ABSTRACT

Title of Thesis: A Comparison of the Biodegradation of Nitrobenzene, 1-Butanol, and 2,4-Dichlorophenoxyacetic Acid Using a Municipal Mixed Liquor and Three Commercial Bacterial Preparations

Salvatore P. Salerno, Master of Science, 1984

Thesis directed by: Dr. Gordon A. Lewandowski
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The biological degradation of nitrobenzene, 1-butanol, and 2,4-dichlorophenoxyacetic acid (2,4-D) was studied in aerated 6 liter batch reactors using activated sludge from the Livingston, NJ wastewater treatment plant-- by itself and in a 10:1 by volume mixture with each of three commercial bacterial preparations: Hydrobac, BI-CHEM DC-1006/7, and Liquid Live Microorganisms (LLMO). Air stripping and adsorption were determined to be insignificant removal mechanisms for the three compounds studied. None of the bacterial mixtures were able to degrade 10 ppm nitrobenzene to any significant extent. A small but noticeable improvement in degradation rates occurred when the Livingston sludge was mixed with the commercial preparations in a 10:1 volume ratio. However, such a ratio would be economically impractical. At the manufacturer's recommended ratio of 10^6:1, the mixture would behave like the Livingston sludge alone.

A Comparison of the Biodegradation of Nitrobenzene, 1-Butanol, and 2,4-Dichlorophenoxyacetic Acid Using a Municipal Mixed Liquor and Three Commercial Bacterial Preparations

by

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Title of Thesis: A Comparison of the Biodegradation of Nitrobenzene, 1-Butanol, and 2,4-Dichlorophenoxyacetic Acid Using a Municipal Mixed Liquor and Three Commercial Bacterial Preparations

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I. INTRODUCTION

The usefulness of microorganisms in detoxifying and degrading sewage and industrial waste has been recognized since 1914, when the activated sludge process was first developed. Microorganisms, which can carry out a wide variety of chemical reactions, have many advantages over chemical reagents. For example, many nonbiological treatment processes such as hydrogen peroxide, chlorine dioxide or catalyzed oxidation are generally expensive and often produce by-products that are pollutants and must be removed in a separate purification step. The most common method of detoxifying waste, thermal oxidation, is energy intensive which makes treatment costs high.

Room temperature biological oxidation is catalyzed by enzymes of considerable specificity and efficiency. One enzyme usually catalyses only one kind of reaction at a specific site on the substrate molecule. The yields in biological reactions can often reach 100 percent.

The activated sludge process depends on a heterogeneous population of microorganisms, the various species of which are capable of degrading different constituents of the waste material. In the near future, with the advent of gene-splicing and recombinant DNA techniques, pure cultures of bacteria may be able to degrade refractory compounds such as DDT and 2,4,5-T [1]. Meanwhile, mixed cultures of

microorganisms are now available commercially for degrading specific compounds or groups of compounds in industrial wastes, such as polychlorinated biphenyls (PCB's) or straight-chain hydrocarbons. These commercial preparations are produced by force-feeding and/or irradiation of naturally occurring bacteria that exhibit a special ability to bioassimilate certain kinds of organic contaminants. The preparations can then be added directly to an activated sludge.

Still, the use of such preparations in all cases and under any conditions should not be considered a panacea. They are no substitute for good operating procedures or applied science. Instead, an improved understanding of the kinetics of biological degradation through experimentation, where the results are reproducible and reliable, is bound to improve the efficiency of wastewater treatment processes and, thereby, benefit our environment.

II. BACKGROUND

A. Literature Search

An extensive literature search was undertaken in order to obtain the published results of other investigators who have also used commercially available mutant bacteria. The abstracts of biology, chemistry, and microbiology were searched for the period 1977-1983 using the following keywords: bacteria, biodegradation, commercial culture, culture. A similar search of the annual indices of Applied Environmental Microbiology, Biotechnology and Bioengineering, Bulletin of Environmental Toxicology, and Environmental Science was performed. Both searches produced large numbers of references, none of which on close inspection were relevant to the use of commercial preparations.

The computer data base containing the publications of the American Chemical Society (ACS), and the Pollution Abstracts (published by Cambridge Scientific Abstracts), was also searched for the years 1974-1984. In order to reduce the number of references that would eventually have to be examined for relevancy, the following specific keywords were used: Bactisolv, BI-CHEM, Hydrobac, Polybac, Sybron. The ACS search produced no results, but in the Pollution Abstracts 11 references were found, 3 of which had relevant subject matter. All these references were found using the keywords Polybac (producer of Hydrobac) and Sybron (producer of

BI-CHEM DC-1006/7).

By using the affiliation index and the author index for the institutions and authors known to be active in this area, the Selected Water Resources Abstracts (published by the National Technical Information Service) and the abstracts of the Engineering Index for the years 1979-1983 were searched. These were the sources in which most of the articles were found.

Once a complete copy of a relevant article was obtained, the references cited within it were also consulted. An additional computer search was conducted using these authors and affiliations as keywords. The Pollution Abstracts and the Selected Water Resources Abstracts for the years 1974-1984 were searched. A total of 37 authors and 8 affiliations were used. At this point the literature search was stopped since only a few of the articles produced were useful, while a majority had previously been found.

B. Literature Review

In the following articles it should be pointed out that Zitrides is President of Polybac Corporation and Thibault was formerly an employee of Polybac.

Zitrides [2] reported using mutant bacteria to control an overabundance of filamentous organisms in an oxygenated secondary treatment plant. A pulp and paper mill was the source of the wastewater. The system was seeded with LIGNOBAC produced by the Polybac Corporation. The product

contains organisms "specifically selected for their ability to digest lignocellulose wastes". The addition of LIGNOBAC reduced the amounts of lignin and tannin in the effluent by about 42%. The filamentous bacteria were brought under control and a healthy biomass was produced. Also, the sludge settled better than it had prior to the onset of filamentous growth.

Zitrides [3] added PHENOBAC, made by the Polybac Corporation, to the biotower of a facility treating process wastewater containing emulsified petroleum waxes, polyacrylic and polyvinyl acetate polymers. These compounds inhibit the growth of the naturally occurring organisms present in the biotower. The bacteria in PHENOBAC can degrade "long- chain hydrocarbons, phenols, cyanides, detergents, and herbicides". Within 30 days after inoculation with PHENOBAC, COD was reduced by 57% compared to 47% prior to seeding. When operating conditions were changed to accomodate a COD load 3 times larger than the design value, a 90% reduction was regularly obtained.

Spraker and Telerchak [4] used BI-CHEM 1004TX to control foaming and degrade nonionic detergents in a wastewater containing ethoxylated nonyl phenols (ENP's) and surfactants. The organisms in BI-CHEM 1004TX are specially adapted to degrade ENP's and reduce foaming. The waste treatment system consisted of a biotower and four lagoons. Prior to seeding, up to 50% of the biomass could be displaced from the biotower due to foaming. After adding a large dose of BI-CHEM 1004TX,

foaming problems subsided and the biotower achieved a 20% reduction of COD and an 85% reduction in phenol. To reduce the load on the biotower each lagoon was also seeded. Data were collected for one year in order to evaluate how BI-CHEM 1004TX affected the performance of the system. Over that period, the average overall reduction of COD was 62.6%. For phenols, the overall reduction was 99.1%.

Blair, et. al., [5] used BI-CHEM DC-1008SF to augment the bacterial cultures in the clarification and activated sludge systems of a plant treating waste from a pulp and paper mill. The mill had been out of compliance on discharge levels of total suspended solids (TSS) and biochemical oxygen demand (BOD) due to wide variations of mixed liquor suspended solids (MLSS) in the system. Addition of BI-CHEM DC-1008SF stabilized the level of MLSS, resulting in a 50% or more reduction in TSS, thus bringing the plant back into compliance.

Davis and Blair [6] isolated and tested a mixture of bacteria capable of reducing the color intensity of Kraft process black liquor waste. A slime layer of the isolated culture was built up on the packing of a bench scale biotower with a volume of 3.25 liters. The biotower was run continuously on Kraft black liquor wastewater from two separate paper mills. The first wastewater experienced a 30 percent drop in color intensity in the first 4 to 17 hours of operation with an additional drop of 16 to 24 percent with recycling. The second wastewater was reduced in color

intensity by 54 percent in 25 hours with no further reduction by recycling. While admitting some part of the color loss is due to adsorption, the authors also point out that the ability to continuously reduce color suggests that enzymatic degradation "was a principal mechanism" for removal.

Thibault and Tracey [7] discuss the addition of mutant bacteria as a way of improving the stability and performance of activated sludge units. They cite examples in which bacterial additives reduced effluent total organic carbon (TOC) by 32%, generally reduced influent and effluent BOD, and improved overall operating stability.

Thibault and Tracey [8] solved several operating problems of an oxygen activated sludge system treating wastewater generated by the production of alcohols, olefins, organic acids and synthetic rubbers. To deal with unacceptably high levels of BOD, total oxygen demand (TOD) and total suspended solids (TSS), the system was inoculated with PHENOBAC Mutant Bacterial Hydrocarbon Degrader. Each microbe in this preparation is capable of degrading a specific class of compounds. Data on TOD, BOD (total and soluble), TSS, and tertiary butanol (TBOH) were taken 50 days prior to the addition of PHENOBAC and 50 days following the beginning of regular inoculation. The presence of PHENOBAC typically reduced effluent TOD by 46%, from 280 mg/l to 150 mg/l. The values of other effluent parameters were also reduced: BOD from 47 mg/l to 12.5 mg/l (73%), soluble BOD from 9.5 mg/l to 3.9 mg/l (59%), average TSS from 37 mg/l to 23 mg/l (38%).

Finally, no measurable amount of TBOH was found in the effluent during the two-month period following regular PHENOBAC addition. This is due to the stabilizing effect that PHENOBAC had on the active biomass of the system.

Tracey and Zitrides [9] used two parallel treatment systems to demonstrate the effectiveness of PHENOBAC Mutant Bacterial Hydrocarbon Degrader on refinery wastewater. One activated sludge system was seeded with the additive while the other served as a control. The levels of total organic carbon (TOC) were used as an indicator of effectiveness. After 12 days, during which the mutant organisms reproduced and adapted to their environment, the performance of the treated unit improved steadily in comparison to the control. Average effluent TOC values were 32% lower in the treated system. When an upset in effluent quality caused deterioration and, finally, shutdown of the control unit, the treated unit was able to handle all the plant flow for two days while maintaining a 71% reduction in TOC.

Hirt, et. al.,[10] reported that changes made in the flow pattern of a paper mill waste treatment plant effectively overcame the sludge bulking problems caused by filamentous growth. The authors first tested a variety of chemical additives for their ability to reduce filamentous growth and improve sludge settling time. Although no details of these tests were given, they concluded that chemicals such as lime, polymers, chlorine and peroxide treated only the symptoms of an operational problem. More importantly, the

use of commercial preparations of microorganisms was evaluated in both bench- scale and pilot-scale biological reactors. Unfortunately, no details of the experiments are provided, nor are any of the preparations mentioned by name. The authors state that "no improvement was noted" from the use of commercial preparations in controlling the persistence of filamentous bacteria. Finally, after a review of the literature concerning the control of filamentous bulking, and yet another set of undescribed tests, an effort was made to improve the levels of dissolved oxygen (DO) and food to mass ratios (F/M) in the four aeration tanks comprising the system. This was achieved by adjusting the flow pattern from tank to tank in such a way as to evenly distribute these measures of organic loading stress. Within 2 weeks, BOD and suspended solids removal were above 96 and 94%, respectively. In the final month of a three-month trial period there was a 95% reduction in filament number with the average filament length decreasing from greater than 400 μm to less than 100 μm.

Qasim and Stinehelfer [11] tested the effectiveness of a "bacterial culture product" in an aerated, continous-flow activated sludge process. Two identical bench-scale systems were operated under similar conditions. Both reactors had a volume of 10.9 liters and were initially filled with a wastewater having a MLSS concentration of 2250 mg/l. A feed rate of 35 l/day was maintained through both units. Each day some sludge was wasted by removing a baffle and mechanically

mixing the contents of the reactors. The waste volume was made-up with distilled water. After the reactors reached steady-state (6 to 8 days of constant sludge growth and percent COD removal), dosing of one reactor began while the other was used as a control. Then, on a daily basis the following parameters were measured: total flow, influent soluble COD and BOD, effluent soluble COD and BOD, effluent suspended solids (SS), volatile suspended solids (VSS), mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS). The data obtained from both systems were used to determine values of kinetic constants that reflect the ability of a microbial media to maintain biological growth and utilize substrates. The comparitive values of these constants indicated that the "bacterial culture product" had some positive effect on sludge growth but no effect on substrate utilization. The authors conclude that the product would have little effect "on the overall performance of a well-designed and well-operated activated sludge plant". They also claim that their experimental procedure "provides a systematic and rational approach" for evaluating bacterial culture products.

Grubbs and Zitrides [12] question the data interpretation and conclusions in the article by Qasim and Stinehelfer. They claim that the data were presented inadequately and that the "scale effects" of biological systems were ignored. The use of only "4-days' data" and the unclear notion of "steady-state" that is applied are challenged. Sludge

residence time (SRT) is seen as being a more appropriate measure. The conclusions, however, drew the sharpest criticism. Contending that the experiments were not performed in a "well-designed and well-operated activated sludge plant", the conclusion that the product would have "little effect" on such a plant is considered to be erroneous. Also, since the authors of the original article did not compare their experimental procedure with those used by other investigators, their claim that they provide a "systematic and rational approach" for evaluating bacterial products is argued to be totally incorrect.

Qasim and Stinehelfer [13] responded to the comments of Grubbs and Zitrides in defense of their original article, stating that while most mutant bacteria product manufacturers talk about their successes, "little has been published about testing methodology". Hence the intent of the paper "was to present a methodology for evaluating such products". The "4-days' data" were only presented so as to reduce the length of the article. The use of all the collected data would produce no difference in the results. Finally, the procedure presented in the original paper is commonly used in "developing design parameters for industrial.... wastewater treatment facilities".

III. OBJECTIVE

The purpose of this study is to obtain kinetic rate constants for the biological degradation of 1-butanol, nitrobenzene, and 2,4-dichlorophenoxyacetic acid (2,4-D). The constants are evaluated from experimental data of substrate concentration vs. time. Also, ammonia concentraton, pH, MLSS, chloride ion and chemical oxygen demand (COD) are monitored during the course of the experiments.

Activated sludge bacteria from the Livingston wastewater treatment plant was used by itself and in a 10:1 by volume mixture with each of three commercial bacterial preparations (Hydrobac, BI-CHEM DC-1006/7, LLMO) to biodegrade the three compounds.

IV. APPARATUS

Cylindrical batch reactors, made of clear lucite, with a volume of six liters were used in all the experiments of this study (see Figure 1). A hole in the loose fitting reactor cover serves as a vent. Laboratory air, filtered by activated carbon and glass wool, was sent to the reactors through 1/4" Tygon tubing ending in an aquarium diffuser stone. Continuous aeration insured that the liquid medium was always saturated with oxygen, while the bubbling action kept it well-mixed. The air flowrate was measured with rotameters, and was usually held constant at 1.0 scfh (500 cc/min). All experiments were performed at room temperature (approximately 26 °C).

V. ANALYTICAL EQUIPMENT

(1) Gas Chromatograph: Tracor, model #560

Operating Temperatures: Injection port--300 °C

: FID--300 °C

Oven Temperatures; Substrate dependant:

: 1-butanol--55 °C

: nitrobenzene--140 °C

: 2,4-D--163 °C

Gas Flowrates:

: N2--40(cc/min)

: H2--30(cc/min)

: Air--400(cc/min)

(2) Automatic Sampler: Tracor, model #770

(3) Automatic Injector: Varian Aerograph

(4) G.C. Column: Supelco 5'x1/8" SS

5% SP2100 on 100/200 Supelcoport

(5) Electronic Integrator: Hewlett-Packard 3390A

(6) Centrifuge: DAMON/IEC, model # IEC HN-SII

(7) COD Reactor: Hach, model # 16500-10

(8) pH Meter: Orion Research, model # 701A/Digital Ionalyzer

(9) pH Electrode: Orion Research, model # 91-04

(10) Ammonia Gas Electrode: Orion Research, model # 95-10

(11) Chloride Electrode: Orion Research, model #94-10

(12) Baker-10 Extraction System, with 1ml Octadecyl

Disposable Extraction Columns

VI. PROCEDURE

A. Air Stripping Experiments

In order to distinguish between biodegradation and air stripping as removal mechanisms, experiments were performed to determine the rate at which each of the three substrates was stripped out of sterile aqueous solution. Initial concentrations were nominally the same or greater than those used in the degradation runs: nitrobenzene-70ppm; 1-butanol-200ppm; 2,4-D-10ppm.

A well-cleaned and disinfected reactor was filled with 2 liters of deionized water that had been boiled for 0.5 hour. The reactor was covered and the water allowed to cool overnight. The next day the reactor was spiked to the appropriate concentration of substrate with aeration occurring at a rate of 500 cc/min. One or two samples per day were taken and analysed until the substrate concentration fell to zero.

B. Acclimation of Livingston Sludge to Phenol

The various microbial preparations were first exposed to phenol for 2-5 days in order to be certain of their viability.

The municipal mixed liquor was obtained from the Livingston, NJ wastewater treatment plant. Samples were taken from several locations within the plant and combined in

a single 8 liter bucket. The Livingston plant, located in a residential area, treats only domestic sewage; the organisms could not have been acclimated to phenol or any other industrial chemicals.

The 8 liters of mixed liquor were then evenly distributed between two batch reactors and aerated. A 10,000 ppm phenol stock solution was used to acclimate the sludge to phenol. The stock solution also contained nitrogen and phosphorus as inorganic nutrients in the form of ammonium carbonate and ammonium phosphate. The solution had a ratio of carbon: nitrogen: phosphorus of approximately 50:14:3 [14] and was made by mixing the following amounts of each compound, then diluting to 1 liter with distilled water: 10.0 gm phenol, 1.805 gm ammonium phosphate and 6.64 gm ammonium carbonate.

Both reactors were spiked with the stock solution to 100 ppm phenol. The next day samples from each reactor were taken and the phenol concentration was determined. If it was at or below 1 ppm, that reactor would again be spiked to 100 ppm phenol. If it was greater than 1 ppm, the reactor phenol concentration would be monitored at regular intervals until it fell to 1 ppm; then it would again be spiked to 100 ppm phenol. When it took longer than 36-48 hours for a reaction mixture to degrade 100 ppm phenol, the mixture was discarded and the process was repeated with a fresh batch of sludge. The sludge was considered ready for substrate testing when it was able to successfully degrade 100 ppm phenol in three consecutive trials. (Note: 1 ppm was approximately the

detection limit of the GC procedure used.)

C._Acclimation_of_Hydrobac_and_BI-CHEM_DC-1006/7_to_Phenol

Hydrobac, produced by Polybac Corporation, and BI-CHEM DC-1006/7, produced by Sybron Corporation, are commercially sold preparations and are supposed to contain strains of bacteria that are specifically adapted to biodegrade organic contaminants. Each product is sold in dehydrated form on bran flakes.

Both were acclimated to phenol in the same way: 12.5 gm of bran flakes were added to 1 liter of distilled water and agitated at room temperature for 2 hours. Agitation was then stopped, the bran flakes were allowed to settle, and 600 ml of the cloudy solution was decanted into one of the reactors. The reactor volume was brought up to 1 liter by adding distilled water that had been aerated overnight.

The reactor liquid was then spiked to 100 ppm phenol using the previously described stock solution. If it took longer than 36-48 hours for the phenol concentration to fall to 1 ppm or less, the mixture was discarded and the process was repeated with a new batch of Hydrobac or BI-CHEM DC-1006/7. When the phenol concentration did fall to 1 ppm or less in the allotted time, the reactor was spiked a second time to 100 ppm phenol. After a second descent to 1 ppm the reactor mixture was considered ready for substrate testing. (A third exposure to 100 ppm phenol usually caused the organisms to die.)

D._Acclimation_of_Liquid_Live_Microorganisms_to_Phenol

The Liquid Live Microorganisms or LLMO, produced by General Environmental Sciences, is also a commercial preparation containing preconditioned bacteria in a liquid with dissolved hydrogen sulfide. The hydrogen sulfide increases the shelf life of LLMO by keeping the microorganisms relatively inactive until a carbon-based food source is present in solution.

Initially, 500 ml of LLMO was added to 500 ml of distilled water in a reactor and acclimated to phenol by the same procedure described for Hydrobac and BI-CHEM DC-1006/7. Unfortunately, this method rarely worked.

Another method was tried and proved to be more successful. A 250 ml portion of well-shaken LLMO was added to a reactor and diluted to 1 liter with distilled water that had been aerated overnight. By aerating the mixture for 18-24 hours the hydrogen sulfide was allowed to strip out of solution before acclimation to phenol began.

Then, using the previously described stock solution, the reactor liquid was spiked to 20 ppm phenol. Usually the phenol concentration fell to 1 ppm or less by the next day. If it did not, the mixture was discarded and the procedure was repeated with a fresh batch of LLMO. If it did, the reactor was spiked to 40 ppm; and so on in increments of 20 ppm until the LLMO was able to successfully degrade 100 ppm phenol. This took a minimum of 5 days. At this point the

LLMO was considered ready for substrate testing.

E. Nitrobenzene, 1-Butanol, and 2,4-D Degradation Runs

The Livingston sludge, Hydrobac, BI-CHEM DC-1006/7, and LLMO were preadapted to phenol in order to be certain that metabolically active microorganisms were present. Once this was established, testing the substrate of interest began immediately. When the GC was not immediately available, the sludge and commercial preparations were maintained on 100 ppm phenol until testing could begin: this was always within 3 or 4 days.

The reactor liquid consisted of either Livingston sludge by itself or Livingston sludge in a mixture with one of the three commercial preparations. When used alone, 2 liters of sludge was placed in a reactor. When used in a mixture, 200 ml of Hydrobac, BI-CHEM DC-1006/7, or LLMO was added to 2 liters of Livingston sludge.

The general procedure for a substrate degradation experiment began by spiking the reactor with one of the three organic compounds. The initial, nominal concentrations were: nitrobenzene-20 ppm, 1-butanol-100 ppm, 2,4-D-10 ppm. Reactors were spiked three times in sucession with their respective substrates. Gas chromatographic analysis was then used to monitor the disappearence of substrate. Since no degradation occurred during the experiments in which nitrobenzene was the target substrate, no pH, MLSS, COD, or ammonia data were taken.

1._Substrate_Analysis

The methods of analysis used for nitrobenzene and 1-butanol were similar. After spiking, 15 ml samples were taken from the reactor every 30 minutes to 1 hour until a preliminary GC analysis indicated that the substrate concentration had either fallen to zero or stopped decreasing. The samples were centrifuged for 4 minutes at 2000 rpm to separate out the bulk of the solids. Then, 10 ml of the supernatant were transferred to a vial containing 0.5 ml of 20,000 ppm copper sulfate and 0.5 ml of an internal standard. The sample vials were sealed with tight fitting plastic caps and refrigerated until they could be placed on the GC autoinjector to be analyzed in chronological order.

The copper sulfate in each vial acted as a biocide [15], thus preventing any further degradation of the substrate in the sample. The internal standards used for nitrobenzene and 1-butanol were 1000 ppm thymol and 1000 ppm iso-amyl alcohol, respectively. The internal standard considerably improves the accuracy of the chromatographic method. The errors in the method of analysis for nitrobenzene and 1-butanol were both on the order of ±2 ppm.

The analysis technique for 2,4-D was necessarily different. The compound is polar enough to prevent it from desorbing from the SP2100 stationary phase in the column of the gas chromatograph. Therefore, the method of analysis was as follows.

After spiking, four 15 ml samples were taken from the reactor every 2 hours over an 8-10 hour period. A final sample was taken after 24 hours. The samples were centrifuged for 4 minutes at 2000 rpm to remove the bulk of the solids. Then, 10 ml portions of the supernatant were placed in each of four vials. Each vial contained 0.5 ml of 20,000 ppm copper sulfate. No internal standard was added at this time. The vials were sealed with plastic snap-caps and refrigerated until sufficient time was available to further prepare the samples for analysis. Only 20 ml of sample were required for 2,4-D analysis, but the remaining amount was needed for the ammonia, chloride ion, and chemical oxygen demand analyses.

The 20 ml sample was placed in a 150 mm x 20 mm test tube and acidified with 0.3 ml of concentrated sulfuric acid. The 2,4-D was then extracted from water using an octadecyl extraction column.

The column was first conditioned by washing under vacuum with two 1 ml portions of methanol followed by two 1 ml portions of acidified water. The acidified water was prepared by slowly adding 0.3 ml of concentrated sulfuric acid to 250 ml of distilled water.

A 50 ml plastic funnel was fixed atop the column and the acidified 2,4-D sample was added, allowing no air bubbles in the column. Vacuum was applied, and after the sample had passed through, the column was washed again with 1 ml of acidified water. The column was then dried under vacuum for

5 minutes.

The 2,4-D was eluted by washing the column under vacuum with two 0.5 ml portions of methanol. The 2,4-D present in solution was then esterified by adding 0.3 ml of concentrated sulfuric acid. The ester of 2,4-D produced was 2,4-dichlorophenoxymethylacetate.

To insure that esterification went as far towards completion as possible, the 1 ml sample was placed in a constant temperature bath at 55 ^{o}C for 30 minutes, then allowed to cool to room temperature overnight. The following day, the solution was neutralized by adding 0.025 gm of sodium bicarbonate. When the bubbling stopped, the sample was ready for GC analysis.

An internal standard was prepared by adding 1.0 gm of cinnamyl alcohol to 100 ml of methanol. Equal volumes, usually 0.5 ml each, of the cinnamyl alcohol internal standard and the neutralized 2,4-D ester solution were combined in an autoinjector vial and loaded onto the GC. Samples were injected in chronological order.

The error in the 2,4-D ester analysis method was about ±4 ppm.

2._Chemical_Oxygen_Demand_(COD)_Determination

Chemical oxygen demand represents the amount of oxygen required in the oxidation of organic and oxidizable inorganic matter in a sample. The theoretical COD can be calculated from a balanced equation for the complete oxidation of a

compound to carbon dioxide and water. This method therefore provides a way of determining whether partial or total oxidation of the substrate is taking place. Chemical oxygen demand analysis was performed on samples from the 1-butanol and 2,4-D degradation runs. The nitrobenzene runs were omitted since no significant biodegradation occurred during these experiments.

As an example of how the theoretical COD of a substrate was determined, consider the following balanced equation for the complete oxidation of 1-butanol:

$$C_4H_9OH + 6O_2 \longrightarrow 4CO_2 + 5H_2O$$

From which:

$$\left[\frac{6 \text{ moles } O_2}{1 \text{ mole } C_4H_9OH}\right] \times \left[\frac{32 \text{ mg } O_2}{74 \text{ mg } C_4H_9OH}\right] = 2.59 \frac{\text{mg COD}}{\text{mg } C_4H_9OH}$$

Table 1 lists the theoretical COD for the compounds of interest and their respective internal standards.

The experimental COD was determined by a slight modification of the Standard Methods procedure as described in the Federal Register [16]. All reducing agents present in a sample were completely oxidized with a solution of potassium dichromate, silver sulfate, mercuric sulfate and sulfuric acid. This digestion solution was made by adding 7.5 gm potassium dichromate, 10.0 gm silver sulfate and 5.0 gm mercuric sulfate to a 2.5 liter bottle of concentrated sulfuric acid. The bottle was placed on a magnetic stirrer/hot plate, then agitated and heated overnight to

dissolve the potassium dichromate and silver sulfate. When both compounds had dissolved, the acid bottle was removed from the hot plate and cooled to room temperature. Five ml of the cooled digestion solution was pipetted into a 16 mm x 100 mm screw-top vial, 2.0-5.0 ml of the filtered sample was added and the cap was screwed on tightly. Several blanks containing 2.0-5.0 ml deionized water were included with each batch of samples. The vials were placed in a Hach COD reactor and heated at 150 °C for 2 hours. After heating, the vials were removed and cooled to room temperature. The contents of the vial were then transferred to a 250 ml Erlenmeyer flask that contained approximately 50 ml water, rinsing the inside of the vial several times with water, adding the rinsings to the flask. Also added to each flask was: 0.03 gm mercuric sulfate to reduce chloride ion interference and 5 drops of Ferrion indicator. This solution was then titrated to a bright orange endpoint with a 0.0125N ferrous ammonium sulfate (FAS) solution. The 0.0125N FAS solution was made by adding 9.8 gm ferrous ammonium sulfate to approximately 1000 ml deionized water, adding 20 ml concentrated sulfuric acid, cooling the solution to room temperature and finally, diluting to 2 liters with deionized water. The blanks were titrated in a similar manner. The experimental COD of a sample was calculated from the following expression:

$$EXP\ COD\ (mg/l) = (A - B) \times N \times \frac{8000}{C}$$

Where:

A = volume of FAS used to titrate blank, ml

B = volume of FAS used to titrate sample, ml

N = normality of FAS solution, equiv/liter

C = volume of sample, ml

Because of the limited amount of sample volume available, the COD analyses for the 1-butanol runs were performed in the presence of the internal standards and biocide. In the case of the 2,4-D runs, only 0.5 ml of copper sulfate was present. A general equation for converting experimental COD to an equivalent concentration of the substrate must therefore be able to account for the theoretical COD of an internal standard as well as the dilution of the sample with copper sulfate and/or internal standard. The relation obtained was:

$$\text{EQUIV COD (ppm)} = \left[\text{EXP COD} - \left(\frac{\text{TCODIS} \times \text{CIS}}{\text{TCODS}}\right)\right] \times \left[\text{SDF}\right]$$

Where:

EXP COD = experimental COD of the sample, mg/l

TCODIS = theoretical COD of internal standard, mgCOD/mgIS

CIS = concentration of internal standard, ppm

TCODS = theoretical COD of substrate, mgCOD/mg subst.

SDF = sample dilution factor

For 1-butanol: SDF=11/10, CIS=45.545

For 2,4-D: SDF=10.5/10, CIS=0.0

In this method, the experimental error associated with titrating the sample and the need to subtract the COD of the

internal standard caused a residual error of about ±20 ppm.

3. Mixed Liquor Suspended Solids (MLSS) Determination

A 10 ml sample of reactor liquid was taken every 1-2 hours during the course of an experiment. The fluid was then pipetted into a numbered, preweighed aluminum dish and evaporated in an oven at 90 °C. When dry, the dishes were cooled in a dessicator and reweighed. The mass of dry solids thus obtained was converted to a mg/l basis.

4. Hydrogen Ion Concentration (pH) Determination

A pH electrode was continuously suspended in the reactor fluid throughout each experiment. No pH data were taken when nitrobenzene was used as the substrate. Meter readings were taken every 0.5 hour. Ocassionally, as an accuracy check, the electrode was removed from the reactor and placed in a standard pH 7 solution. After adjusting the meter accordingly, the electrode was rinsed with distilled water and placed back in the reactor.

The error in pH measurement was about ±0.05 pH units.

5. Ammonia Concentration Determination

The concentration of ammonia was determined in samples from the 1-butanol and 2,4-D experiments using an ammonia gas electrode. No ammonia analysis was performed on samples from the nitrobenzene runs. A direct measurement method was used, as sussested by the electrode manufacturer [17]. A 0.1M

ammonium chloride standard solution was made by adding 0.535 gm reagent grade ammonium chloride to 50 ml distilled water in a 100 ml volumetric flask, stirring to dissolve, then diluting to volume with distilled water. Additional standards, having concentrations of 0.01M, 0.001M, and 0.0001M, were prepared by serial dilution of the 0.1M solution.

The electrode was placed in 100 ml of the 0.001M standard and 1 ml of 10M sodium hydroxide was added while the solution was agitated with a magnetic stirrer. The meter reading on the relative millivolt scale was then set to 000.0 by adjusting the calibration control.

The electrode was rinsed and placed in 100 ml of continuously stirred 0.0001M standard with 1 ml of 10M sodium hydroxide. The meter reading was recorded. The same procedure was repeated using the 0.01M standard. A calibration curve was made by plotting the millivolt readings (linear axis) versus their corresponding concentrations (log axis) on 4-cycle semilogarithmic paper.

Since only a limited amount of sample volume was available and the ammonia electrode is relatively large, it was necessary to dilute a portion of each sample with distilled water. One ml of sample was pipetted into a sample vial containing 10 ml distilled water, 3 drops of 10M sodium hydroxide, and a magnetic stirring bar. The vial was placed on a magnetic stirrer and, while being agitated, the ammonia electrode was submerged. A reading was taken after about 2

minutes, when the meter displayed a constant value. The experimental values of ammonia concentration were obtained from the calibration curve and, after accounting for sample dilution, converted to a ppm basis (17 ppm [=] 0.001M).

At regular intervals, the electrode was rinsed with distilled water and placed in one or two of the standard ammonium chloride solutions as an accuracy check on the millivolt readings. Although there was always some drift, it was never great enough to warrant recalibrating the meter.

The error in ammonia concentration measurement was estimated to be ±5 ppm.

6._Chloride_Ion_Determination

The concentration of inorganic chloride was measured in samples from the 2,4-D degradation runs with a chloride ion electrode. According to the manufacturer [18], the electrode required no sample agitation and only enough liquid to wet the membrane.

An ionic strength adjustor (ISA) was added to all standards and samples so that the background ionic strength was constant relative to the variable concentrations of chloride. For all halide electrodes, sodium nitrate was used as the ISA. A 5M solution was made by dissolving 42.5 gm in 100 ml distilled water.

For direct measurements in units of parts per million, a 1000 ppm stock solution of sodium chloride was prepared by placing 1.65 gm in a 1 liter volumetric flask, dissolving

with about 500 ml distilled water, and diluting to 1 liter. Two additional standards, having concentrations of 100 ppm and 10 ppm, were prepared by serial dilution of the 1000 ppm stock solution. The ISA was added to each solution using a ratio of 2 ml of ISA per 100 ml of standard.

The electrode was placed in the 100 ppm standard. By turning the calibration control, the meter reading on the relative millivolt scale was set to zero. Very often the meter could not be set to exactly 000.0, in which case the millivolt reading was recorded.

The electrode was rinsed, placed in the 1000 ppm standard, and the meter reading was recorded. The same procedure was repeated using the 10 ppm standard. A calibration curve was prepared by plotting the millivolt readings (linear axis) versus their corresponding concentrations (log axis) on 4-cycle semilogarithmic paper.

The electrode was then placed in 1 ml of sample with 1 drop of ISA. The millivolt reading was recorded and the chloride ion concentration determined directly from the calibration curve. After about 2 hours of use, the meter was recalibrated by placing the electrode in the midrange standard and setting the millivolt reading to its original value.

The error in chloride ion concentration was estimated to be about ±20 ppm.

VII. RESULTS

The results of the air stripping experiments indicate that negligible amounts of each solute are stripped out of solution in the time it takes to complete their respective degradation runs. Tables 2 to 7 and Figures 2 to 7 present the experimental data that support this assertion. In addition to this, an examination of the activity coefficients of 1-butanol and nitrobenzene at infinite dilution in water indicates that neither compound is hydrophobic. No data are available for 2,4-D. Table 8 provides the relevant thermodynamic data for each compound as well as a comparison of the actual (experimental) and theoretical (i.e., obtained via material balance) time required for complete solute removal. Experimental and vapor-liquid-equilibria considerations both support the same conclusion: air stripping does not represent a significant removal mechanism for any of the compounds used in this work.

Adsorption can be recognized when the rate of substrate loss on initial exposure is significantly greater than that observed on subsequent exposures. The experimental concentration versus time data for consecutive runs, listed in Tables 9 to 45 and plotted in Figures 45 to 47, do not exhibit this phenomena. Undoubtedly, some small amount of each substrate was adsorbed on the bacterial flocs, but evidently the rate at which this occurred was insignificant in comparison to the rate of bioassimilation. This means

that adsorption for these compounds was negligible, which, in the case of 2,4-D, is also supported by the findings of Shamat and Maier [19].

The pH and ammonia concentration of each reaction mixture during the course of the 1-butanol and 2,4-D experiments are included in Tables 9 to 23 and 35 to 45, respectively. The trend, in all runs, was for the pH to remain relatively constant, never changing by more than ±0.05 pH units from start to finish. Also, the pH for all runs always remained in the range of 6.2-8.1, thus remaining within, or close to, the limits suggested by Kim and Armstrong [20] and Barth and Bunch [21]. Only in one case (1-butanol,Liv/BI-CHEM,RunII) was it necessary to adjust the pH by adding sodium carbonate.

Since, in the case of 2,4-D, one of the products of oxidation is HCl(g), it is reasonable to expect that the pH would decrease with time rather than remain constant. This did not happen because the Livingston mixed liquor and all the commercial preparations initially contained enough buffer to prevent any significant fall in the pH.

The initial amounts of nitrogen present in the Livingston sludge and commercial preparations ranged from 15 ppm ammonia for 1-butanol to 120 ppm ammonia for 2,4-D. At these levels, the nutrient requirements of the microorganisms can be adequately provided for.

As expected, the ammonia concentration decreased as the substrate was metabolized. The decline in the nitrogen concentration during the course of an experiment ranged from

5 to 15 ppm.

Chloride ion data for the 2,4-D runs are shown in tables 35 to 45. The chloride ion concentration represents the amount of inorganic chloride produced when 2,4-D is mineralized plus the amount that is always present in the various mixed liquors.

The amount of chloride originally present in solution was quite high, ranging from 70 to 130 ppm. When the levels are that high, the inorganic chloride produced by the oxidation of 2,4-D is too small to be detected above the larger concentration of background chloride. This makes the results of this method somewhat inconclusive. A more sensitive method, such as mass spectroscopy, would be more appropriate.

The mixed liquor suspended solids (MLSS) data are included in Tables 9 to 45. All the data indicate a roughly constant MLSS during each experiment.

There are, however, some inadequacies in this method which make it an inappropriate way of measuring the amount of active biomass. The first is that not all the solids measured are living organisms. Some of the organisms are dead, and detritus accounts for some portion of the solids. Also, a small sample weight of 1 to 10 mg is measured above a tare weight of about 1300 mg; this makes the mass found by difference inaccurate. Finally, significant changes in the biomass are not likely to be observed in the relatively short time it takes to complete an experiment.

The results of the COD analyses for the 1-butanol and

2,4-D runs are listed in Tables 9 to 23 and 35 to 45, respectively. Figures 8 through 22 for 1-butanol indicate that the COD decreased as the substrate disappeared. This means that the alcohol is indeed being converted to water and carbon dioxide.

The size of the residual error in this method is about ±20 ppm (see PROCEDURE,sect. E2). Therefore, when the substrate concentration falls below this level, the results of COD measurements are unreliable. Since the concentration of 2,4-D was always far below 20 ppm, no conclusions can be drawn from the data.

Raw kinetic data, in the form of substrate concentration versus time, for the 1-butanol, 2,4-D and nitrobenzene runs are presented in Tables 9 to 45. Some of the degradation data are displayed sequentially in Figures 45 through 47 to illustrate and compare the rates of substrate loss after successive shock loadings to the reactor. The sources of the microbial population present in the reactor are indicated on the graphs. These graphs demonstrate that when any of the three commercial preparations was added to the Livingston mixed liquor, the rate of degradation generally improved. However, the 1:10 volume ratio of commercial preparation to Livingston sludge used in these experiments would be impractical for economic reasons, while the manufacturer's recommended ratio of $1:10^6$ is too small to be effective.

Three mathematical models were used to correlate the experimental data:zero-order

kinetics, Monod's model [22], and Haldane's model [23].

The zero-order kinetic model assumes that the rate of substrate disappearance, -dS/dt, is constant and independent of the substrate concentration at all times. In differential form, it is given by:

$$-dS/dt = k \qquad (1)$$

or, in integrated form:

$$So-S = kt \qquad (2)$$

where:

S = substrate concentration at time t (mg/l)

So = initial substrate concentration (mg/l)

k = zero-order kinetic rate constant (mg/l hr)

t = time (hr)

In order to find the "best" value of k, a computer program (see APPENDIX 1.) was used to perform a least squares regression of the experimental concentration versus time data. Since equation (2) is linear in form, the degree of fit of each data set to a straight line was evaluated by the correlation coefficient.

Using the Monod equation, which assumes a constant biomass concentration at all times, the rate of substrate utilization is:

$$-\frac{dS}{dt} = \frac{k_1 S}{k_2 + S} \qquad (3)$$

which, in integrated form becomes:

$$\left(\frac{k_2}{k_1}\right) ln\left(\frac{S_o}{S}\right) + \frac{1}{k_1}(S_o - S) = t \qquad (4)$$

where:

S = substrate concentration at time t (mg/l)

So = initial substrate concentration (mg/l)

k1 = rate constant (mg/l hr)

k2 = substrate utilization constant (mg/l)

t = time (hr)

A linear regression was used to solve for the rate constants (the computer program is listed in APPENDIX 1.) Equation (4) is too complicated to obtain a corresponding expression for the correlation coefficient, so the degree of fit was evaluated by determining the residual at each data point and the average absolute residual for each set of data.

The Haldane model for substrate inhibition kinetics, when a constant biomass concentration is assumed, is given by:

$$-\frac{dS}{dt} = \frac{k_1 S}{k_2 + S + \frac{S^2}{k_3}} \qquad (5)$$

or, in integrated form:

$$\left(\frac{k_2}{k_1}\right) ln\left(\frac{S_o}{S}\right) + \frac{1}{k_1}(S_o - S) + \frac{1}{2k_1 k_3}(S_o^2 - S^2) = t \qquad (6)$$

where:

S = substrate concentration at time t (mg/l)

So = initial substrate concentration (mg/l)

k1 = kinetic rate constant (mg/l hr)

k2 = substrate saturation constant (mg/l)

k3 = inhibition constant (mg/l)

t = time (hr)

The constants in equation (6) were evaluated by again making use of the Gaussian elimination routine, and the degree of fit of the data was indicated by the absolute average residual.

The constants for the three models used to regress all sets of data are listed in Tables 46 through 156.

Generally, the expression for zero-order kinetics best represents the rates of substrate utilization. This is particularly true for 1-butanol and 2,4-D. In the case of nitrobenzene, all three models were equally unsatisfactory. This is probably because nitrobenzene was never significantly degraded.

All three models, however, either suffer from inherent inadequacies or are simply incapable of fitting the experimental data without their respective kinetic constants acquiring physically impossible values. For example, the zero-order kinetic equation, when extrapolated, will yield negative values of substrate concentration rather than assymtotically approaching zero as time increases. The Haldane and Monod equations can very often represent the degradation data with relatively small average residuals only

if one or more of their kinetic constants are negative. This not only makes the constants physically meaningless, but it sometimes causes the kinetic expressions to violate the Law of Conservation of Mass (c.f. 2,4-D,Liv,RunII in Table 136).

The 1-butanol degradation data, regardless of the microbial media used, was successfully fitted by the zero-order kinetic equation. The value of k ranged from 9.8-50.1 mg/l hr. With the exception of one experiment that had an initial concentration well below the nominal 100 mg/l, the correlation coefficient was never less than 0.973. The highest values of k appear for the Livingston sludge-Hydrobac combinations in runs IA,IIA, and IIIA: 50.1,44.5,and 40.8 mg/l hr, respectively.

The 2,4-D degradation data was also best represented by the zero-order kinetic equation. For the runs that had an initial 2,4-D concentration close to 10 mg/l, and where correlation coefficients were 0.90 or more, the values of k ranged from 0.28-0.81 mg/l hr.

