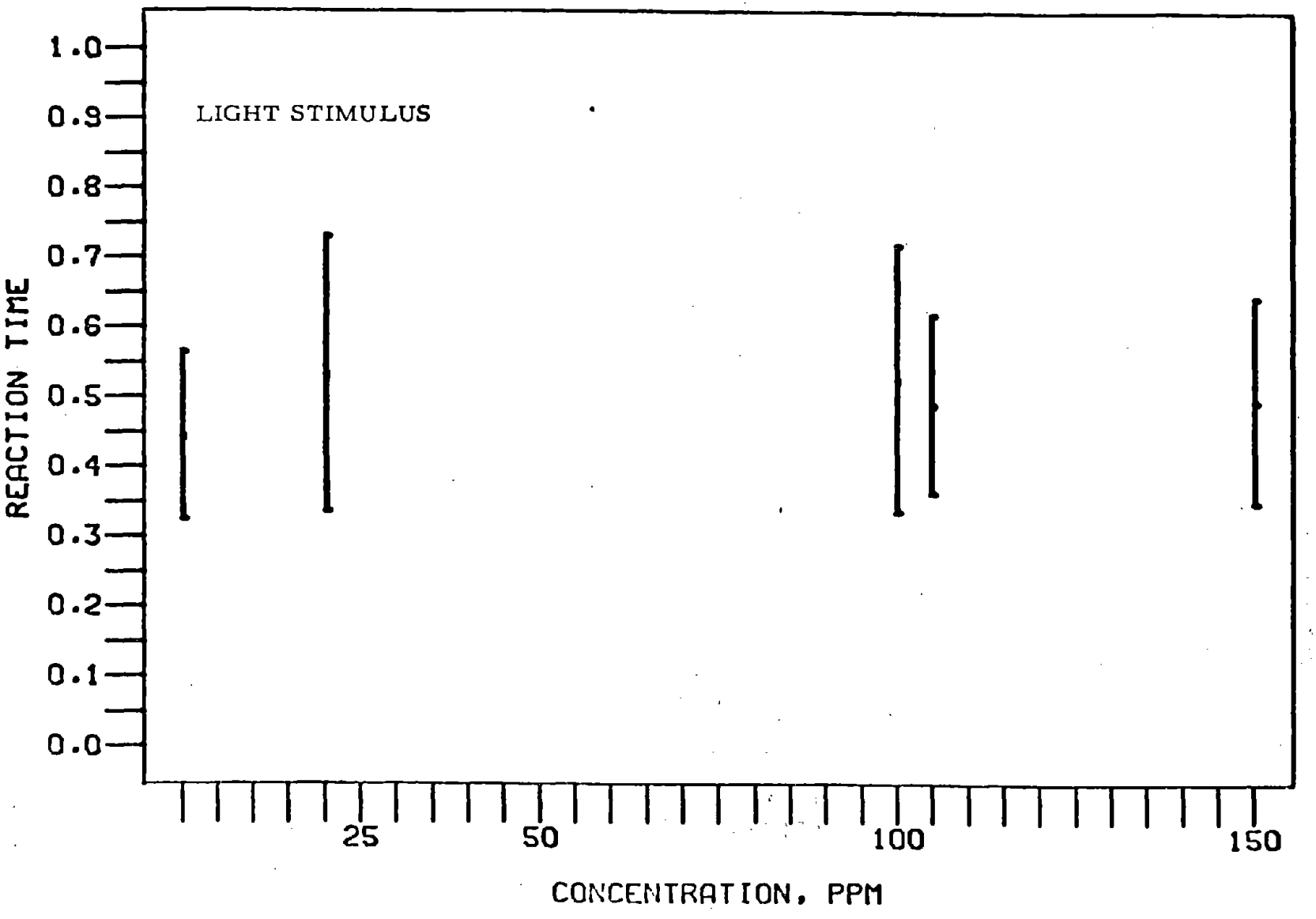


FIGURE 66

The Effect of Exposure to Tetrachloroethylene on
The Arithmetic Test - 3 Hour Exposure