The Haldane equation also seems to fit the 2,4-D degradation data. After excluding the experiments where the constants have physically unrealistic values, k2 ranged from 0.001-0.075 mg/l, while k3 ranged from 0.004-0.013 mg/l. The average absolute residual for these runs ranged from 0.393-1.28 mg/l. The ostensibly good results with this model may be, for statistical reasons, only an illusion. The 2,4-D degradation experiments had an average of 5 data points each; the minimum number was 3 and the maximum was 7. When such a

small number of data points are correlated with a three-constant expression like the Haldane model, the results, which will almost always indicate a good degree of fit, should be interpreted with caution. Therefore, the statistical basis to support the Haldane model in its ability to represent the 2,4-D data is not as strong as that for the zero-order equation.

The nitrobenzene degradation data was not successfully represented by any of the mathematical models used in this study. When the zero-order model was used, only two experiments out of eleven had correlation coefficients greater than 0.90, but their respective values of k are drastically different: 2.1 mg/l hr for run III with Livingston sludge, and 0.45 mg/l hr for run III with Livingston sludge-BI-CHEM DC-1006/7. The differences between the two types of microbial media used and the experimental conditions in each case are not great enough to explain the large difference in the k values. The Monod equation had negative values of the constant, k1, for nine of the eleven experiments. In the two cases in which k1 was positive, the expression seems incapable of representing the concentration data in and around the center of the experimental time range (see Tables 102 through 112). The Haldane equation usually had reasonable values for its kinetic constants, but it was incapable of consistently estimating substrate concentrations over the entire experimental time range (see Tables 113 to 123). The percent error in calculated values of substrate

concentration can vary from 10% to over 100% in data from a single experiment (see Table 120).

The lack of any significant degradation taking place during the course of the experiments was the major factor in producing these results. The considerable amount of scatter in the concentration versus time data, which can be seen in Figures 23 to 33, also contributed to the failure of all models to correlate the data.

Various investigators have also studied the biodegradation of 2,4-D and nitrobenzene. However, their experimental conditions,techniques, and procedures are often quite different from those of this work. In addition, it seems that this study represents the first documented attempt at using Hydrobac, BI-CHEM DC-1006/7, or LLMO in combination with an activated sludge bacteria to treat these compounds. For these reasons a direct, quantitative comparison of results is inappropriate. The published results of others in the following paragraphs should therefore only be compared qualitatively with the results of this study.

Papanastasiou and Maier [24] used mixed liquor from the Metropolitan Wastewater Treatment Plants of St. Paul, MN to biodegrade 2,4-D. The degradation data obtained thereby was correlated to the Haldane model. The reported values of k2 and k3 are 40 mg/l and31 mg/l, respectively. These results are of questionable validity because the authors typically ran their experiments with an initial 2,4-D concentration of about 100 mg/l. This probably exceeds the solubility limit

of the compound [25].

Shamat and Maier [19] also studied the ability of activated sludge from the Metropolitan Wastewater Treatment Plants in St. Paul to metabolize 2,4-D in continuous-flow and batch tests. The continuous-flow tests had an initial 2,4-D concentration of 98 ppm (again above the solubility limit). The authors report a "10-day lag" period followed by "rapid disappearance once metabolism began". Both the continuous-flow and batch data were correlated to the Monod equation and a k2 value of about 5.4 mg/l was the result in each case. They also concluded that 2,4-D had been completely biodegraded since a one-to-one correspondence between substrate disappearance and chloride release was observed.

Nitrobenzene was one of 123 compounds tested by Pitter [26] to determine its biological degradability. Activated sludge from a sewage treatment plant was preadapted to the compound for 20 days in a medium that also contained glucose and peptone. The degradation runs were performed in batch reactors and the nitrobenzene concentration was measured in terms of its equivalent in mg of COD. The degradation data were fit to the zero-order kinetic model. Nitrobenzene was found to be completely degradable at a rate of 14 mgCOD/gmMLSS hr.

No published results are available for 1-butanol as a target substrate.

VIII. CONCLUSIONS

1. Livingston sludge by itself or in a mixture with any of the three commercial preparations can significantly degrade 1-butanol and 2,4-D at concentrations up to 100 ppm and 10 ppm, respectively.

2. A small but noticeable increase in the degradation rate of these compounds occurrs when Livingston sludge is used in combination with Hydrobac, BI-CHEM DC-1006/7, or LLMO. However, this minor improvement is obtained at the expense of adding economically prohibitive amounts of each preparation. The manufacturer's recommended ratio is too small to be effective.

3. Under the experimental conditions of this study, none of the microbial agents used were able to biodegrade nitrobenzene.

4. The zero order kinetic model can successfully represent 1-butanol and 2,4-D degradation data. Zero-order kinetics for 1-butanol yields a rate constant that varies from 9.8-50.1 mg/l hr. For 2,4-D the zero order rate constant ranged from 0.28-0.81 mg/l hr.

5. Both the Monod and Haldane models were unable to describe

the 1-butanol and 2,4-D degradation data since regression of the data often yielded negative values for their constants. The Haldane model can represent the 2,4-D degradation data with values of k2 ranging from 0.001-0.075 mg/l and k3 ranging from 0.004-0.013 mg/l. This model was "successful" only because the average number of data points it had to represent were close to the number of constants it contains.

6. No model was able to represent the nitrobenzene data due to the lack of any significant degradation in these experiments.

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TABLES

Table 1

Theoretical COD of Selected Compounds

Compound	Theoretical COD (mgCOD/mg compound)
1-butanol	2.59
2,4-D	1.16
nitrobenzene	1.95
thymol	2.77
isoamyl alcohol	2.72
cinnamyl alcohol	2.62

Table 2

Results, 1st 1-Butanol Air Stripping Experiment

SUBSTRATE :1-BUTANOL
MEDIA :WATER
CONCENTRATION:200 PPM (NOMINAL)
DATE :09-29-83
RUN :I
TEMPERATURE :26 C

TIME (HR)	CONCENTRATION (PPM)
0.0	204.8
1.0	221.4
2.5	192.2
3.0	206.6
5.0	204.7
96.0	131.2
97.0	132.9
98.0	131.4
100.0	131.6
144.0	106.9
145.0	105.8
148.0	105.2
149.0	104.3
168.0	89.9
172.0	89.1
263.0	46.2
264.0	46.3

Table 3

Results, 2nd 1-Butanol Air Stripping Experiment

SUBSTRATE :1-BUTANOL
MEDIA :WATER
CONCENTRATION:200 PPM (NOMINAL)
DATE :10-17-83
RUN :II
TEMPERATURE :26 C

TIME (HR)	CONCENTRATION (PPM)
0.0	205.9
1.0	202.1
3.0	202.1
4.0	201.3
5.0	205.5
51.0	151.6
52.0	153.9
53.0	148.3
74.5	126.4
76.5	126.7
77.5	120.6
98.5	88.1
100.5	86.4
193.0	20.9

Table 4

Results, 1st Nitrobenzene Air Stripping Experiment

SUBSTRATE	:NITROBENZENE
MEDIA	:WATER
CONCENTRATION	:70 PPM (NOMINAL)
DATE	:10-12-83
RUN	:I
TEMPERATURE	:26 C

TIME (HR)	CONCENTRATION (PPM)
0.0	74.0
0.5	67.9
1.0	66.7
2.0	61.4
3.0	61.2
4.0	58.3
5.0	52.3
23.0	19.2
24.0	13.7

Table 5

Results, 2nd Nitrobenzene Air Stripping Experiment

SUBSTRATE :NITROBENZENE
MEDIA :WATER
CONCENTRATION:70 PPM (NOMINAL)
DATE :10-14-83
RUN :II
TEMPERATURE :26 C

TIME (HR)	CONCENTRATION (PPM)
0.0	79.9
1.0	85.7
2.0	81.7
3.0	87.2
4.0	87.8
6.5	73.8
148.0	56.5
149.5	44.7
166.5	38.1
168.0	39.7
265.5	16.0
266.0	20.1
287.0	13.3
291.0	12.4

Table 6

Results, 3rd Nitrobenzene Air Stripping Experiment

SUBSTRATE :NITROBENZENE
MEDIA :WATER
CONCENTRATION:120 PPM (NOMINAL)
DATE :10-27-83
RUN :III
TEMPERATURE :26 C

TIME (HR)	CONCENTRATION (PPM)
0.0	131.7
1.0	131.2
2.0	131.1
24.5	108.8
25.5	113.4
26.5	112.0
96.0	46.9
97.0	48.9
99.0	49.6
120.0	45.2
121.0	44.0
122.0	39.5
145.5	36.6
146.0	35.1
147.0	38.3
193.0	22.9
194.0	24.1

Table 7

Results, 2,4-D Air Stripping Experiment

SUBSTRATE :2,4-D
MEDIA :WATER
CONCENTRATION:10 PPM (NOMINAL)
DATE :01-11-84
RUN :I
TEMPERATURE :26 C

TIME (HR)	CONCENTRATION (PPM)
0.0	11.0
47.0	12.0
143.0	11.2
335.0	11.3

Table 8

Thermodynamic Data of Selected Compounds

Compound	Psat@26C (mmHg)	Activity Coeffic.	Actual time for total removal (hr)	Theoretical time for total removal (hr)
1-butanol	7.6[27]	30[28]	335	1225
nitro-benzene	0.29[27]	3350[28]	330	221
2,4-D	---	---	---	---

Table 9
Data Summary,1-Butanol,Liv,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON
CONCENTRATION:100 PPM NOMINAL
DATE :11-01-83
RUN :I
TEMPERATURE :29 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
5.0	113.2	--	7.2	181	--	--
19.0	108.9	262.0	7.3	--	17	--
29.0	106.0	273.0	7.4	--	--	--
46.0	104.8	--	7.4	187	--	--
115.0	84.0	--	7.4	181	--	--
155.0	72.9	244.0	7.4	--	--	--
181.0	64.5	--	7.4	178	--	--
214.0	58.6	--	--	--	10	--
248.0	43.5	216.0	7.4	184	--	--
273.0	38.7	--	7.3	--	--	--
305.0	29.3	172.0	7.3	--	--	--
335.0	21.0	--	7.3	--	--	--
363.0	13.1	--	--	--	--	--
394.0	6.2	164.0	--	--	--	--
424.0	0.6	179.0	--	--	2	--

Table 10
Data Summary,1-Butanol,Liv,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON
CONCENTRATION:100 PPM NOMINAL
DATE :11-05-83
RUN :II
TEMPERATURE :25 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	119.7	186.0	6.9	193	16	--
34.0	111.3	228.0	7.3	--	--	--
64.0	97.7	--	7.5	201	--	--
94.0	87.2	238.0	7.5	--	--	--
125.0	74.8	--	7.6	190	--	--
155.0	62.3	273.0	7.6	--	14	--
189.0	50.6	--	7.4	194	--	--
214.0	37.0	--	7.4	--	--	--
244.0	25.4	186.0	7.4	191	--	--
273.0	14.6	--	7.4	--	--	--
304.0	9.6	--	7.4	201	9	--
337.0	0.3	98.0	7.4	--	--	--

Table 11
Data Summary,1-Butanol,Liv,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON
CONCENTRATION:100 PPM NOMINAL
DATE :11-09-83
RUN :III
TEMPERATURE :26 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
8.0	116.4	132.0	7.2	187	2	--
36.0	112.7	125.0	7.2	--	--	--
66.0	104.7	--	7.2	177	--	--
95.0	99.4	--	7.2	--	--	--
126.0	91.6	154.0	7.2	171	--	--
156.0	81.8	--	7.2	--	--	--
185.0	78.9	--	7.2	169	--	--
214.0	68.9	--	7.2	--	--	--
245.0	60.2	141.0	7.2	168	2	--
275.0	53.3	--	7.3	--	--	--
305.0	47.4	--	7.3	168	--	--
335.0	40.9	--	7.3	--	--	--
365.0	31.6	133.0	7.3	160	--	--
398.0	22.9	--	7.3	--	--	--
425.0	16.0	--	7.3	162	--	--
455.0	8.8	--	7.4	--	--	--
485.0	1.4	130.0	7.4	166	--	--

Table 12
Data Summary,1-Butanol,Liv/BI-CHEM,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:100 PPM NOMINAL
DATE :11-05-83
RUN :I
TEMPERATURE :25 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	110.3	86.0	6.9	164	5	--
35.0	107.2	106.0	7.0	--	--	--
64.0	107.6	--	7.0	160	--	--
94.0	100.2	87.0	6.9	--	--	--
126.0	93.5	--	6.9	147	--	--
155.0	88.5	104.0	6.9	--	--	--
189.0	81.7	--	6.9	164	--	--
214.0	71.4	96.0	6.9	--	3	--
244.0	66.9	--	6.9	162	--	--
273.0	60.5	--	6.9	--	--	--
304.0	56.7	--	6.9	174	--	--
337.0	48.9	121.0	6.9	--	2	--

Table 13
Data Summary,1-Butanol,Liv/BI-CHEM,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:100 PPM NOMINAL
DATE :11-05-83
RUN :II
TEMPERATURE :25 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS ms/l	NH4+ PPM	CL- PPM
8.0	117.1	138.0	5.4	174	0	--
34.0	105.1	119.0	7.1	--	--	--
65.0	94.3	--	7.3	157	--	--
93.0	81.4	--	7.3	--	--	--
126.0	67.4	--	7.4	169	--	--
160.0	50.4	86.0	7.4	--	43	--
184.0	38.9	--	7.3	175	--	--
214.0	25.4	--	7.3	--	--	--
243.0	12.7	--	7.3	180	--	--
274.0	1.6	58.0	7.2	--	--	--
304.0	0.2	61.0	7.2	169	39	--

Table 14
Data Summary,1-Butanol,Liv/BI-CHEM,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:100 PPM NOMINAL
DATE :11-09-83
RUN :III
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS ms/l	NH4+ PPM	CL- PPM
6.0	116.1	101.0	7.0	195	30	--
38.0	106.8	100.0	7.4	--	--	--
63.0	96.4	--	7.5	199	--	--
93.0	85.8	--	7.6	--	--	--
124.0	68.9	--	7.6	207	--	--
156.0	56.7	68.0	7.5	--	23	--
190.0	37.5	--	7.5	209	--	--
220.0	20.0	--	7.5	--	--	--
245.0	4.7	39.0	7.5	204	--	--
273.0	0.3	44.0	7.4	--	16	--

Table 15
Data Summary,1-Butanol,Liv/Hyd,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :11-18-83
RUN :I
TEMPERATURE :25 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	87.6	102.0	6.9	179	38	--
34.0	86.9	116.0	7.1	--	--	--
64.0	83.8	--	7.2	186	--	--
96.0	78.3	--	7.2	--	--	--
128.0	75.1	--	7.2	192	--	--
155.0	71.0	104.0	7.2	--	--	--
184.0	66.6	108.0	7.2	197	--	--
243.0	57.6	--	7.2	173	--	--
277.0	52.3	--	7.1	--	26	--
304.0	48.0	--	7.1	172	--	--
337.0	41.8	--	7.0	--	--	--
365.0	37.1	--	7.0	171	--	--
396.0	31.2	75.0	7.0	--	--	--
424.0	25.4	--	6.9	177	--	--
455.0	19.1	--	6.9	--	--	--
484.0	13.2	--	6.9	192	--	--
515.0	7.5	--	6.9	--	--	--
544.0	2.0	39.0	6.8	195	--	--
574.0	0.2	58.0	6.8	--	19	--

Table 16
Data Summary,1-Butanol,Liv/Hyd,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :11-19-83
RUN :II
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS ms/l	NH4+ PPM	CL- PPM
8.0	101.5	117.0	7.1	208	12	--
35.0	98.3	111.0	7.5	--	--	--
67.0	90.8	--	7.7	218	--	--
95.0	82.8	--	7.7	--	--	--
125.0	75.6	--	7.7	196	--	--
154.0	67.2	--	7.7	--	--	--
186.0	58.2	84.0	7.8	214	4	--
213.0	50.7	--	7.8	--	--	--
245.0	40.3	--	7.8	223	--	--
274.0	31.5	--	7.8	--	--	--
306.0	22.6	--	7.8	217	--	--
333.0	14.6	--	7.8	--	--	--
363.0	5.7	46.0	7.8	223	--	--
386.0	0.5	42.0	7.8	--	7	--

Table 17
Data Summary,1-Butanol,Liv/Hyd,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :11-22-83
RUN :III
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
7.0	103.3	128.0	7.9	168	14	--
37.0	99.4	122.0	8.0	--	--	--
67.0	93.9	--	8.0	172	--	--
99.0	90.4	--	7.9	--	--	--
127.0	87.3	--	7.9	173	--	--
156.0	83.6	--	7.9	--	--	--
191.0	78.9	--	7.9	164	--	--
221.0	73.7	--	7.9	--	--	--
245.0	70.2	--	7.8	169	--	--
275.0	64.3	92.0	7.8	--	10	--
311.0	58.7	--	7.8	182	--	--
340.0	53.7	--	7.8	--	--	--
365.0	48.3	--	7.7	175	--	--
396.0	43.4	--	7.7	--	--	--
425.0	38.1	--	7.7	181	--	--
456.0	32.4	--	7.6	--	--	--
485.0	26.7	--	7.6	187	--	--
516.0	20.7	58.0	7.7	--	--	--
544.0	15.9	51.0	7.7	187	4	--

Table 18
Data Summary,1-Butanol,Liv/Hyd,RunIA

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :01-06-84
RUN :IA
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	97.4	148.0	7.9	138	70	--
37.0	67.3	119.0	7.7	--	--	--
63.0	41.3	--	7.7	131	67	--
92.0	13.3	--	7.7	--	--	--
126.0	0.5	85.0	7.6	175	63	--

Table 19
Data Summary,1-Butanol,Liv/Hyd,RunIIA

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :01-07-84
RUN :IIA
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	109.2	154.0	7.8	151	53	--
37.0	77.6	116.0	7.7	--	--	--
65.0	55.8	--	7.6	126	52	--
97.0	32.0	91.0	7.6	--	--	--
125.0	8.2	80.0	7.6	244	--	--
156.0	0.4	--	7.6	--	48	--

Table 20
Data Summary,1-Butanol,Liv/Hyd,RunIIIA

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :01-07-84
RUN :IIIA
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
16.0	88.1	147.0	7.6	--	43	--
35.0	74.8	141.0	7.6	115	--	--
63.0	54.0	124.0	7.5	--	39	--
95.0	27.4	115.0	7.5	148	--	--
124.0	3.9	141.0	7.4	--	--	--
155.0	0.3	97.0	7.5	155	35	--

Table 21
Data Summary,1-Butanol,Liv/LLMO,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:100 PPM NOMINAL
DATE :01-18-84
RUN :I
TEMPERATURE :24 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	82.0	123.0	7.7	165	31	--
33.0	56.9	116.0	7.8	--	--	--
64.0	29.8	--	7.8	164	34	--
93.0	2.6	76.0	7.8	--	--	--
154.0	0.3	72.0	7.8	--	32	--

Table 22
Data Summary,1-Butanol,Liv/LLMO,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:100 PPM NOMINAL
DATE :01-19-84
RUN :II
TEMPERATURE :24 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
6.0	95.7	143.0	7.8	104	34	--
35.0	88.5	157.0	7.8	--	--	--
62.0	74.8	--	7.7	119	--	--
94.0	60.6	--	7.7	--	--	--
127.0	44.9	112.0	7.7	138	33	--
157.0	30.2	--	7.6	--	--	--
197.0	11.5	--	7.6	110	--	--
252.0	3.0	90.0	7.6	151	--	--
273.0	0.2	77.0	7.6	--	30	--

Table 23
Data Summary,1-Butanol,Liv/LLMO,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:100 PPM NOMINAL
DATE :01-20-84
RUN :III
TEMPERATURE :24 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
8.0	94.2	149.0	7.6	98	26	--
36.0	90.9	154.0	7.6	--	--	--
65.0	85.0	--	7.6	124	--	--
93.0	76.7	--	7.5	--	--	--
124.0	68.0	--	7.5	113	25	--
155.0	57.6	136.0	7.5	--	--	--
184.0	48.1	--	7.5	120	--	--
217.0	36.8	--	7.4	--	--	--
270.0	17.0	120.0	7.4	157	21	--
308.0	2.8	115.0	7.4	--	--	--

Table 24
Data Summary,Nitrobenzene,Liv/Hyd,RunI

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:20 PPM NOMINAL
DATE :12-02-83
RUN :I
TEMPERATURE :UNKNOWN

TIME	CONC.	COD	pH	MLSS	NH4+	CL-
16.0	27.3	--	--	--	--	--
71.0	7.1	--	--	--	--	--
140.0	8.5	--	--	--	--	--
194.0	8.5	--	--	--	--	--
250.0	7.5	--	--	--	--	--
1394.0	9.4	--	--	--	--	--
1420.0	7.3	--	--	--	--	--
1449.0	7.9	--	--	--	--	--
1479.0	9.8	--	--	--	--	--
1510.0	9.0	--	--	--	--	--
1630.0	7.8	--	--	--	--	--
1688.0	9.3	--	--	--	--	--
4210.0	8.1	--	--	--	--	--

Table 25
Data Summary,Nitrobenzene,Liv/Hyd,RunII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:20 PPM NOMINAL
DATE :12-07-83
RUN :II
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM		pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	11.3	--	--	--	--	--	--
72.0	12.0	--	--	--	--	--	--
125.0	11.0	--	--	--	--	--	--
190.0	10.9	--	--	--	--	--	--
249.0	11.3	--	--	--	--	--	--
305.0	11.6	--	--	--	--	--	--
1543.0	9.5	--	--	--	--	--	--
1567.0	10.7	--	--	--	--	--	--
1630.0	11.2	--	--	--	--	--	--
1688.0	12.1	--	--	--	--	--	--
1749.0	12.8	--	--	--	--	--	--
1818.0	4.6	--	--	--	--	--	--
4385.0	9.2	--	--	--	--	--	--
4426.0	8.4	--	--	--	--	--	--

Table 26
Data Summary,Nitrobenzene,Liv/Hyd,RunIII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:20 PPM NOMINAL
DATE :12-12-83
RUN :III
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
12.0	11.8	--	--	--	--	--
59.0	13.3	--	--	--	--	--
125.0	14.9	--	--	--	--	--
200.0	13.0	--	--	--	--	--
248.0	11.6	--	--	--	--	--
336.0	15.7	--	--	--	--	--
365.0	14.5	--	--	--	--	--
429.0	14.5	--	--	--	--	--
1394.0	8.6	--	--	--	--	--
1445.0	8.1	--	--	--	--	--
1505.0	7.7	--	--	--	--	--
1884.0	3.6	--	--	--	--	--
2828.0	0.1	--	--	--	--	--

Table 27
Data Summary,Nitrobenzene,Liv/BI-CHEM,RunI

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :12-21-83
RUN :I
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
15.0	2.2	--	--	--	--	--
78.0	3.8	--	--	--	--	--
132.0	3.8	--	--	--	--	--
192.0	8.1	--	--	--	--	--
254.0	15.3	--	--	--	--	--
323.0	13.8	--	--	--	--	--
387.0	13.4	--	--	--	--	--
438.0	10.5	--	--	--	--	--
1573.0	12.0	--	--	--	--	--
1640.0	12.2	--	--	--	--	--
1689.0	10.9	--	--	--	--	--
1938.0	11.8	--	--	--	--	--
2958.0	10.1	--	--	--	--	--

Table 28
Data Summary,Nitrobenzene,Liv/BI-CHEM,RunII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :12-27-83
RUN :II
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
13.0	19.2	--	--	--	--	--
65.0	18.6	--	--	--	--	--
128.0	21.2	--	--	--	--	--
187.0	22.0	--	--	--	--	--
251.0	18.1	--	--	--	--	--
1471.0	19.4	--	--	--	--	--
1509.0	22.5	--	--	--	--	--
1563.0	21.8	--	--	--	--	--
1627.0	23.0	--	--	--	--	--
1683.0	21.4	--	--	--	--	--
2867.0	11.7	--	--	--	--	--

Table 29
Data Summary,Nitrobenzene,Liv/BI-CHEM,RunIII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :01-02-84
RUN :III
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	11.9	--	--	--	--	--
71.0	12.1	--	--	--	--	--
151.0	10.3	--	--	--	--	--
204.0	11.0	--	--	--	--	--
260.0	8.1	--	--	--	--	--
312.0	9.1	--	--	--	--	--
380.0	7.5	--	--	--	--	--
1572.0	0.2	--	--	--	--	--

Table 30
Data Summary,Nitrobenzene,Liv,RunII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :II
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	34.0	--	--	--	--	--
245.0	20.1	--	--	--	--	--
370.0	14.9	--	--	--	--	--
455.0	14.5	--	--	--	--	--
635.0	12.4	--	--	--	--	--
1447.0	0.5	--	--	--	--	--

Table 31
Data Summary,Nitrobenzene,Liv,RunIII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :III
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	25.3	--	--	--	--	--
65.0	24.9	--	--	--	--	--
125.0	23.8	--	--	--	--	--
185.0	21.9	--	--	--	--	--
245.0	18.1	--	--	--	--	--
305.0	16.5	--	--	--	--	--
365.0	16.1	--	--	--	--	--
425.0	13.5	--	--	--	--	--
620.0	3.9	--	--	--	--	--

Table 32
Data Summary,Nitrobenzene,Liv/BI-CHEM,RunIA

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :IA
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	19.5	--	--	--	--	--
125.0	18.5	--	--	--	--	--
245.0	17.1	--	--	--	--	--
1327.0	11.0	--	--	--	--	--
1447.0	10.4	--	--	--	--	--
1567.0	8.3	--	--	--	--	--
1655.0	7.7	--	--	--	--	--
2646.0	7.9	--	--	--	--	--
2765.0	6.8	--	--	--	--	--

Table 33
Data Summary,Nitrobenzene,Liv/BI-CHEM,RunIIA

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :IIA
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
7.0	12.2	--	--	--	--	--
125.0	11.4	--	--	--	--	--
246.0	9.8	--	--	--	--	--
367.0	5.6	--	--	--	--	--

Table 34
Data Summary,Nitrobenzene,Liv/BI-CHEM,RunIIIA

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :IIIA
TEMPERATURE :UNKNOWN

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
8.0	14.4	--	--	--	--	--
127.0	13.8	--	--	--	--	--
255.0	12.0	--	--	--	--	--
367.0	10.3	--	--	--	--	--
635.0	10.2	--	--	--	--	--

Table 35
Data Summary,2,4-D,Liv,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON
CONCENTRATION:10 PPM NOMINAL
DATE :02-01-84
RUN :I
TEMPERATURE :23 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
100.0	11.5	--	7.4	169	119	--
190.0	11.1	--	7.4	--	118	--
280.0	8.8	--	7.5	171	119	--
380.0	8.8	--	7.5	--	118	--
465.0	8.2	--	7.5	172	119	--
555.0	7.2	--	7.5	164	119	--

Table 36
Data Summary,2,4-D,Liv,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON
CONCENTRATION:10 PPM NOMINAL
DATE :02-01-84
RUN :II
TEMPERATURE :23 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
130.0	2.2	--	7.4	--	96	130.0
255.0	2.2	--	7.4	--	94	134.0
510.0	1.9	--	7.4	141	98	133.0

Table 37
Data Summary,2,4-D,Liv/Hyd,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:10 PPM NOMINAL
DATE :02-22-84
RUN :I
TEMPERATURE :24 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS ms/l	NH4+ PPM	CL- PPM
9.0	5.9	--	8.0	159	81	83.0
148.0	4.5	--	8.2	--	81	84.0
432.0	3.5	--	8.0	--	84	86.0
1650.0	2.7	--	--	174	89	87.0

Table 38
Data Summary,2,4-D,Liv/Hyd,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:10 PPM NOMINAL
DATE :02-23-84
RUN :II
TEMPERATURE :24 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
15.0	8.2	92.0	7.7	127	73	70.0
130.0	7.9	84.0	7.8	--	73	67.0
245.0	4.8	94.0	8.0	122	74	68.0
365.0	2.7	--	8.0	--	74	69.0
480.0	2.9	82.0	8.0	124	75	68.0

Table 39
Data Summary,2,4-D,Liv/Hyd,RunIII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:10 PPM NOMINAL
DATE :02-24-84
RUN :III
TEMPERATURE :23 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
125.0	10.7	87.0	7.1	110	62	67.0
365.0	4.5	87.0	6.7	--	61	70.0
480.0	6.0	89.0	7.5	94	60	71.0

Table 40
Data Summary,2,4-D,Liv/BI-CHEM,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:10 PPM NOMINAL
DATE :02-14-84
RUN :I
TEMPERATURE :23 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
9.0	4.4	326.0	7.7	189	67	87.0
120.0	3.9	217.0	7.7	--	67	92.0
270.0	4.0	--	7.6	193	63	85.0
390.0	4.0	77.0	7.8	--	60	92.0
510.0	4.1	--	7.8	184	59	89.0
610.0	3.5	66.0	7.9	--	57	91.0
1580.0	3.0	60.0	7.6	--	71	82.0

Table 41
Data Summary,2,4-D,Liv/BI-CHEM,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:10 PPM NOMINAL
DATE :02-15-84
RUN :II
TEMPERATURE :25 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	2.5	101.0	7.6	147	65	92.0
130.0	1.1	118.0	8.0	--	62	90.0
250.0	0.7	--	7.9	--	64	90.0
370.0	1.3	98.0	7.8	--	66	87.0
605.0	1.0	105.0	7.9	149	68	90.0
1400.0	1.2	127.0	8.0	143	68	90.0

Table 42
Data Summary,2,4-D,Liv/BI-CHEM,RunIII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:10 PPM NOMINAL
DATE :02--6-84
RUN :III
TEMPERATURE :25 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
10.0	7.9	55.0	7.9	117	61	77.0
130.0	6.6	51.0	8.0	--	60	73.0
375.0	5.9	--	8.1	--	61	73.0
490.0	5.2	55.0	8.0	--	65	74.0
605.0	5.0	53.0	8.0	--	68	69.0

Table 43
Data Summary,2,4-D,Liv/LLMO,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:10 PPM NOMINAL
DATE :03-02-84
RUN :I
TEMPERATURE :23 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
11.0	6.7	86.0	6.7	170	75	99.0
129.0	5.0	77.0	7.9	--	71	104.0
255.0	5.8	89.0	7.9	--	78	102.0
367.0	3.9	78.0	7.9	156	72	104.0
487.0	3.5	83.0	7.9	161	72	102.0

Table 44
Data Summary,2,4-D,Liv/LLMO,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:10 PPM NOMINAL
DATE :03-04-84
RUN :II
TEMPERATURE :23 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
9.0	8.7	94.0	7.8	124	67	85.0
150.0	8.6	84.0	7.8	--	65	83.0
248.0	6.5	94.0	8.1	59	65	84.0
367.0	4.8	86.0	8.1	--	67	81.0
484.0	7.1	101.0	8.1	116	64	88.0

Table 45
Data Summary,2,4-D,Liv/LLMO,RunIII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:10 PPM NOMINAL
DATE :03-06-84
RUN :III
TEMPERATURE :22 C

TIME MINS	CONC. PPM	COD PPM	pH	MLSS mg/l	NH4+ PPM	CL- PPM
20.0	9.1	111.0	7.6	92	42	73.0
127.0	6.5	102.0	7.7	--	41	69.0
265.0	7.9	112.0	7.6	80	68	70.0
365.0	7.5	103.0	7.5	--	40	68.0
488.0	9.5	125.0	7.4	81	39	66.0

Table 46

Zero-order model,1-Butanol,Liv,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-01-83

RUN :I

TEMPERATURE :29 C

TIME (MIN)	PPMEXP	PPMCAL	DY
5.0000	113.20	113.66	0.46434
19.000	108.90	109.79	0.88597
29.000	106.00	107.02	1.0157
46.000	104.80	102.31	-2.4937
115.00	84.000	83.192	-0.80849
155.00	72.900	72.110	-0.78952
181.00	64.500	64.908	0.40781
214.00	58.600	55.766	-2.8341
248.00	43.500	46.347	2.8471
273.00	38.700	39.421	0.72144
305.00	29.300	30.557	1.2566
335.00	21.000	22.246	1.2458
363.00	13.100	14.489	1.3891
394.00	6.2000	5.9013	-0.29869
424.00	0.60000	-2.4095	-3.0095

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 115.049 ± 0.99 mg/l

K2= 16.622 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99814

THE ABSOLUTE AVERAGE RESIDUAL = 0.42457

Table 47

Zero-order model,1-Butanol,Liv,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-05-83

RUN :II

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	119.70	119.46	-0.23895
34.000	111.30	108.88	-2.4159
64.000	97.700	97.552	-0.14839
94.000	87.200	86.219	-0.98087
125.00	74.800	74.509	-0.29109
155.00	62.300	63.176	0.87642
189.00	50.600	50.333	-0.26704
214.00	37.000	40.889	3.8892
244.00	25.400	29.557	4.1568
273.00	14.600	18.602	4.0020
304.00	9.6000	6.8918	-2.7082
337.00	0.30000	-5.5739	-5.8739

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 121.728 ± 2.03 mg/l

K2= -22.665 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99470

THE ABSOLUTE AVERAGE RESIDUAL = 0.82521

Table 48

Zero-order model,1-Butanol,Liv,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-09-83

RUN :III

TEMPERATURE :26 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	116.40	119.42	3.0170
36.000	112.70	112.53	-0.16986
66.000	104.70	105.15	0.45132
95.000	99.400	98.018	-1.3815
126.00	91.600	90.394	-1.2063
156.00	81.800	83.015	1.2148
185.00	78.900	75.882	-3.0180
214.00	68.900	68.749	-0.15088
245.00	60.200	61.124	0.92433
275.00	53.300	53.745	0.44550
305.00	47.400	46.367	-1.0333
335.00	40.900	38.988	-1.9122
365.00	31.600	31.609	0.90179E-02
398.00	22.900	23.492	0.59232
425.00	16.000	16.851	0.85136
455.00	8.8000	9.4725	0.67253
485.00	1.4000	2.0937	0.69370

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 121.385 ± 0.75 mg/l

K2= -14.758 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99860

THE ABSOLUTE AVERAGE RESIDUAL = 0.32800

Table 49

Zero-order model,1-Butanol,Liv/BI-CHEM,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:100 PPM NOMINAL

DATE :11-05-83

RUN :I

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	110.30	115.30	4.9961
35.000	107.20	109.55	2.3498
64.000	107.60	103.80	-3.7965
94.000	100.20	97.859	-2.3409
126.00	93.500	91.518	-1.9816
155.00	88.500	85.772	-2.7279
189.00	81.700	79.035	-2.6650
214.00	71.400	74.081	2.6813
244.00	66.900	68.137	1.2369
273.00	60.500	62.391	1.8906
304.00	56.700	56.248	-0.45201
337.00	48.900	49.709	0.80911

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 116.485 ± 1.86 mg/l

K2= -11.889 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.98401

THE ABSOLUTE AVERAGE RESIDUAL = 0.75461

Table 50

Zero-order model,1-Butanol,Liv/BI-CHEM,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:100 PPM NOMINAL

DATE :11-05-83

RUN :II

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	117.10	116.17	-0.92598
34.000	105.10	105.19	0.85297E-01
65.000	94.300	92.083	-2.2166
93.000	81.400	80.249	-1.1507
126.00	67.400	66.302	-1 979
160.00	50.400	51.932	1.5322
184.00	38.900	41.789	2.8887
214.00	25.400	29.109	3.7094
243.00	12.700	16.853	4.1528
274.00	1.6000	3.7508	2.1508
304.00	0.20000	-8.9285	-9.1285

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 119.555 ± 2.69 mg/l

K2= -25.359 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99214

THE ABSOLUTE AVERAGE RESIDUAL = 1.0678

Table 51

Zero-order model,1-Butanol,Liv/BI-CHEM,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:100 PPM NOMINAL

DATE :11-09-83

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	116.10	121.77	5.6682
38.000	106.80	106.94	0.14368
63.000	96.400	95.362	-1 379
93.000	85.800	81.464	-4.3359
124.00	68.900	67.103	-1.7971
156.00	56.700	52.278	-4.4216
190.00	37.500	36.527	-0.97266
220.00	20.000	22.629	2.6294
245.00	4.7000	11.048	6.3477
273.00	0.30000	-1.9237	-2.2237

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 124.548 ± 2.94 mg/l

K2= -27.796 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99208

THE ABSOLUTE AVERAGE RESIDUAL = 1.1309

Table 52

Zero-order model,1-Butanol,Liv/Hyd,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :11-18-83

RUN :I

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	87.600	93.784	6.1844
34.000	86.900	89.193	2.2927
64.000	83.800	84.273	0.47287
96.000	78.300	79.025	0.72510
128.00	75.100	73.777	-1.3227
155.00	71.000	69.350	-1.6505
184.00	66.600	64.594	-2.0063
243.00	57.600	54.918	-2.6818
277.00	52.300	49.342	-2.9576
304.00	48.000	44.915	-3.0854
337.00	41.800	39.503	-2.2972
365.00	37.100	34.911	-2.1890
396.00	31.200	29.827	-1.3727
424.00	25.400	25.235	-0.16452
455.00	19.100	20.152	1.0517
484.00	13.200	15.396	2.1959
515.00	7.5000	10.312	2.8121
544.00	2.0000	5.5563	3.5563
574.00	0.20000	0.63655	0.43655

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 94.768 ± 1.28 mg/l

K2= -9.840 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99270

THE ABSOLUTE AVERAGE RESIDUAL = 0.56897

Table 53

Zero-order model,1-Butanol,Liv/Hyd,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :11-19-83

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	101.50	106.23	4.7304
35.000	98.300	98.700	0.39975
67.000	90.800	89.775	-1.254
95.000	82.800	81.965	-0.83495
125.00	75.600	73.598	-2.0023
154.00	67.200	65.509	-1.6907
186.00	58.200	56.584	-1.6159
213.00	50.700	49.053	-1.6465
245.00	40.300	40.128	-0.17172
274.00	31.500	32.040	0.53984
306.00	22.600	23.115	0.51465
333.00	14.600	15.584	0.98405
363.00	5.7000	7.2167	1.5167
386.00	0.50000	0.80171	0.30171

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 108.462 ± 1.08 mg/l

K2= -16.735 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99739

THE ABSOLUTE AVERAGE RESIDUAL = 0.45412

Table 54

Zero-order model,1-Butanol,Liv/Hyd,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :11-22-83

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
7.0000	103.30	106.44	3.1447
37.000	99.400	101.54	2.1351
67.000	93.900	96.625	2.7254
99.000	90.400	91.388	0.98848
127.00	87.300	86.806	-0.49388
156.00	83.600	82.060	-1.5399
191.00	78.900	76.332	-2.5678
221.00	73.700	71.423	-2.2775
245.00	70.200	67.495	-2.7052
275.00	64.300	62.585	-1.7148
311.00	58.700	56.694	-2.0064
340.00	53.700	51.948	-1.7524
365.00	48.300	47.856	-0.44379
396.00	43.400	42.783	-0.61710
425.00	38.100	38.037	-0.63095E-01
456.00	32.400	32.964	0.56360
485.00	26.700	28.218	1.5176
516.00	20.700	23.144	2.4443
544.00	15.900	18.562	2.6620

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 107.590 ± 0.99 mg/l

K2= -9.819 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.99481

THE ABSOLUTE AVERAGE RESIDUAL = 0.44306

Table 55

Zero-order model,1-Butanol,Liv/Hyd,RunIA

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :01-06-84

RUN :IA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	97.400	93.057	-4.3431
37.000	67.300	67.172	-0.12753
63.000	41.300	45.463	4.1629
92.000	13.300	21.248	7.9485
126.00	0.50000	-7.1409	-7.6409

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 98.067 ±10.51 mg/l

K2= -50.099 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.97470

THE ABSOLUTE AVERAGE RESIDUAL = 2.5121

Table 56

Zero-order model,1-Butanol,Liv/Hyd,RunIIA

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :01-07-84

RUN :IIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	109.20	102.82	-6.3790
37.000	77.600	79.831	2.2310
65.000	55.800	59.066	3.2658
97.000	32.000	35.334	3.3342
125.00	8.2000	14.569	6.3690
156.00	0.40000	-8.4211	-8.8211

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 107.271 ± 7.84 mg/l

K2= -44.497 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.97885

THE ABSOLUTE AVERAGE RESIDUAL = 2.2720

Table 57

Zero-order model,1-Butanol,Liv/Hyd,RunIIIA

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :01-07-84

RUN :IIIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
16.000	88.100	85.855	-2.2447
35.000	74.800	72.932	-1.8682
63.000	54.000	53.887	-0.11330
95.000	27.400	32.121	4.7208
124.00	3.9000	12.395	8.4955
155.00	0.30000	-8.6902	-8.9902

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 96.738 ± 7.81 mg/l

K2= -40.811 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.97275

THE ABSOLUTE AVERAGE RESIDUAL = 2.2597

Table 58

Zero-order model, 1-Butanol, Liv/LLMO, RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:100 PPM NOMINAL

DATE :01-18-84

RUN :I

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	82.000	70.742	-11.258
33.000	56.900	55.376	-1.5237
64.000	29.800	37.735	7.9345
93.000	2.6000	21.231	18.631
154.00	0.30000	-13.483	-13.783

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 74.156 ±22.48 mg/l

K2= -34.145 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.85321

THE ABSOLUTE AVERAGE RESIDUAL = 5.4005

Table 59

Zero-order model,1-Butanol,Liv/LLMO,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:100 PPM NOMINAL

DATE :01-19-84

RUN :II

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	95.700	94.559	-1.1406
35.000	88.500	83.413	-5.0872
62.000	74.800	73.035	-1.7650
94.000	60.600	60.735	0.13531
127.00	44.900	48.051	3.1513
157.00	30.200	36.520	6.3204
197.00	11.500	21.146	9.6458
252.00	3.0000	0.57220E-02	-2.9943
273.00	0.20000	-8.0659	-8.2659

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 96.866 ± 4.76 mg/l

K2= -23.062 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.97660

THE ABSOLUTE AVERAGE RESIDUAL = 1.7587

Table 60

Zero-order model,1-Butanol,Liv/LLMO,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:100 PPM NOMINAL

DATE :01-20-84

RUN :III

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	94.200	100.92	6.7187
36.000	90.900	92.152	1.2517
65.000	85.000	83.072	-1.9284
93.000	76.700	74.305	-2.3954
124.00	68.000	64.598	-3.4017
155.00	57.600	54.892	-2.7080
184.00	48.100	45.812	-2.2881
217.00	36.800	35.479	-1.3206
270.00	17.000	18.885	1.8848
308.00	2.8000	6.9867	4.1867

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 103.424 ± 2.64 mg/l

K2= -18.786 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.98834

THE ABSOLUTE AVERAGE RESIDUAL = 1.0155

Table 61

Monod model,1-Butanol,Liv,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-01-83

RUN :I

TEMPERATURE :29 C

TIME (MIN)	PPMEXP	PPMCAL	DY
5.0000	113.20	113.20	0.00000
24.000	108.90	107.10	1.8002
34.000	106.00	103.90	2.0950
51.000	104.80	98.501	6.2989
120.00	84.000	76.986	7.0142
160.00	72.900	64.905	7.9947
186.00	64.500	57.257	7.2435
219.00	58.600	47.838	10.762
253.00	43.500	38.563	4.9370
278.00	38.700	32.096	6.6038
310.00	29.300	24.382	4.9181
340.00	21.000	17.885	3.1150
368.00	13.100	12.639	0.46147
399.00	6.2000	7.9485	-1.7485
429.00	0.60000	4.6477	-4.0477

KINETIC CONSTANTS

MONOD MODEL

K1= 14.095 ± 0.00 mg/l

K2= 21.730 ± 0.00 mg/l.hr

Table 62

Monod model,1-Butanol,Liv,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-05-83

RUN :II

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	119.70	119.70	0.00000
40.000	111.30	105.99	5.3140
70.000	97.700	93.965	3.7347
100.00	87.200	82.039	5.1613
131.00	74.800	69.842	4.9585
161.00	62.300	58.201	4.0993
195.00	50.600	45.280	5.3200
220.00	37.000	36.046	0.95378
250.00	25.400	25.427	-0.27435E-01
279.00	14.600	15.953	-1.3528
310.00	9.6000	7.4435	2.1565
343.00	0.30000	1.8725	-1.5725

KINETIC CONSTANTS

MONOD MODEL

K1= 6.133 ± 0.00 mg/l

K2= 25.518 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.0151

Table 63

Monod model,1-Butanol,Liv,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-09-83

RUN :III

TEMPERATURE :26 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	116.40	116.40	0.00000
44.000	112.70	108.92	3.7839
74.000	104.70	102.65	2.0517
103.00	99.400	96.558	2.8415
134.00	91.600	90.010	1.5902
164.00	81.800	83.628	-1.8276
193.00	78.900	77.409	1.4913
222.00	68.900	71.131	-2.2313
253.00	60.200	64.342	-4.1415
283.00	53.300	57.672	-4.3718
313.00	47.400	50.874	-3.4741
343.00	40.900	43.900	-2.9999
373.00	31.600	36.664	-5.0639
406.00	22.900	28.184	-5.2845
433.00	16.000	20.369	-4.3689
463.00	8.8000	5.8321	2.9679
493.00	1.4000	5.2428	-3.8428

KINETIC CONSTANTS

MONOD MODEL

K1= -8.012 ± 0.00 mg/l

K2= 11.586 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.81771

Table 64

Monod model,1-Butanol,Liv/BI-CHEM,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:100 PPM NOMINAL

DATE :11-05-83

RUN :I

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	110.30	110.30	0.00000
41.000	107.20	106.47	0.72659
70.000	107.60	103.17	4.4336
100.00	100.20	99.586	0.61368
132.00	93.500	95.544	-2.0439
161.00	88.500	91.621	-3.1208
195.00	81.700	86.580	-4.8797
220.00	71.400	82.421	-11.021
250.00	66.900	76.550	-9.6501
279.00	60.500	68.639	-8.1391
310.00	56.700	57.895	-1.1948
343.00	48.900	116.95	-68.048

KINETIC CONSTANTS

MONOD MODEL

K1= -59.382 ± 0.00 mg/l

K2= 2.966 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 5.8755

Table 65

Monod model,1-Butanol,Liv/BI-CHEM,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:100 PPM NOMINAL

DATE :11-05-83

RUN :II

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	117.10	117.10	0.00000
42.000	105.10	101.41	3.6866
73.000	94.300	87.233	7.0674
101.00	81.400	74.555	6.8447
134.00	67.400	59.832	7.5678
168.00	50.400	45.023	5.3768
192.00	38.900	34.906	3.9942
222.00	25.400	22.903	2.4966
251.00	12.700	12.526	0.17392
282.00	1.6000	4.2114	-2.6114
312.00	0.20000	0.70846	-0.50846

KINETIC CONSTANTS

MONOD MODEL

K1= 6.245 ± 0.00 mg/l

K2= 29.267 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.3663

Table 66

Monod model,1-Butanol,Liv/BI-CHEM,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:100 PPM NOMINAL

DATE :11-09-83

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	116.10	116.10	0.00000
44.000	106.80	103.90	2.9022
69.000	96.400	95.778	0.62175
99.000	85.800	85.913	-0.11258
130.00	68.900	75.537	-6.6372
162.00	56.700	64.560	-7.8602
196.00	37.500	52.444	-14.944
226.00	20.000	41.083	-21.083
251.00	4.7000	2.3738	2.3262
279.00	0.30000	8.9771	-8.6771

KINETIC CONSTANTS

MONOD MODEL

K1= -11.044 ± 0.00 mg/l

K2= 17.330 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 2.9380

Table 67

Monod model,1-Butanol,Liv/Hyd,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :11-18-83

RUN :I

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	87.600	87.600	0.00000
40.000	86.900	83.496	3.4044
70.000	83.800	79.857	3.9432
102.00	78.300	75.956	2.3442
134.00	75.100	72.032	3.0682
161.00	71.000	68.701	2.2991
190.00	66.600	65.100	1.4998
249.00	57.600	57.687	-0.86731E-01
283.00	52.300	53.349	-1.0487
310.00	48.000	49.861	-1.8611
343.00	41.800	45.536	-3.7357
371.00	37.100	41.799	-4.6989
402.00	31.200	37.570	-6.3699
430.00	25.400	33.641	-8.2410
461.00	19.100	29.121	-10.021
490.00	13.200	24.646	-11.446
521.00	7.5000	19.385	-11.885
550.00	2.0000	4.0084	-2.0084
580.00	0.20000	5.5240	-5.3240

KINETIC CONSTANTS

MONOD MODEL

K1= -7.736 ± 0.00 mg/l

K2= 6.588 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.2932

Table 68

Monod model,1-Butanol,Liv/Hyd,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :11-19-83

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	101.50	101.50	0.00000
43.000	98.300	93.977	4.3226
75.000	90.800	87.048	3.7518
103.00	82.800	80.937	1.8630
133.00	75.600	74.330	1.2703
162.00	67.200	67.871	-0.67123
194.00	58.200	60.642	-2.4421
221.00	50.700	54.435	-3.7346
253.00	40.300	46.903	-6.6035
282.00	31.500	39.844	-8.3439
314.00	22.600	31.631	-9.0309
341.00	14.600	24.037	-9.4374
371.00	5.7000	4.8965	0.80349
394.00	0.50000	6.3669	-5.8669

KINETIC CONSTANTS

MONOD MODEL

K1= -8.323 ± 0.00 mg/l

K2= 11.797 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.3871

Table 69

Monod model,1-Butanol,Liv/Hyd,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :11-22-83

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
7.0000	103.30	103.30	0.00000
44.000	99.400	98.349	1.0509
74.000	93.900	94.300	-0.39981
106.00	90.400	89.942	0.45828
134.00	87.300	86.091	1.2086
163.00	83.600	82.062	1.5376
198.00	78.900	77.136	1.7641
228.00	73.700	72.848	0.85168
252.00	70.200	69.368	0.83220
282.00	64.300	64.943	-0.64284
318.00	58.700	59.500	-0.80026
347.00	53.700	54.983	-1.2830
372.00	48.300	50.966	-2.6660
403.00	43.400	45.775	-2.3749
432.00	38.100	40.620	-2.5198
463.00	32.400	34.591	-2.1907
492.00	26.700	27.975	-1.2754
523.00	20.700	0.68996	20.010
551.00	15.900	16.510	-0.60984

KINETIC CONSTANTS

MONOD MODEL

K1= -15.738 ± 0.00 mg/l

K2= 6.775 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.1025

Table 70

Monod model,1-Butanol,Liv/Hyd,RunIA

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :01-06-84

RUN :IA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	97.400	97.400	0.00000
43.000	67.300	62.289	5.0114
69.000	41.300	38.660	2.6402
98.000	13.300	14.974	-1.6745
132.00	0.50000	0.60885	-0.10885

KINETIC CONSTANTS

MONOD MODEL

K1= 6.411 ± 0.00 mg/l

K2= 61.585 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.1815

Table 71

Monod model,1-Butanol,Liv/Hyd,RunIIA

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :01-07-84

RUN :IIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	109.20	109.20	0.00000
43.000	77.600	77.756	-0.15605
71.000	55.800	54.522	1.2778
103.00	32.000	29.219	2.7807
131.00	8.2000	10.061	-1.8614
162.00	0.40000	0.41124	-0.11241E-01

KINETIC CONSTANTS

MONOD MODEL

K1= 5.732 ± 0.00 mg/l

K2= 54.147 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.59756

Table 72

Monod model,1-Butanol,Liv/Hyd,RunIIIA

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:100 PPM NOMINAL

DATE :01-07-84

RUN :IIIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
16.000	88.100	88.100	0.00000
51.000	74.800	50.311	24.489
79.000	54.000	27.391	26.609
111.00	27.400	11.028	16.372
140.00	3.9000	4.0711	-0.17110
171.00	0.30000	1.2679	-0.96792

KINETIC CONSTANTS

MONOD MODEL

K1= 45.750 ± 0.00 mg/l

K2= 108.722 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 6.6181

Table 73

Monod model,1-Butanol,Liv/LLMO,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:100 PPM NOMINAL

DATE :01-18-84

RUN :I

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	82.000	82.000	0.00000
39.000	56.900	40.656	16.244
70.000	29.800	15.838	13.962
99.000	2.6000	5.0943	-2.4943
160.00	0.30000	0.32673	-0.26731E-01

KINETIC CONSTANTS

MONOD MODEL

K1= 49.422 ± 0.00 mg/l

K2= 138.213 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 4.3129

Table 74

Monod model,1-Butanol,Liv/LLMO,RunII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:100 PPM NOMINAL

DATE :01-19-84

RUN :II

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	95.700	95.700	0.00000
41.000	88.500	79.724	8.7757
68.000	74.800	67.606	7.1938
100.00	60.600	53.565	7.0349
133.00	44.900	39.615	5.2854
163.00	30.200	27.661	2.5385
203.00	11.500	13.667	-2.1669
258.00	3.0000	2.1169	0.88306
279.00	0.20000	0.73044	-0.53044

KINETIC CONSTANTS

MONOD MODEL

K1= 8.590 ± 0.00 mg/l

K2= 30.076 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.6420

Table 75

Monod model,1-Butanol,Liv/LLMO,RunIII

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:100 PPM NOMINAL

DATE :01-20-84

RUN :III

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	94.200	94.200	0.00000
44.000	90.900	86.458	4.4418
73.000	85.000	80.136	4.8638
101.00	76.700	73.943	2.7567
132.00	68.000	66.960	1.0399
163.00	57.600	59.804	-2.2042
192.00	48.100	52.898	-4.7979
225.00	36.800	44.672	-7.8719
278.00	17.000	29.791	-12.791
316.00	2.8000	18.480	-15.680

KINETIC CONSTANTS

MONOD MODEL

K1= -12.491 ± 0.00 mg/l

K2= 11.118 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 2.3482

Table 76

Haldane model,1-Butanol,Liv,RunI

SUBSTRATE :1-BUTANOL

MEDIA :LIVINGSTON

CONCENTRATION:100 PPM NOMINAL

DATE :11-01-83

RUN :I

TEMPERATURE :29 C

TIME (MIN)	PPMEXP	PPMCAL	DY
5.0000	113.20	94.653	18.547
24.000	108.90	92.550	16.350
34.000	106.00	91.433	14.567
51.000	104.80	89.521	15.279
120.00	84.000	81.538	2.4625
160.00	72.900	76.721	-3.8207
186.00	64.500	73.500	-9.0002
219.00	58.600	69.293	-10.693
253.00	43.500	64.793	-21.293
278.00	38.700	61.353	-22.653
310.00	29.300	56.748	-27.448
340.00	21.000	6.3075	14.693
368.00	13.100	7.5931	5.5069
399.00	6.2000	9.5470	-3.3470
429.00	0.60000	12.489	-11.889

KINETIC CONSTANTS

HALDANE MODEL

K1= 23.130 ± 0.00 mg/l

K2= 6.396 ± 0.00 mg/l.hr

K3= -0.001 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 3.8825

Table 77
Haldane model,1-Butanol,Liv,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON
CONCENTRATION:100 PPM NOMINAL
DATE :11-05-83
RUN :II
TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	119.70	97.436	22.264
40.000	111.30	92.873	18.427
70.000	97.700	88.676	9.0237
100.00	87.200	84.292	2.9082
131.00	74.800	79.528	-4.7284
161.00	62.300	74.646	-12.346
195.00	50.600	68.700	-18.100
220.00	37.000	63.963	-26.963
250.00	25.400	7.6826	17.717
279.00	14.600	10.281	4.3188
310.00	9.6000	15.023	-5.4231
343.00	0.30000	33.324	-33.024

KINETIC CONSTANTS

HALDANE MODEL

K1= 36.260 ± 0.00 ms/l

K2= 15.800 ± 0.00 ms/l.hr

K3= -0.007 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 5.0049

Table 78
Haldane model,1-Butanol,Liv,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON
CONCENTRATION:100 PPM NOMINAL
DATE :11-09-83
RUN :III
TEMPERATURE :26 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	116.40	91.379	25.021
44.000	112.70	88.174	24.526
74.000	104.70	85.513	19.187
103.00	99.400	82.947	16.453
134.00	91.600	80.208	11.392
164.00	81.800	77.560	4.2402
193.00	78.900	75.000	3.9002
222.00	68.900	72.437	-3.5371
253.00	60.200	69.692	-9.4916
283.00	53.300	67.025	-13.725
313.00	47.400	64.345	-16.945
343.00	40.900	61.647	-20.747
373.00	31.600	58.926	-27.326
406.00	22.900	55.896	-32.996
433.00	16.000	4.1280	11.872
463.00	8.8000	4.6016	4.1984
493.00	1.4000	5.1513	-3.7513

KINETIC CONSTANTS

HALDANE MODEL

K1= 17.630 ± 0.00 mg/l

K2= 2.895 ± 0.00 mg/l.hr

K3= 0.001 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 4.1785

Table 79
Haldane model,1-Butanol,Liv/BI-CHEM,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:100 PPM NOMINAL
DATE :11-05-83
RUN :I
TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	110.30	92.115	18.185
41.000	107.20	90.430	16.770
70.000	107.60	89.035	18.565
100.00	100.20	87.591	12.609
132.00	93.500	86.050	7.4505
161.00	88.500	84.652	3.8479
195.00	81.700	83.012	-1.3124
220.00	71.400	81.806	-10.406
250.00	66.900	80.356	-13.456
279.00	60.500	78.952	-18.452
310.00	56.700	77.449	-20.749
343.00	48.900	75.845	-26.945

KINETIC CONSTANTS

HALDANE MODEL

K1= 18.316 ± 0.00 mg/l

K2= 1.721 ± 0.00 mg/l.hr

K3= 0.001 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 4.5445

Table 80
Haldane model,1-Butanol,Liv/BI-CHEM,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:100 PPM NOMINAL
DATE :11-05-83
RUN :II
TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	117.10	96.687	20.413
42.000	105.10	92.296	12.804
73.000	94.300	88.020	6.2802
101.00	81.400	83.883	-2.4830
134.00	67.400	78.579	-11.179
168.00	50.400	72.455	-22.055
192.00	38.900	67.551	-28.651
222.00	25.400	13.530	11.870
251.00	12.700	20.072	-7.3723
282.00	1.6000	41.442	-39.842
312.00	0.20000	44.900	-44.700

KINETIC CONSTANTS

HALDANE MODEL

K1= -69.347 ± 0.00 mg/l

K2= -50.325 ± 0.00 mg/l.hr

K3= 0.044 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 6.9468

Table 81
Haldane model,1-Butanol,Liv/BI-CHEM,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:100 PPM NOMINAL
DATE :11-09-83
RUN :III
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	116.10	96.497	19.603
44.000	106.80	91.222	15.578
69.000	96.400	87.601	8.7989
99.000	85.800	83.072	2.7283
130.00	68.900	78.142	-9.2418
162.00	56.700	72.725	-16.025
196.00	37.500	66.498	-28.998
226.00	20.000	6.5443	13.456
251.00	4.7000	8.3402	-3.6402
279.00	0.30000	11.304	-11.004

KINETIC CONSTANTS

HALDANE MODEL

K1= 35.182 ± 0.00 mg/l

K2= 15.733 ± 0.00 mg/l.hr

K3= -0.007 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 4.7014

Table 82
Haldane model,1-Butanol,Liv/Hyd,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :11-18-83
RUN :I
TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	87.600	72.750	14.850
40.000	86.900	70.945	15.955
70.000	83.800	69.328	14.472
102.00	78.300	67.578	10.722
134.00	75.100	65.800	9.3004
161.00	71.000	64.275	6.7250
190.00	66.600	62.611	3.9887
249.00	57.600	59.134	-1.5337
283.00	52.300	57.066	-4.7660
310.00	48.000	55.386	-7.3863
343.00	41.800	53.283	-11.483
371.00	37.100	51.449	-14.349
402.00	31.200	49.359	-18.159
430.00	25.400	47.409	-22.009
461.00	19.100	45.170	-26.070
490.00	13.200	5.3018	7.8982
521.00	7.5000	6.0043	1.4957
550.00	2.0000	6.7910	-4.7910
580.00	0.20000	7.7873	-7.5873

KINETIC CONSTANTS

HALDANE MODEL

K1= 20.279 ± 0.00 mg/l

K2= 3.484 ± 0.00 mg/l.hr

K3= -0.003 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 2.8844

Table 83
Haldane model,1-Butanol,Liv/Hyd,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :11-19-83
RUN :II
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	101.50	82.510	18.990
43.000	98.300	79.302	18.998
75.000	90.800	76.328	14.472
103.00	82.800	73.688	9.1118
133.00	75.600	70.818	4.7823
162.00	67.200	67.996	-0.79610
194.00	58.200	64.822	-6.6222
221.00	50.700	62.088	-11.388
253.00	40.300	58.769	-18.469
282.00	31.500	55.675	-24.175
314.00	22.600	52.144	-29.544
341.00	14.600	4.7774	9.8226
371.00	5.7000	5.5970	0.10298
394.00	0.50000	6.3656	-5.8656

KINETIC CONSTANTS

HALDANE MODEL

K1= 19.356 ± 0.00 mg/l

K2= 4.484 ± 0.00 mg/l.hr

K3= -0.000 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 4.0027

Table 84
Haldane model,1-Butanol,Liv/Hyd,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :11-22-83
RUN :III
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
7.0000	103.30	80.309	22.991
44.000	99.400	78.239	21.161
74.000	93.900	76.572	17.328
106.00	90.400	74.802	15.598
134.00	87.300	73.260	14.040
163.00	83.600	71.669	11.931
198.00	78.900	69.757	9.1432
228.00	73.700	68.123	5.5770
252.00	70.200	66.819	3.3811
282.00	64.300	65.192	-0.89169
318.00	58.700	63.242	-4.5423
347.00	53.700	61.673	-7.9732
372.00	48.300	60.321	-12.021
403.00	43.400	58.643	-15.243
432.00	38.100	57.071	-18.971
463.00	32.400	55.388	-22.988
492.00	26.700	53.808	-27.108
523.00	20.700	52.112	-31.412
551.00	15.900	3.2560	12.644

KINETIC CONSTANTS

HALDANE MODEL

K1= 15.360 ± 0.00 mg/l

K2= 1.622 ± 0.00 mg/l.hr

K3= 0.002 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 3.8016

Table 85
Haldane model,1-Butanol,Liv/Hyd,RunIA

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :01-06-84
RUN :IA
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	97.400	85.325	12.075
43.000	67.300	75.913	-8.6131
69.000	41.300	67.499	-26.199
98.000	13.300	26.698	-13.398
132.00	0.50000	33.458	-32.958

KINETIC CONSTANTS

HALDANE MODEL

K1= -3.791 ± 0.00 ms/l

K2= -17.952 ± 0.00 ms/l.hr

K3= 0.014 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 9.3212

Table 86
Haldane model,1-Butanol,Liv/Hyd,RunIIA

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :01-07-84
RUN :IIA
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	109.20	93.969	15.231
43.000	77.600	85.715	-8.1148
71.000	55.800	78.195	-22.395
103.00	32.000	21.841	10.159
131.00	8.2000	43.554	-35.354
162.00	0.40000	14.033	-13.633

KINETIC CONSTANTS

HALDANE MODEL

K1= -3.485 ± 0.00 mg/l

K2= -15.577 ± 0.00 mg/l.hr

K3= 0.012 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 8.0595

Table 87
Haldane model,1-Butanol,Liv/Hyd,RunIIIA

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:100 PPM NOMINAL
DATE :01-07-84
RUN :IIIA
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
16.000	88.100	75.239	12.861
51.000	74.800	69.391	5.4091
79.000	54.000	64.089	-10.089
111.00	27.400	7.6113	19.789
140.00	3.9000	12.881	-8.9810
171.00	0.30000	21.713	-21.413

KINETIC CONSTANTS

HALDANE MODEL

K1= -29.345 ± 0.00 mg/l

K2= -35.243 ± 0.00 mg/l.hr

K3= 0.034 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 5.8386

Table 88
Haldane model,1-Butanol,Liv/LLMO,RunI

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:100 PPM NOMINAL
DATE :01-18-84
RUN :I
TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	82.000	74.086	7.9144
39.000	56.900	68.425	-11.525
70.000	29.800	25.459	4.3411
99.000	2.6000	0.89523E-01	2.5105
160.00	0.30000	0.19577E-01	0.28042

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.768 ± 0.00 mg/l

K2= -5.566 ± 0.00 mg/l.hr

K3= 0.010 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 2.9712

Table 89
Haldane model,1-Butanol,Liv/LLMO,RunII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:100 PPM NOMINAL
DATE :01-19-84
RUN :II
TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
6.0000	95.700	82.229	13.471
41.000	88.500	78.210	10.290
68.000	74.800	74.853	-0.53162E-01
100.00	60.600	70.499	-9.8986
133.00	44.900	65.415	-20.515
163.00	30.200	11.545	18.655
203.00	11.500	19.391	-7.8915
258.00	3.0000	70.635	-67.635
279.00	0.20000	29.104	-28.904

KINETIC CONSTANTS

HALDANE MODEL

K1= -11.436 ± 0.00 mg/l

K2= -13.594 ± 0.00 mg/l.hr

K3= 0.019 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 9.0447

Table 90
Haldane model,1-Butanol,Liv/LLMO,RunIII

SUBSTRATE :1-BUTANOL
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:100 PPM NOMINAL
DATE :01-20-84
RUN :III
TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	94.200	78.046	16.154
44.000	90.900	74.831	16.069
73.000	85.000	72.255	12.745
101.00	76.700	69.778	6.9221
132.00	68.000	67.043	0.95731
163.00	57.600	64.312	-6.7117
192.00	48.100	61.757	-13.657
225.00	36.800	58.845	-22.045
278.00	17.000	54.139	-37.139
316.00	2.8000	3.1435	-0.34346

KINETIC CONSTANTS

HALDANE MODEL

K1= 15.394 ± 0.00 mg/l

K2= 2.754 ± 0.00 mg/l.hr

K3= 0.002 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 5.3173

Table 91

Zero-order model,Nitrobenzene,Liv/Hyd,RunI

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-02-83

RUN :I

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
16.000	27.300	11.347	-15.953
71.000	7.1000	11.275	4.1746
140.00	8.5000	11.184	2.6840
194.00	8.5000	11.113	2.6132
250.00	7.5000	11.040	3.5396
1394.0	9.4000	9.5380	0.13800
1420.0	7.3000	9.5039	2.2039
1449.0	7.9000	9.4658	1.5658
1479.0	9.8000	9.4264	-0.37358
1510.0	9.0000	9.3857	0.38573
1630.0	7.8000	9.2282	1.4282
1688.0	9.3000	9.1521	-0.14792
4210.0	8.1000	5.8416	-2.2584

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 11.368 ± 3.26 mg/l

K2= -0.079 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.78644E-01

THE ABSOLUTE AVERAGE RESIDUAL = 1.3615

Table 92

Zero-order model,Nitrobenzene,Liv/Hyd,RunII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-07-83

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	11.300	11.363	0.63453E-01
72.000	12.000	11.324	-0.67602
125.00	11.000	11.290	0.29024
190.00	10.900	11.249	0.34886
249.00	11.300	11.211	-0.88696E-01
305.00	11.600	11.176	-0.42435
1543.0	9.5000	10.388	0.88754
1567.0	10.700	10.372	-0.32774
1630.0	11.200	10.332	-0.86785
1688.0	12.100	10.295	-1.8048
1749.0	12.800	10.256	-2.5436
1818.0	4.6000	10.212	5.6125
4385.0	9.2000	8.5783	-0.62170
4426.0	8.4000	8.5522	0.15220

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 11.370 ± 1.12 mg/l

K2= -0.038 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.20367

THE ABSOLUTE AVERAGE RESIDUAL = 0.47456

Table 93

Zero-order model,Nitrobenzene,Liv/Hyd,RunIII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-12-83

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
12.000	11.800	14.693	2.8925
59.000	13.300	14.456	1.1565
125.00	14.900	14.125	-0.77495
200.00	13.000	13.748	0.74841
248.00	11.600	13.507	1.9074
336.00	15.700	13.065	-2.6346
365.00	14.500	12.920	-1.5802
429.00	14.500	12.598	-1.9016
1394.0	8.6000	7.7524	-0.84761
1445.0	8.1000	7.4963	-0.60372
1505.0	7.7000	7.1950	-0.50503
1884.0	3.6000	5.2917	1.6917
2828.0	0.10000	0.55114	0.45114

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 14.753 ± 1.04 mg/l

K2= -0.301 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.88088

THE ABSOLUTE AVERAGE RESIDUAL = 0.43487

Table 94

Zero-order model,Nitrobenzene,Liv/BI-CHEM,RunI

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :12-21-83

RUN :I

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
15.000	2.2000	8.5049	6.3049
78.000	3.8000	8.6005	4.8005
132.00	3.8000	8.6824	4.8824
192.00	8.1000	8.7735	0.67351
254.00	15.300	8.8676	-6.4324
323.00	13.800	8.9724	-4.8277
387.00	13.400	9.0695	-4.3305
438.00	10.500	9.1469	-1.3531
1573.0	12.000	10.870	-1.1303
1640.0	12.200	10.971	-1.2286
1689.0	10.900	11.046	0.14573
1938.0	11.800	11.424	-0.37632
2958.0	10.100	12.972	2.8719

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 8.482 ± 2.49 mg/l

K2= 0.091 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.11852

THE ABSOLUTE AVERAGE RESIDUAL = 1.0422

Table 95

Zero-order model,Nitrobenzene,Liv/BI-CHEM,RunII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :12-27-83

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
13.000	19.200	21.012	1.8121
65.000	18.600	20.955	2.3554
128.00	21.200	20.887	-0.31331
187.00	22.000	20.822	-1.1776
251.00	18.100	20.753	2.6526
1471.0	19.400	19.423	0.22598E-01
1509.0	22.500	19.381	-3.1188
1563.0	21.800	19.322	-2.4777
1627.0	23.000	19.253	-3.7475
1683.0	21.400	19.191	-2.2085
2867.0	11.700	17.901	6.2007

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 21.026 ± 2.17 mg/l

K2= -0.065 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.10518

THE ABSOLUTE AVERAGE RESIDUAL = 0.86526

Table 96

Zero-order model,Nitrobenzene,Liv/BI-CHEM,RunIII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :01-02-84

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	11.900	11.460	-0.44032
71.000	12.100	11.005	-1 952
151.00	10.300	10.408	0.10818
204.00	11.000	10.013	-0.98706
260.00	8.1000	9.5953	1.4953
312.00	9.1000	9.2075	0.10753
380.00	7.5000	8.7004	1.2004
1572.0	0.20000	-0.18887	-0.38887

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 11.534 ± 0.88 mg/l

K2= -0.447 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.94009

THE ABSOLUTE AVERAGE RESIDUAL = 0.31173

Table 97

Zero-order model,Nitrobenzene,Liv,RunII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	34.000	26.464	-7.5364
245.00	20.100	21.738	1.6377
370.00	14.900	19.224	4.3240
455.00	14.500	17.515	3.0146
635.00	12.400	13.895	1.4948
1447.0	0.50000	-2.4347	-2.9347

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 26.665 ± 5.62 mg/l

K2= -1.207 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.83579

THE ABSOLUTE AVERAGE RESIDUAL = 1.6508

Table 98.

Zero-order model,Nitrobenzene,Liv,RunIII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	25.300	27.015	1.7151
65.000	24.900	25.085	0.18497
125.00	23.800	22.979	-0.82066
185.00	21.900	20.874	1.0263
245.00	18.100	18.768	0.66811
305.00	16.500	16.662	0.16249
365.00	16.100	14.557	-1.5431
425.00	13.500	12.451	1.0487
620.00	3.9000	5.6080	1.7080

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 27.366 ± 1.02 ms/l

K2= -2.106 ± 0.00 ms/l.hr

THE CORRELATION COEFFICIENT = 0.96907

THE ABSOLUTE AVERAGE RESIDUAL = 0.37800

Table 99

Zero-order model,Nitrobenzene,Liv/BI-CHEM,RunIA

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :IA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	19.500	17.930	-1.5699
125.00	18.500	17.397	-1.1025
245.00	17.100	16.842	-0.25827
1327.0	11.000	11.831	0.83082
1447.0	10.400	11.275	0.87508
1567.0	8.3000	10.719	2.4193
1655.0	7.7000	10.312	2.6118
2646.0	7.9000	5.7223	-2.1777
2765.0	6.8000	5.1712	-1.6288

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 17.976 ± 1.50 mg/l

K2= -0.278 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.87613

THE ABSOLUTE AVERAGE RESIDUAL = 0.55858

Table 100

Zero-order model,Nitrobenzene,Liv/BI-CHEM,RunIIA

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :IIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
7.0000	12.200	12.950	0.74951
125.00	11.400	10.843	-0.55672
246.00	9.8000	8.6835	-1.1165
367.00	5.6000	6.5237	0.92371

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 13.074 ± 2.64 mg/l

K2= -1.071 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.88549

THE ABSOLUTE AVERAGE RESIDUAL = 0.43095

Table 101

Zero-order model,Nitrobenzene,Liv/BI-CHEM,RunIIIA

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :IIIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	14.400	14.141	-0.25887
127.00	13.800	13.260	-0.53955
255.00	12.000	12.313	0.31317
367.00	10.300	11.484	1.1843
635.00	10.200	9.5009	-0.69906

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 14.200 ± 1.26 mg/l

K2= -0.444 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.84383

THE ABSOLUTE AVERAGE RESIDUAL = 0.30643

Table 102

Monod model,Nitrobenzene,Liv/Hyd,RunI

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-02-83

RUN :I

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
16.000	27.300	27.300	0.00000
87.000	7.1000	8.0133	-0.91328
156.00	8.5000	8.0250	0.47495
210.00	8.5000	8.0343	0.46573
266.00	7.5000	8.0439	-0.54388
1410.0	9.4000	8.2453	1.1547
1436.0	7.3000	8.2499	-0.94994
1465.0	7.9000	8.2552	-0.35521
1495.0	9.8000	8.2606	1.5394
1526.0	9.0000	8.2663	0.73373
1646.0	7.8000	8.2881	-0.48810
1704.0	9.3000	8.2987	1.0013
4226.0	8.1000	8.7901	-0.69015

KINETIC CONSTANTS

MONOD MODEL

K1= -15.725 ± 0.00 mg/l

K2= 0.010 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.22505

Table 103

Monod model,Nitrobenzene,Liv/Hyd,RunII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-07-83

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	11.300	11.300	0.00000
82.000	12.000	11.285	0.71495
135.00	11.000	11.274	-0.27401
200.00	10.900	11.260	-0.36042
259.00	11.300	11.248	0.51929E-01
315.00	11.600	11.236	0.36369
1553.0	9.5000	10.968	-1.4683
1577.0	10.700	10.963	-0.26298
1640.0	11.200	10.949	0.25112
1698.0	12.100	10.936	1.1641
1759.0	12.800	10.922	1.8779
1828.0	4.6000	5.4874	-0.88737
4395.0	9.2000	10.276	1.0758
4436.0	8.4000	10.265	-1.8647

KINETIC CONSTANTS

MONOD MODEL

K1= -7.889 ± 0.00 mg/l

K2= 0.004 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.26189

Table 104

Monod model,Nitrobenzene,Liv/Hyd,RunIII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-12-83

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
12.000	11.800	11.800	0.00000
71.000	13.300	11.971	1.3293
137.00	14.900	12.159	2.7405
212.00	13.000	12.371	0.62874
260.00	11.600	12.505	-0.90539
348.00	15.700	12.749	2.9514
377.00	14.500	12.828	1.6719
441.00	14.500	13.002	1.4978
1406.0	8.6000	15.473	-6.8726
1457.0	8.1000	15.597	-7.4969
1517.0	7.7000	15.742	-8.0424
1896.0	3.6000	0.83239	2.7676
2840.0	0.10000	0.59712	-0.49712

KINETIC CONSTANTS

MONOD MODEL

K1= -5.279 ± 0.00 mg/l

K2= -0.097 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 1.0886

Table 105

Monod model,Nitrobenzene,Liv/BI-CHEM,RunI

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :12-21-83

RUN :I

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
15.000	2.2000	2.2000	0.00000
93.000	3.8000	2.2232	1.5768
147.00	3.8000	2.2394	1.5606
207.00	8.1000	13.184	-5.0844
269.00	15.300	13.122	2.1782
338.00	13.800	13.052	0.74828
402.00	13.400	12.986	0.41355
453.00	10.500	12.934	-2.4342
1588.0	12.000	11.713	0.28662
1655.0	12.200	11.637	0.56291
1704.0	10.900	11.581	-0.68093
1953.0	11.800	11.291	0.50947
2973.0	10.100	9.9829	0.11707

KINETIC CONSTANTS

MONOD MODEL

K1= -6.192 ± 0.00 mg/l

K2= 0.032 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.50623

Table 106

Monod model,Nitrobenzene,Liv/BI-CHEM,RunII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :12-27-83

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
13.000	19.200	19.200	0.00000
78.000	18.600	19.403	-0.80293
141.00	21.200	19.583	1.6166
200.00	22.000	19.741	2.2590
264.00	18.100	19.902	-1.8021
1484.0	19.400	22.098	-2.6983
1522.0	22.500	22.153	0.34706
1576.0	21.800	22.230	-0.42978
1640.0	23.000	22.320	0.68040
1696.0	21.400	22.397	-0.99718
2880.0	11.700	12.229	-0.52909

KINETIC CONSTANTS

MONOD MODEL

K1= -17.404 ± 0.00 mg/l

K2= -0.018 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.41592

Table 107

Monod model,Nitrobenzene,Liv/BI-CHEM,RunIII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :01-02-84

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	11.900	11.900	0.00000
81.000	12.100	10.853	1.2472
161.00	10.300	9.7161	0.58392
214.00	11.000	8.9903	2.0097
270.00	8.1000	8.2490	-0.14898
322.00	9.1000	7.5855	1.5145
390.00	7.5000	6.7563	0.74372
1582.0	0.20000	0.24888	-0.48884E-01

KINETIC CONSTANTS

MONOD MODEL

K1= 6.311 ± 0.00 mg/l

K2= 1.376 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.37095

Table 108

Monod model,Nitrobenzene,Liv,RunII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :II

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	34.000	34.000	0.00000
255.00	20.100	22.124	-2.0241
380.00	14.900	17.049	-2.1494
465.00	14.500	14.027	0.47324
645.00	12.400	8.8237	3.5763
1457.0	0.50000	0.57546	-0.75458E-01

KINETIC CONSTANTS

MONOD MODEL

K1= 23.824 ± 0.00 mg/l

K2= 5.415 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.77704

Table 109

Monod model,Nitrobenzene,Liv,RunIII

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :III

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	25.300	25.300	0.00000
75.000	24.900	23.846	1.0539
135.00	23.800	22.473	1.3267
195.00	21.900	21.065	0.83517
255.00	18.100	19.612	-1.5119
315.00	16.500	18.102	-1.6021
375.00	16.100	16.516	-0.41597
435.00	13.500	14.820	-1.3204
630.00	3.9000	6.8840	-2.9840

KINETIC CONSTANTS

MONOD MODEL

K1= -6.584 ± 0.00 mg/l

K2= 0.982 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.48739

Table 110

Monod model,Nitrobenzene,Liv/BI-CHEM,RunIA

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :IA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	19.500	19.500	0.00000
135.00	18.500	20.167	-1.6666
255.00	17.100	20.741	-3.6411
1337.0	11.000	9.1523	1.8477
1457.0	10.400	8.9670	1.4330
1577.0	8.3000	8.7902	-0.49018
1665.0	7.7000	8.6655	-0.96552
2656.0	7.9000	7.4831	0.41691
2775.0	6.8000	7.3624	-0.56245

KINETIC CONSTANTS

MONOD MODEL

K1= -15.652 ± 0.00 mg/l

K2= -0.067 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.53478

Table 111

Monod model,Nitrobenzene,Liv/BI-CHEM,RunIIA

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :IIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
7.0000	12.200	12.200	0.00000
132.00	11.400	11.175	0.22497
253.00	9.8000	10.007	-0.20658
374.00	5.6000	5.6528	-0.52838E-01

KINETIC CONSTANTS

MONOD MODEL

K1= -6.915 ± 0.00 mg/l

K2= 0.201 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.77491E-01

Table 112

Monod model,Nitrobenzene,Liv/BI-CHEM,RunIIIA

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:20 PPM NOMINAL

DATE :UNKNOWN

RUN :IIIA

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	14.400	14.400	0.00000
135.00	13.800	14.496	-0.69600
263.00	12.000	14.589	-2.5889
375.00	10.300	10.557	-0.25709
643.00	10.200	10.415	-0.21484

KINETIC CONSTANTS

MONOD MODEL

K1= -12.500 ± 0.00 mg/l

K2= -0.006 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.54033

Table 113

Haldane model,Nitrobenzene,Liv/Hyd,RunI

SUBSTRATE :NITROBENZENE

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:20 PPM NOMINAL

DATE :12-02-83

RUN :I

TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
16.000	27.300	21.506	5.7937
87.000	7.1000	0.98179	6.1182
156.00	8.5000	1.0849	7.4151
210.00	8.5000	1.1722	7.3278
266.00	7.5000	1.2693	6.2307
1410.0	9.4000	13.219	-3.8192
1436.0	7.3000	6.3844	0.91558
1465.0	7.9000	6.7385	1.1615
1495.0	9.8000	12.016	-2.2160
1526.0	9.0000	11.405	-2.4046
1646.0	7.8000	7.1569	0.64307
1704.0	9.3000	7.4618	1.8382
4226.0	8.1000	7.4576	0.64244

KINETIC CONSTANTS

HALDANE MODEL

K1= -5.505 ± 0.00 ms/l

K2= -0.552 ± 0.00 ms/l.hr

K3= 0.083 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 1.2167

Table 114
Haldane model,Nitrobenzene,Liv/Hyd,RunII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:20 PPM NOMINAL
DATE :12-07-83
RUN :II
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	11.300	11.144	0.15598
82.000	12.000	11.127	0.87287
135.00	11.000	11.115	-0.11469
200.00	10.900	11.099	-0.19942
259.00	11.300	11.086	0.21445
315.00	11.600	11.072	0.52762
1553.0	9.5000	10.778	-1.2785
1577.0	10.700	10.773	-0.72725E-01
1640.0	11.200	10.758	0.44238
1698.0	12.100	10.744	1.3563
1759.0	12.800	10.729	2.0709
1828.0	4.6000	10.712	-6.1125
4395.0	9.2000	10.082	-0.88206
4436.0	8.4000	10.072	-1.6718

KINETIC CONSTANTS

HALDANE MODEL

K1= 4.454 ± 0.00 mg/l

K2= 0.007 ± 0.00 mg/l.hr

K3= 0.003 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.50539

Table 115
Haldane model,Nitrobenzene,Liv/Hyd,RunIII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:20 PPM NOMINAL
DATE :12-12-83
RUN :III
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
12.000	11.800	13.547	-1.7467
71.000	13.300	13.379	-0.79192E-01
137.00	14.900	13.187	1.7128
212.00	13.000	12.963	0.37194E-01
260.00	11.600	12.815	-1.2153
348.00	15.700	12.536	3.1636
377.00	14.500	12.442	2.0581
441.00	14.500	12.228	2.2718
1406.0	8.6000	9.5544	-0.95443
1457.0	8.1000	5.1088	2.9912
1517.0	7.7000	1.6689	6.0311
1896.0	3.6000	19.684	-16.084
2840.0	0.10000	0.80258E-02	0.91974E-01

KINETIC CONSTANTS

HALDANE MODEL

K1= -2.688 ± 0.00 mg/l

K2= -0.308 ± 0.00 mg/l.hr

K3= 0.112 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 1.4012

Table 116
Haldane model,Nitrobenzene,Liv/BI-CHEM,RunI

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :12-21-83
RUN :I
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
15.000	2.2000	1.2932	0.90678
93.000	3.8000	1.3076	2.4924
147.00	3.8000	1.3176	2.4824
207.00	8.1000	12.269	-4.1687
269.00	15.300	12.217	3.0828
338.00	13.800	12.160	1.6403
402.00	13.400	12.106	1.2938
453.00	10.500	12.063	-1.5634
1588.0	12.000	11.079	0.92149
1655.0	12.200	11.018	1.1819
1704.0	10.900	10.974	-0.73771E-01
1953.0	11.800	10.746	1.0541
2973.0	10.100	9.7605	0.33954

KINETIC CONSTANTS

HALDANE MODEL

K1= 5.075 ± 0.00 mg/l

K2= 0.032 ± 0.00 mg/l.hr

K3= -0.002 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.54591

Table 117
Haldane model,Nitrobenzene,Liv/BI-CHEM,RunII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :12-27-83
RUN :II
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
13.000	19.200	20.757	-1.5566
78.000	18.600	20.722	-2.1215
141.00	21.200	20.688	0.51237
200.00	22.000	20.656	1.3442
264.00	18.100	20.621	-2.5212
1484.0	19.400	19.957	-0.55733
1522.0	22.500	19.936	2.5635
1576.0	21.800	19.907	1.8932
1640.0	23.000	19.872	3.1283
1696.0	21.400	19.841	1.5591
2880.0	11.700	19.184	-7.4840

KINETIC CONSTANTS

HALDANE MODEL

K1= 6.756 ± 0.00 ms/l

K2= 0.021 ± 0.00 ms/l.hr

K3= 0.001 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 0.88160

Table 118
Haldane model,Nitrobenzene,Liv/BI-CHEM,RunIII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :01-02-84
RUN :III
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	11.900	10.725	1.1749
81.000	12.100	10.313	1.7873
161.00	10.300	9.7992	0.50083
214.00	11.000	9.4209	1.5791
270.00	8.1000	8.9752	-0.87520
322.00	9.1000	8.5006	0.59936
390.00	7.5000	7.7270	-0.22697
1582.0	0.20000	0.10547E-03	0.19989

KINETIC CONSTANTS

HALDANE MODEL

K1= 0.519 ± 0.00 mg/l

K2= -0.271 ± 0.00 mg/l.hr

K3= 0.082 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.36520

Table 119
Haldane model,Nitrobenzene,Liv,RunII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :II
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	34.000	29.791	4.2088
255.00	20.100	26.618	-6.5175
380.00	14.900	10.536	4.3639
465.00	14.500	12.822	1.6781
645.00	12.400	0.20463	12.195
1457.0	0.50000	0.23035E-01	0.47696

KINETIC CONSTANTS

HALDANE MODEL

K1= 2.338 ± 0.00 ms/l

K2= -0.364 ± 0.00 ms/l.hr

K3= 0.025 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 2.5331

Table 120
Haldane model,Nitrobenzene,Liv,RunIII

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :III
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	25.300	21.658	3.6416
75.000	24.900	21.176	3.7244
135.00	23.800	20.729	3.0715
195.00	21.900	20.280	1.6203
255.00	18.100	19.829	-1.7291
315.00	16.500	19.376	-2.8761
375.00	16.100	18.921	-2.8205
435.00	13.500	18.462	-4.9620
630.00	3.9000	1.9546	1.9454