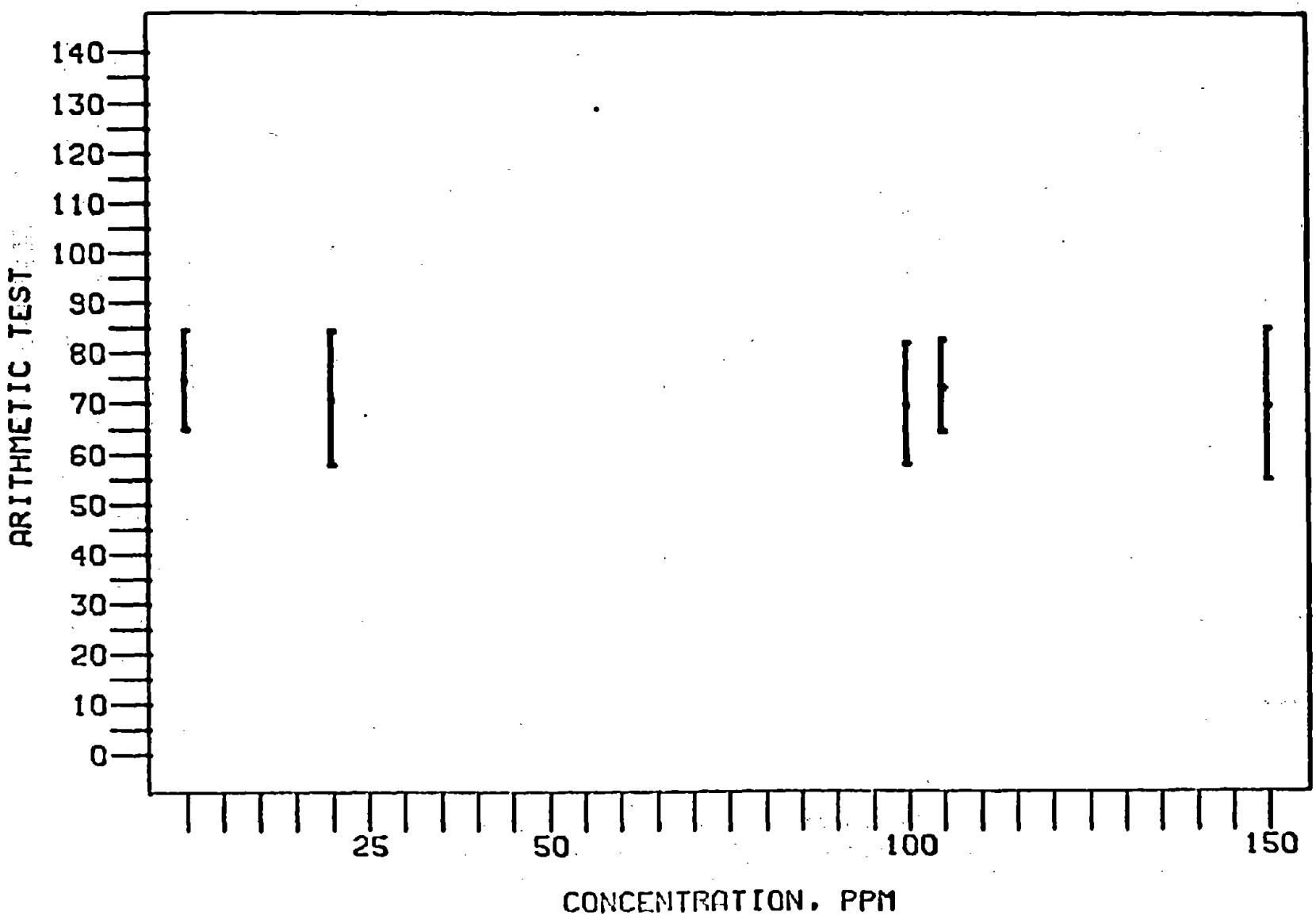


FIGURE 67

The Effect of Exposure to Tetrachloroethylene on
The Inspection Test - 3 Hour Exposure

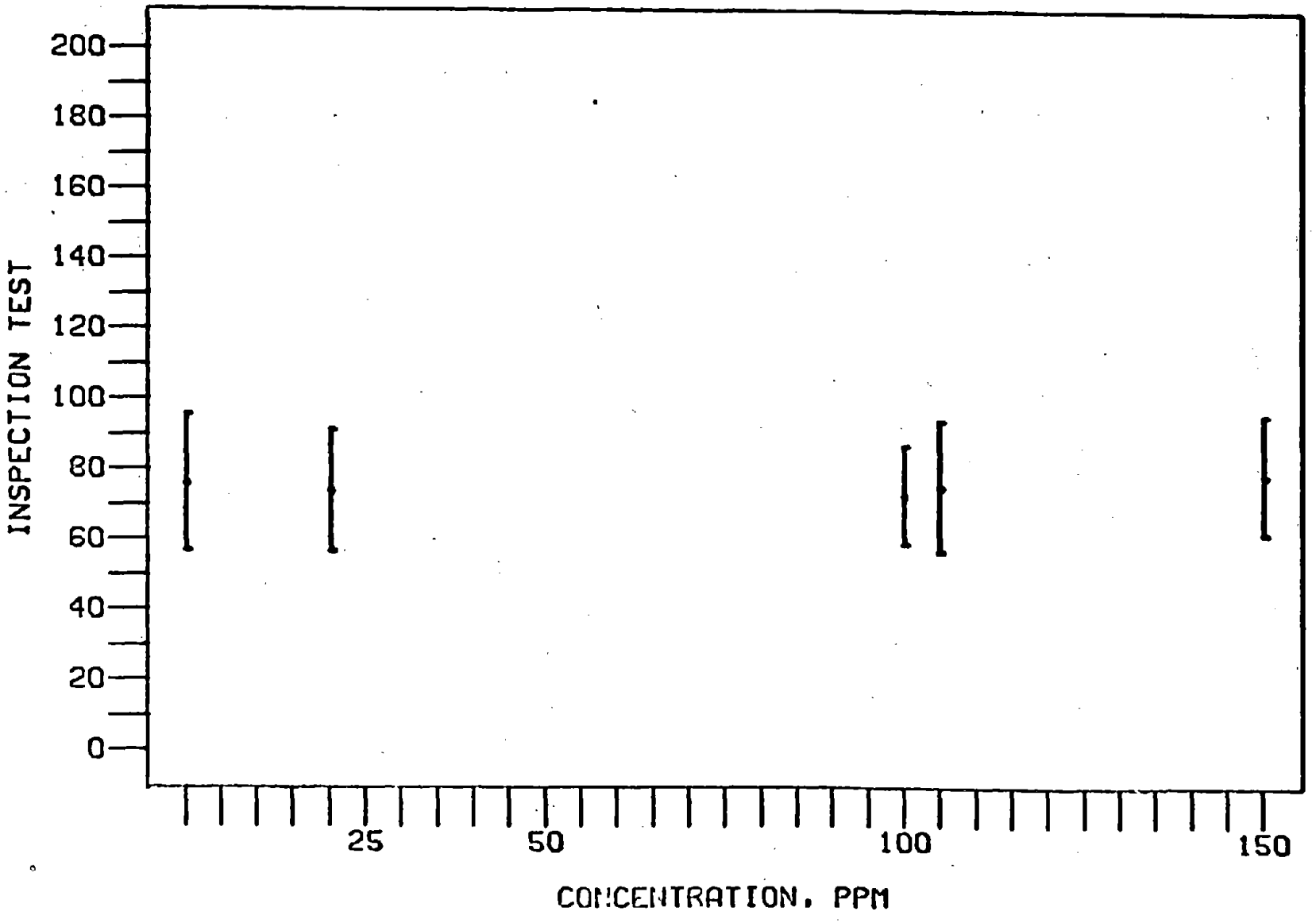


FIGURE 68

The Effect of Exposure to Tetrachloroethylene on
The Coordination Test - 3 Hour Exposure