KINETIC CONSTANTS

HALDANE MODEL

K1= 6.243 ± 0.00 ms/l

K2= 0.214 ± 0.00 ms/l.hr

K3= 0.005 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 1.0353

Table 121
Haldane model,Nitrobenzene,Liv/BI-CHEM,RunIA

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :IA
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	19.500	15.747	3.7530
135.00	18.500	15.467	3.0332
255.00	17.100	15.197	1.9029
1337.0	11.000	12.713	-1.7131
1457.0	10.400	12.428	-2.0277
1577.0	8.3000	12.139	-3.8392
1665.0	7.7000	11.925	-4.2254
2656.0	7.9000	9.2918	-1.3918
2775.0	6.8000	8.9247	-2.1247

KINETIC CONSTANTS

HALDANE MODEL

K1= 4.934 ± 0.00 mg/l

K2= 0.056 ± 0.00 mg/l.hr

K3= 0.009 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.94932

Table 122.
Haldane model,Nitrobenzene,Liv/BI-CHEM,RunIIA

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :IIA
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
7.0000	12.200	10.954	1.2463
132.00	11.400	10.496	0.90433
253.00	9.8000	10.042	-0.24202
374.00	5.6000	9.5756	-3.9756

KINETIC CONSTANTS

HALDANE MODEL

K1= 4.178 ± 0.00 ms/l

K2= 0.096 ± 0.00 ms/l.hr

K3= 0.008 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 1.0676

Table 123
Haldane model,Nitrobenzene,Liv/BI-CHEM,RunIIIA

SUBSTRATE :NITROBENZENE
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:20 PPM NOMINAL
DATE :UNKNOWN
RUN :IIIA
TEMPERATURE :UNKNOWN

TIME (MIN)	PPMEXP	PPMCAL	DY
8.0000	14.400	12.679	1.7206
135.00	13.800	12.502	1.2976
263.00	12.000	12.323	-0.32262
375.00	10.300	12.164	-1.8641
643.00	10.200	11.780	-1.5802

KINETIC CONSTANTS

HALDANE MODEL

K1= 4.714 ± 0.00 ms/l

K2= 0.043 ± 0.00 ms/l.hr

K3= 0.004 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 0.65483

Table 124
Zero-order model,2,4-D,Liv,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON
CONCENTRATION:10 PPM NOMINAL
DATE :02-01-84
RUN :I
TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
100.00	11.500	11.419	-0.81074E-01
190.00	11.100	10.571	-0.52941
280.00	8.8000	9.7223	0.92225
380.00	8.8000	8.7797	-0.20344E-01
465.00	8.2000	7.9784	-0.22155
555.00	7.2000	7.1301	-0.69888E-01

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 12.362 ± 0.62 mg/l

K2= -0.566 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.91603

THE ABSOLUTE AVERAGE RESIDUAL = 0.18195

Table 125

Zero-order model,2,4-D,Liv,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON

CONCENTRATION:10 PPM NOMINAL

DATE :02-(

RUN :II

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
130.00	2.2000	2.2425	0.42490E-01
255.00	2.2000	2.1367	-0.63320E-01
510.00	1.9000	1.9208	0.20828E-01

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 2.353 ± 0.58 mg/l

K2= -0.051 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.89586

THE ABSOLUTE AVERAGE RESIDUAL = 0.26349E-01

Table 126

Zero-order model,2,4-D,Liv/Hyd,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:10 PPM NOMINAL

DATE :02-22-84

RUN :I

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	5.9000	5.0053	-0.89466
148.00	4.5000	4.7895	0.28946
432.00	3.5000	4.3484	0.84840
1650.0	2.7000	2.4568	-0.24321

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 5.019 ± 1.96 mg/l

K2= -0.093 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.70874

THE ABSOLUTE AVERAGE RESIDUAL = 0.32241

Table 127

Zero-order model,2,4-D,Liv/Hyd,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:10 PPM NOMINAL

DATE :02-23-84

RUN :II

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
15.000	8.2000	8.4485	0.24848
130.00	7.9000	6.8878	-1.0122
245.00	4.8000	5.3271	0.52714
365.00	2.7000	3.6986	0.99861
480.00	2.9000	2.1379	-0.76206

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 8.652 ± 1.42 ms/l

K2= -0.814 ± 0.00 ms/l.hr

THE CORRELATION COEFFICIENT = 0.89470

THE ABSOLUTE AVERAGE RESIDUAL = 0.34305

Table 128

Zero-order model,2,4-D,Liv/Hyd,RunIII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:10 PPM NOMINAL

DATE :02-24-84

RUN :III

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
125.00	10.700	10.073	-0.62685
365.00	4.5000	6.4350	1.9350
480.00	6.0000	4.6918	-1.3082

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 11.968 ±17.87 mg/l

K2= -0.910 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.72051

THE ABSOLUTE AVERAGE RESIDUAL = 0.80614

Table 129

Zero-order model,2,4-D,Liv/BI-CHEM,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:10 PPM NOMINAL

DATE :02-14-84

RUN :I

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	4.4000	4.2317	-0.16834
120.00	3.9000	4.1435	0.24348
270.00	4.0000	4.0243	0.24319E-01
390.00	4.0000	3.9290	-0.71010E-01
510.00	4.1000	3.8337	-0.26634
610.00	3.5000	3.7542	0.25422
1580.0	3.0000	2.9837	-0.16344E-01

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 4.239 ± 0.21 mg/l

K2= -0.048 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.81780

THE ABSOLUTE AVERAGE RESIDUAL = 0.68376E-01

Table 130

Zero-order model,2,4-D,Liv/BI-CHEM,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:10 PPM NOMINAL

DATE :02-15-84

RUN :II

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	2.5000	1.4726	-1.0274
130.00	1.1000	1.4266	0.32665
250.00	0.70000	1.3807	0.68071
370.00	1.3000	1.3348	0.34772E-01
605.00	1.0000	1.2448	0.24481
1400.0	1.2000	0.94047	-0.25953

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 1.476 ± 0.75 mg/l

K2= -0.023 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.95809E-01

THE ABSOLUTE AVERAGE RESIDUAL = 0.22074

Table 131

Zero-order model,2,4-D,Liv/BI-CHEM,RunIII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:10 PPM NOMINAL

DATE :02-16-84

RUN :III

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	7.9000	7.5580	-0.34203
130.00	6.6000	7.0049	0.40490
375.00	5.9000	5.8757	-0.24273E-01
490.00	5.2000	5.3457	0.14571
605.00	5.0000	4.8157	-0.18432

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 7.604 ± 0.48 mg/l

K2= -0.277 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.93931

THE ABSOLUTE AVERAGE RESIDUAL = 0.11606

Table 132

Zero-order model,2,4-D,Liv/LLMO,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:10 PPM NOMINAL

DATE :03-02-84

RUN :I

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
11.000	6.7000	6.4746	-0.22541
129.00	5.0000	5.7361	0.73605
255.00	5.8000	4.9475	-0.85255
367.00	3.9000	4.2465	0.34647
487.00	3.5000	3.4954	-0.45767E-02

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 6.543 ± 0.99 ms/l

K2= -0.376 ± 0.00 ms/l.hr

THE CORRELATION COEFFICIENT = 0.79401

THE ABSOLUTE AVERAGE RESIDUAL = 0.23996

Table 133

Zero-order model,2,4-D,Liv/LLMO,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:10 PPM NOMINAL

DATE :03-04-84

RUN :II

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	8.7000	8.5684	-0.13156
150.00	8.6000	7.7382	-0.86178
248.00	6.5000	7.1612	0.66120
367.00	4.8000	6.4605	1.6605
484.00	7.1000	5.7716	-1.3284

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 8.621 ± 1.97 mg/l

K2= -0.353 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.45284

THE ABSOLUTE AVERAGE RESIDUAL = 0.47829

Table 134

Zero-order model,2,4-D,Liv/LLMO,RunIII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:10 PPM NOMINAL

DATE :03-06-84

RUN :III

TEMPERATURE :22 C

TIME (MIN)	PPMEXP	PPMCAL	DY
20.000	9.1000	7.7153	-1.3847
127.00	6.5000	7.8919	1.3919
265.00	7.9000	8.1198	0.21981
365.00	7.5000	8.2849	0.78494
488.00	9.5000	8.4880	-1.0120

KINETIC CONSTANTS

ZERO ORDER MODEL

K1= 7.682 ± 1.94 mg/l

K2= 0.099 ± 0.00 mg/l.hr

THE CORRELATION COEFFICIENT = 0.63600E-01

THE ABSOLUTE AVERAGE RESIDUAL = 0.47089

Table 135

Monod model,2,4-D,Liv,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON

CONCENTRATION:10 PPM NOMINAL

DATE :02-01-84

RUN :I

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
100.00	11.500	11.500	0.00000
290.00	11.100	11.285	-0.18497
380.00	8.8000	11.176	-2.3758
480.00	8.8000	11.048	-2.2477
565.00	8.2000	7.9472	0.25277
655.00	7.2000	8.0541	-0.85412

KINETIC CONSTANTS

MONOD MODEL

K1= -9.360 ± 0.00 mg/l

K2= 0.012 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.56579

Table 136

Monod model,2,4-D,Liv,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON

CONCENTRATION:10 PPM NOMINAL

DATE :02-01-84

RUN :II

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
130.00	2.2000	2.2000	0.00000
385.00	2.2000	2.2000	0.95367E-06
640.00	1.9000	1.9000	0.00000

KINETIC CONSTANTS

MONOD MODEL

K1= -2.046 ± 0.00 mg/l

K2= 0.000 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.31789E-06

Table 137

Monod model,2,4-D,Liv/Hyd,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:10 PPM NOMINAL

DATE :02-22-84

RUN :I

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	5.9000	5.9000	0.00000
157.00	4.5000	6.3447	-1.8447
441.00	3.5000	3.6411	-0.14106
1659.0	2.7000	2.6907	0.92583E-02

KINETIC CONSTANTS

MONOD MODEL

K1= -5.120 ± 0.00 mg/l

K2= -0.029 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.46253

Table 138

Monod model,2,4-D,Liv/Hyd,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:10 PPM NOMINAL

DATE :02-23-84

RUN :II

TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
15.000	8.2000	8.2000	0.00000
145.00	7.9000	8.0442	-0.14424
260.00	4.8000	7.9022	-3.1022
380.00	2.7000	3.0205	-0.32046
495.00	2.9000	3.1028	-0.20280

KINETIC CONSTANTS

MONOD MODEL

K1= -5.019 ± 0.00 mg/l

K2= 0.027 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.62572

Table 139

Monod model,2,4-D,Liv/Hyd,RunIII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/HYDROBAC

CONCENTRATION:10 PPM NOMINAL

DATE :02-24-84

RUN :III

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
125.00	10.700	10.700	0.00000
490.00	4.5000	4.5000	-0.47684E-05
605.00	6.0000	5.9997	0.26226E-03

KINETIC CONSTANTS

MONOD MODEL

K1= -6.160 ± 0.00 mg/l

K2= 0.142 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.87434E-04

Table 140

Monod model,2,4-D,Liv/BI-CHEM,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:10 PPM NOMINAL

DATE :02-14-84

RUN :I

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	4.4000	4.4000	0.00000
129.00	3.9000	3.8611	0.38850E-01
279.00	4.0000	4.7983	-0.79826
399.00	4.0000	4.9079	-0.90789
519.00	4.1000	5.0039	-0.90393
619.00	3.5000	3.4867	0.13314E-01
1589.0	3.0000	3.0930	-0.92999E-01

KINETIC CONSTANTS

MONOD MODEL

K1= -4.232 ± 0.00 mg/l

K2= -0.007 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.21613

Table 141

Monod model,2,4-D,Liv/BI-CHEM,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:10 PPM NOMINAL

DATE :02-15-84

RUN :II

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	2.5000	2.5000	0.00000
140.00	1.1000	2.4522	-1.3522
260.00	0.70000	0.90172	-0.20172
380.00	1.3000	2.3595	-1.0595
615.00	1.0000	0.98066	0.19335E-01
1410.0	1.2000	1.2919	-0.91926E-01

KINETIC CONSTANTS

MONOD MODEL

K1= -1.533 ± 0.00 mg/l

K2= 0.008 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.28870

Table 142

Monod model,2,4-D,Liv/BI-CHEM,RunIII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/BI-CHEM

CONCENTRATION:10 PPM NOMINAL

DATE :02-16-84

RUN :III

TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	7.9000	7.9000	0.00000
140.00	6.6000	6.6126	-0.12609E-01
385.00	5.9000	5.6279	0.27209
500.00	5.2000	5.3082	-0.10822
615.00	5.0000	5.0346	-0.34626E-01

KINETIC CONSTANTS

MONOD MODEL

K1= -8.285 ± 0.00 mg/l

K2= -0.086 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.59027E-01

Table 143

Monod model,2,4-D,Liv/LLMO,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:10 PPM NOMINAL

DATE :03-02-84

RUN :I

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
11.000	6.7000	6.7000	0.00000
140.00	5.0000	6.8356	-1.8356
266.00	5.8000	6.9595	-1.1595
378.00	3.9000	3.8932	0.67577E-02
498.00	3.5000	3.8223	-0.32227

KINETIC CONSTANTS

MONOD MODEL

K1= -5.322 ± 0.00 mg/l

K2= -0.013 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.43899

Table 144

Monod model,2,4-D,Liv/LLMO,RunII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:10 PPM NOMINAL

DATE :03-04-84

RUN :II

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	8.7000	8.7000	0.00000
159.00	8.6000	8.3287	0.27129
257.00	6.5000	8.0544	-1.5544
376.00	4.8000	5.2008	-0.40082
493.00	7.1000	7.1454	-0.45370E-01

KINETIC CONSTANTS

MONOD MODEL

K1= -6.353 ± 0.00 mg/l

K2= 0.038 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.32572

Table 145

Monod model,2,4-D,Liv/LLMO,RunIII

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON/LLMO

CONCENTRATION:10 PPM NOMINAL

DATE :03-06-84

RUN :III

TEMPERATURE :22 C

TIME (MIN)	PPMEXP	PPMCAL	DY
20.000	9.1000	9.1000	0.00000
147.00	6.5000	6.9224	-0.42238
285.00	7.9000	9.0806	-1.1806
385.00	7.5000	9.0732	-1.5732
508.00	9.5000	9.0641	0.43593

KINETIC CONSTANTS

MONOD MODEL

K1= -7.957 ± 0.00 mg/l

K2= 0.001 ± 0.00 mg/l.hr

THE ABSOLUTE AVERAGE RESIDUAL = 0.41170

Table 146

Haldane model,2,4-D,Liv,RunI

SUBSTRATE :2,4-D

MEDIA :LIVINGSTON

CONCENTRATION:10 PPM NOMINAL

DATE :02-01-84

RUN :I

TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
100.00	11.500	9.7683	1.7317
290.00	11.100	9.5833	1.5167
380.00	8.8000	9.4947	-0.69472
480.00	8.8000	9.3956	-0.59562
565.00	8.2000	9.3108	-1.1108
655.00	7.2000	9.2203	-2.0203

KINETIC CONSTANTS

HALDANE MODEL

K1= 4.131 ± 0.00 ms/l

K2= 0.029 ± 0.00 ms/l.hr

K3= 0.004 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 0.56402

Table 147
Haldane model,2,4-D,Liv,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON
CONCENTRATION:10 PPM NOMINAL
DATE :02-01-84
RUN :II
TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
130.00	2.2000	3.5547	-1.3547
385.00	2.2000	3.5604	-1.3604
640.00	1.9000	2.0901	-0.19005

KINETIC CONSTANTS

HALDANE MODEL

K1= 2.872 ± 0.00 mg/l

K2= -0.000 ± 0.00 mg/l.hr

K3= -0.007 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.64307

Table 148
Haldane model,2,4-D,Liv/Hyd,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:10 PPM NOMINAL
DATE :02-22-84
RUN :I
TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	5.9000	5.0801	0.81991
157.00	4.5000	4.9836	-0.48356
441.00	3.5000	4.7889	-1.2889
1659.0	2.7000	3.5652	-0.86517

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.032 ± 0.00 mg/l

K2= 0.013 ± 0.00 mg/l.hr

K3= 0.006 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.45524

Table 149
Haldane model,2,4-D,Liv/Hyd,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:10 PPM NOMINAL
DATE :02-23-84
RUN :II
TEMPERATURE :24 C

TIME (MIN)	PPMEXP	PPMCAL	DY
15.000	8.2000	7.3963	0.80365
145.00	7.9000	6.9877	0.91227
260.00	4.8000	6.6080	-1.8080
380.00	2.7000	2.0594	0.64058
495.00	2.9000	2.2660	0.63400

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.345 ± 0.00 mg/l

K2= 0.065 ± 0.00 mg/l.hr

K3= 0.013 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.47156

Table 150
Haldane model,2,4-D,Liv/Hyd,RunIII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/HYDROBAC
CONCENTRATION:10 PPM NOMINAL
DATE :02-24-84
RUN :III
TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
125.00	10.700	8.8743	1.8257
490.00	4.5000	7.6450	-3.1450
605.00	6.0000	7.2206	-1.2206

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.753 ± 0.00 mg/l

K2= 0.075 ± 0.00 mg/l.hr

K3= 0.011 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 1.2786

Table 151
Haldane model,2,4-D,Liv/BI-CHEM,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:10 PPM NOMINAL
DATE :02-14-84
RUN :I
TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	4.4000	3.9851	0.41486
129.00	3.9000	3.9751	-0.75077E-01
279.00	4.0000	3.9624	0.37599E-01
399.00	4.0000	3.9522	0.47815E-01
519.00	4.1000	3.9419	0.15810
619.00	3.5000	3.9333	-0.43327
1589.0	3.0000	3.8466	-0.84656

KINETIC CONSTANTS

HALDANE MODEL

K1= 2.827 ± 0.00 mg/l

K2= 0.001 ± 0.00 mg/l.hr

K3= 0.005 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.15056

Table 152
Haldane model,2,4-D,Liv/BI-CHEM,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:10 PPM NOMINAL
DATE :02-15-84
RUN :II
TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	2.5000	2.3929	0.10708
140.00	1.1000	1.0882	0.11806E-01
260.00	0.70000	1.1814	-0.48141
380.00	1.3000	1.3042	-0.42143E-02
615.00	1.0000	1.3888	-0.38884
1410.0	1.2000	1.6067	-0.40674

KINETIC CONSTANTS

HALDANE MODEL

K1= -3.829 ± 0.00 mg/l

K2= -0.098 ± 0.00 mg/l.hr

K3= 0.998 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.12472

Table 153
Haldane model,2,4-D,Liv/BI-CHEM,RunIII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/BI-CHEM
CONCENTRATION:10 PPM NOMINAL
DATE :02-16-84
RUN :III
TEMPERATURE :25 C

TIME (MIN)	PPMEXP	PPMCAL	DY
10.000	7.9000	6.5826	1.3174
140.00	6.6000	6.4709	0.12913
385.00	5.9000	6.2545	-0.35449
500.00	5.2000	6.1499	-0.94991
615.00	5.0000	6.0431	-1.0431

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.312 ± 0.00 mg/l

K2= 0.020 ± 0.00 mg/l.hr

K3= 0.008 ± 0.00 1/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.39337

Table 154
Haldane model,2,4-D,Liv/LLMO,RunI

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:10 PPM NOMINAL
DATE :03-02-84
RUN :I
TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
11.000	6.7000	5.6786	1.0214
140.00	5.0000	5.5149	-0.51487
266.00	5.8000	5.3482	0.45176
378.00	3.9000	5.1933	-1.2933
498.00	3.5000	5.0185	-1.5185

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.101 ± 0.00 mg/l

K2= 0.026 ± 0.00 mg/l.hr

K3= 0.009 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.46865

Table 155
Haldane model,2,4-D,Liv/LLMO,RunII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:10 PPM NOMINAL
DATE :03-04-84
RUN :II
TEMPERATURE :23 C

TIME (MIN)	PPMEXP	PPMCAL	DY
9.0000	8.7000	7.7712	0.92881
159.00	8.6000	7.5705	1.0295
257.00	6.5000	7.4368	-0.93677
376.00	4.8000	7.2712	-2.4712
493.00	7.1000	7.1048	-0.47703E-02

KINETIC CONSTANTS

HALDANE MODEL

K1= 3.628 ± 0.00 ms/l

K2= 0.035 ± 0.00 ms/l.hr

K3= 0.006 ± 0.00 l/ms

THE ABSOLUTE AVERAGE RESIDUAL = 0.59690

Table 156
Haldane model,2,4-D,Liv/LLMO,RunIII

SUBSTRATE :2,4-D
MEDIA :LIVINGSTON/LLMO
CONCENTRATION:10 PPM NOMINAL
DATE :03-06-84
RUN :III
TEMPERATURE :22 C

TIME (MIN)	PPMEXP	PPMCAL	DY
20.000	9.1000	8.4328	0.66725
147.00	6.5000	8.3369	-1.8369
285.00	7.9000	8.2315	-0.33150
385.00	7.5000	8.1543	-0.65434
508.00	9.5000	8.0585	1.4415

KINETIC CONSTANTS

HALDANE MODEL

K1= 4.000 ± 0.00 mg/l

K2= 0.025 ± 0.00 mg/l.hr

K3= -0.001 ± 0.00 l/mg

THE ABSOLUTE AVERAGE RESIDUAL = 0.50736

FIGURES

Figure 1
Diagram of Reactor System

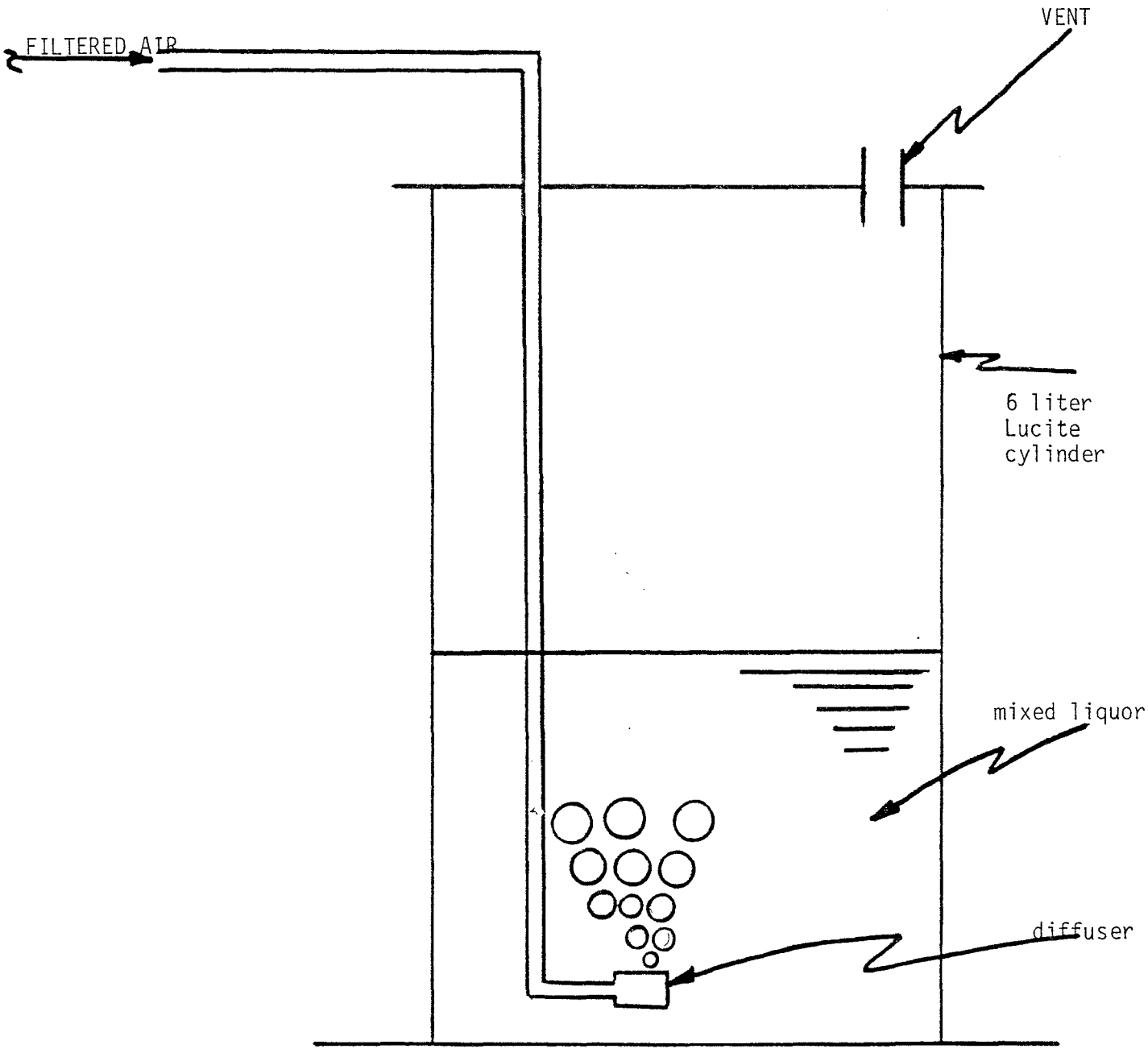


Figure 2

1-Butanol Concentration vs Time, 1st Air Stripping Experiment

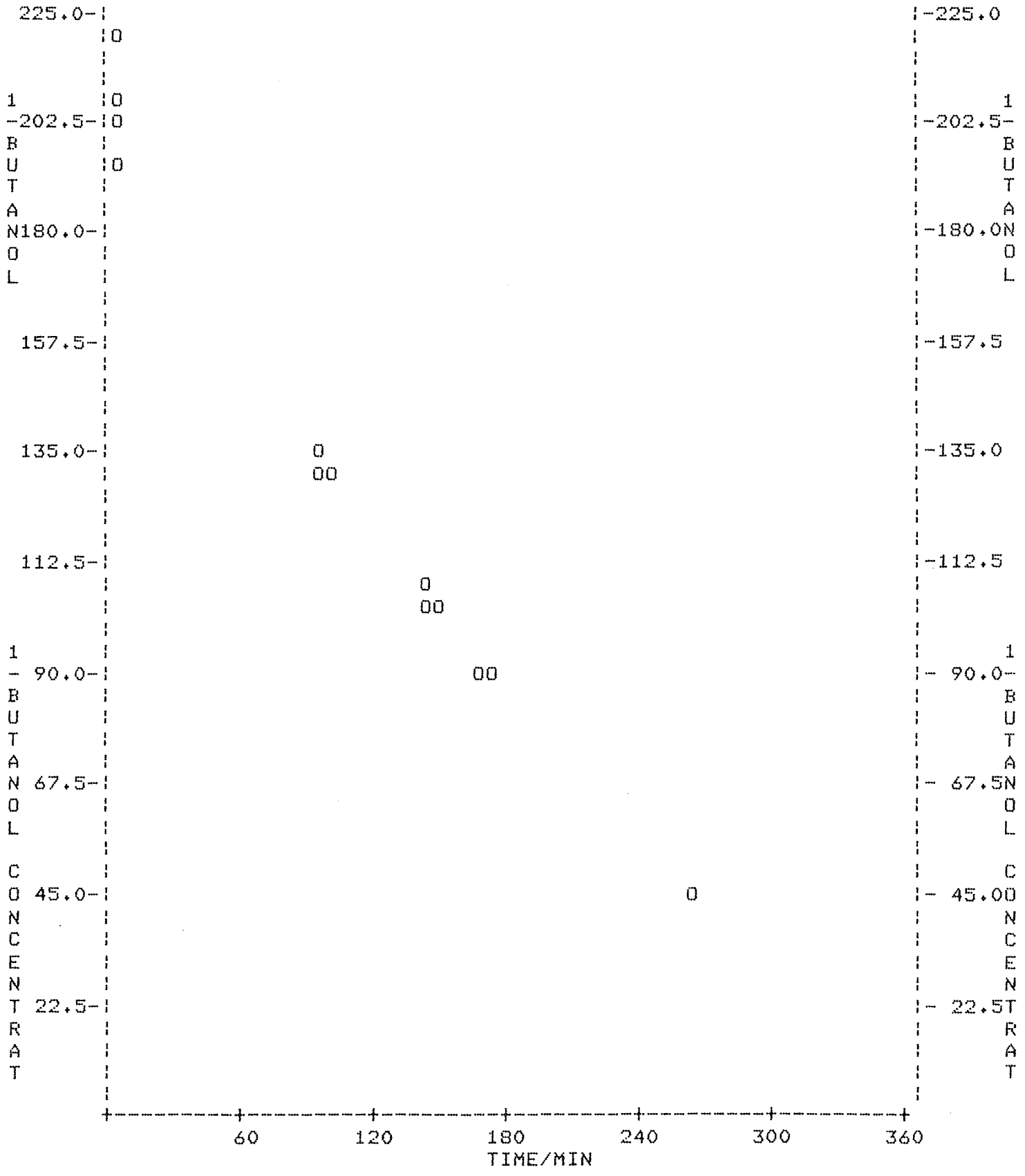


Figure 3

1-Butanol Concentration vs Time, 2nd Air Stripping Experiment

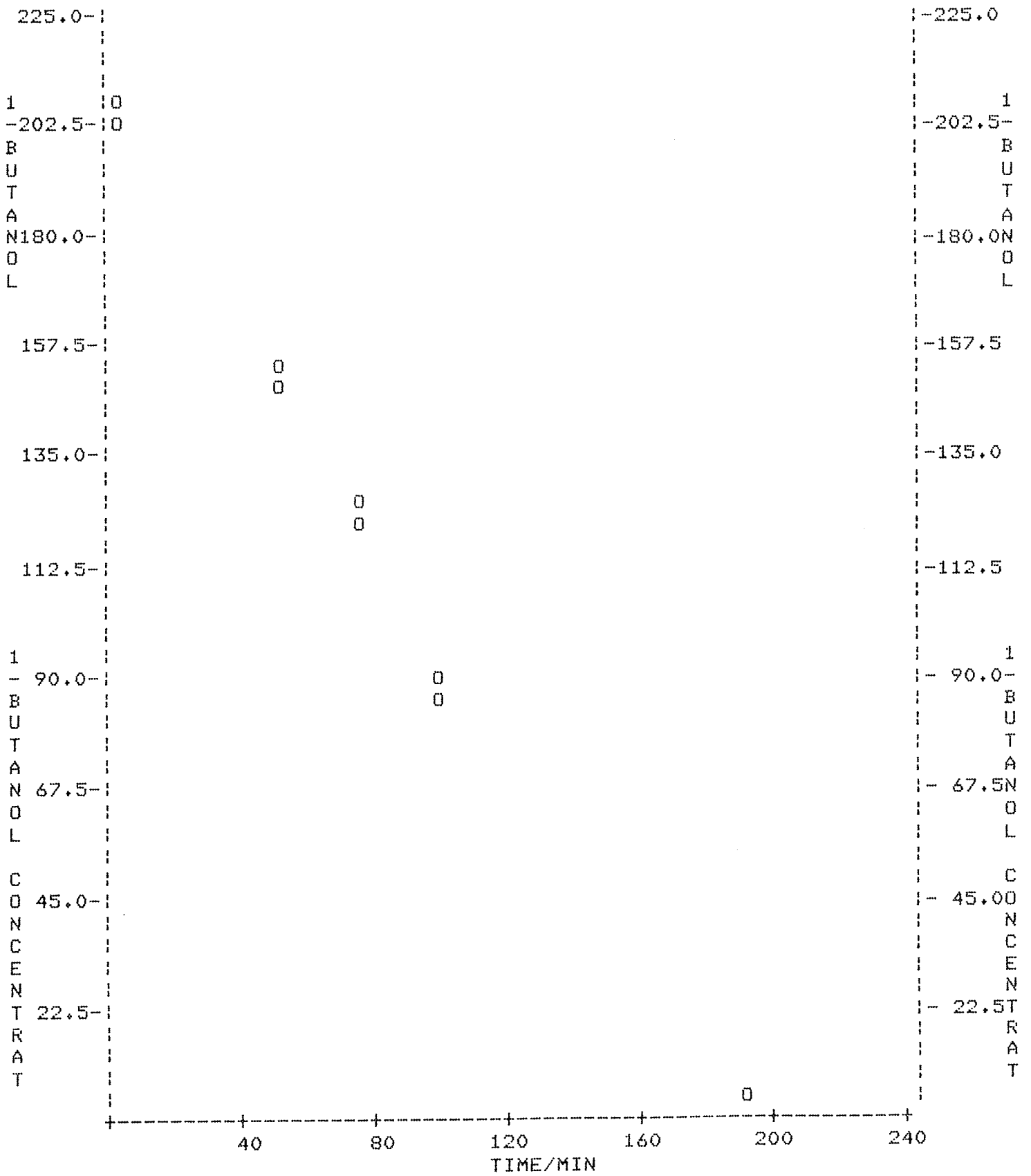


Figure 4

Nitrobenzene Concentration vs Time, 1st Air Stripping Experiment

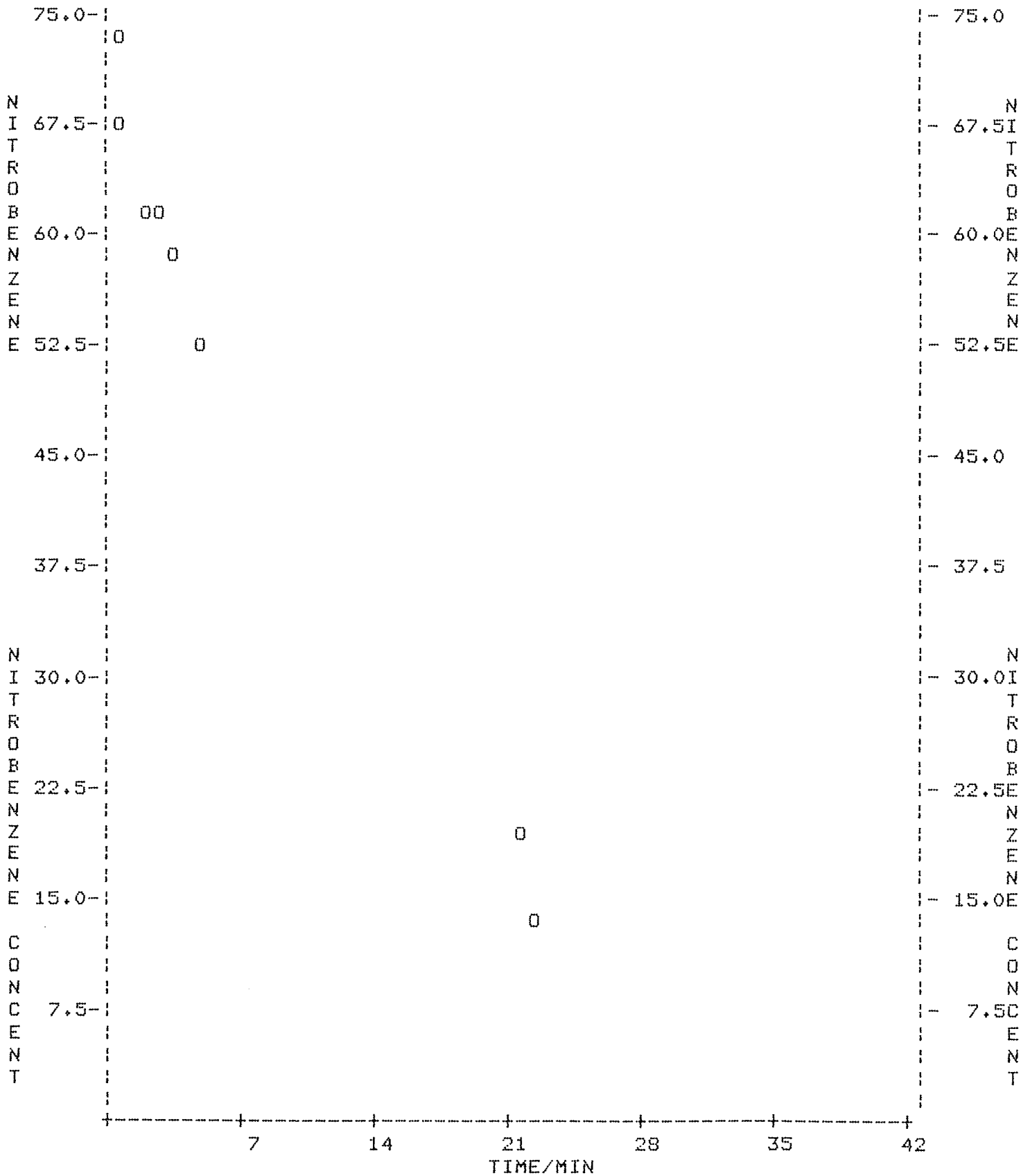
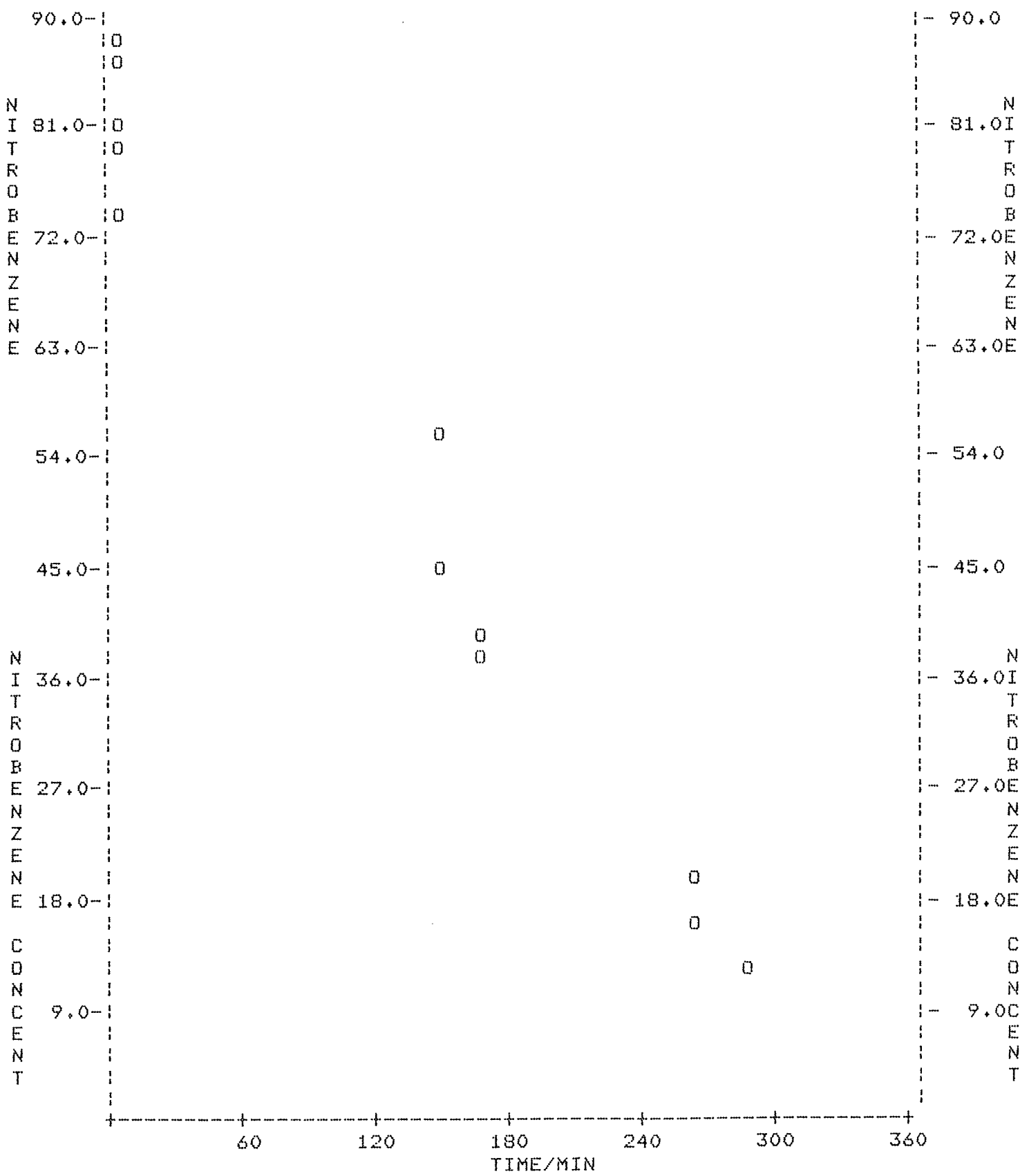