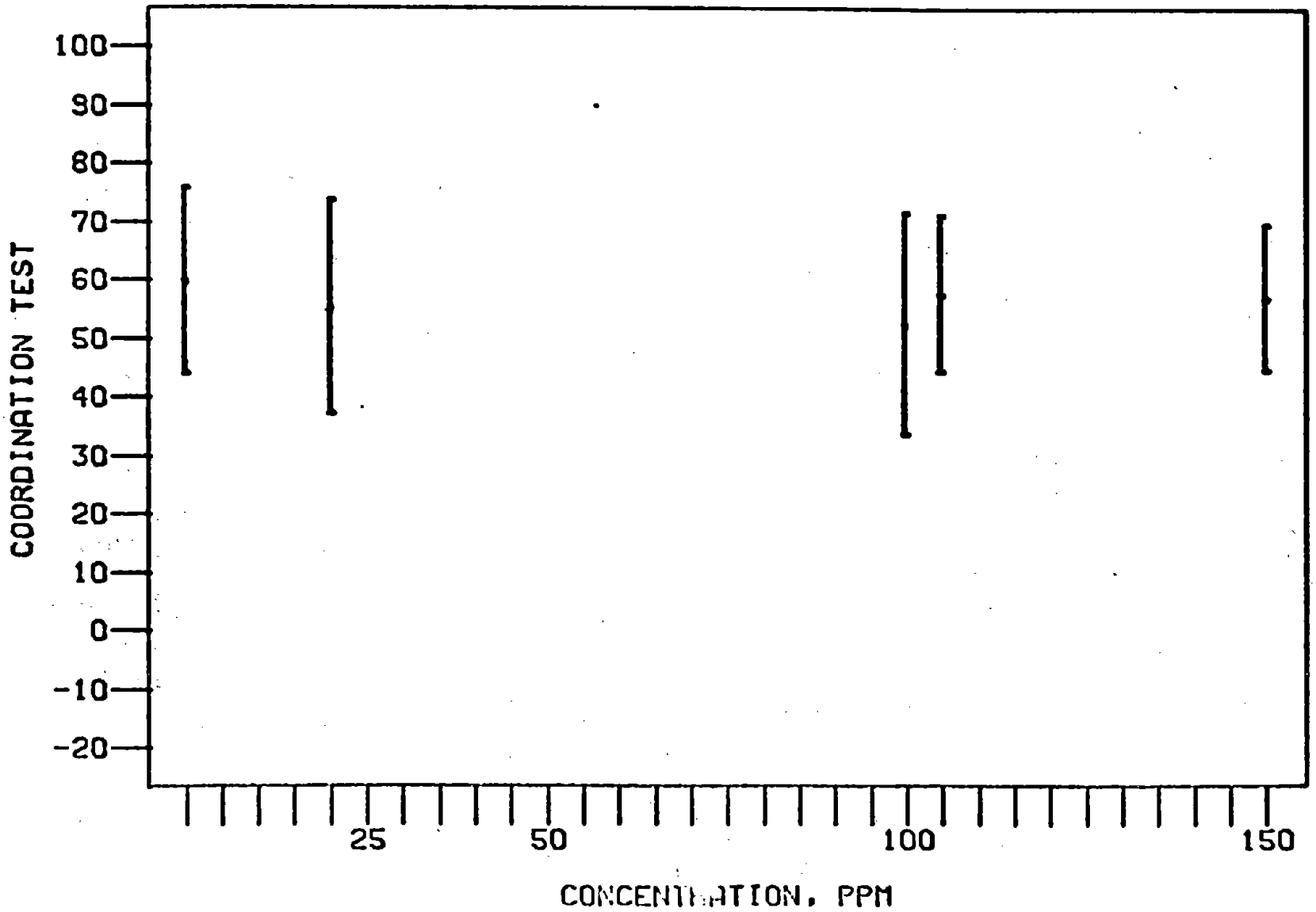


Figure 69

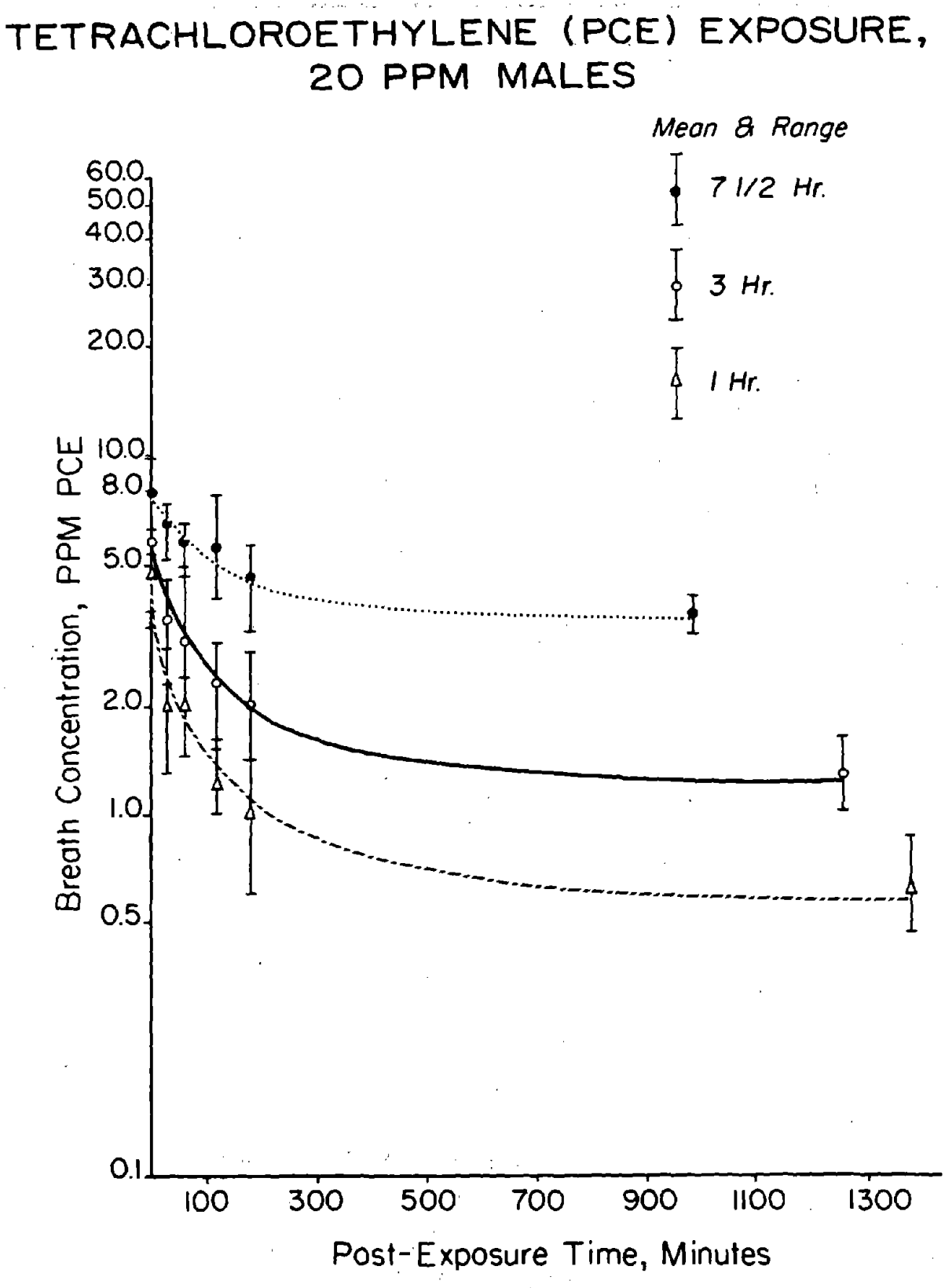

TETRACHLOROETHYLENE (PCE) EXPOSURE,
20 PPM MALES
Mean & Range
7 1/2 Hr.
3 Hr.
1 Hr.
60.0
50.0
40.0
30.0
20.0
10.0
8.0
5.0
2.0
1.0
0.5
0.1
Breath Concentration, PPM PCE
100
300
500
700
900
1100
1300
Post-Exposure Time, Minutes

Figure 70

TETRACHLOROETHYLENE (PCE) EXPOSURE
100 PPM MALES

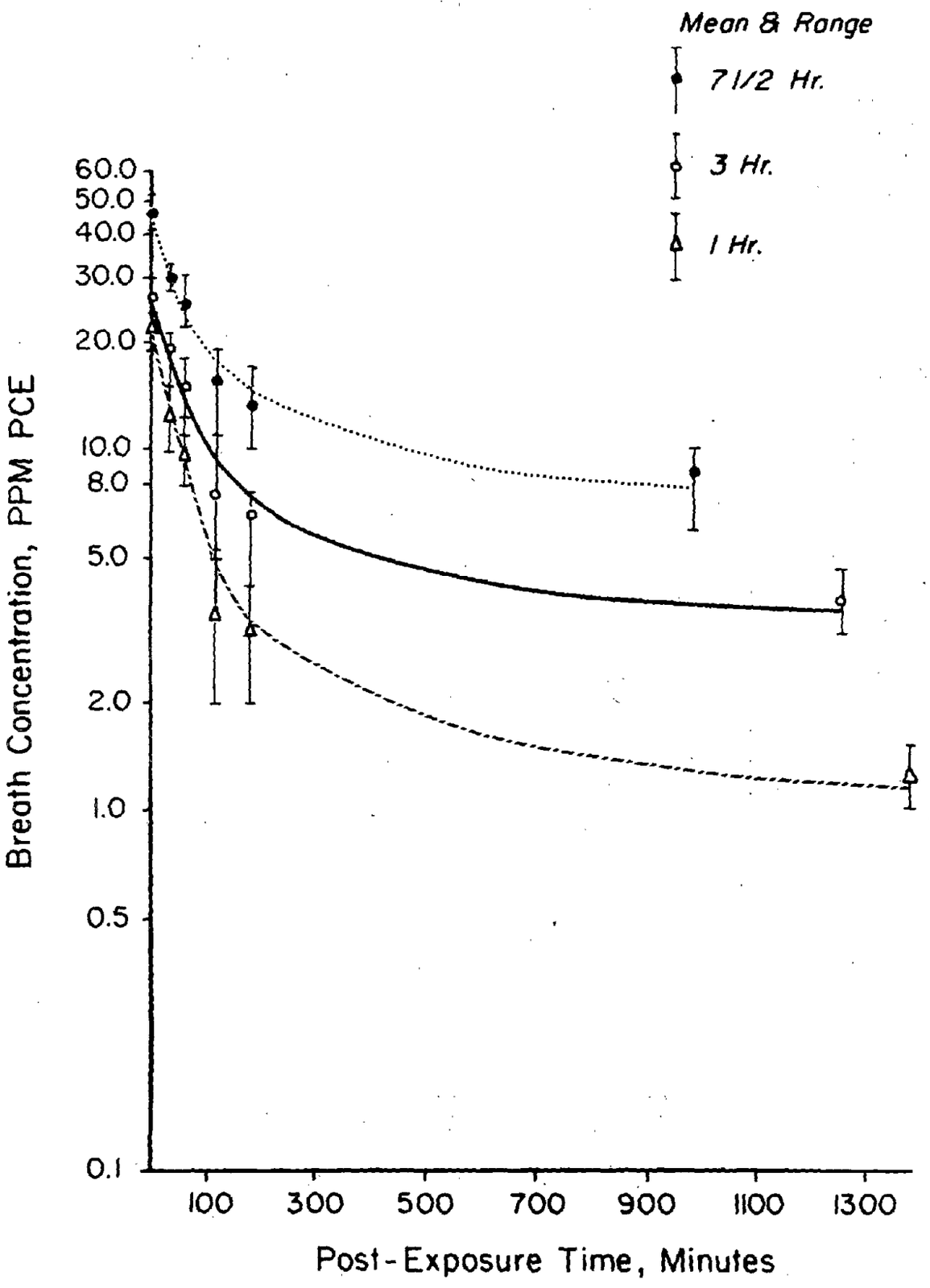


Figure 71

TETRACHLOROETHYLENE (PCE) EXPOSURE
150 PPM MALES

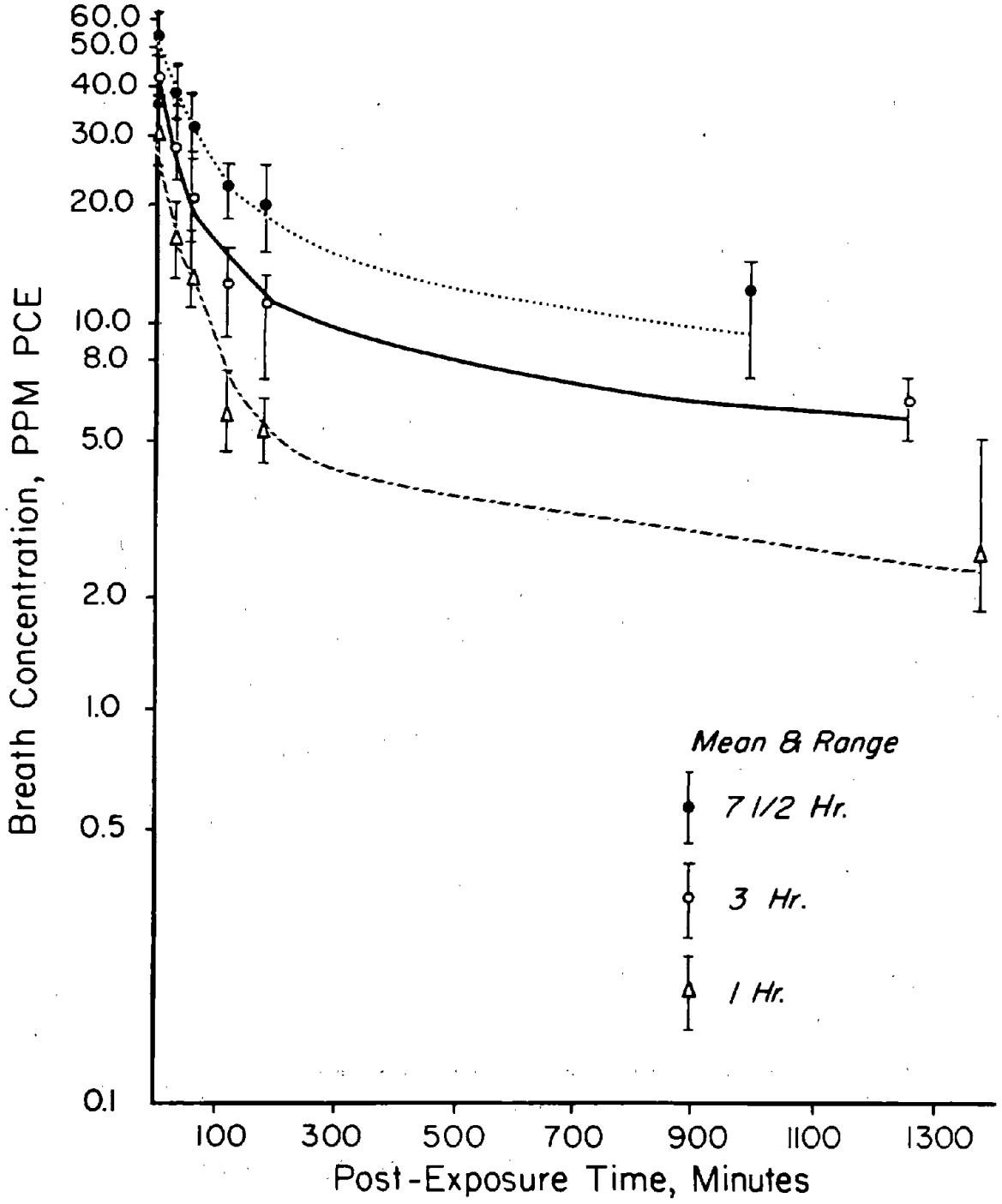


Figure 72

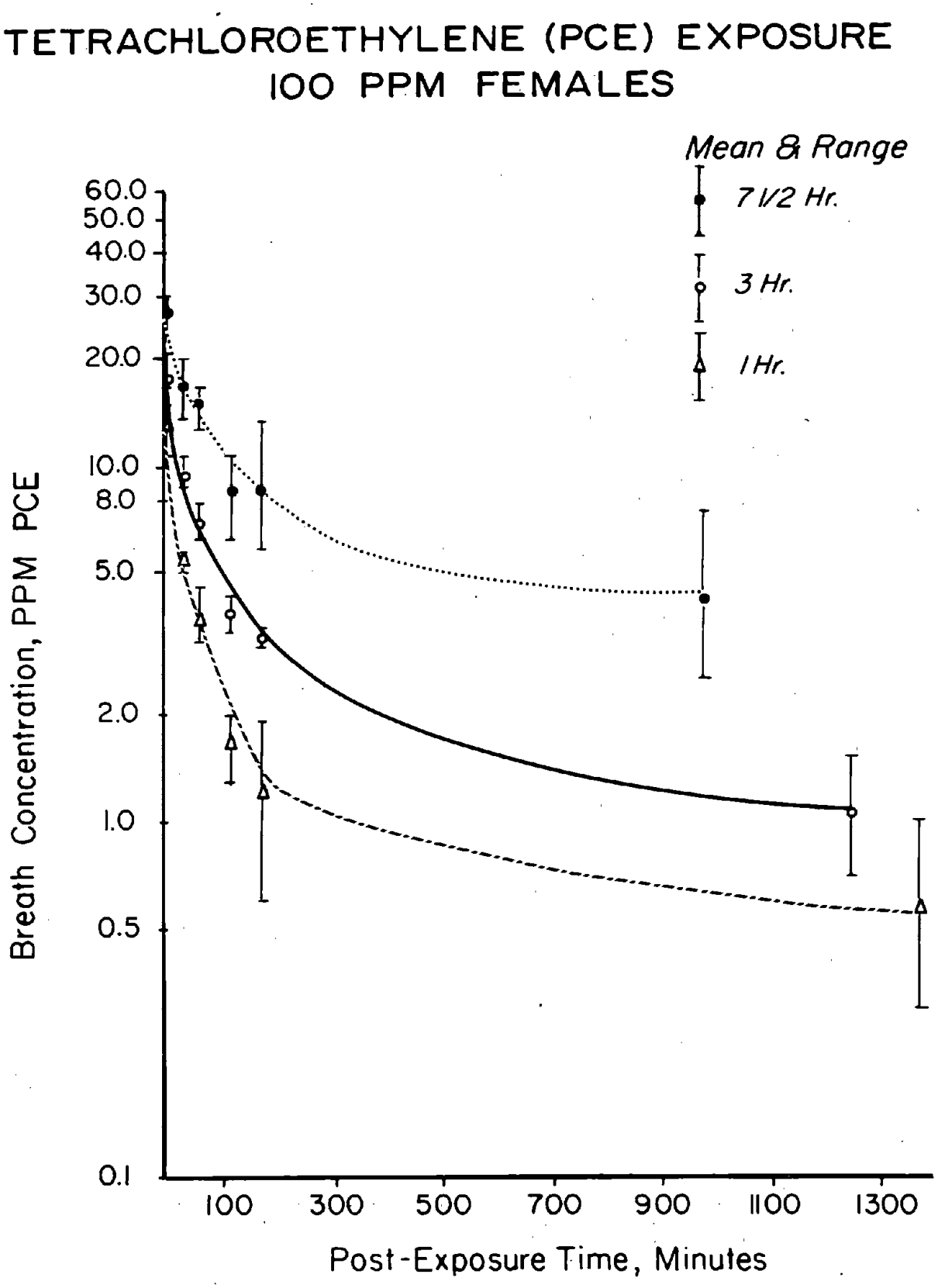

TETRACHLOROETHYLENE (PCE) EXPOSURE
100 PPM FEMALES
Mean & Range
7 1/2 Hr.
3 Hr.
1 Hr.
60.0
50.0
40.0
30.0
20.0
10.0
8.0
5.0
2.0
1.0
0.5
0.1
Breath Concentration, PPM PCE
100
300
500
700
900
1100
1300
Post-Exposure Time, Minutes