Figure 5

Nitrobenzene Concentration vs Time, 2nd Air Stripping Experiment



Fisure 6

Nitrobenzene Concentration vs Time, 3rd Air Stripping Experiment

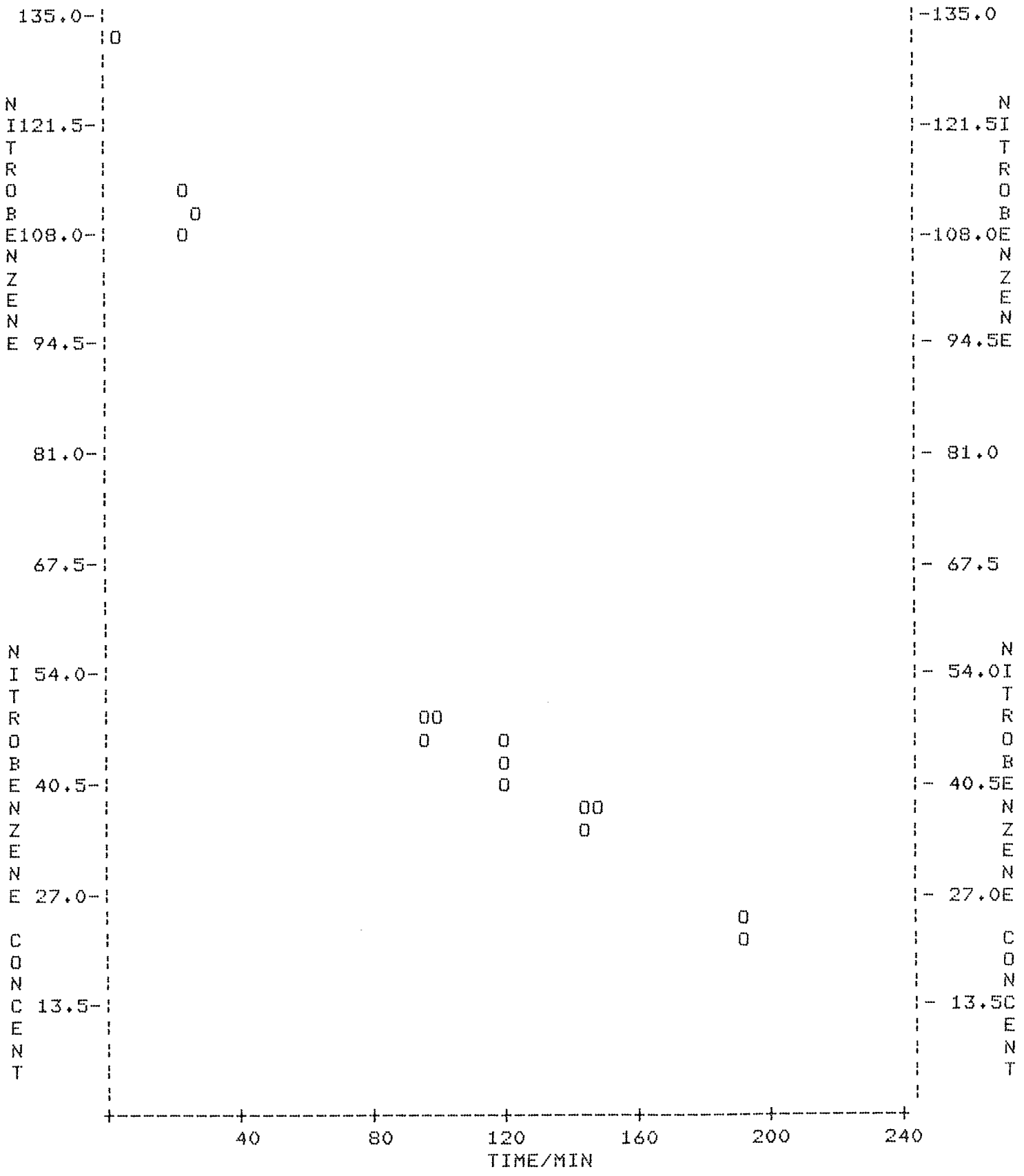
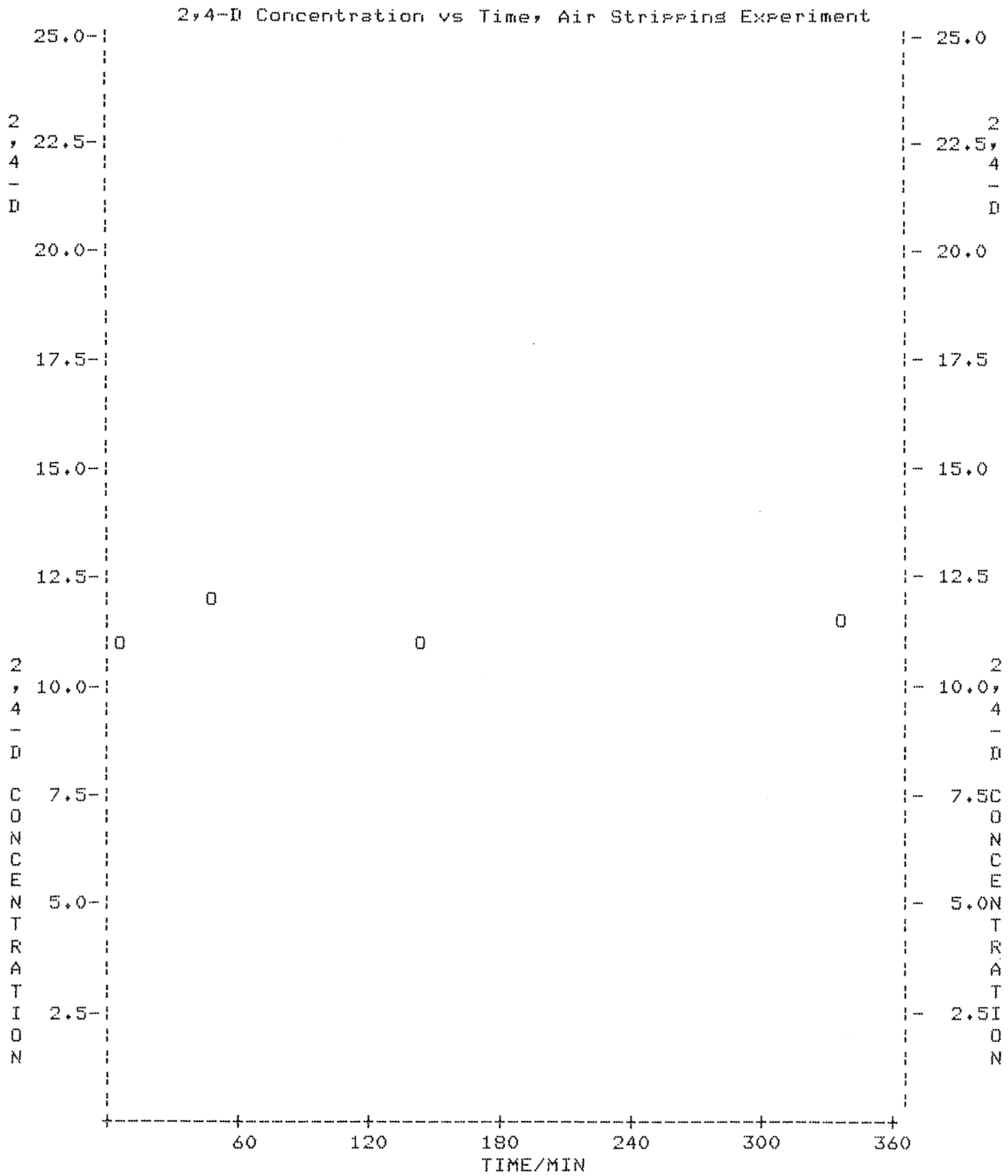


Figure 7


2,4-D Concentration vs Time, Air Stripping Experiment
2,4-D CONCENTRATION
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
60
120
180
240
300
360
TIME/MIN

In the following Figures the following symbols represent:

O = Substrate Concentration, ppm
+ = COD Concentration Equivalent, ppm

Figure 8
1-Butanol Conc. & COD vs Time; Liv.,run I

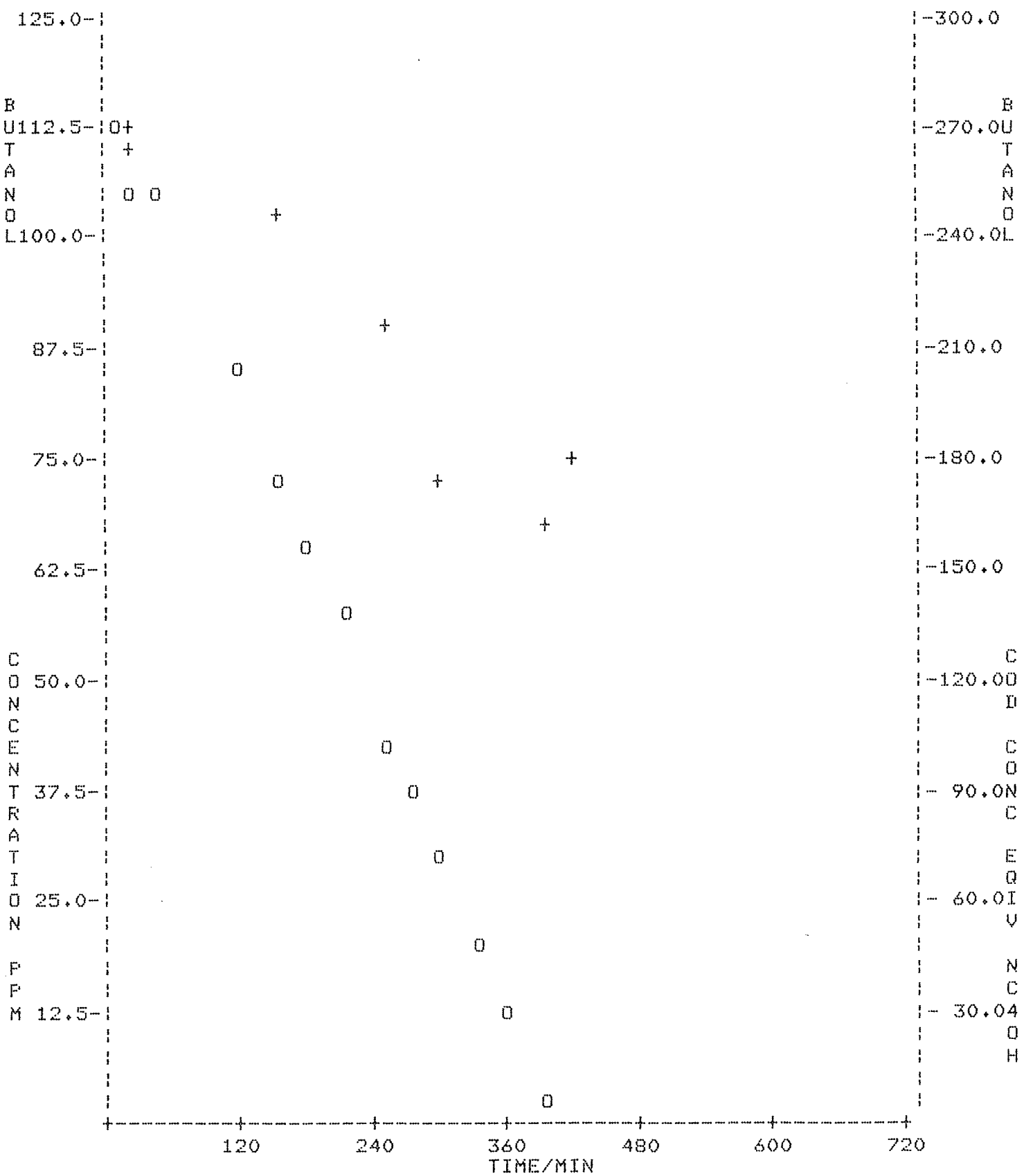
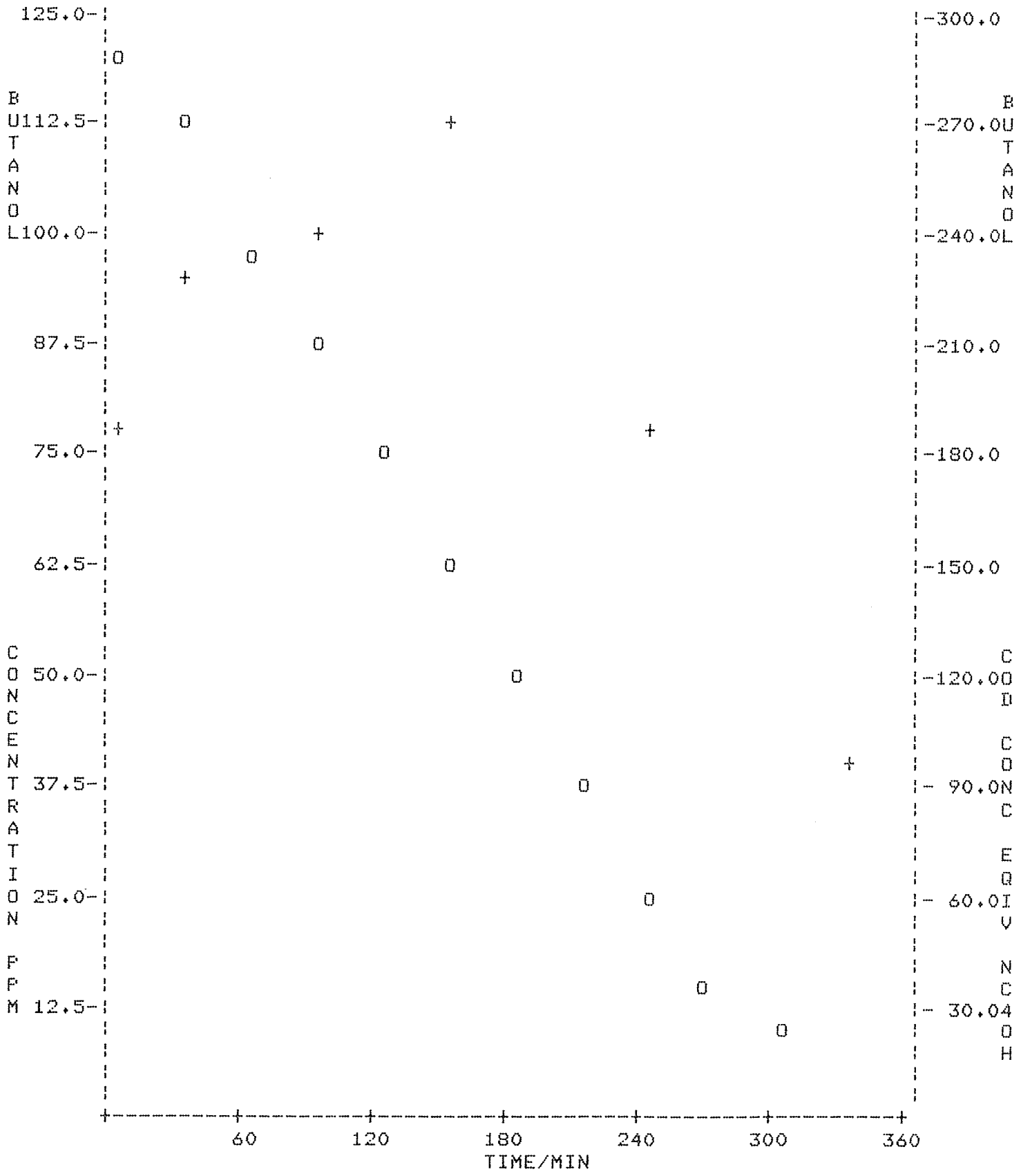