Figure 73

TETRACHLOROETHYLENE
PCE VAPOR CONCENTRATION: 150 PPM
EXPOSURE TIME: 30 MINUTES
MALE SUBJECT

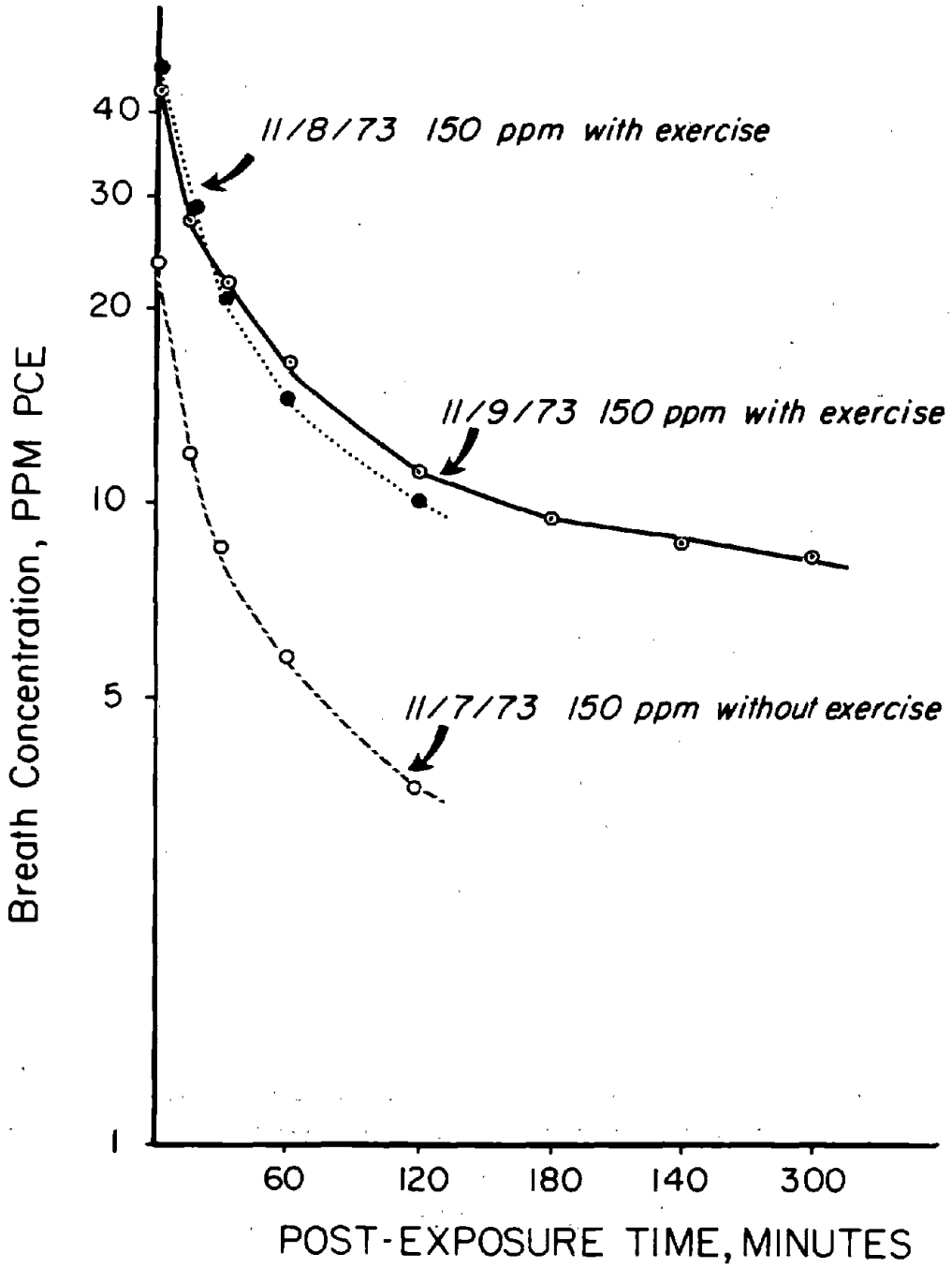
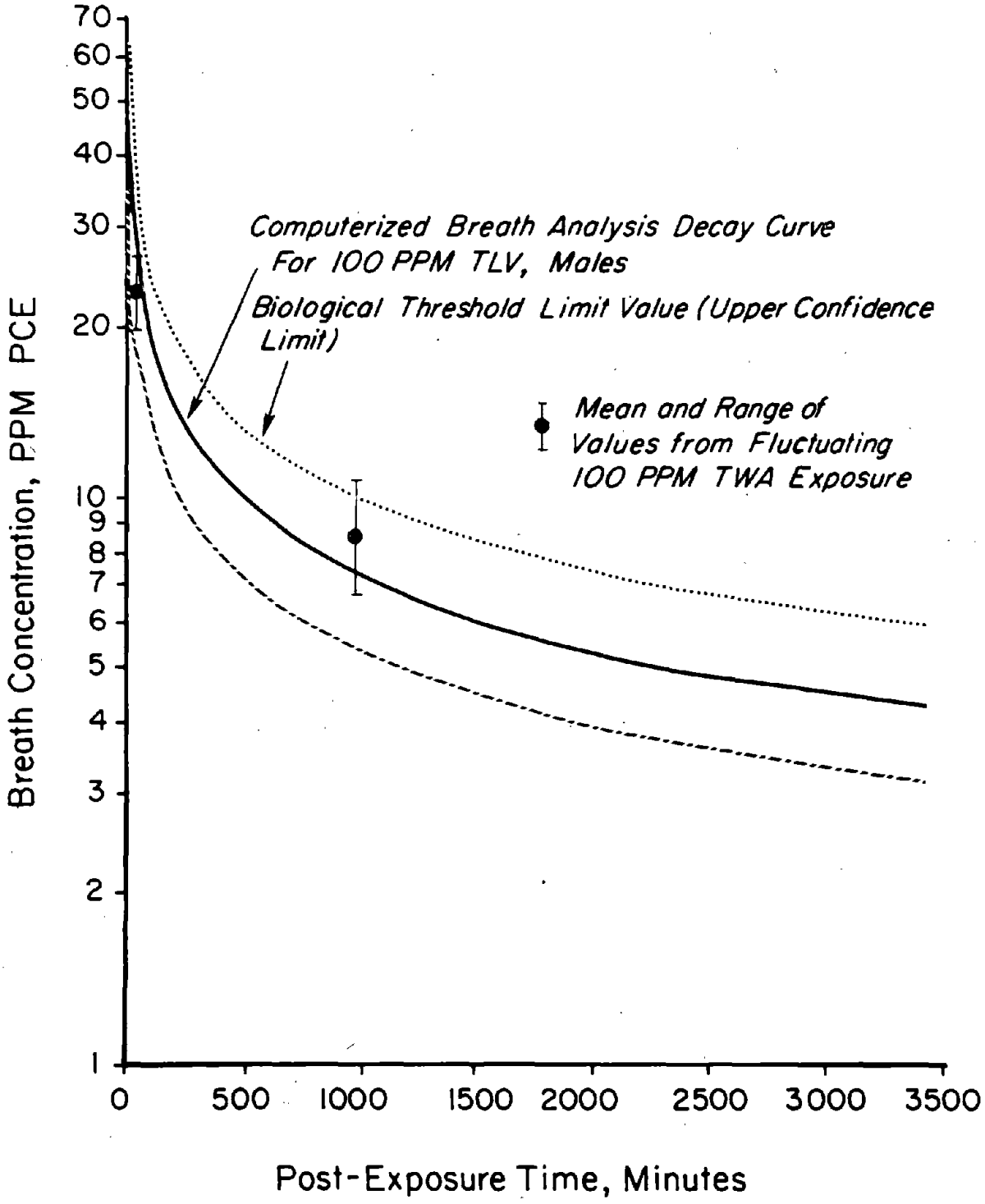


Figure 74

TETRACHLOROETHYLENE (PCE)
BADC



APPENDIX I

STATEMENT OF VOLUNTARY CONSENT

FOR RESEARCH INVESTIGATION OF

HUMAN EXPOSURE TO:

TETRACHLOROETHYLENE

I, _____, hereby agree to participate as a subject, in a program of research investigation under the direction and supervision of Dr. R. D. Stewart.