Figure 9
1-Butanol Conc. & COD vs Time; Liv.,RunII



Fisure 10
1-Butanol Conc. & COD vs Time; Liv.,RunIII

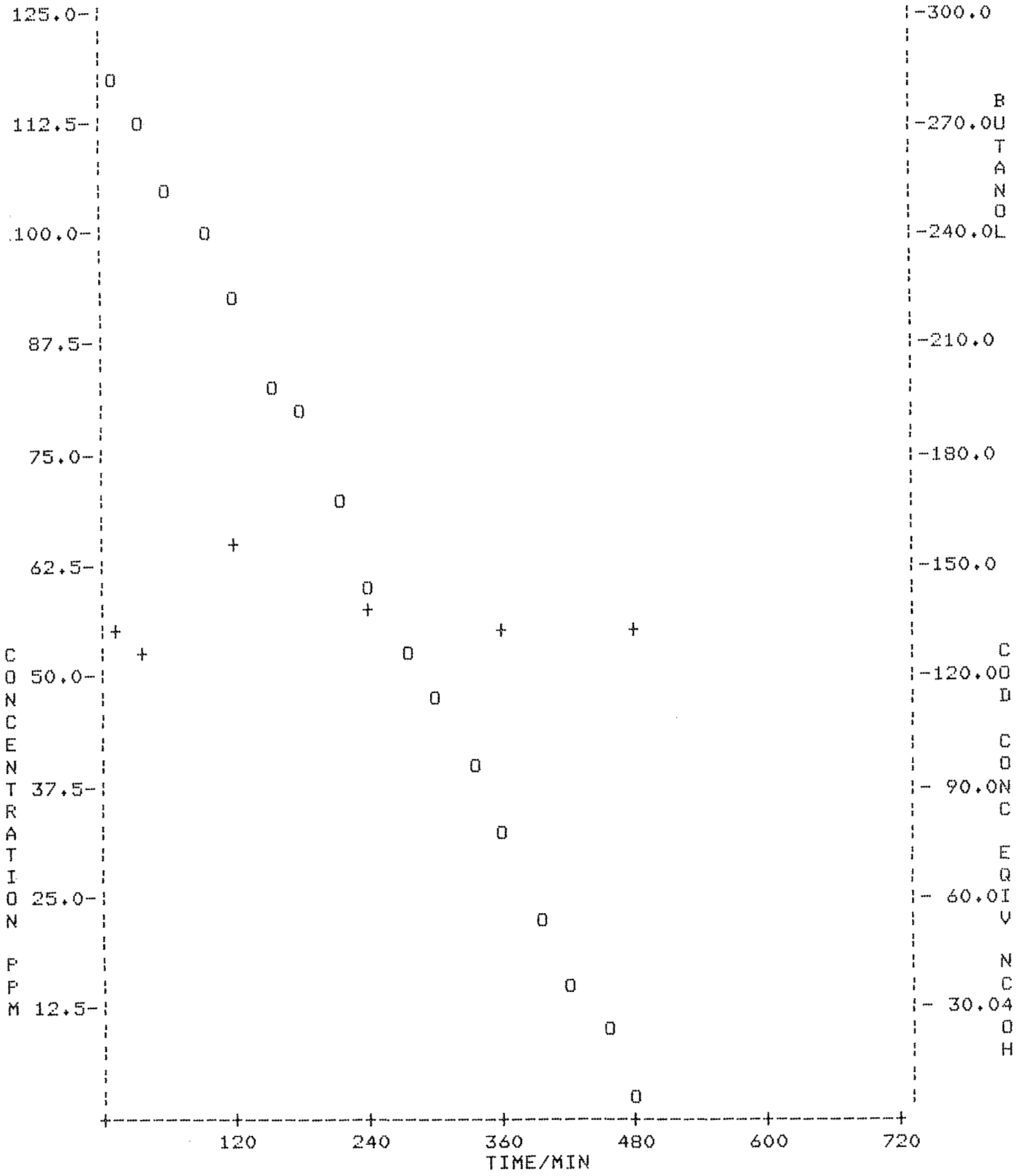


Figure 11
1-Butanol Conc. & COD vs Time; Liv/BI-CHEM,RunI

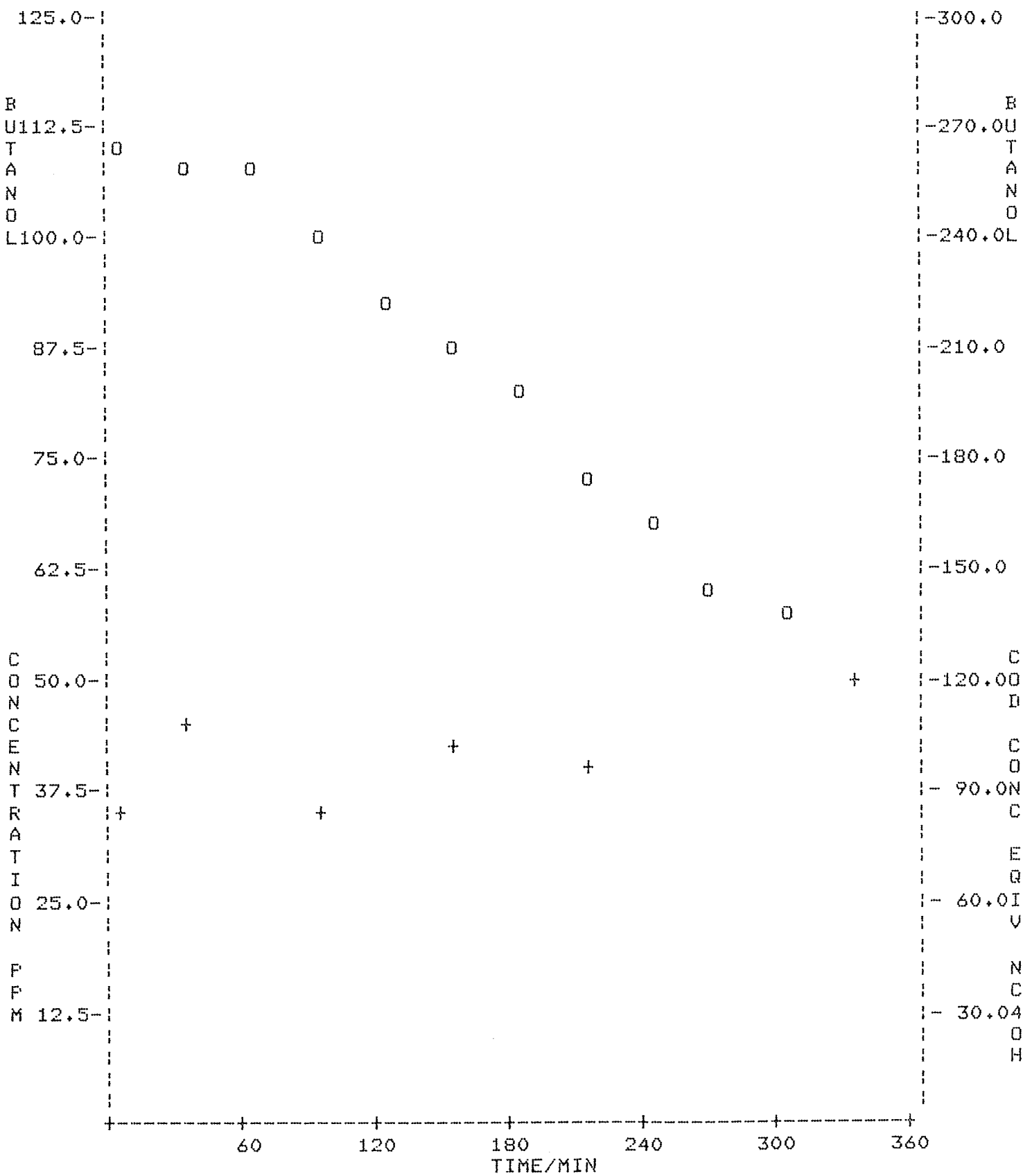


Figure 12
1-Butanol Conc. & COD vs Time; Liv/BI-CHEM,RunII

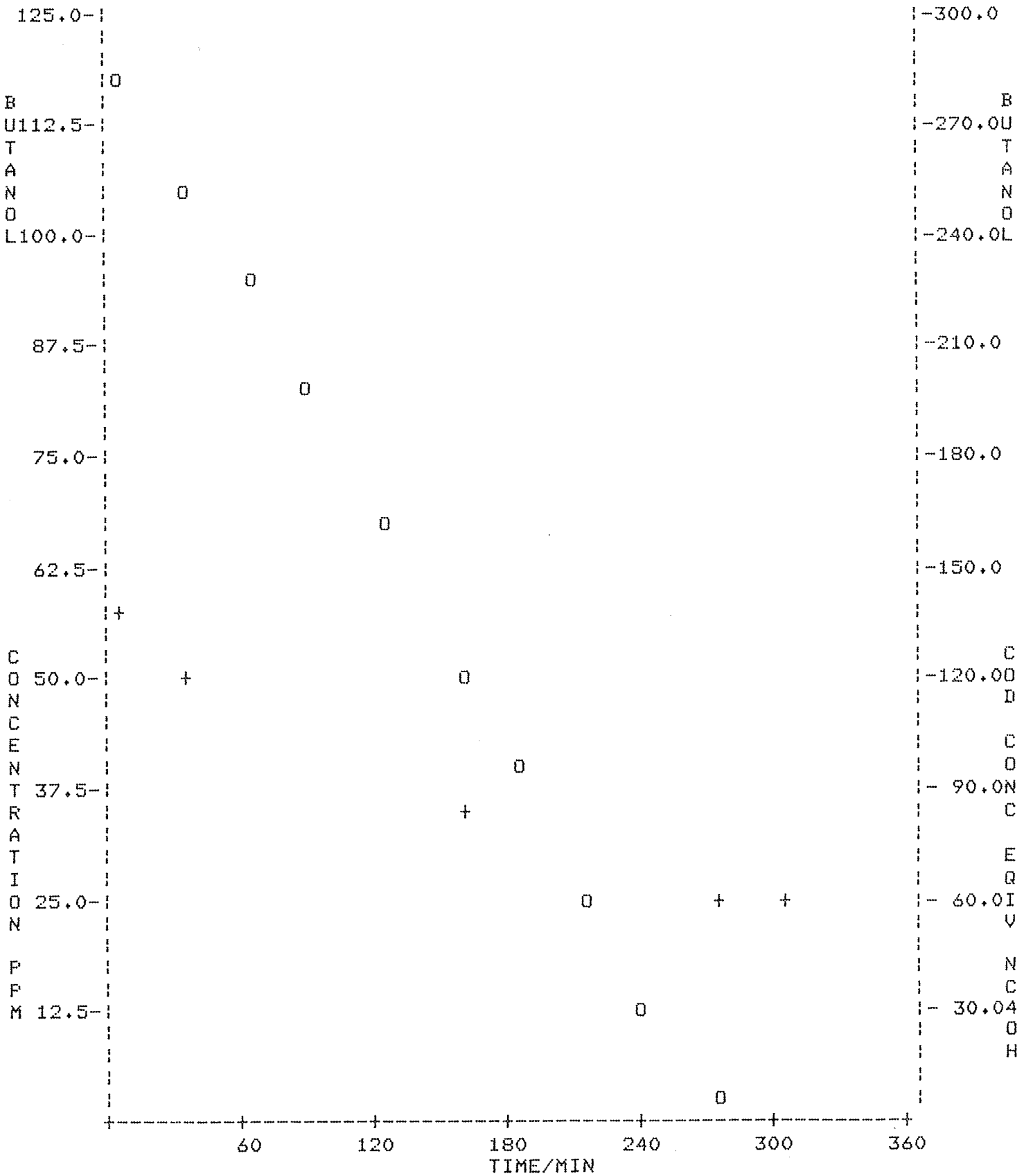


Figure 13
1-Butanol Conc. & COD vs Time; Liv/BI-CHEM,RunIII

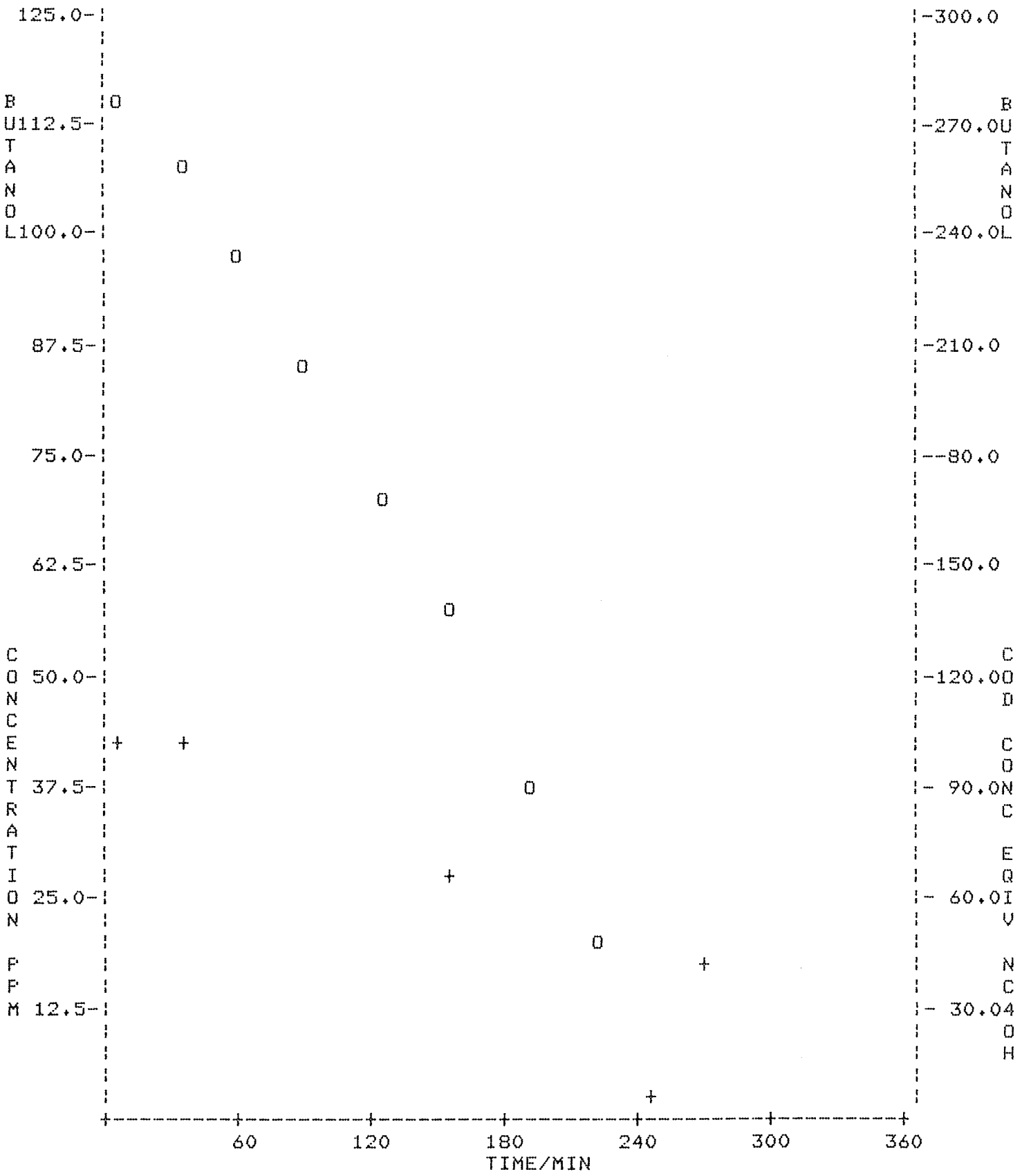


Figure 14
1-Butanol Conc. & COD vs Time; Liv/Hyd,Run1

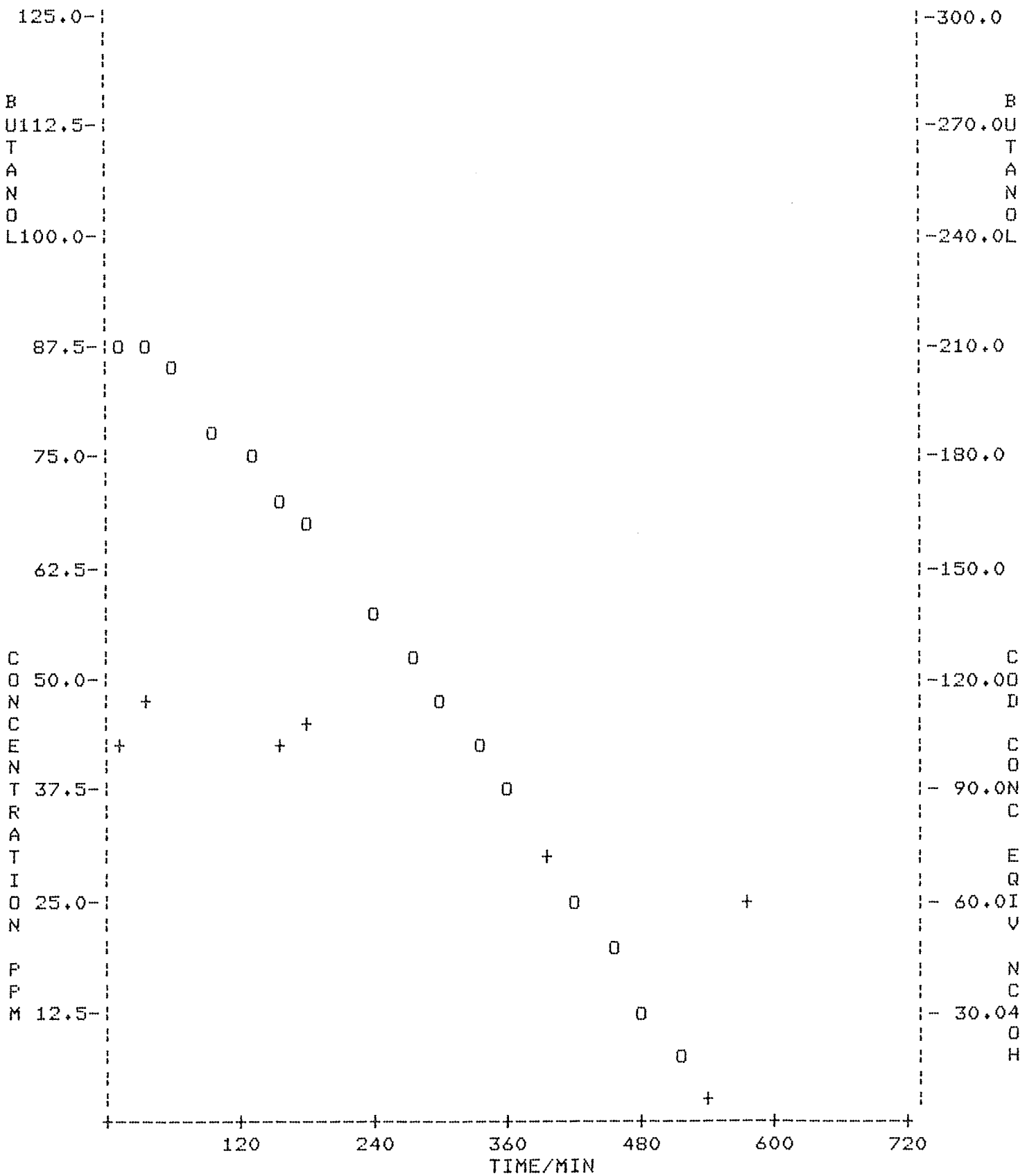


Figure 15
1-Butanol Conc. & COD vs Time; Liv/Hyd,RunII

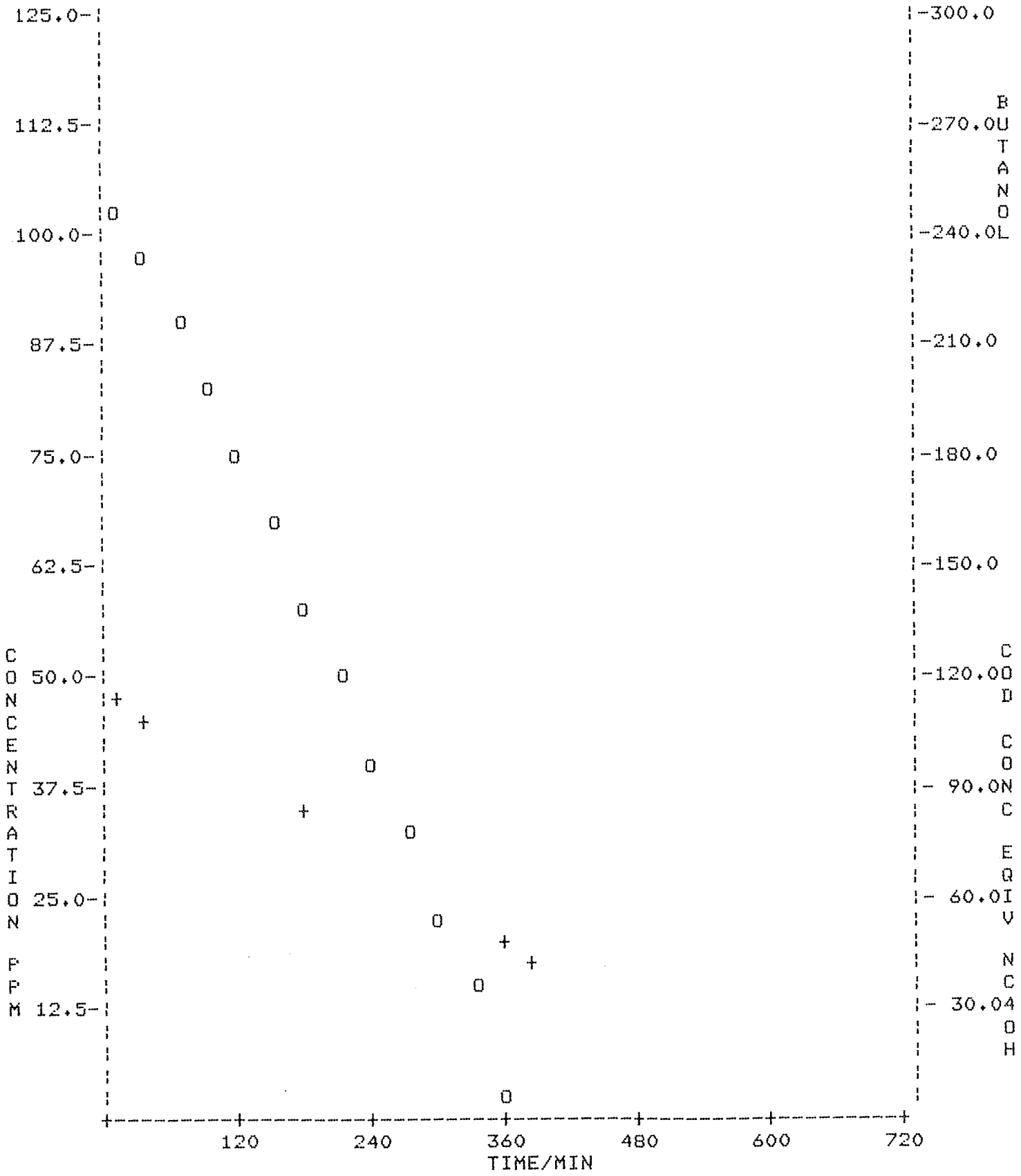


Figure 16
1-Butanol Conc. & COD vs Time; Liv/Hyd,RunIII

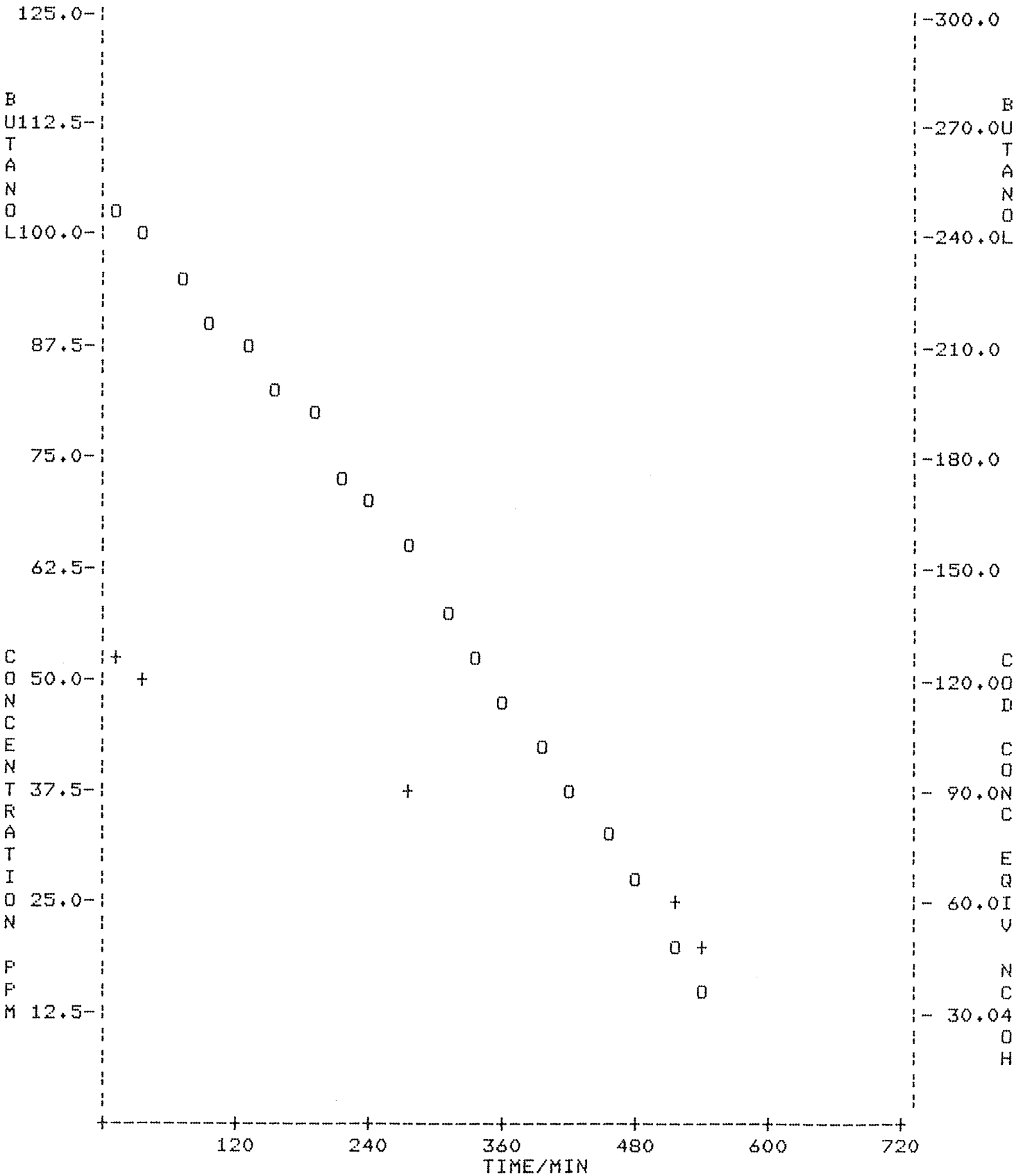


Figure 17
1-Butanol Conc. & COD vs Time; Liv/Hyd,RunIA

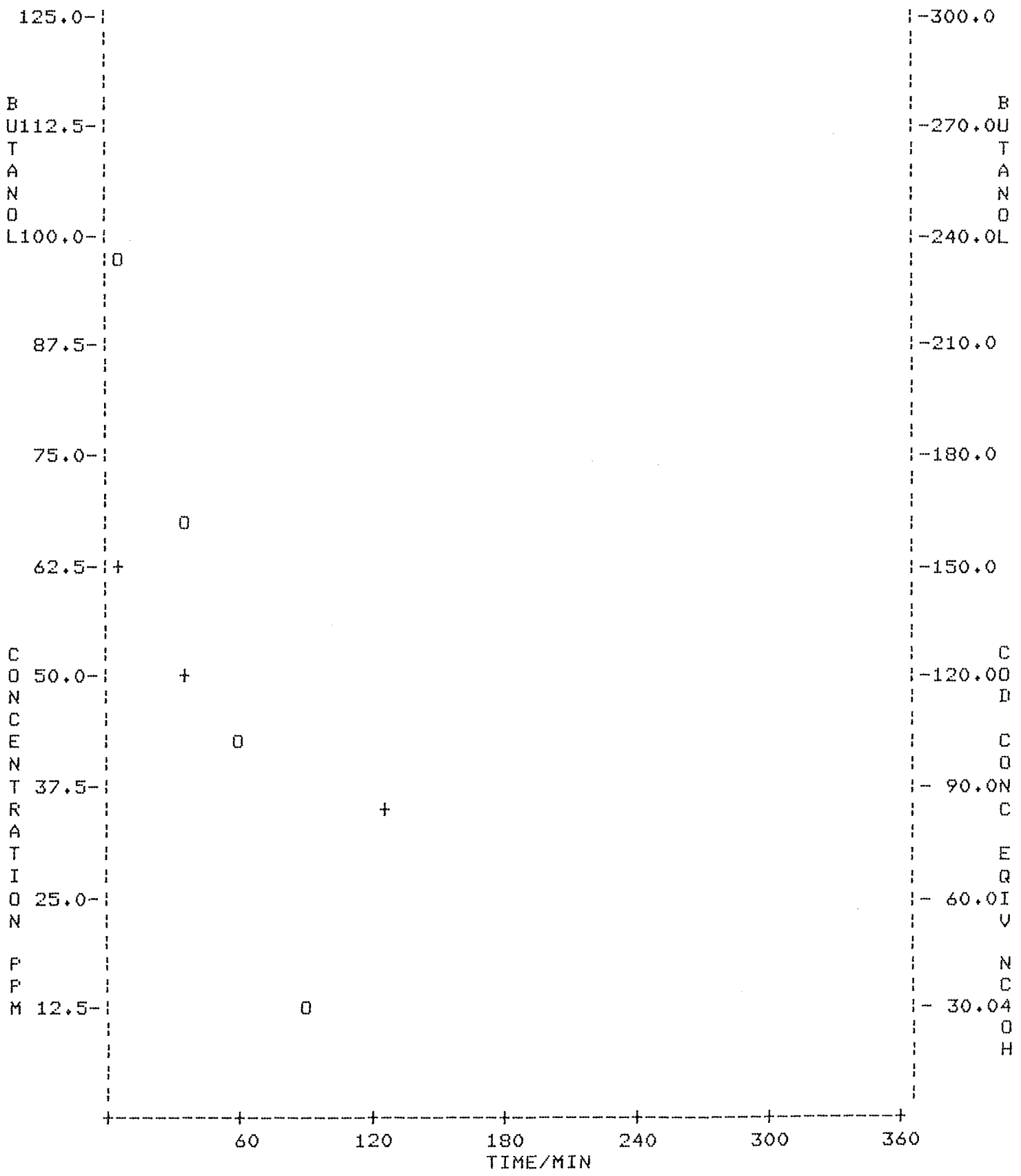


Figure 18
1-Butanol Conc. & COD vs Time; Liv/Hyd,RunIIA

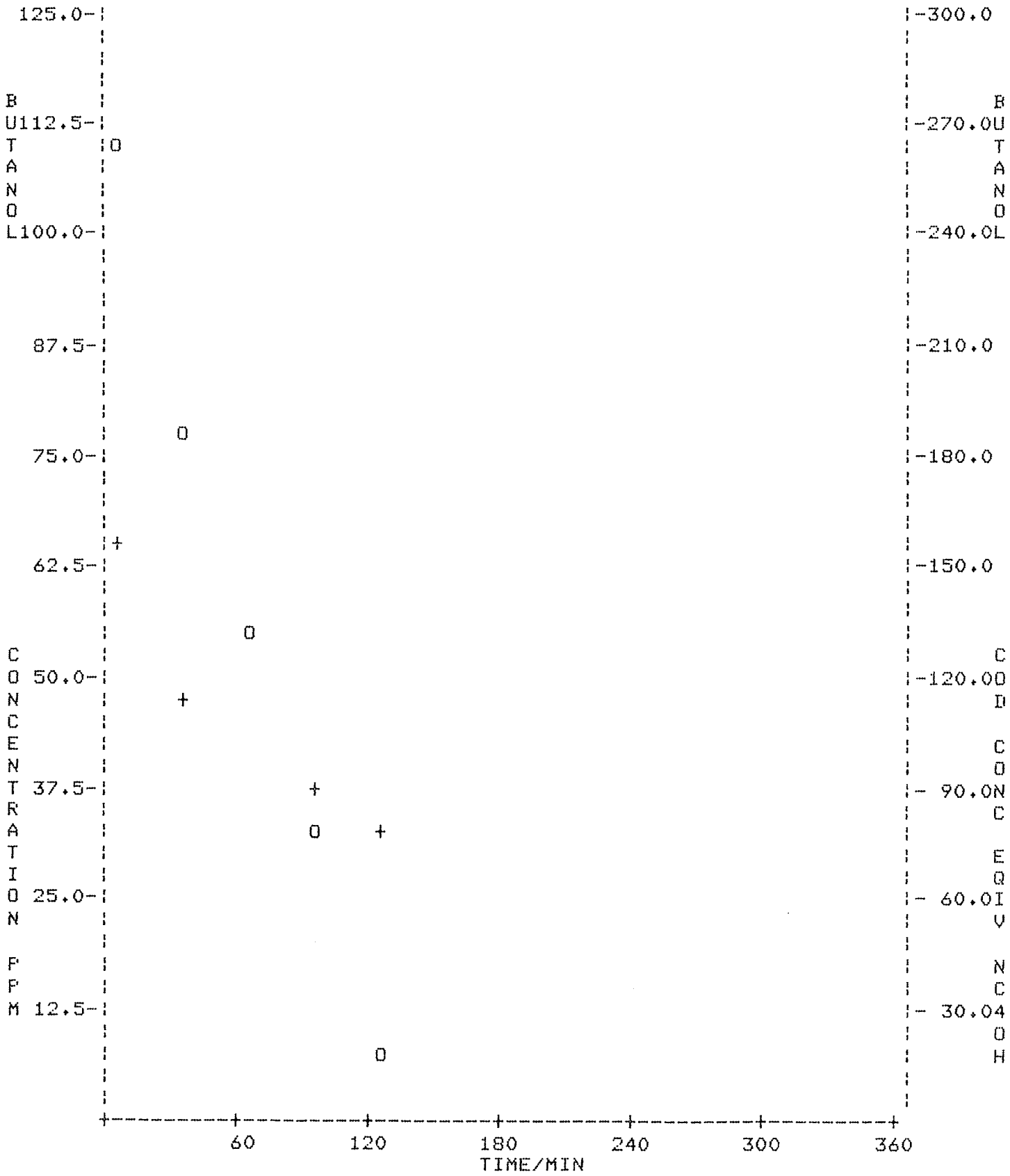


Figure 19
1-Butanol Conc. & COD vs Time; Liv/Hyd,RunIIIA

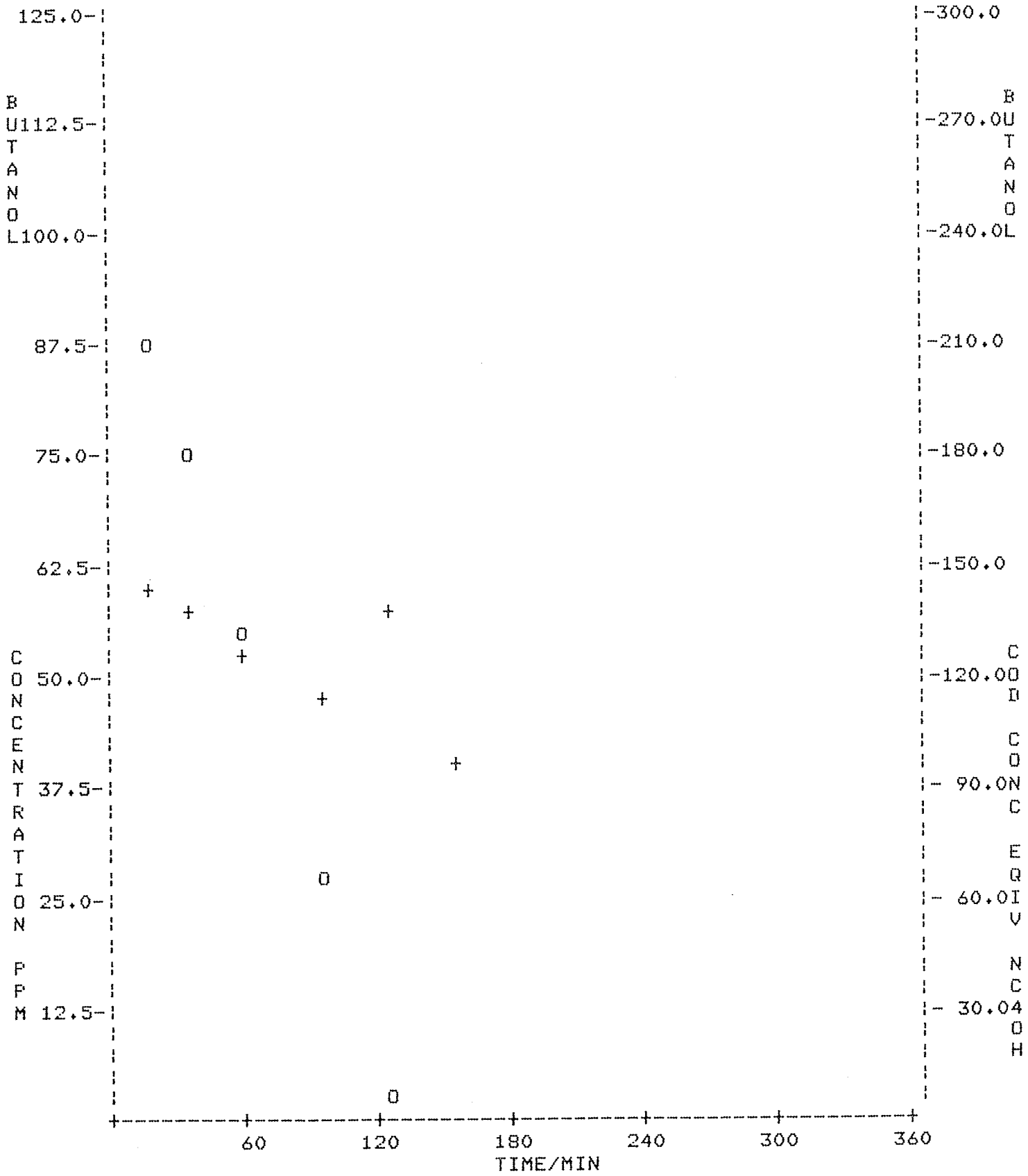


Figure 20
1-Butanol Conc. & COD vs Time; Liv/LLMO,RunI

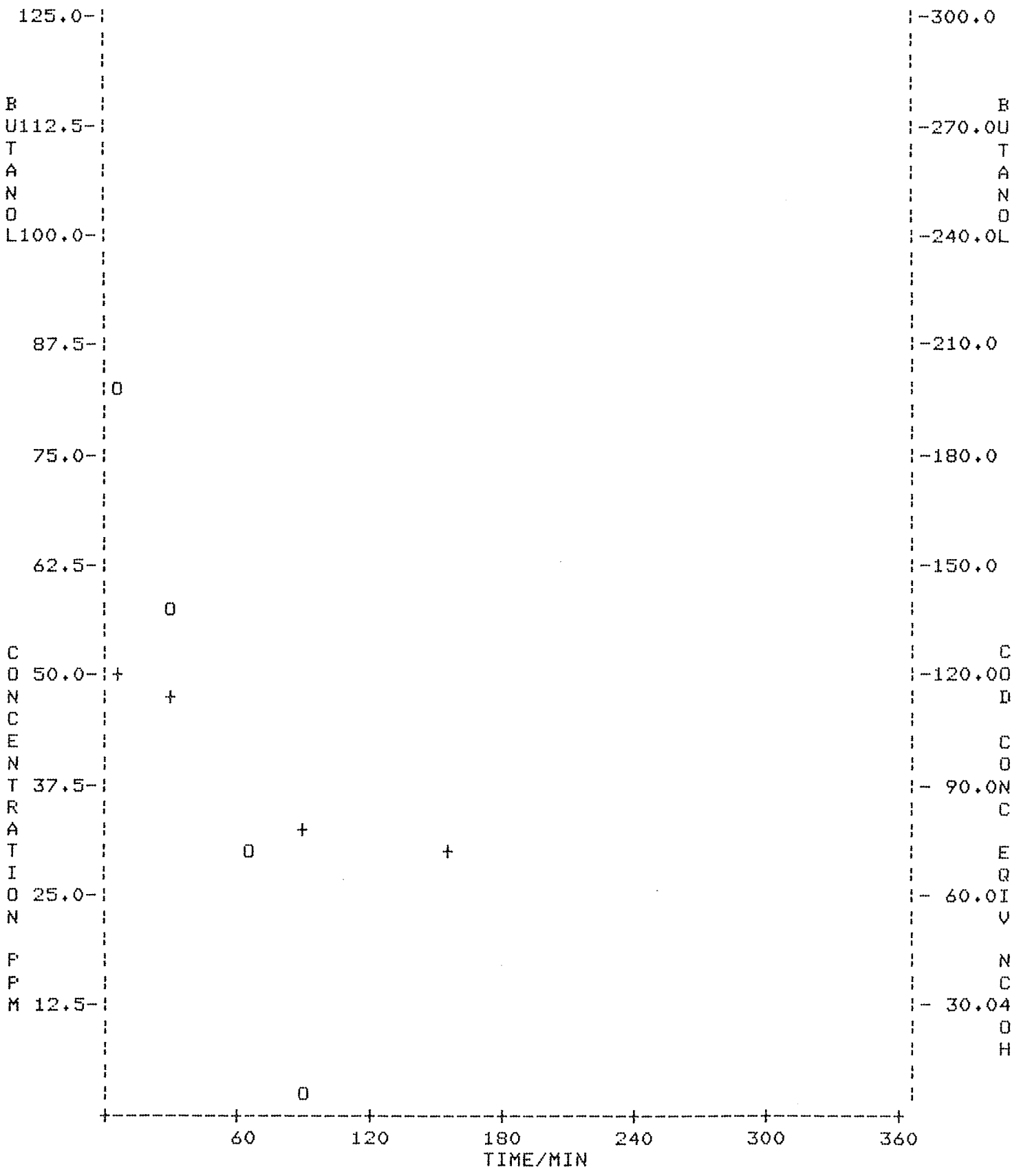


Figure 21
1-Butanol Conc. & COD vs Time; Liv/LLMO,RunII

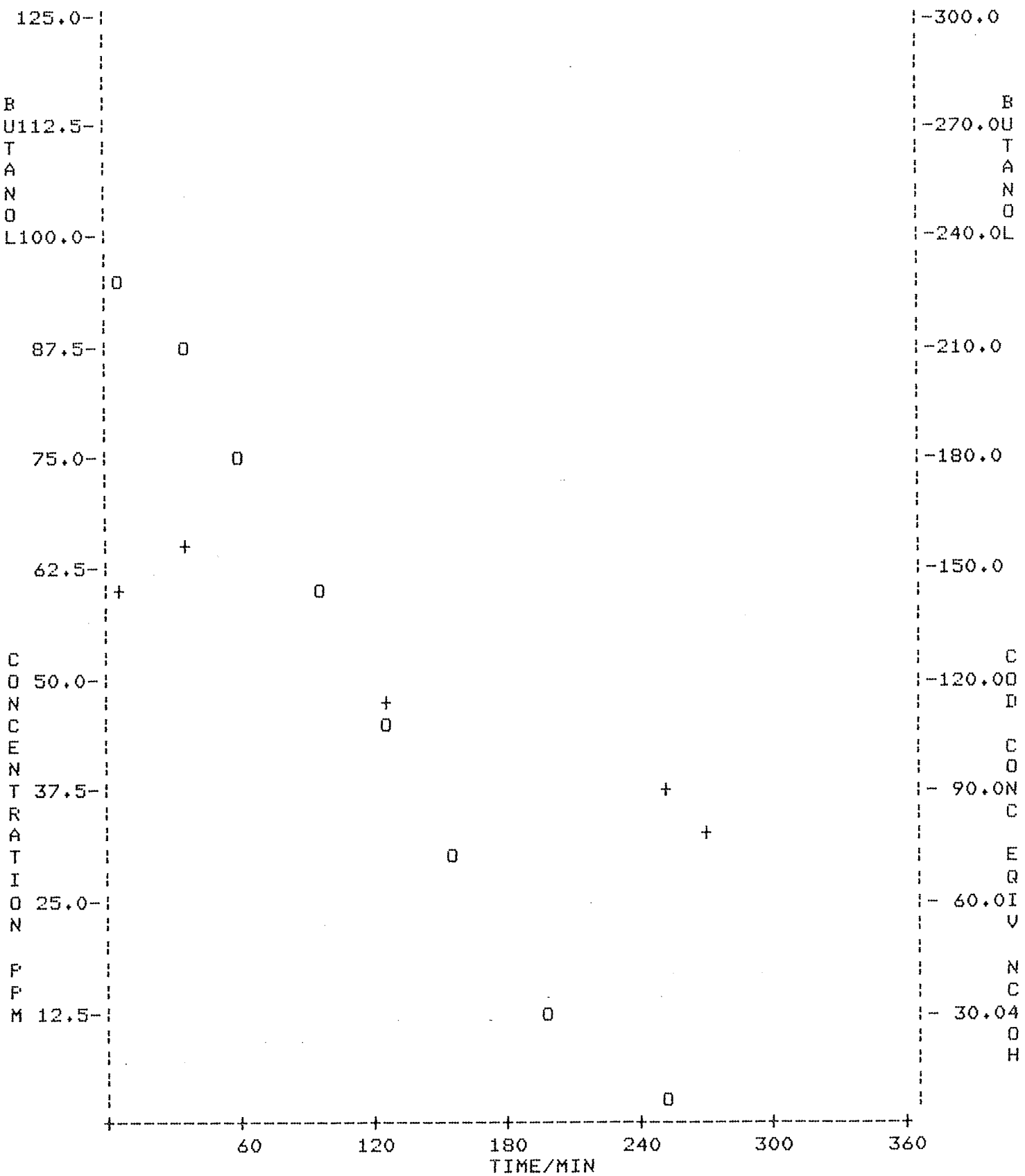


Figure 22
1-Butanol Conc. & COD vs Time; Liv/LLMO;RunIII

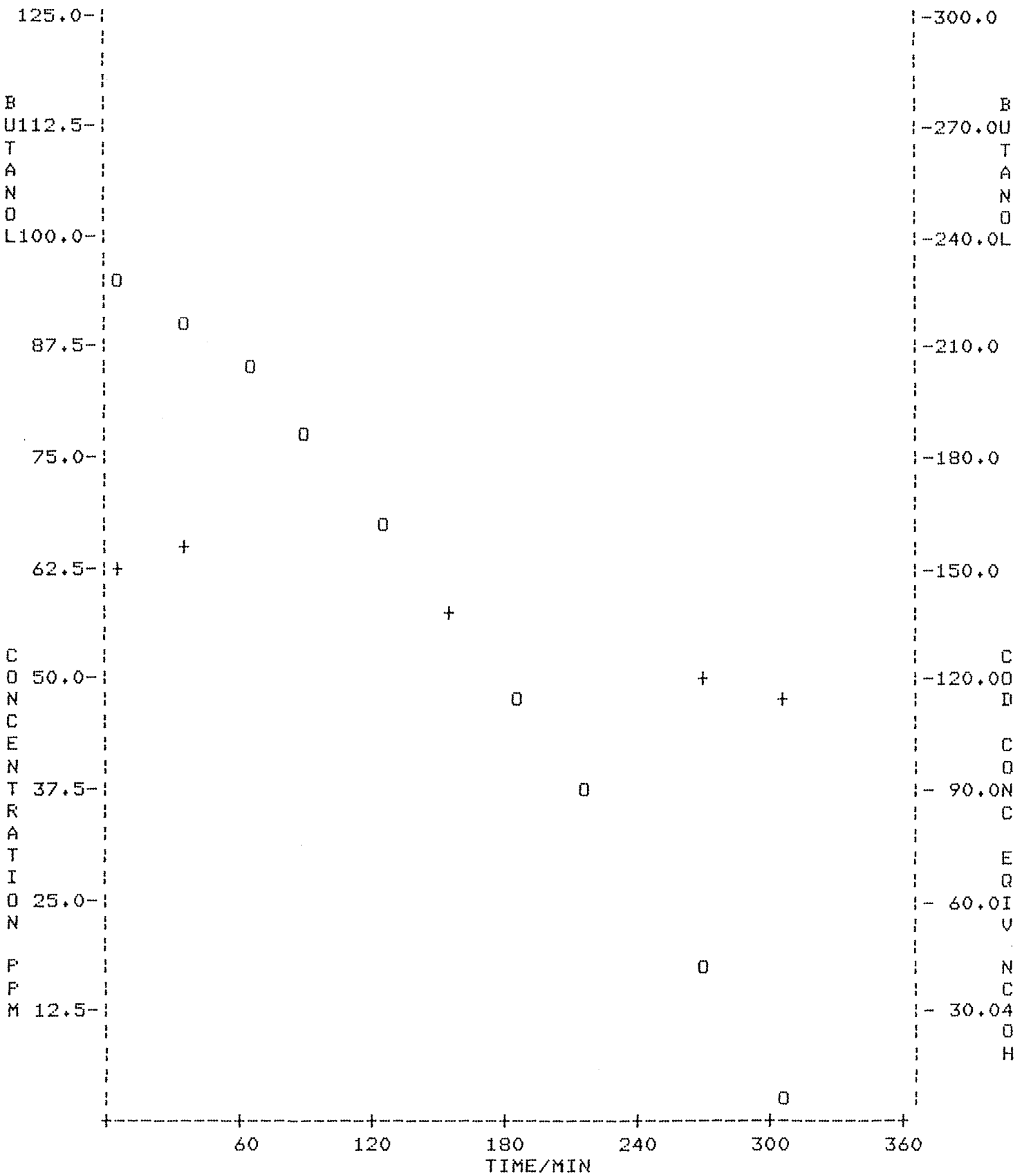


Figure 23
Nitrobenzene Conc. & COD vs Time; Liv/Hyd,RunI

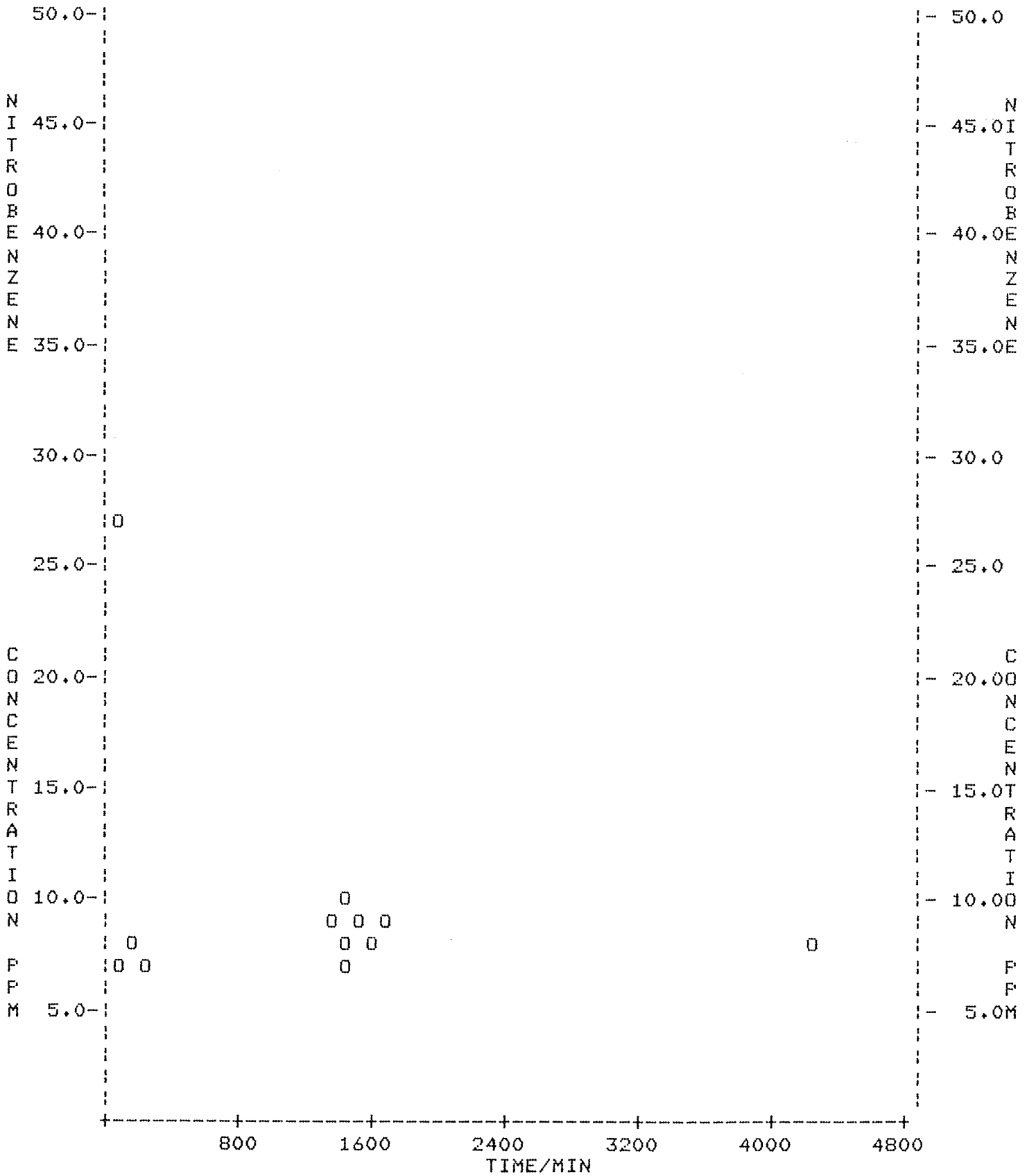


Figure 24
Nitrobenzene Conc. & COD vs Time; Liv/Hyd,RunII

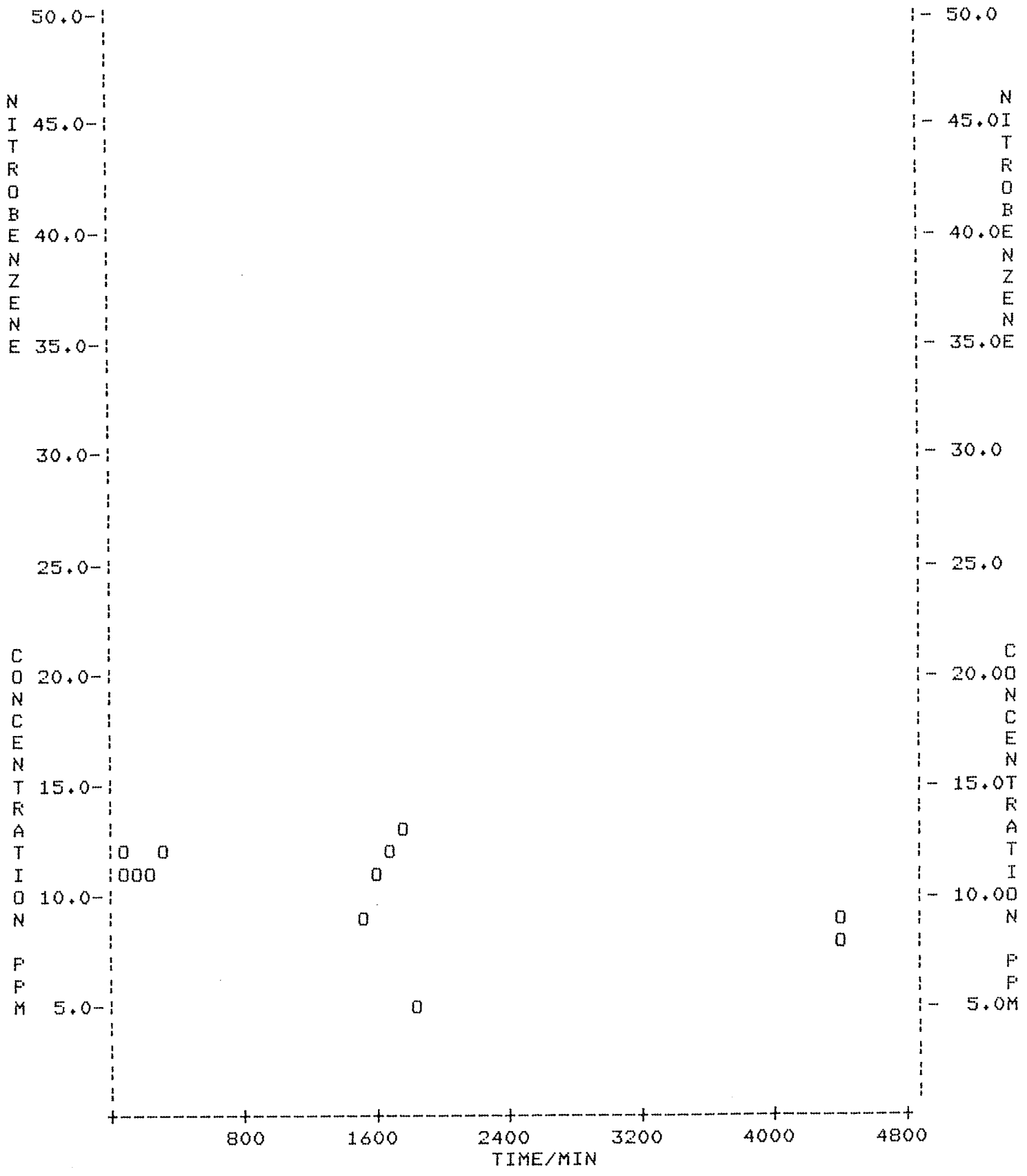


Figure 25
Nitrobenzene Conc. & COD vs Time; Liv/Hyd,RunIII

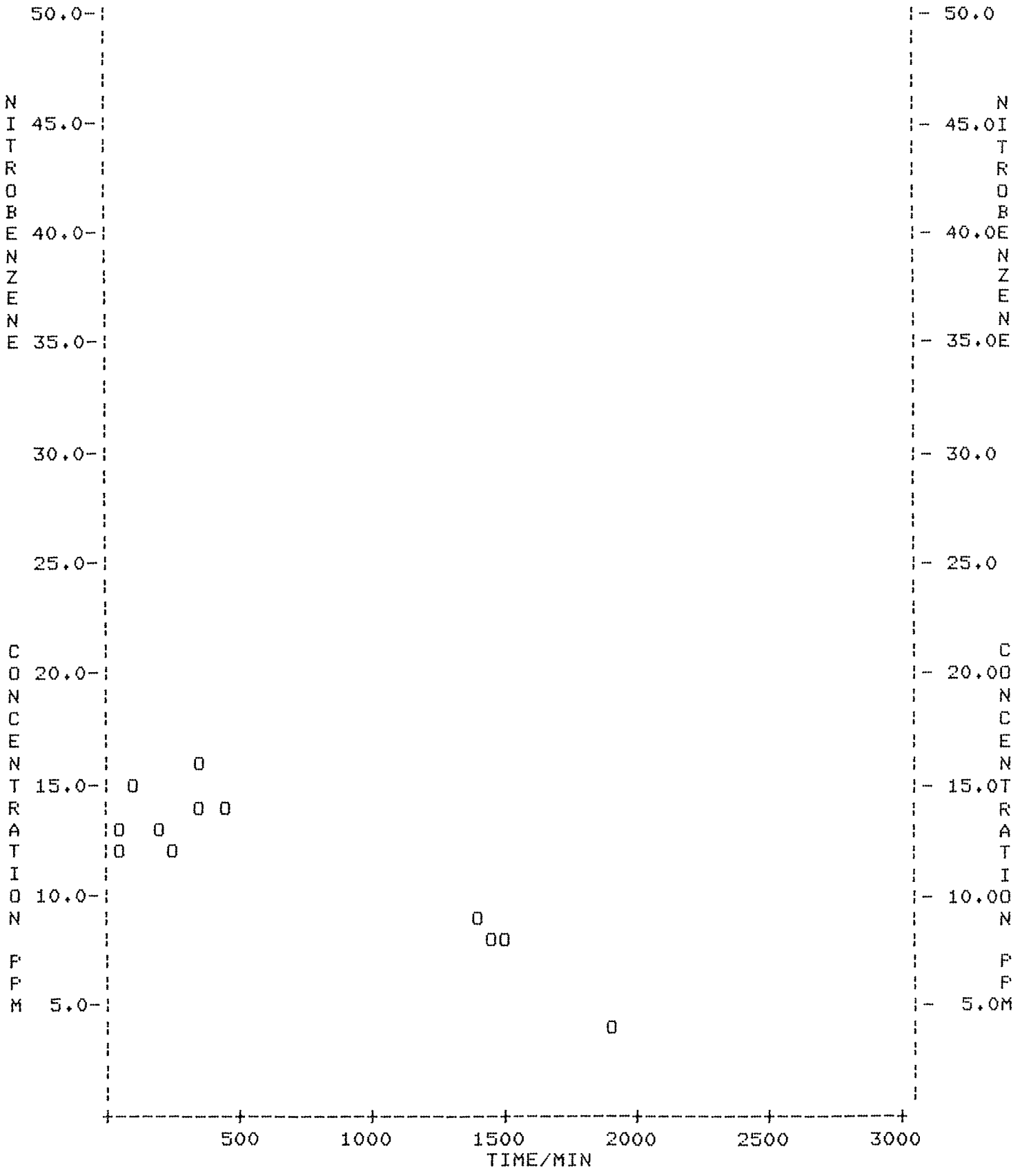


Figure 26
Nitrobenzene Conc. & COD vs Time;Liv/BI-CHEM;RunI

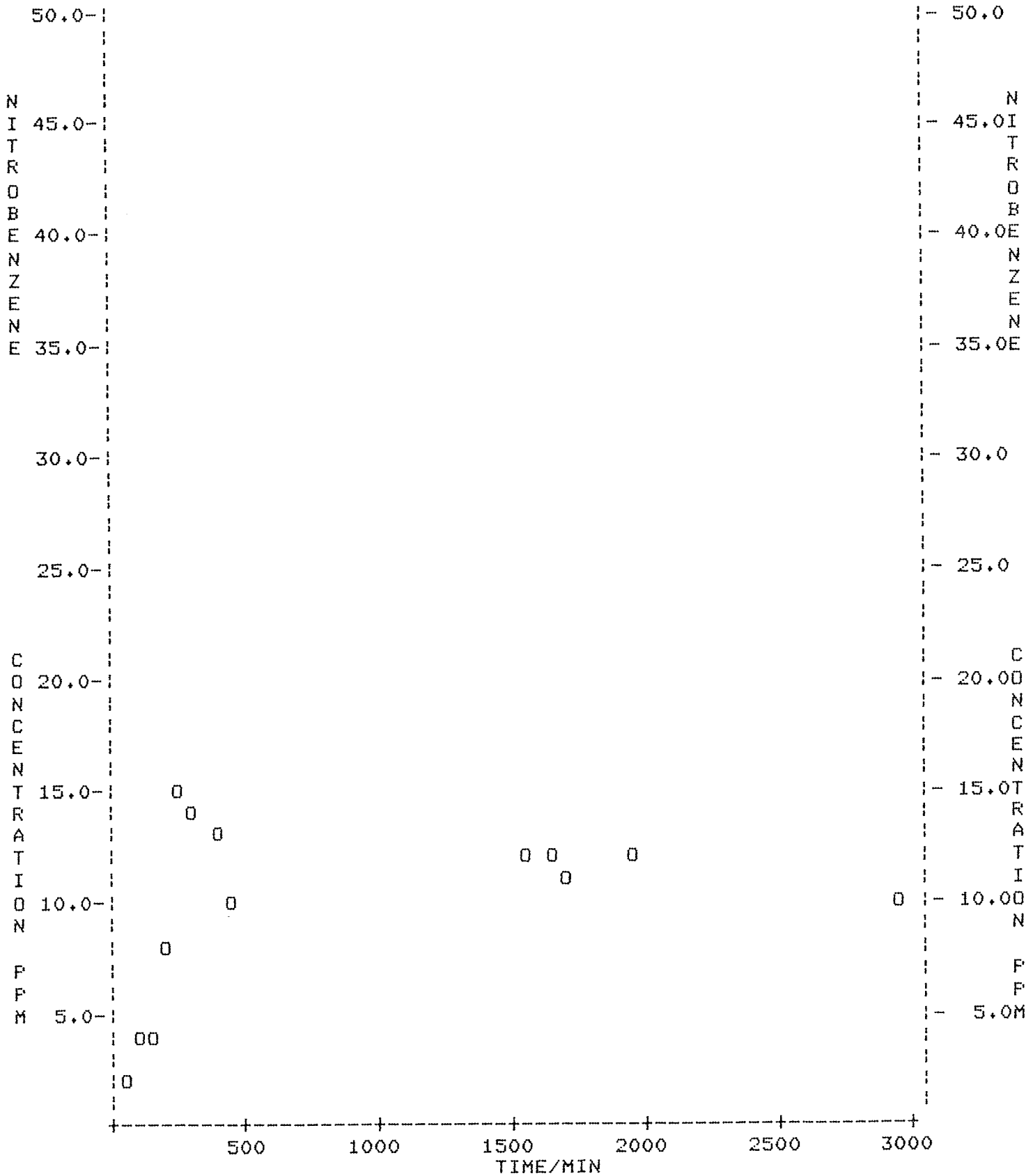


Figure 27
Nitrobenzene Conc. & COD vs Time; Liv/BI-CHEM,RunII

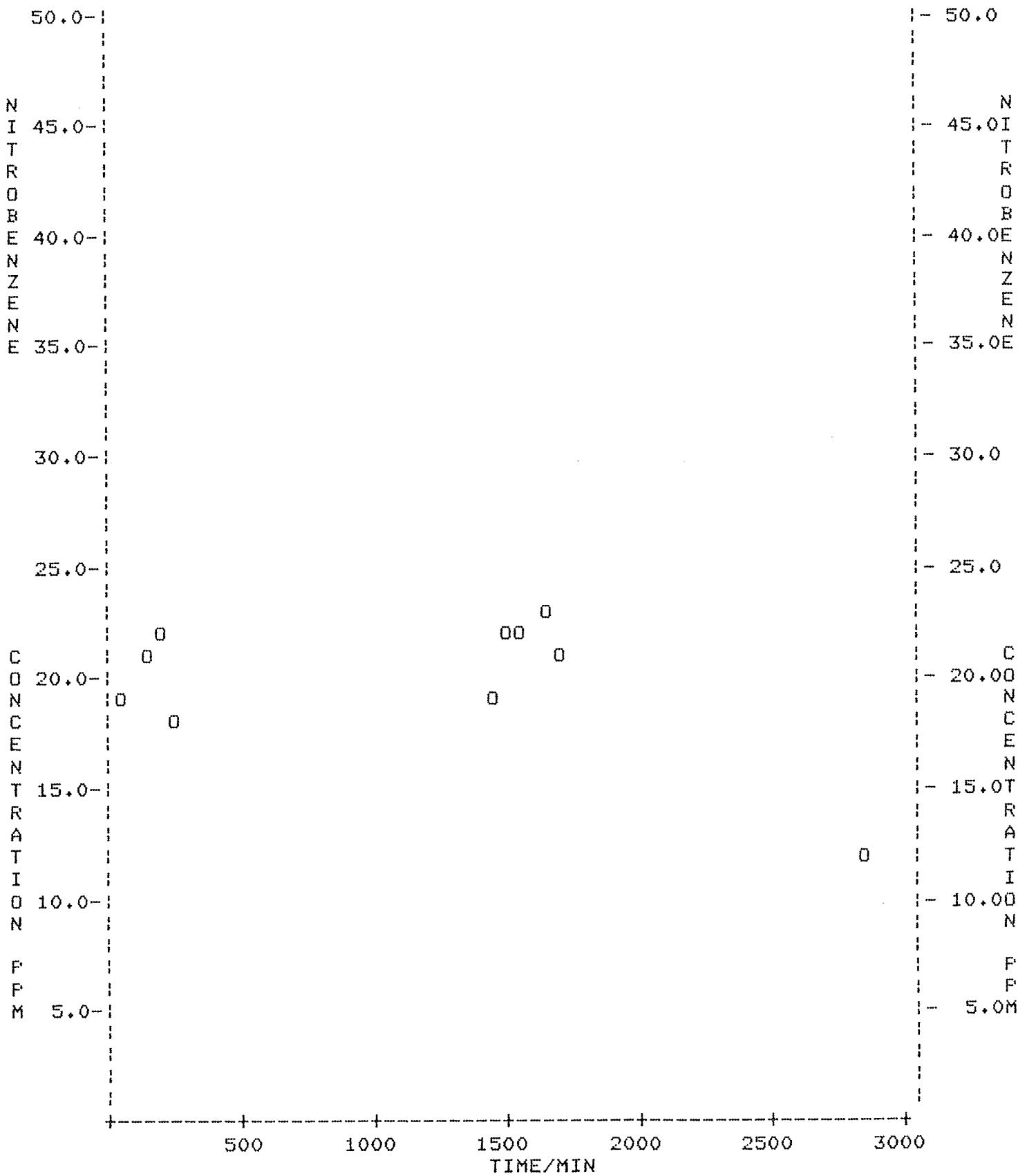


Figure 28
Nitrobenzene Conc. & COD vs Time; Liv/BI-CHEM,RunIII

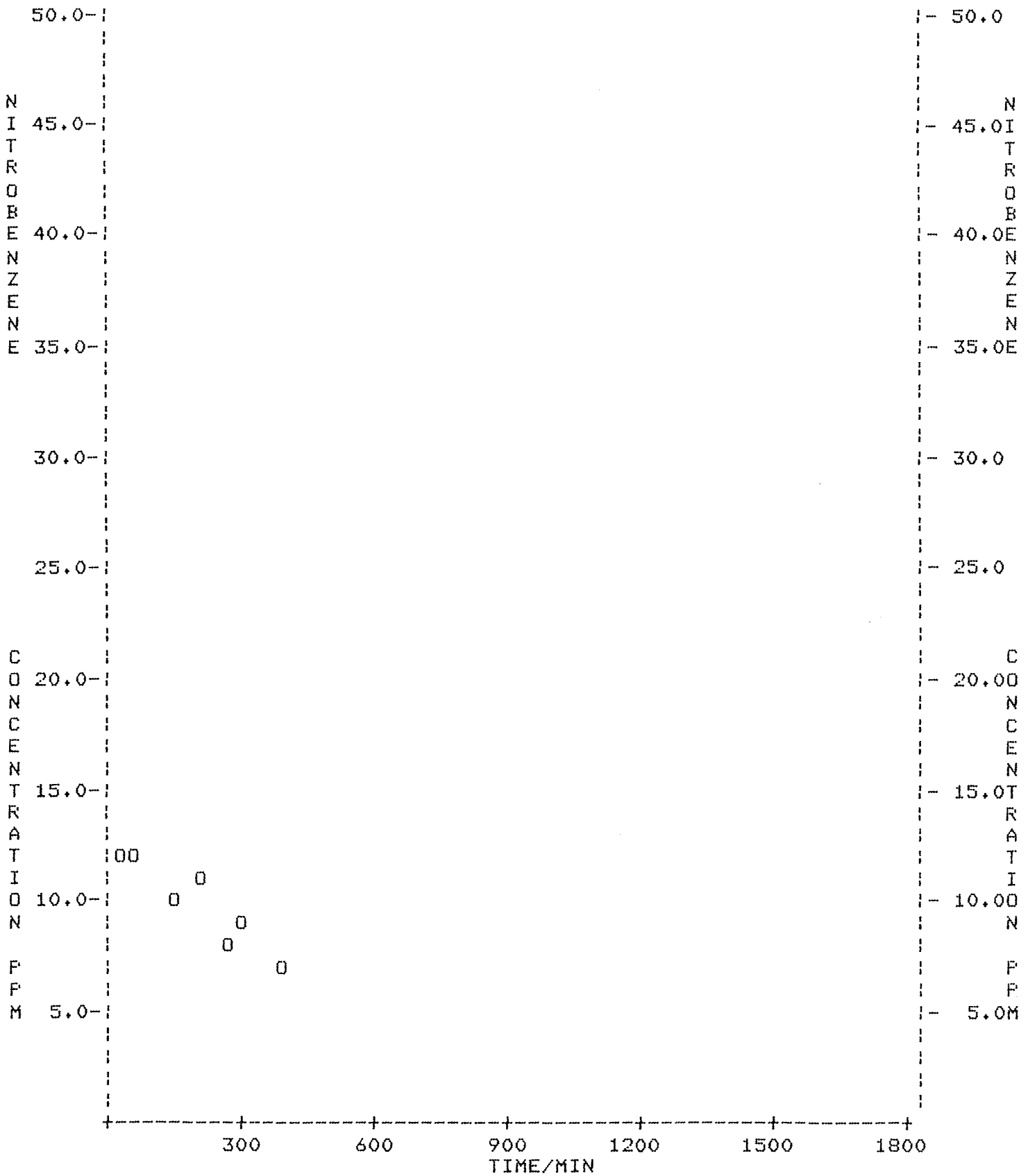


Figure 29
Nitrobenzene Conc. & COD vs Time; Liv.,RunI

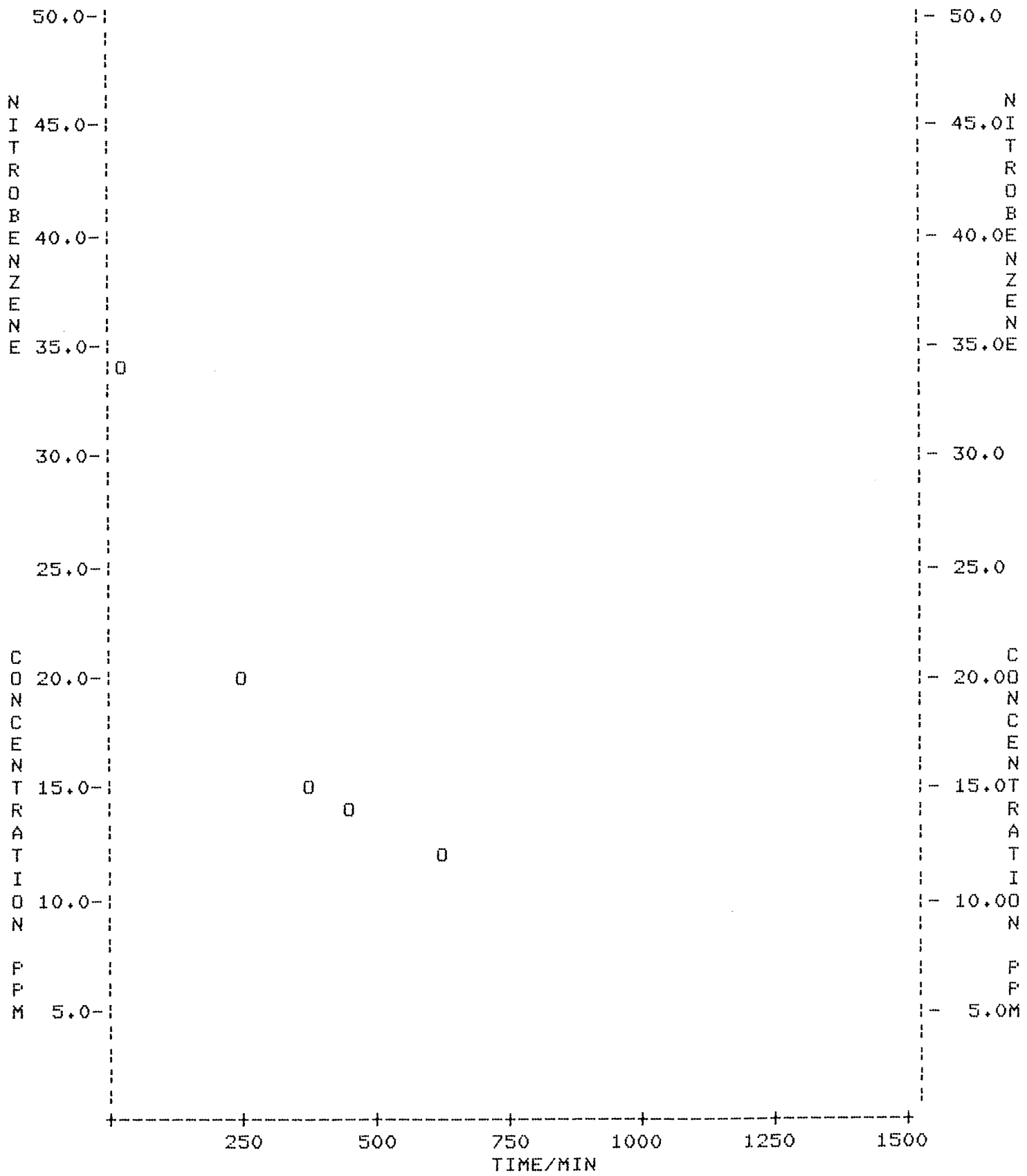
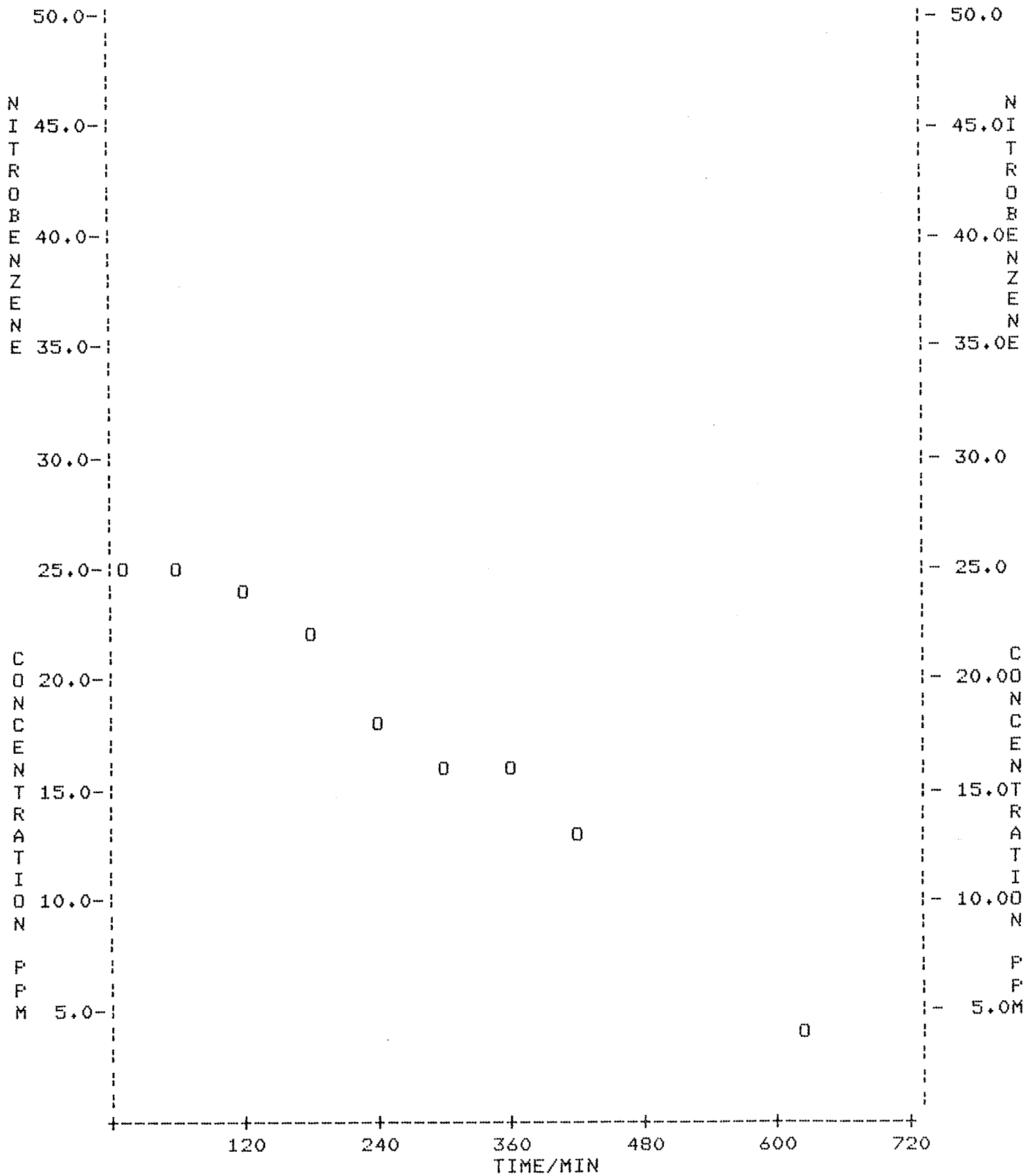