The general purpose of this research is to determine rates of uptake, excretion and metabolism of tetrachloroethylene.

The studies have been described to me and the known risks involved in this experimental procedure have been explained to me. I understand that the most frequently described known risks are: none known at this level of exposure.

I understand also that it is not possible to identify all potential risks in experimental procedures which involve controlled exposures to the chemical in a specially designed chamber.

I further understand that reasonable precautions and safeguards have been and will be taken to remove and reduce both the known and the potential but unknown risks and to provide for my safety and comfort.

I also understand that, while the program will be under the direction and supervision of Dr. R. D. Stewart, other professional persons who work with him may be designated to assist him or to act for him.

In view of those considerations, I hereby authorize Dr. R. D. Stewart and his representatives to proceed with the investigation on the understanding that I may terminate my service as a subject in this research at any time I so desire. I also authorize Dr. R. D. Stewart to use any type of data, pictures, films etc. for use in any scientific report or publication.

I am offering my service freely, in consideration of similar actions on the part of other subjects involved in like voluntary efforts to improve our society through research.

Witness _____ **Signed** _____

Investigator **Subject**

Date _____

APPENDIX II

HISTORY PART I

NAME	DATE

HISTORY

PART 2

NAME | DATE

P. M. H.

GENERAL HEALTH | WT

ILLNESSES | OP | HOSP. | INJ

S.F

R.F.

D. MELL

T.B.C.

TYPHOID

MALARIA

NER. BK.

GOUT

MEDICATION

P. H.

RELIG. | ED.

VOCAT.

MARITAL

HABITS | SLEEP | COFFEE | CIG. | ALCOL.

WK. HRS./WK.

IMMUNIZATIONS

SMALLPOX

TETANUS

DIPTH.

POLIO

INFLU.

TYPH.

MEAS.

F. H.

M | W/H

F

MM

MF

FM

FF

D. MELL

LARGE INFANTS

STILLBORN

TBC

B.P.

HEART

COR. THROM

ANGINA

STROKE

BLEED. TEND.

CA

ASTHMA

HAY FEVER

EPILEPSY

NER. BK.

INSANITY

GOUT

KIDNEY

EYES	VISION	PAIN	GLASSES	
EARS	HEARING	DISCHARGE	PAIN	TINNITUS
NOSE	SMELL	OBST.	EPIS	DISCH.
C.R.	URI YR	SORE THROATS	HORSENESS	COUGH
	SPUTUM	HEMOP	NIGHT SWEATS	FEVER
	WHEEZE	PAIN	DOE	
	EPEMA	OTHOP	PND	† B.P
G.I.	MOUTH			
	APPETITE	DIET	DYSPHAGIA	
	N & V	PAIN		
	STOOLS			
	JAUNDICE	MASS		
G.U.	FREQ.	NOC	PAIN	DYSURIA
	INCONTIN.	COLOR		
	ALB	SUGAR	WBC	RBC
	V.D.			
M.S.	PREV. TRAUMA			
	NECK	BACK	VAR. VEIN	
	JOINTS		LEG CRAMPS	
NEURO	HEADACHE	TRAUMA		
	ATAXIA	PARALYSIS		
	ANESTH·PARE	TREMOR		
	FAINTING	CONVUL.		
	MEMORY	PERSONALITY		
SKIN	ERUPTION			
	ITCHING	COLOR CHANGE		
LYMPH·HEMAT.	BLEEDING DISORDER			
END.				
ALLERGY				
MENSES	ONSET	LAST WEEKS AGO	DURATION	FREQUENCY / PAIN
	MENOPAUSE	SPOTTING		
	V.D.	VAGINAL DISCHARGE		
BREASTS				

A-III

APPENDIX III

PHYSICAL EXAMINATION

X = NOT EXAMINED - = NO, NEGATIVE
✓ = NORMAL, YES O = ABSENT

NAME | DATE

TEMP. | B.P. | P. | HT. | WT. | ST. WT.

APPEARANCE | POSTURE

HAIR: COLOR | TEXTURE | DISTRIBUTION

SCALP: CLEAN | ERUPTION | ALOPECIA

SKULL: DEFORMITIES | TENDERNESS

FACE: PALSIES | EXPRESSION | LIPS

EARS: CERUMEN | TYM MEMB | WATCH HEARD R / L | TOPHI

NOSE: DISCHARGE | OBSTRUCTION | PERFORATION

MOUTH: BREATH | ULCERS | AB. PIGMENTATION

TEETH: R 8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8 L | X = CARIOUS, O = ABSENT
R 8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8 L | CLEAN | ADEQUATE CHEWING SURFACE

GUMS: RETRACTION | PYORRHEA

TONGUE: PROTRUDED MIDLINE | TREMOR | ATROPHY

TONSILS: STATUS | ENLARGED | INJECTION | EXUDATE

PHARYNX: GAG REFLEX | INJECTION | EXUDATE

EYES: COLOR | ARCUS SENILIS | PERRLA | NEOM | NYSTAGMUS
EXOPHTHAL | LID LAG | PTOSIS | PERIORBITAL EDEMA
VISION | NEAR R / L | FAR R / L | FIELDS
OPHTHAL | DISC | H GR. | A GR. | TONOMETER R / L

LARYNX: VOICE NORMAL | MIDLINE | TUG

NECK: STIFFNESS | NODES | VEINS | CAROTID | TRACHEA | THYROID | PALPABLE

SPINE: TENDERNESS | RIGIDITY | AB. CURVATURE

THORAX: SYMMETRICAL | CVA TENDERNESS | STERNAL TENDERNESS

RESPIRA: RATE | REGULAR | DEPTH | SYMMETRICAL | FORCED

LUNGS: COUGH | SPUTUM | PERCUSSION
RESONANT | BREATH SOUNDS | VESICULAR
RALES | TACTILE FREMITUS | VOICE SOUNDS

HEART: HEAVE | SHOCK | THRILL
APEX IMPULSE PALPABLE IN _____ I.C.S. _____ CM. FROM M.S.L. TO L. OF M.C.L. | B.C.D. EXTENDS _____ CM. TO L. OF M.S.L. _____ I.C.S.
SOUNDS A_2 P_2 M_1 M_2 | RHYTHM | MURMUR

BREASTS: SIZE NORMAL | TENDERNESS | MASSES

ABDOMEN: SYMMETRICAL | DILATED VEINS | ASCITES
PALPABLE LIVER | SPLEEN | KIDNEY | MASSES
TENDERNESS | RIGIDITY | SOUNDS | HERNIA