Figure 30
Nitrobenzene Conc. & COD vs Time; Liv.,RunII



Fisure 31
Nitrobenzene Conc. & COD vs Time; Liv/BI-CHEM,RunIA

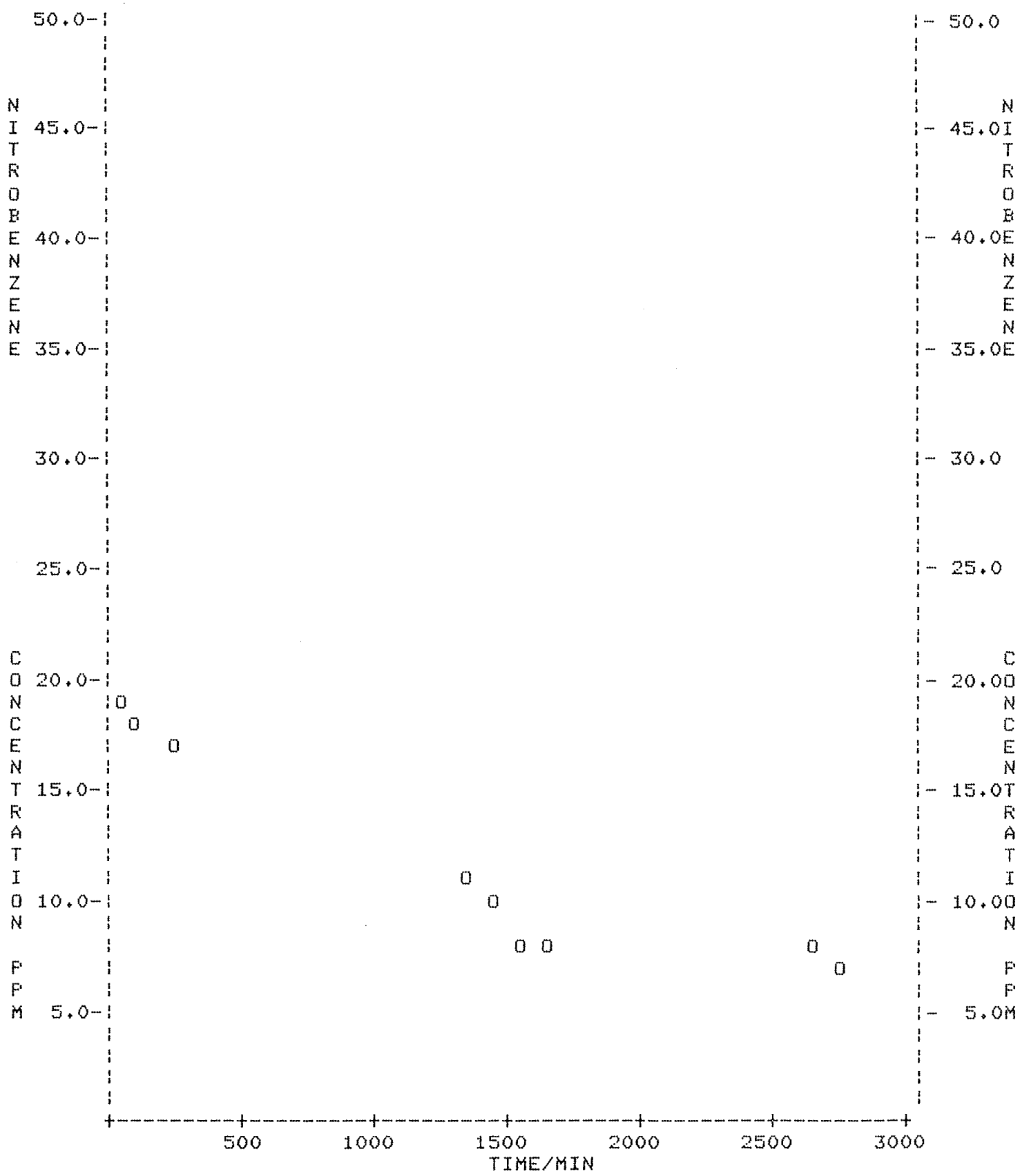


Figure 32
Nitrobenzene Conc. & COD vs Time; Liv/BI-CHEM,RunIIA

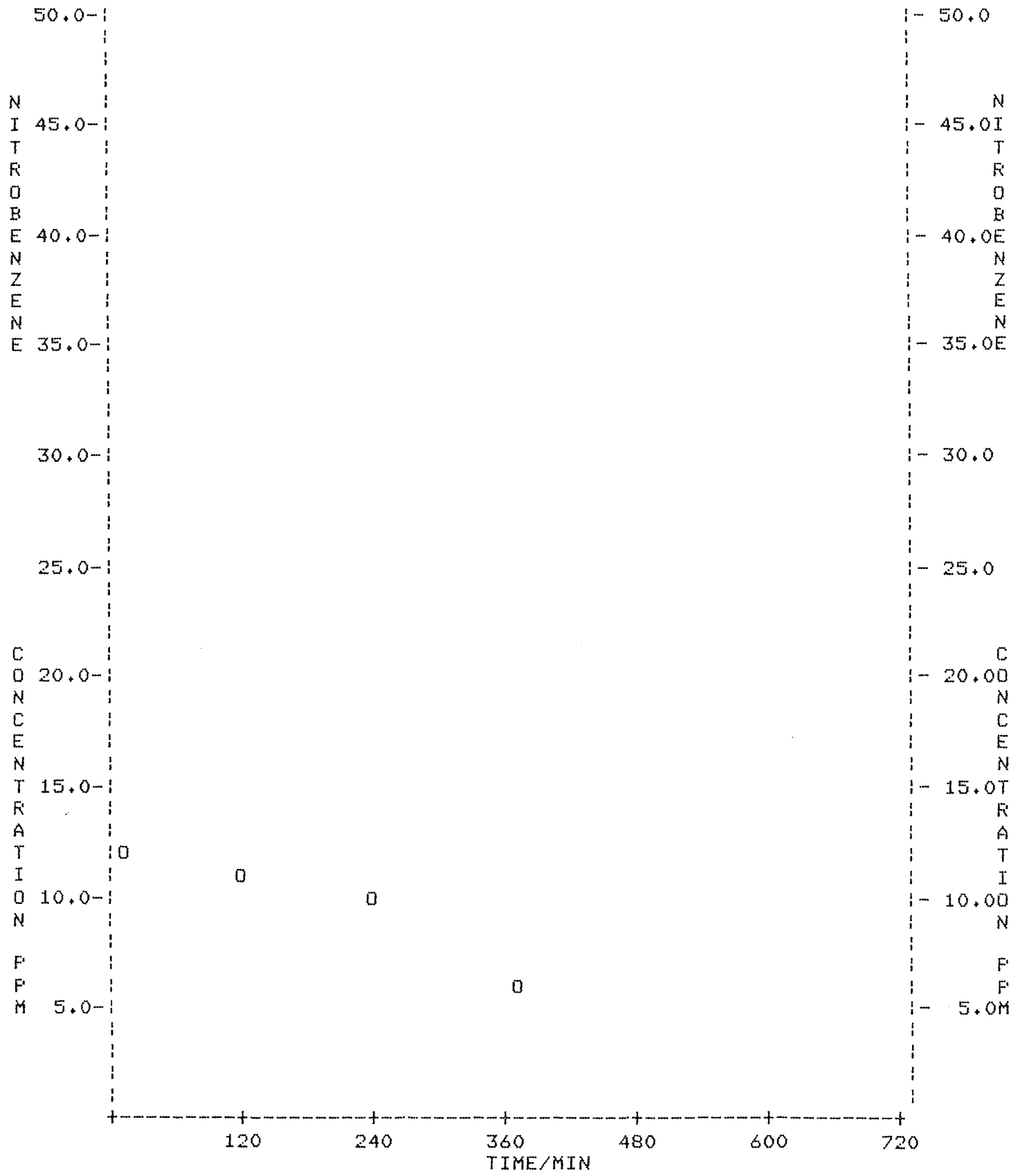


Figure 33
Nitrobenzene Conc. & COD vs Time; Liv/BI-CHEM,RunIIIA

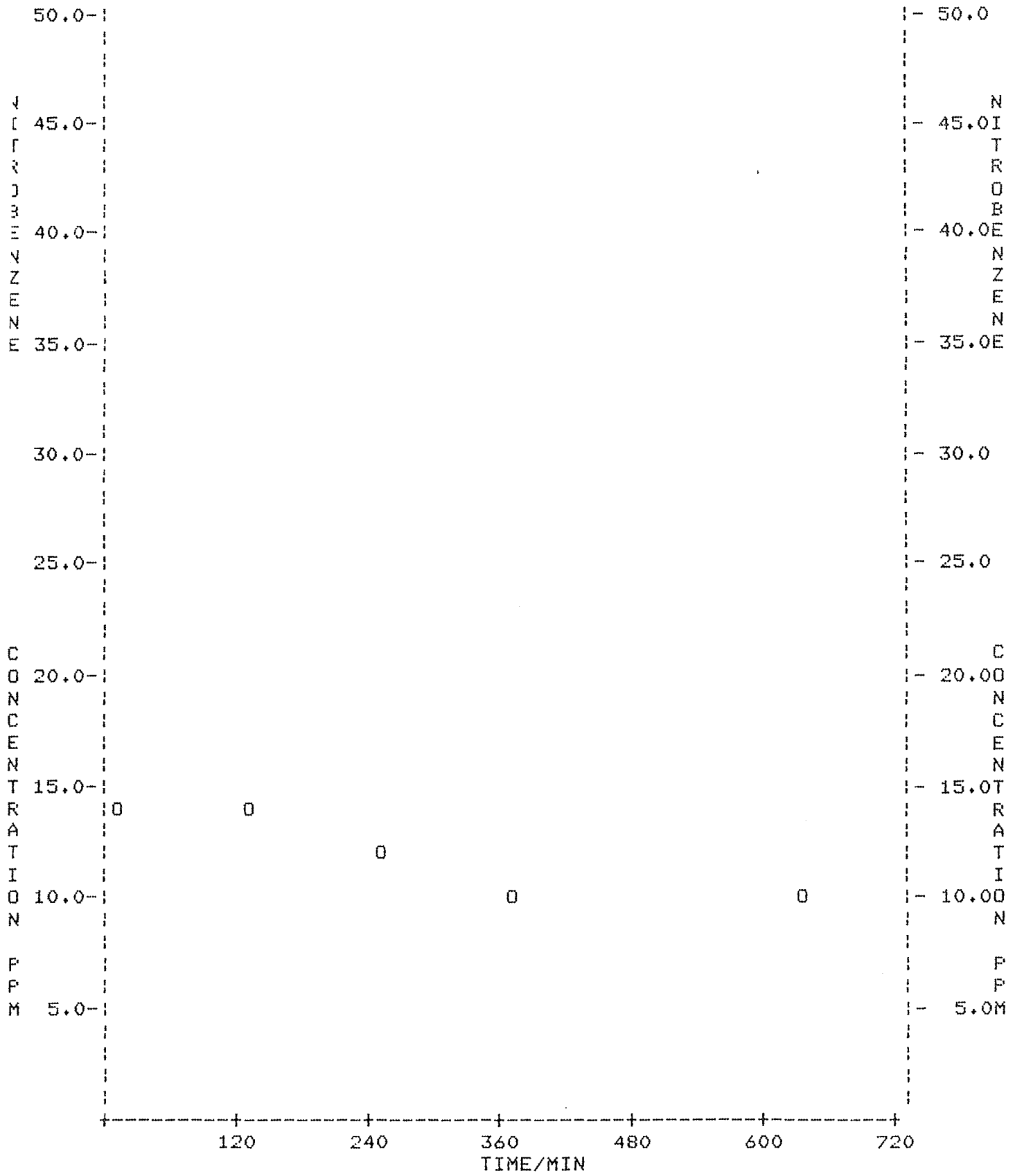


Figure 34
2,4-D Conc. & COD vs Time; Liv.,RunI

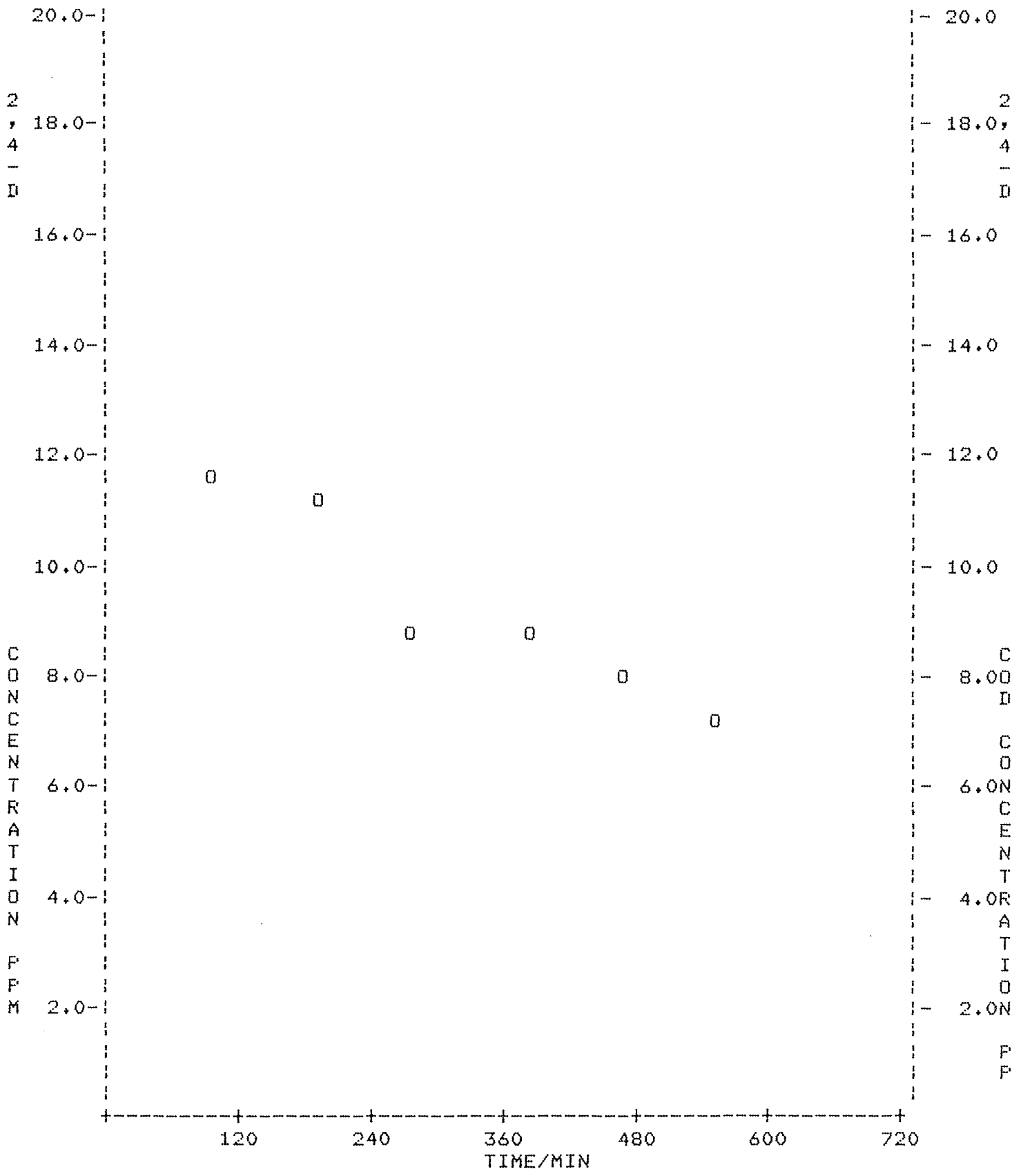


Figure 35
2,4-D Conc. & COD vs Time; Liv.,RunII

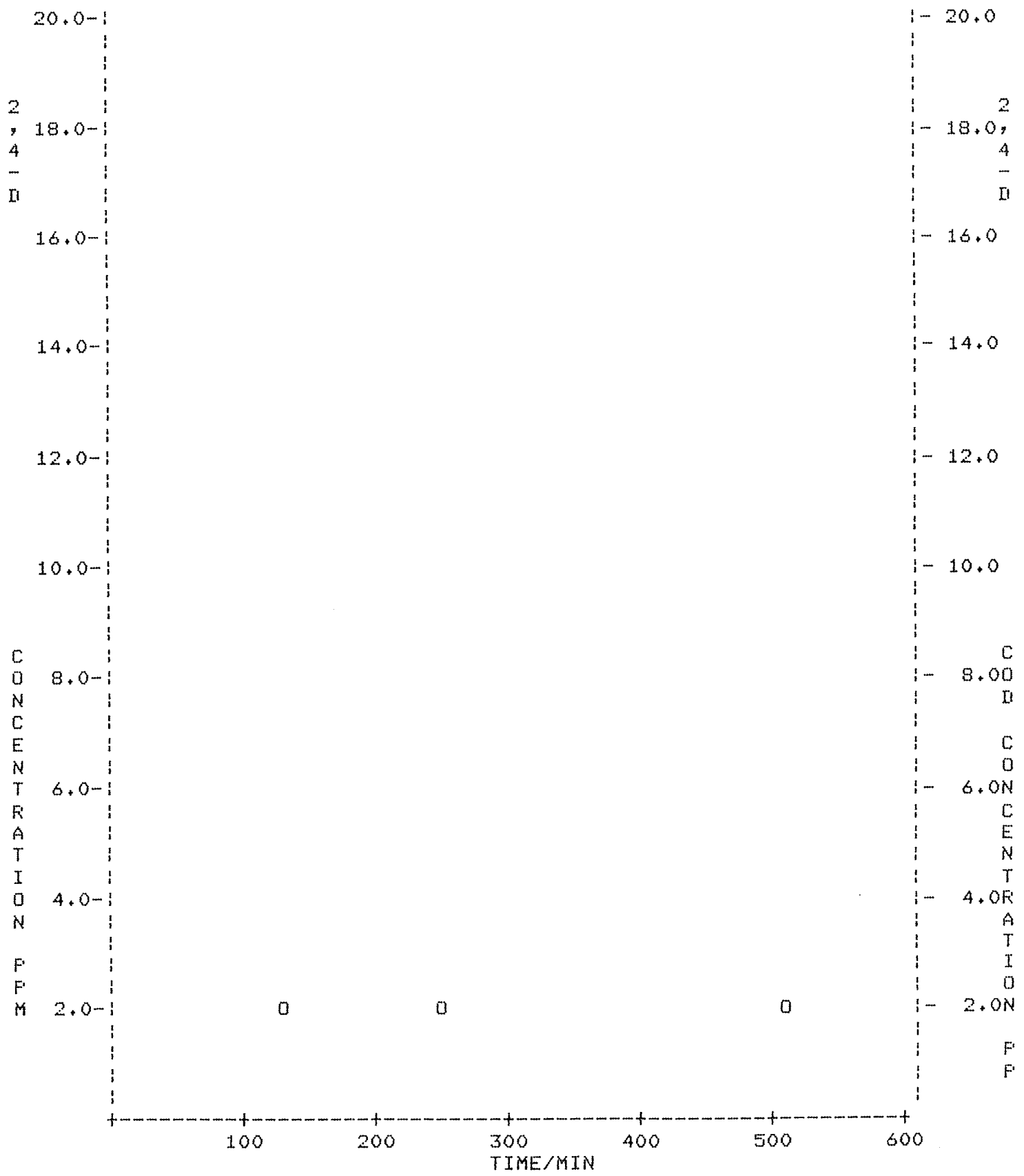


Figure 36
2,4-D Conc. & COD vs Time; Liv/Hyd,RunI

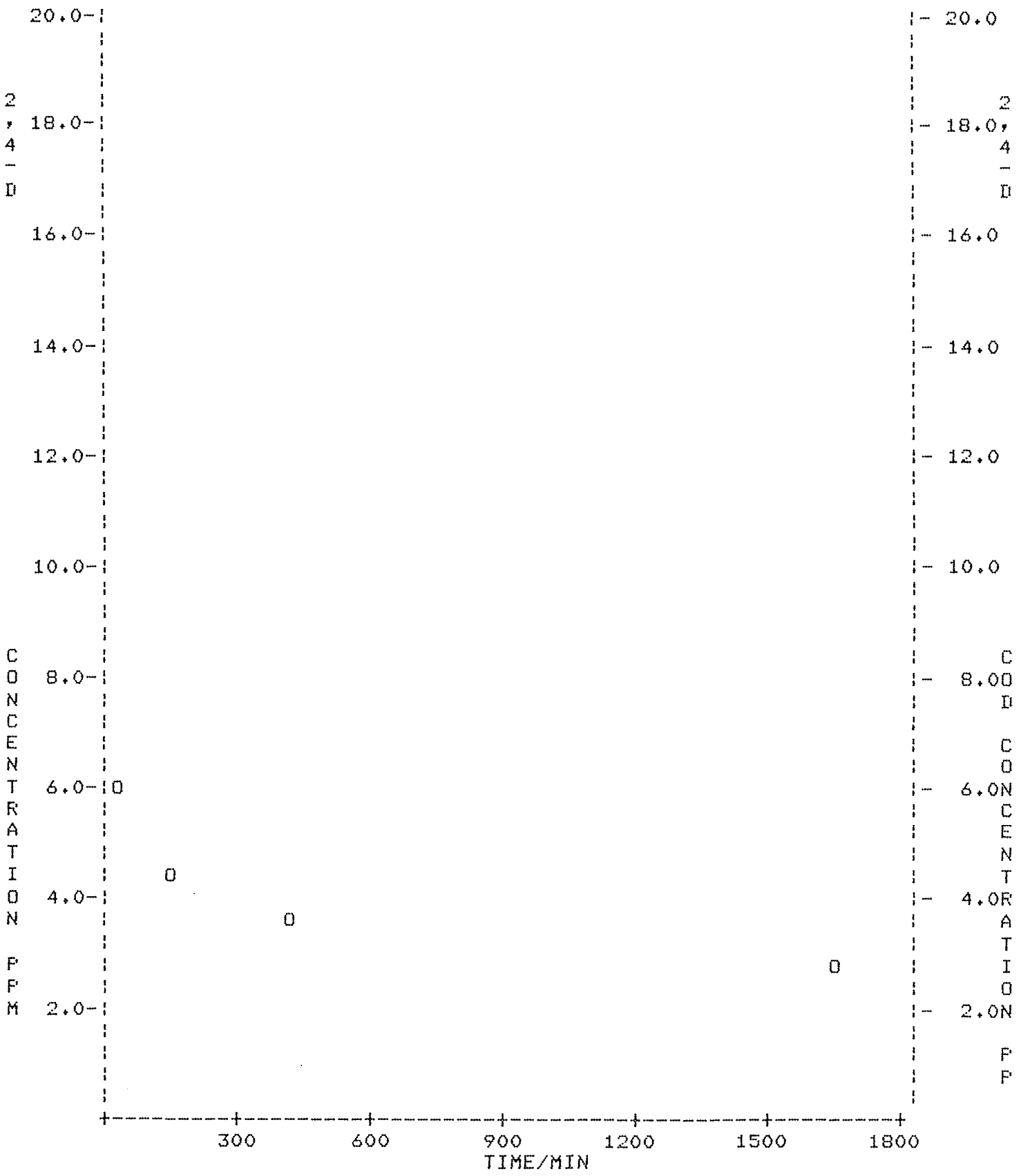


Figure 37
2,4-D Conc. & COD vs Time; Liv/Hyd,RunII

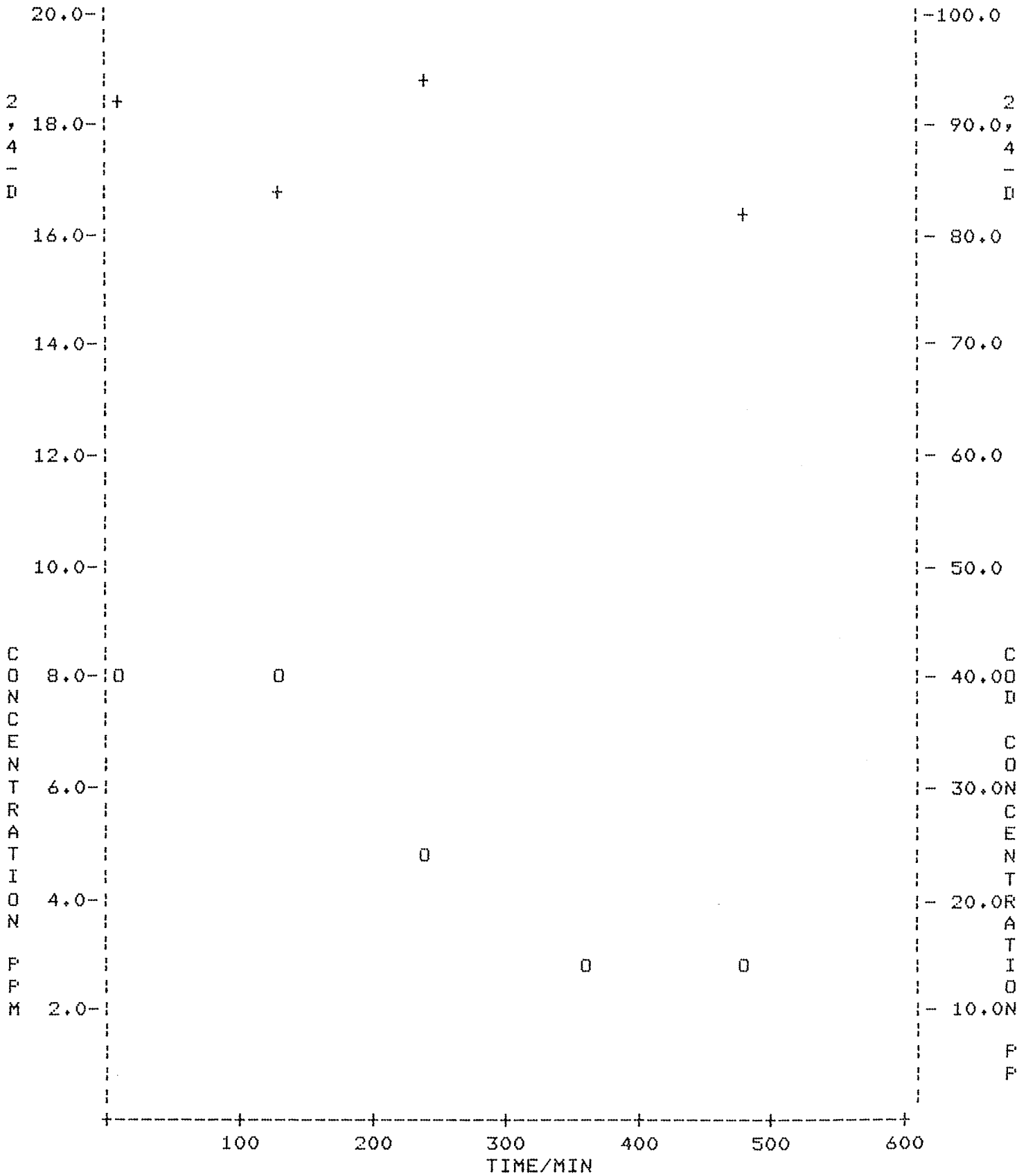
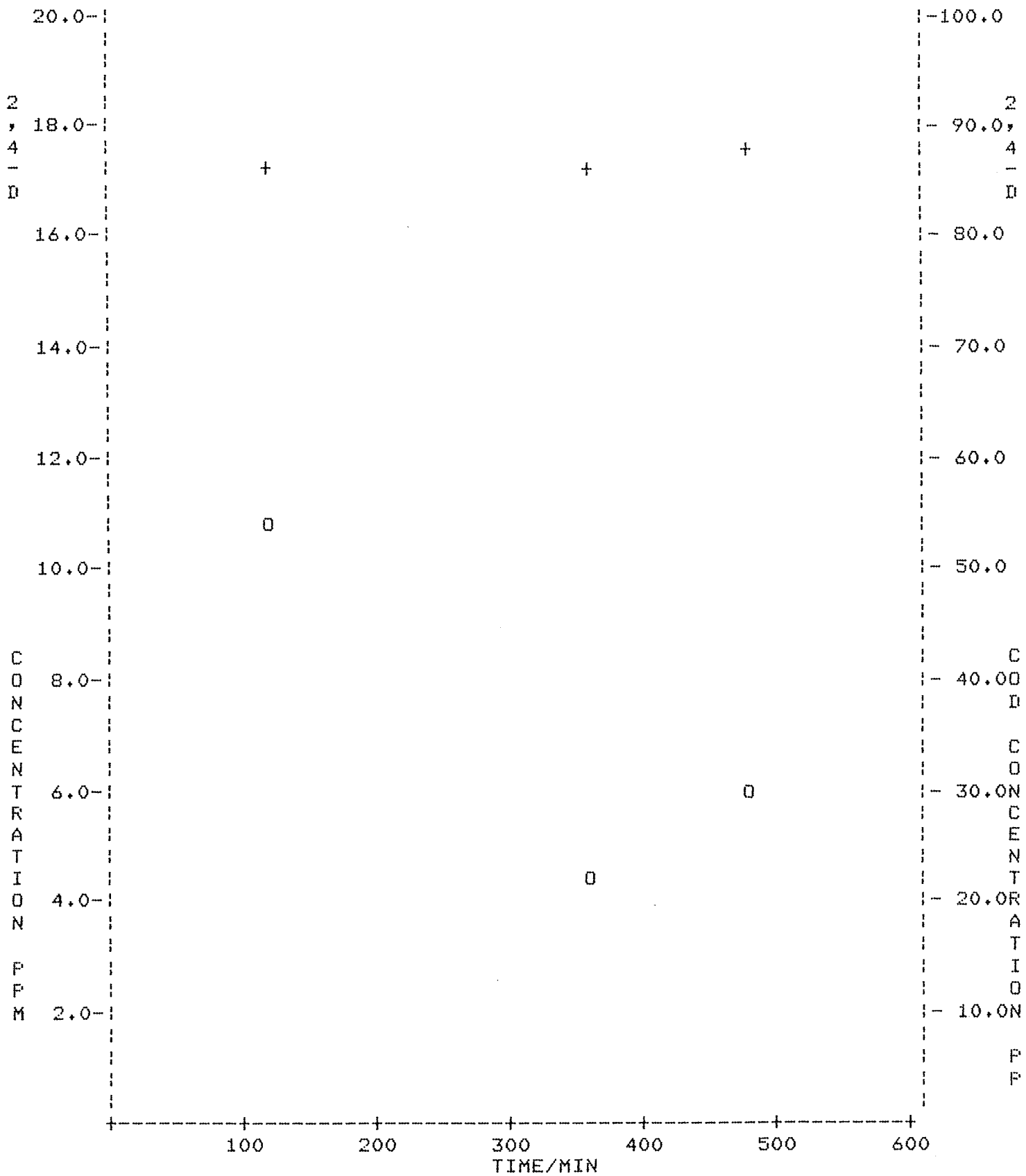
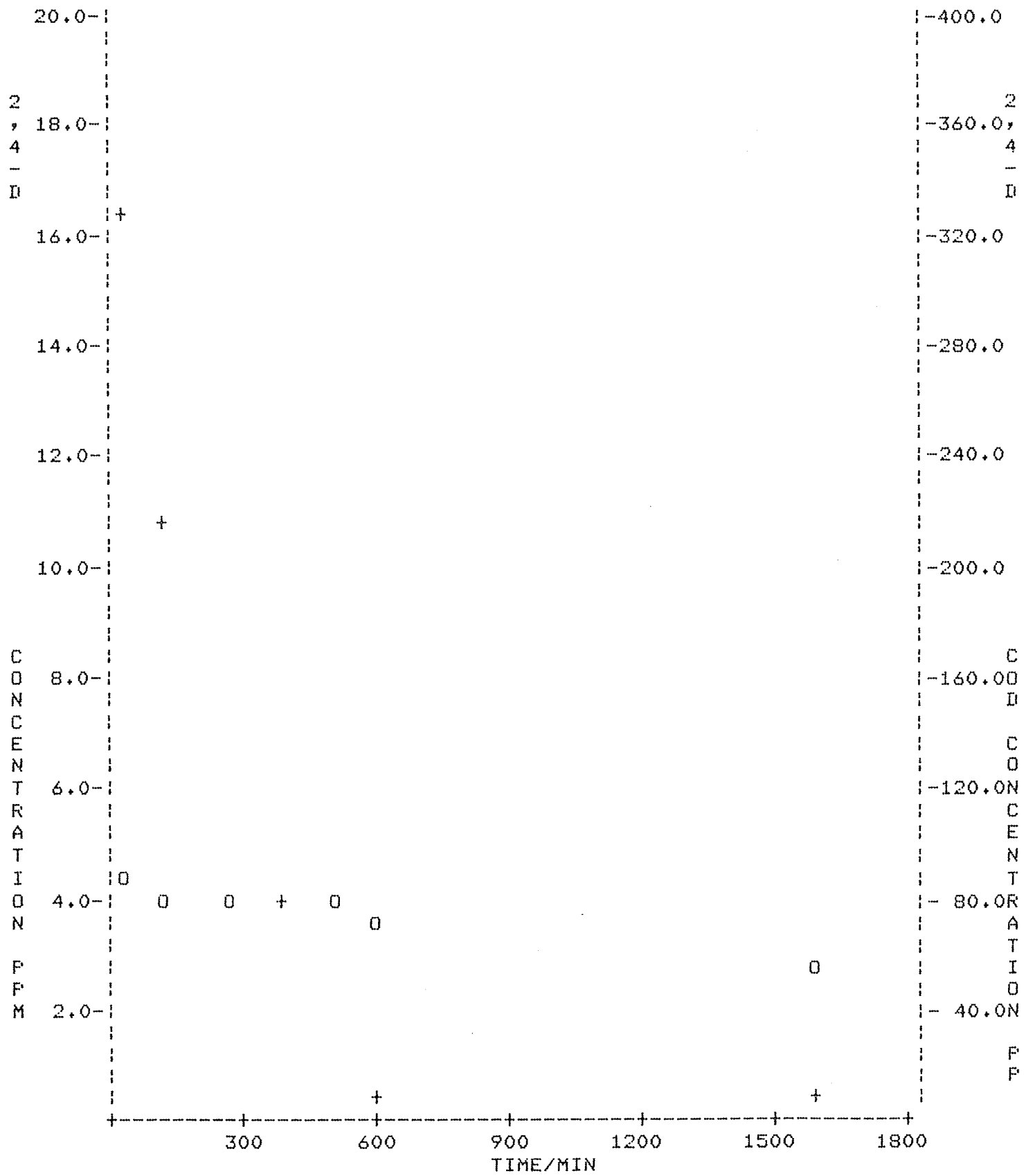