GENIT-ALIA: DISCHARGE | SKIN LESION | TESTES
PELVIC

ARMS: RADIAL PULSE | TREMOR | CLUBBING | CYANOSIS | JOINTS

LEGS: DORSALIS PEDIS | VARICOSITIES | EDEMA | ULCER
JOINTS

A - V

L. NODES	CERVICAL	AXILLARY	INGUINAL	ENLARGED
SKIN	IDENT. MARKS			TEXTURE
	COLOR	JAUNDICE	ERUPTION	AB. PIGMENTATION
RECTAL	HEMORRHOIDS	MASSES	TENDERNESS	COLOR FECES
PROSTATE	ENLARGED	TENDER	MASS	
NEURO-LOGICAL				

CRANIAL NERVES

R		L
	SMELL	
	VISION	
	FIELD	
	FUNDUS	
	OCULAR MOVEMENTS	
	PTOSIS	
	NYSTAGMUS	
	PUPILS SIZE - SHAPE	
	PUPILS REFLEXES	
	HEARING	
	TASTE	

SWALLOWING

REFLEXES (ENCIRCLE REINFORCED)

R		L
	CORNEAL CR.	
	SUCKING	
	PHARYNX CR. IX, X	
	JAW CR. V	
	BICEPS C56	
	BRACHIORADIALIS C-56	
	TRICEPS C678	
	HOFFMANN	
	EPIGASTRIC T6-9	
	MID. ABD. T9-11	
	HYPOGASTRIC T11-L1	
	CREMASTERIC L12	
	QUADRICIPS L234	
	GASTROC. SOLEUS L5 S12	
	CLONUS (ANKLE)	
	HAMSTR. INT. L45 S12	
	HAMSTR. EXT. L5 S12	
	ANAL S34	
	BULBOCAV S34	
	BABINSKI	

ROMBERG

FACIES - POSTURE

SPEECH

HANDEDNESS RT. LT.

MENTAL STATUS

TREMOR

STATION

GAIT

R		L
	ON TOES	
	ON HEELS	
	HOPPING	
	ARM SWING	

STRAIGHT AWAY

ON TURNS

TANDEM

DESCRIPTION

MUSCLES

A = ATROPHY F = FASCULATION

R	STRENGTH	L
	TEMPORAL CR V	
	MASSETER V	
	FOREHEAD VII	
	ORBIC. OC. VII	
	MOUTH VII	
	SOFT PALATE X	
	PHARYNX X	
	STERNOMASTOID XI	
	TONGUE XII	
	NECK FLEX. C 1-6	
	NECK EXT. C1-T1	
	SCAPULAR C4-7	
	PECTORALIS MAJ. 5-T1	
	DELTOID C 56	
	BICEPS BRACH. 56	
	TRICEPS 6 78	
	WRIST EXT. 678	
	WRIST FLEX. 678 T1	
	DIGITS EXT. 678	
	DIGITS FLEX. 78 T1	
	THENAR 8 1	
	HYPOTHENAR 8 1	
	INTEROSSEI 8 1	
	BACK	
	ABDOMAN T6-L1	
	ILIOPSOAS L1234	
	ADDUCTORS, THIGH 234	
	ABDUCTORS, THIGH 45 S1	
	GLUTEUS MAX. 5 12	
	QUADRICEPS 234	
	HAMSTRINGS 45 12	
	TIBIALIS ANT. 45 1	
	TOES EXT. 45 1	
	PERONEI 45 1	
	TIBIALIS POST 5 1	
	GASTROC. SOLEUS 5 12	
	TOES FLEX. 5 12	

ALT. MOT. RATE (A.M.R.)

R		L
	HANDS (PRO. SUP.)	
	FINGERS	
	FEET	

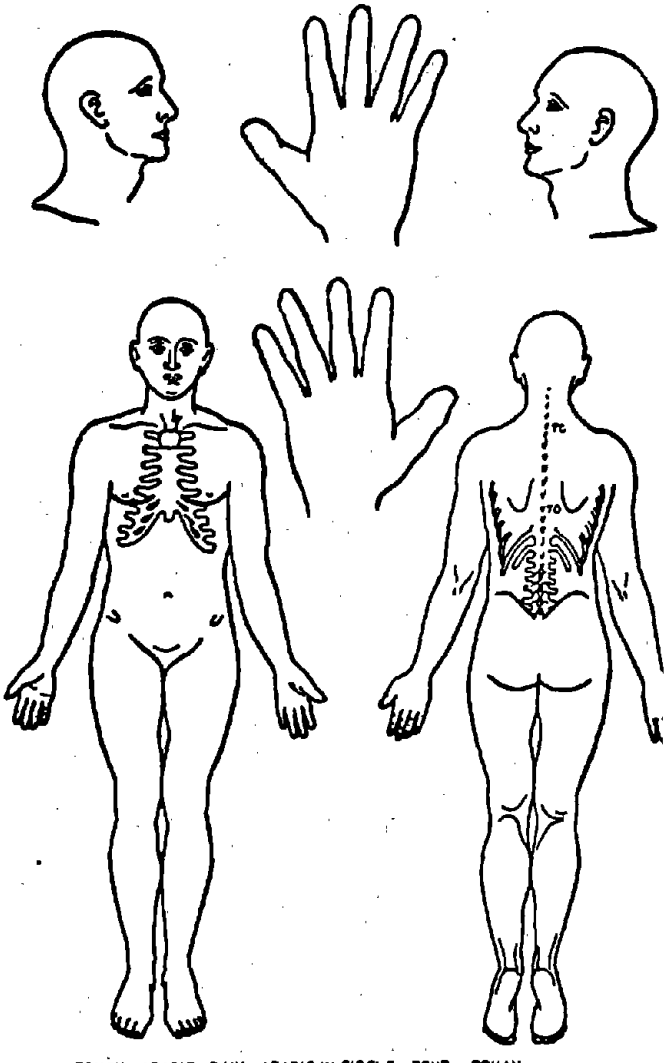
TONGUE

COORDINATION

R		L
	NOSE-FINGER-NOSE	
	KNEE PAT. (PRO. SUP)	
	TOE-FINGER	
	FINGER - NOSE	
	HEEL - KNEE	

(UNDERLINE IF NORMAL - OTHERWISE ENCIRCLE AND CHART)

TOUCH
PAIN
TEMPERATURE
DEEP PAIN
VIBRATION
JOINT SENSE
STEREOGNOSIS
TRACED FIGURES
TWO POINT



TOUCH - ARABIC; PAIN - ARABIC IN CIRCLE; TEMP. - ROMAN

LOW BACK SYNDROMES

R		L
	S.L.R.	
	LOC. PAIN	
	FABERE	
	KERNIG	
	SPASM	

CHIN-CHEST

LIST

SCOLIOSIS

LORDOSIS

L R

FLEX

RECTAL (SACRUM, SPHINCTER)

STIFF NECK

CRANIUM

BRUIT

A-VI

NAME

IMPRESSIONS:

PROGRAM:

A-XII