Figure 38
2,4-D Conc. & COD vs Time; Liv/Hyd,RunIII



Fisure 39
2,4-D Conc. & COD vs Time; Liv/BI-CHEM,RunI



Fisure 40
2,4-D Conc. & COD vs Time; Liv/BI-CHEM,RunII

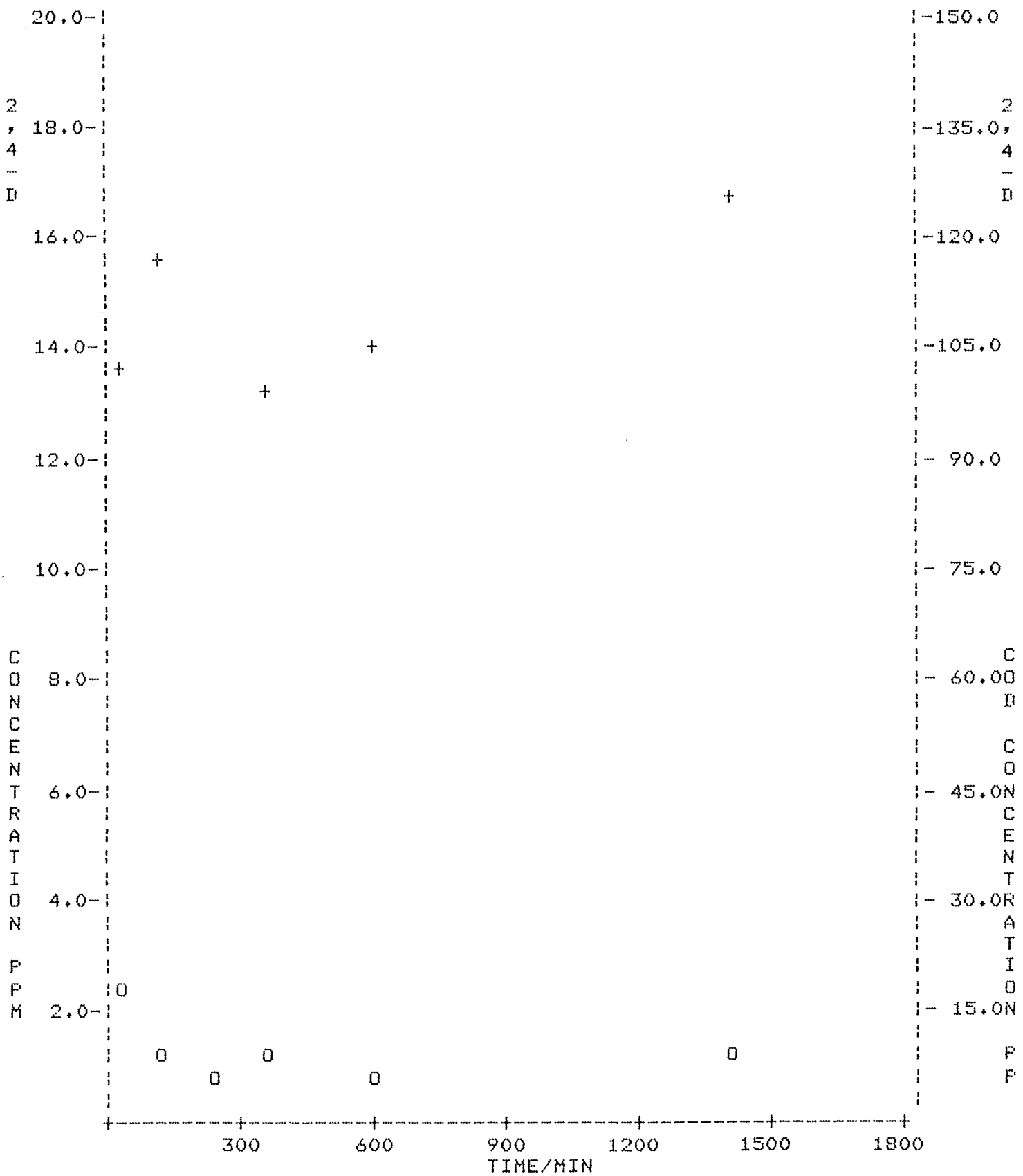


Figure 41
2,4-D Conc. & COD vs Time; Liv/BI-CHEM,RunIII

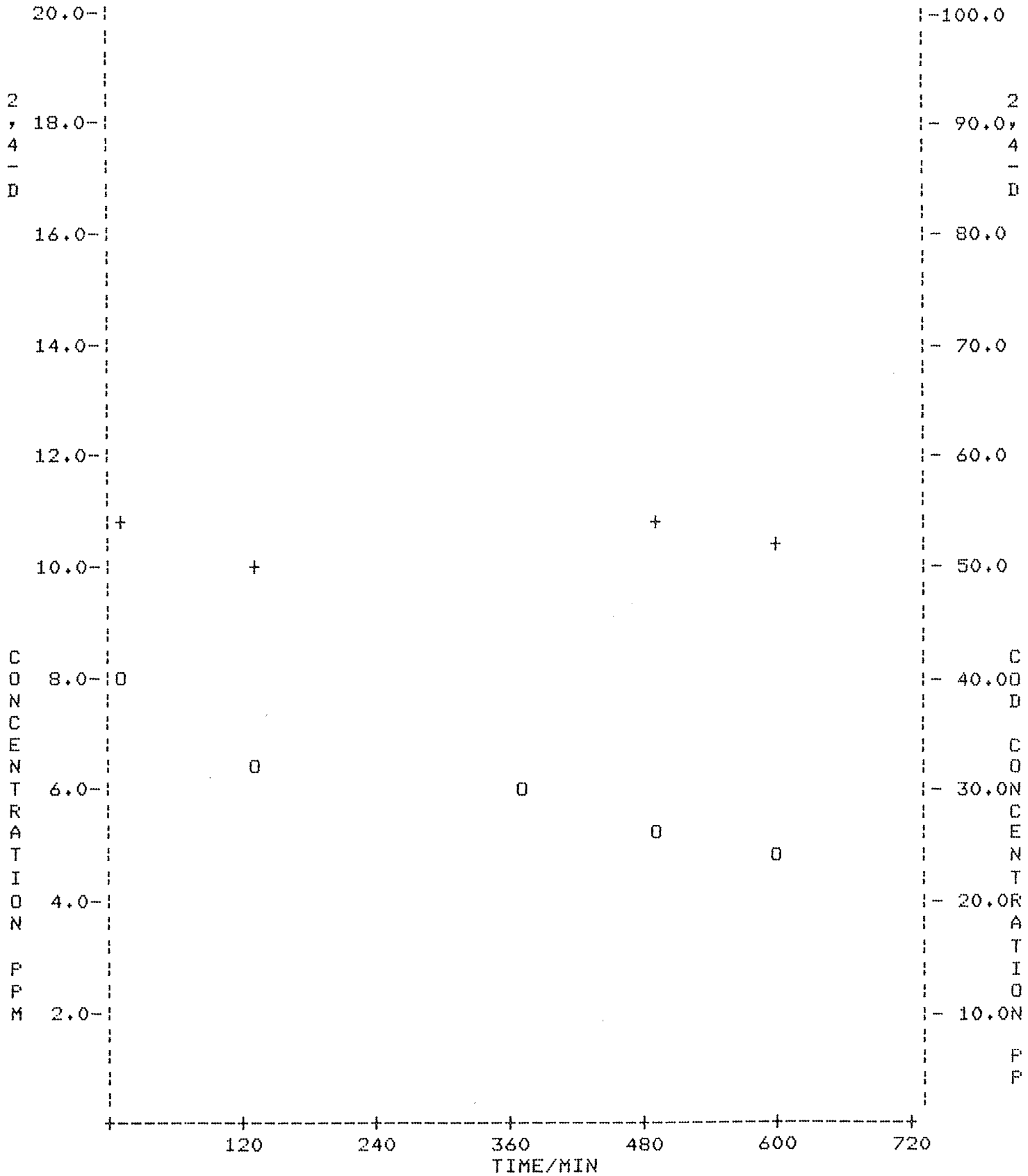


Figure 42
2,4-D Conc. & COD vs Time; Liv/LLMO,RunI

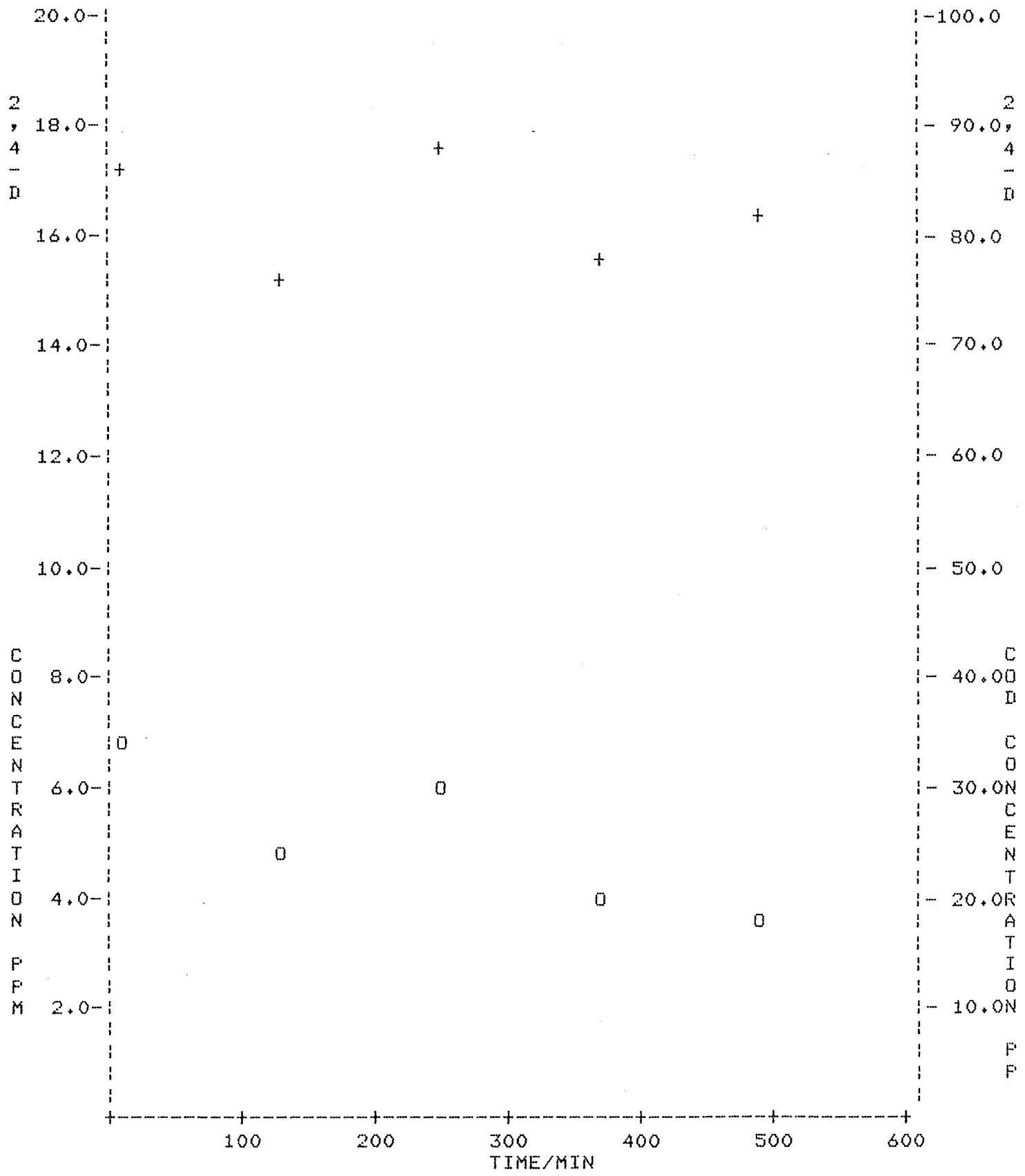


Figure 43
2,4-D Conc. & COD vs Time; Liv/LLMO,RunII

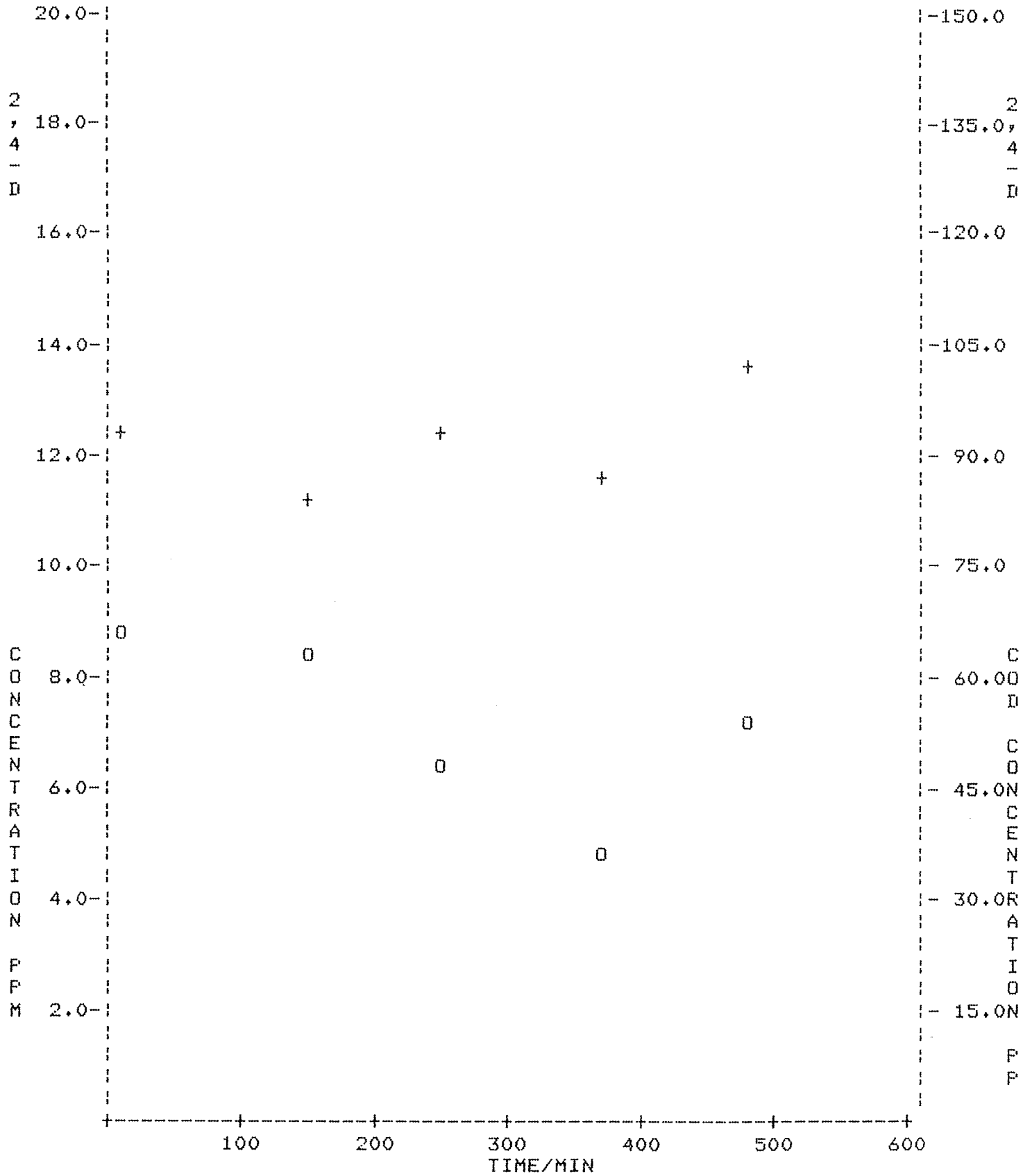


Figure 44
2,4-D Conc. & COD vs Time; Liv/LLMO,RunIII

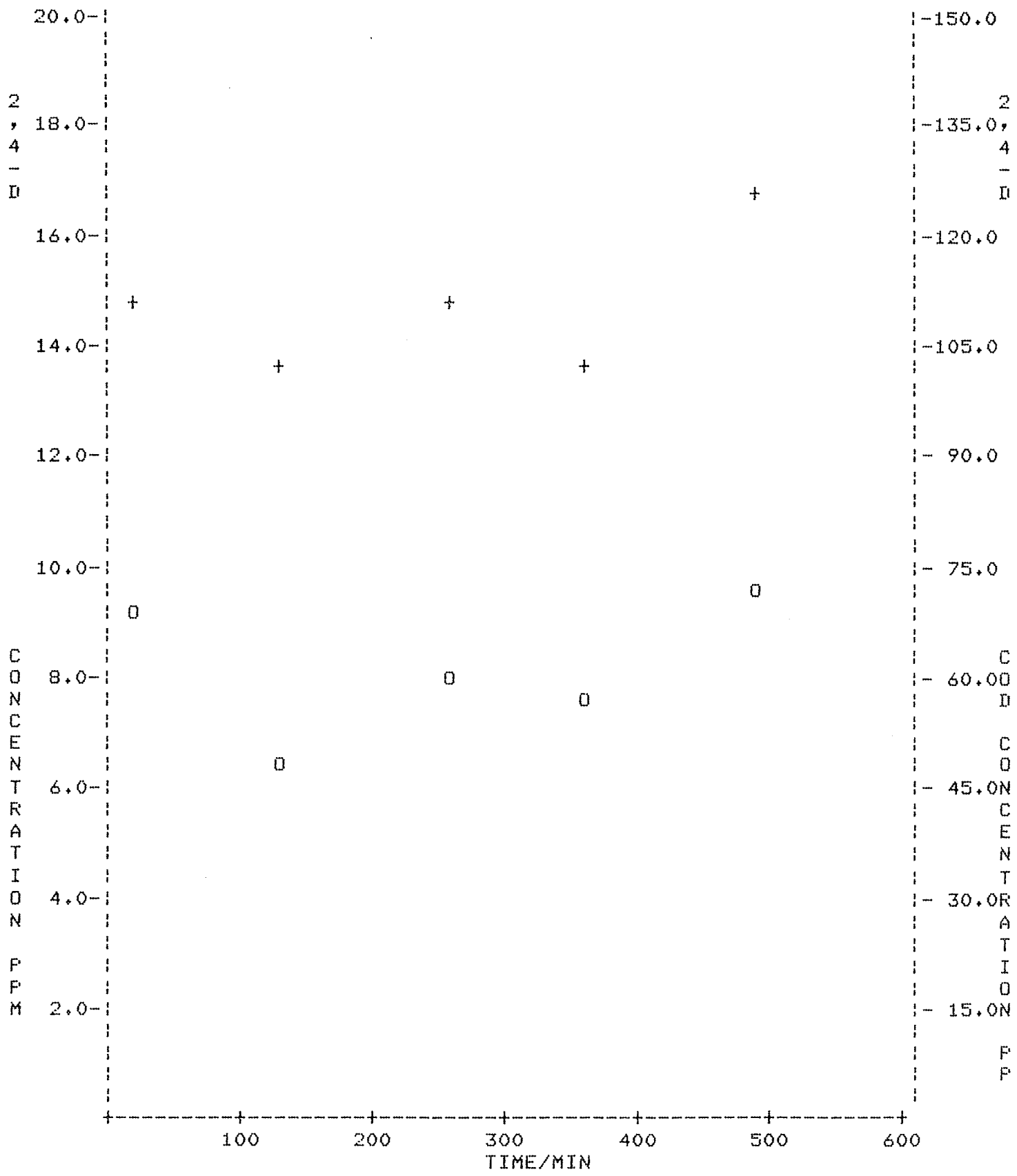


Figure 45

1-Butanol Conc. versus Time; Consecutive Runs

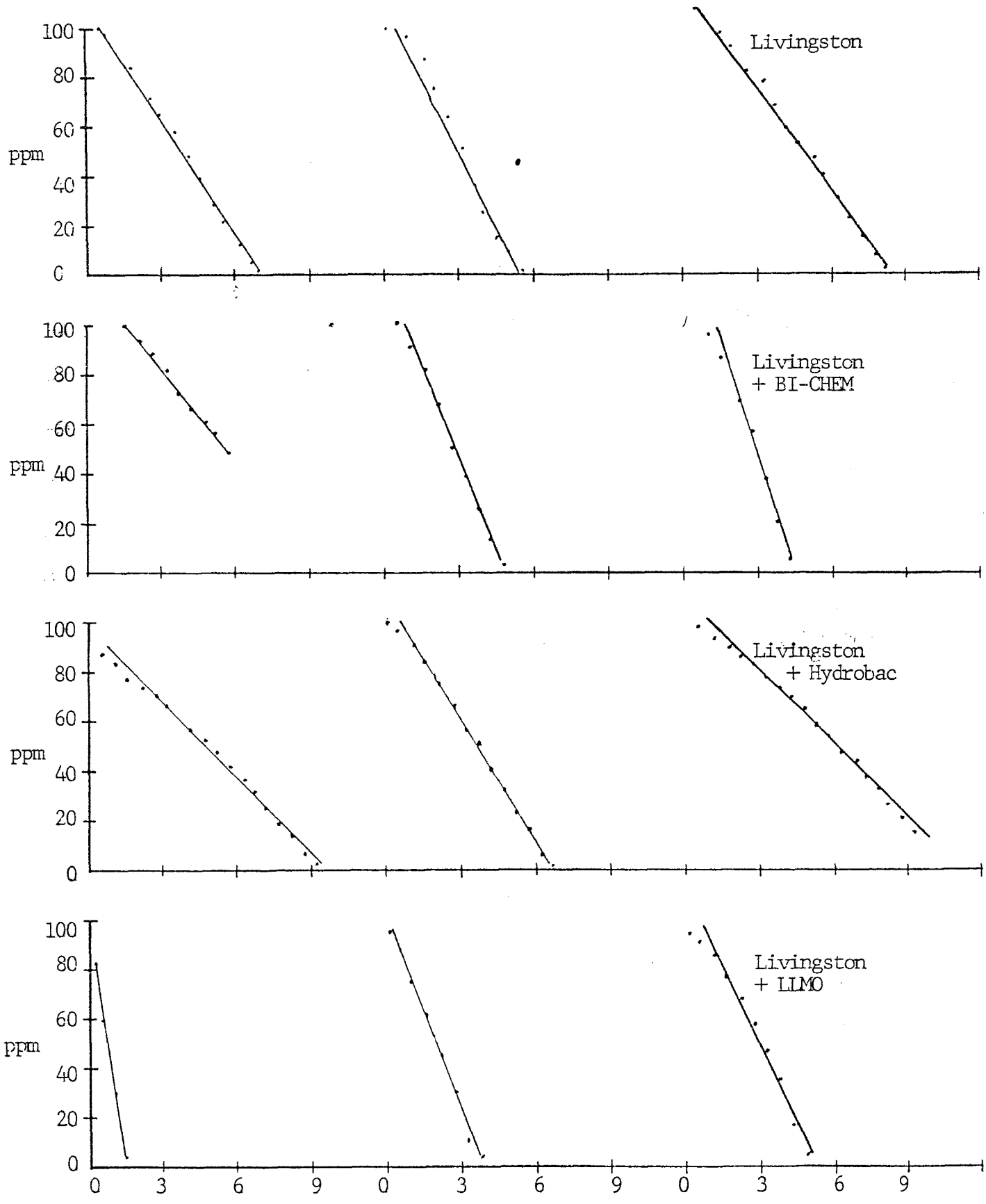
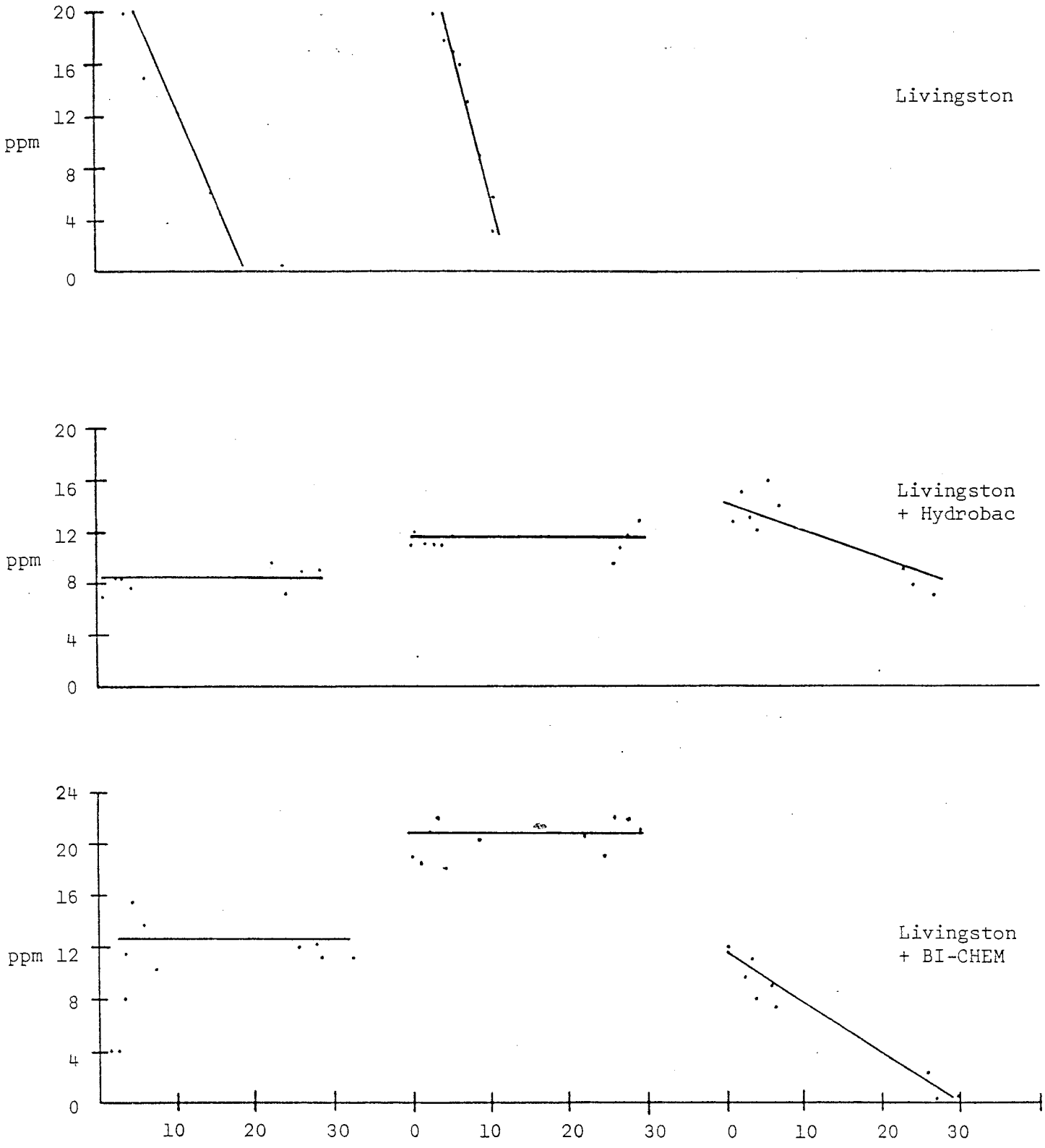


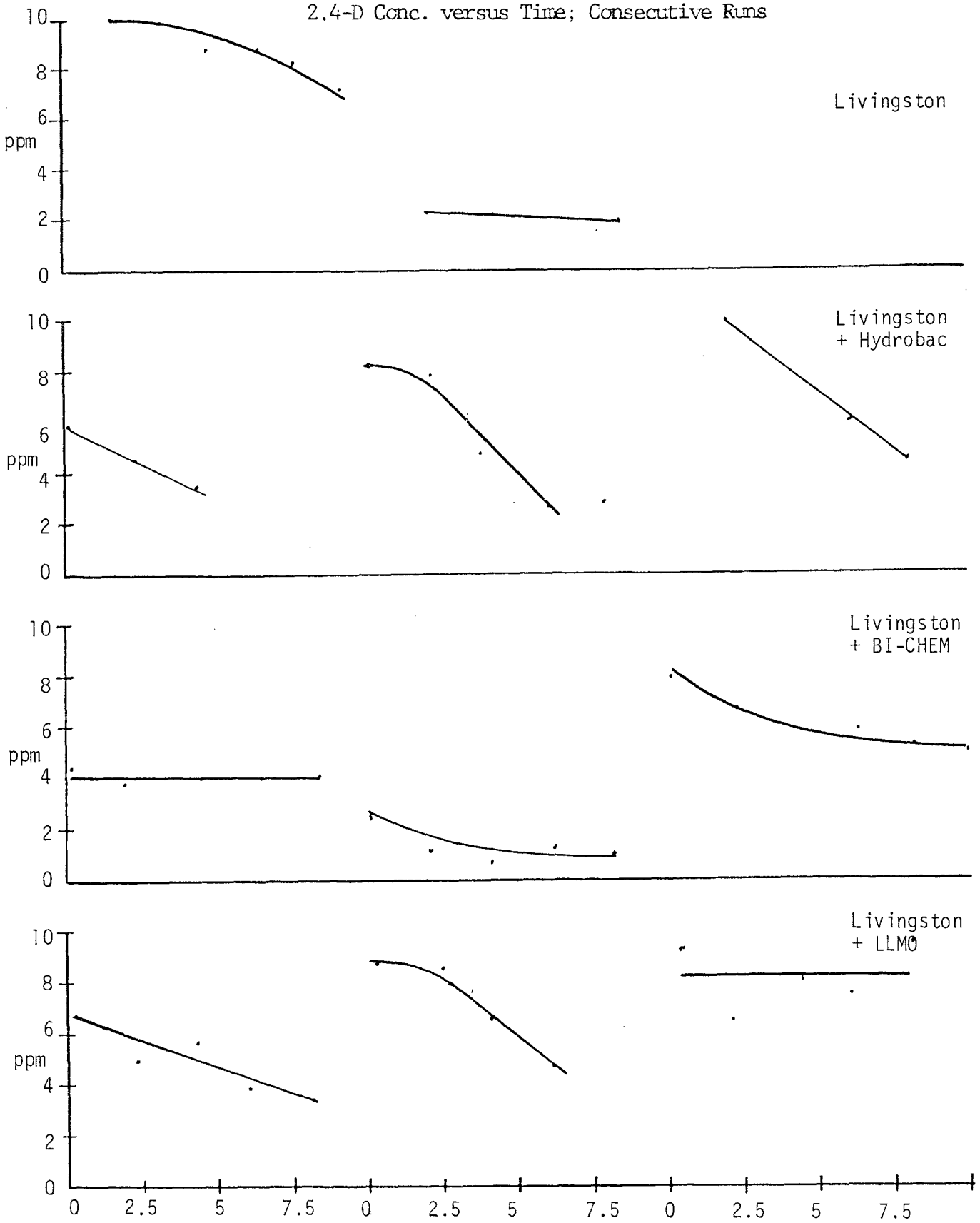
Figure 46
Nitrobenzene Conc. versus Time; Consecutive Runs



NITROBENZENE

Figure 47

2,4-D Conc. versus Time; Consecutive Runs



2,4-D

APPENDIX 1. COMPUTER PROGRAM

```
C
C ***********************************************************
C *                                                         *
C *     Program FIT written by Nisel McMullen 1983-84       *
C *                                                         *
C *     Purpose: To fit sets of kinetic degradation data    *
C *              to the zero order, Monod, and Haldane      *
C *              models, and to plot and summarize the      *
C *              data.                                      *
C *                                                         *
C ***********************************************************
C
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION Y(23),X(23),TITLE(23,20),A(23,7,7),R(23,7),
     %XLABEL(23,20),YLABEL(23,20),RUN(23,15),IPICT(51,65),
     %YCAL(23),TIME(23),PPM(23),COD(23),PH(23),MLSS(23),
     %G(2,3),NH(23),F(23,50),S(50),B(23,7,7),RLABEL(23,20)
     %,CL(23),DELTAY(23)
C       X - INDEPENDENT VARIABLE
C       Y - DEPENDENT VARAIABLE
C      NP - # OF POINTS
C     NOL - # OF LAG POINTS AT START OF RUN
C    TEMP - TEMPERATURE (CELCIUS)
C    CONC - CONCENTRATION OF SUBSTRATE (PPM)
C     COD - COD CONCENTRATION (PPM)
C    DATE - DATE THAT RUN WAS PERFORMED
C   SUBST - SUBSTRATE NAME
C   TITLE - MEDIA NAME
C       A - CONSTANTS OF INTERGRATION
C       R - REGRESSION COEFFICIENT
C    TIME - TIME OF BIOCIDE ADDED TO SAMPLE (MIN)
C      PH - pH (-log10[H+])
C      NH - AMMONIA CONCENTRATION (PPM)
C    MLSS - MIXED LIQUOR SUSPENDED SOLIDS (PPM)
C      CL - CHLORINE CONCENTRATION (PPM)
C
C
      IC=0
1     LC=1
      IC=IC+1
      CALL INPUT(NP,TIME,PPM,COD,PH,NH,MLSS,TITLE,RUN,MAXORD,
     %CL,XS,RS,YS,NOL,XLABEL,YLABEL,RLABEL,IC)
      MODE=-1
      ID=1
      NPT=NP
      DO 11 ISW=1,2
      CALL ZERO(NP,TITLE,RUN,MAXORD,IC,LC,NOL,ISW,
     %TIME,PPM,COD,XS,RS,YS,MODE,XLABEL,RLABEL,YLABEL
     %,A,B,R,DELTAY,YCAL,ERROR)
11    CONTINUE
      NP=NPT
      K1=2
      CALL REPORT(ID,K1,NP,TIME,PPM,COD,PH,NH,MLSS,TITLE,RUN,
     %CL,A,B,R,YCAL,DELTAY,IC,LC,ERROR)
      LC=LC+1
      NP=NPT
      K1=2
      CALL MONOD(TIME,PPM,NP,IC,LC,A,B,R,YCAL,DELTAY,ERROR)
```

```
      CALL REPORT(ID,K1,NP,TIME,PPM,COD,PH,NH,MLSS,TITLE,RUN,
     %CL,A,B,R,YCAL,DELTAY,IC,LC,ERROR)
      LC=LC+1
      K1=3
      CALL HALDAN(TIME,PPM,NP,IC,LC,A,B,R,YCAL,DELTAY,ERROR)
      CALL REPORT(ID,K1,NP,TIME,PPM,COD,PH,NH,MLSS,TITLE,RUN,
     %CL,A,B,R,YCAL,DELTAY,IC,LC,ERROR)
      READ(1,*)MORE
      IF(MORE) 17,17,1
17    CALL RESULT(A,R,TITLE,RUN,IC,LC)
      WRITE(2,9090)
9090   FORMAT('1',5X,'TOP OF PAGE')
      WRITE(2,4010)
4010  FORMAT('0',',page')
      WRITE(2,4017)
4017  FORMAT('0',',asis')
       STOP
       END
```

```
      SUBROUTINE INPUT(NP,TIME,PPM,COD,PH,NH,MLSS,TITLE,RUN,
C
C ***************************************************************
C *                                                             *
C *     Subroutine INPUT                                        *
C *                                                             *
C *     Purpose: To read into the program the data from         *
C *              one run, along with the scales for the         *
C *              the plot and the number of lag points          *
C *              at the start of each run.                      *
C *                                                             *
C ***************************************************************
C
     %MAXORD,CL,XS,RS,YS,NOL,XLABEL,YLABEL,RLABEL,IC)
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION TITLE(23,20),TIME(23),PPM(23),RUN(23,15),
     %XLABEL(23,20),YLABEL(23,20),COD(23),PH(23),MLSS(23),
     %CL(23),NH(23),RLABEL(23,20)
      IF(IC.GT.1) GO TO 9093
      READ(1,9099)(XLABEL(IC,I),I=1,20)
9099  FORMAT(23A1)
      WRITE(2,9098)(XLABEL(IC,I),I=1,20)
9098  FORMAT('0',5X,20A1)
      READ(1,9095)(RLABEL(IC,I),I=1,20)
9095  FORMAT(23A1)
      WRITE(2,9094)(RLABEL(IC,I),I=1,20)
9094  FORMAT('0',5X,20A1)
      READ(1,9097)(YLABEL(IC,I),I=1,20)
9097  FORMAT(23A1)
      WRITE(2,9096)(YLABEL(IC,I),I=1,20)
9096  FORMAT('0',5X,20A1)
9093  READ(1,9002)(SUBST(IC,I),I=1,25)
9002  FORMAT(25A1)
      WRITE(2,9018)(SUBST(IC,I),I=1,25)
9018  FORMAT('0',5X,25A1)
      READ(1,9004)(TITLE(IC,I),I=1,20)
9004  FORMAT(23A1)
      WRITE(2,9005)(TITLE(IC,I),I=1,20)
9005  FORMAT('0',5X,20A1)
      READ(1,9003)(CONC(IC,I),I=1,8)
9003  FORMAT(8A1)
      WRITE(2,9012)(CONC(IC,I),I=1,8)
9012  FORMAT('0',5X,8A1)
      READ(1,9013)(DATE(IC,I),I=1,8)
9013  FORMAT(8A1)
      WRITE(2,9014)(DATE(IC,I),I=1,8)
9014  FORMAT('0',5X,8A1)
      READ(1,9007)(RUN(IC,I),I=1,15)
9007  FORMAT(15A1)
      WRITE(2,9008)(RUN(IC,I),I=1,15)
9008  FORMAT('0',5X,15A1)
      READ(1,9016)(TEMP(IC,I),I=1,8)
9016  FORMAT(8A1)
      WRITE(2,9017)(TEMP(IC,I),I=1,8)
9017  FORMAT('0',5X,8A1)
      READ(1,*)NP
      WRITE(2,9000)NP
9000  FORMAT('A',5X,'NUMBER OF PTS = ',I3)
```

```
      WRITE(2,9001)
9001  FORMAT('0',5X,'TIME(I)',10X,'PPM(I)',10X,'COD(I)')
      DO 10 I=1,NP
      READ(1,*)TIME(I),PPM(I),COD(I),PH(I),MLSS(I),NH(I),CL(I)
      WRITE(2,*)TIME(I),PPM(I),COD(I)
10    CONTINUE
      READ(1,*)MAXORD
      READ(1,*)XS,RS,YS,NOL
      RETURN
      END
```

```
      SUBROUTINE ZERO(NP,TITLE,RUN,MAXORD,IC,LC,NOL,ISW,
C
C ***************************************************************
C *                                                             *
C *     Subroutine ZERO                                         *
C *                                                             *
C *     PURPOSE: To execute first substrate concentration*
C *              followed by COD concentration in to a   *
C *              series of subroutines to determine the  *
C *              constants of intersration by the method *
C *              of least-squares for the zero order     *
C *              model.                                  *
C *                                                             *
C ***************************************************************
C
     %TIME,PPM,COD,XS,RS,YS,MODE,XLABEL,RLABEL,YLABEL
     %,A,B,R,DELTAY,YCAL,ERROR)
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION Y(23),X(23),TITLE(23,20),A(23,7,7),R(23,7),
     %XLABEL(23,20),YLABEL(23,20),RUN(23,15),IPICT(51,65),
     %YCAL(23),TIME(23),PPM(23),COD(23),PH(23),MLSS(23),
     %B(23,7,7),DELTAY(23),NH(23),RLABEL(23,20)
      IF(ISW.GT.1) GO TO 4500
      DO 4030 I=1,NP
      X(I)=TIME(I)
      Y(I)=PPM(I)
4030  CONTINUE
      GO TO 4070
4500  DO 4050 I=1,NP
      Y(I)=COD(I)
      X(I)=TIME(I)
4050  CONTINUE
      MODE=-1
C     IF MODE > 0 DO NOT PLOT DATA
C     IF MODE 0 PLOT COD AND SUBSTRATE VS TIME DATA
4070  CALL EXECUT(NP,TIME,PPM,X,Y,TITLE,RUN,MAXORD,IC,LC,NOL,ISW,
     %A,B,YCAL,DELTAY,R,XS,RS,YS,MODE,XLABEL,RLABEL,YLABEL,ERROR)
      RETURN
      END
```

```
      SUBROUTINE EXECUT(NP,TIME,PPM,X,Y,TITLE,RUN,MAXORD,IC,LC,NOL,ISW,
     %A,B,YCAL,DELTAY,R,XS,RS,YS,MODE,XLABEL,RLABEL,YLABEL,ERROR)
C
C ***************************************************************
C *                                                             *
C *       SUBROUTINE EXECUT                                     *
C *                                                             *
C *       Purpose: To sort the input data so that if any        *
C *                lag points are included at the start         *
C *                of a data set they are not used in any       *
C *                calculations for the kinetic constants       *
C *                                                             *
C ***************************************************************
C
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION Y(23),X(23),TITLE(23,20),A(23,7,7),R(23,7),
     %XLABEL(23,20),YLABEL(23,20),RUN(23,15),IPICT(51,65),
     %YCAL(23),TIME(23),PPM(23),COD(23),PH(23),MLSS(23),
     %NH(23),B(23,7,7),DELTAY(23),RLABEL(23,20)
      IF(ISW.EQ.1) GO TO 19
      DO 15 I=1,NP
      IF(Y(I).GE.0) GO TO 15
      L=I+1
      DO 12 J=L,NP
      K=J-1
      X(K)=X(J)
      Y(K)=Y(J)
12    CONTINUE
      NP=NP-1
15    CONTINUE
19    DO 18 LAG=1,NOL
      IF(ISW.GT.1) GO TO 98
      CALL FITIT(K1,NP,LAG,X,Y,MAXORD,YCAL,DELTAY,IC,LC,
     %A,B,R,ERROR)
98    CALL PLOT(TITLE,ISW,XS,YS,NP,IC,LAG,MODE,X,Y,XLABEL,
     %RS,RLABEL,YLABEL)
18    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FITIT(K1,NP,LAG,X,Y,MAXORD,YCAL,DELTAY,IC,LC,
     %A,B,R,ERROR)
C
C       THIS PROGRAM FITS A POLYNOMIAL OF ORDER 6
C
        DIMENSION SIGMAY(23),X(23),Y(23),DELTAY(23),YCAL(23)
     %,A(23,7,7),B(23,10,10),R(23,7)
        IF(NP.LT.3) GO TO 99
C
        DO 2 I=LAG,NP
        SIGMAY(I)=0.
2       CONTINUE
        NCODE=0
C       MAXORD=NP/2
C       IF(NP.LE.4) MAXORD=2
C       IF(MAXORD.GT.6) MAXORD=6
        NNK=MAXORD
        DO 3 K=1,NNK
        K1=K+1
C
        CALL POLIFI(X,Y,SIGMAY,NP,K1,0,A,B,CHISQR,IC,LC,LAG)
C
        ERROR=0.0
       L=0.0
       NLAG=LAG-1
        DO 4 J=LAG,NP
        SUM=A(IC,LC,1)
        DO 5 I=2,K1
        SUM=SUM+A(IC,LC,I)*X(J)**(I-1)
5       CONTINUE
        YCAL(J)=SUM
        DELTAY(J)=YCAL(J)-Y(J)
       IF((NLAG.EQ.0).OR.(L.EQ.NLAG)) GO TO 4
       DO 125 L=1,NLAG
       DELTAY(L)=0.0
       YCAL(L)=Y(L)
125    CONTINUE
       L=NLAG
4       ERROR=ERROR+DELTAY(J)**2
        ERROR=ERROR/NP-LAG+1
       CALL CORR(Y,ERROR,R,IC,LC,NP)
C
3       CONTINUE
C
99      RETURN
        END
```

```
      SUBROUTINE POLIFI(X,Y,SIGMAY,NPTS,NTERMS,MODE,A,B,
     %CHISQR,IC,LC,LAG)
C
C     EXTRACTED FROM: BEVINGTON,P. R., "DATA REDUCTION AND
C     ERROR ANALYSIS FOR THE PHYSICAL SCIENCES", MCGRAW HILL,1969
C
C     SUBROUTINE POLIFIT PURPOSE
C
C     MAKE A LEAST-SQUARES FIT TO DATA WITH A POLYNOMIAL CURVE
C     Y = A(1) + A(2)*X + A(3)*X**2 + A(4)*X**3 + ...
C
C     DESCRIPTION OF PARAMETERS
C     X    -ARRAY OF DATA POINTS FOR INDEPENDENT VARIABLE
C     Y    -ARRAY OF DATA POINTS FOR DEPENDENT VARIABLE
C     SIGMAY - ARRAY OF STANDARD DEVIATIONS FOR Y DATA POINTS
C     NPTS   -NUMBER OF PAIRS OF DATA POINTS
C     NTERMS -NUMBER OF COEFFICIENTS(DEGREE OF POLYNOMIAL + 1)
C     MODE   -DETERMINANTS METHOD OF WEIGHTING LEAST-SQUARES FIT
C               +1 (INSTRUMENTAL) WEIGHT(I)=1./SIGMAY(I)**2
C                0 (NO WEIGHTING) WEIGHT =1.
C               -1 (STATISTICAL) WEIGHT(I) = 1./Y(I)
C     A  - ARRAY OF COEFFICIENTS OF POLYNOMIAL
C     CHISQR - REDUCED CHI SQUARE FOR FIT
C
C       DELTERM (ARRAY,NORDER)
C       EVALUATES THE DETERMINANTS OF A SYMMETRIC TWO-DIMENSIONAL
C       MATRIX OF NORDER
C
      DOUBLE PRECISION SUMX,SUMY,XTERM,YTERM,ARRAY,CHISQ
      DIMENSION X(23),Y(23),A(23,7,7),B(23,10,10),
     % SIGMAY(23),SUMX(23),SUMY(23),ARRAY(8,8)
C
C     ACCUMULATE WEIGHTING SUMS
C
11    NMAX = 2*NTERMS - 1
      DO 13 N=1, NMAX
13    SUMX(N) = 0.
      DO 15 J=1, NTERMS
15    SUMY(J)= 0.
      CHISQ =0.
21    DO 50 I=LAG, NPTS
      XI=X(I)
      YI= Y(I)
31    IF (MODE) 32,37,39
32    IF(YI) 35,37,33
33    WEIGHT = 1./YI
      GO TO 41
35    WEIGHT = 1./(-YI)
      GO TO 41
37    WEIGHT = 1.
      GO TO 41
39    WEIGHT = 1. / SIGMAY(I)**2
41    XTERM=WEIGHT
      DO 44 N=1,NMAX
      SUMX(N) = SUMX(N) + XTERM
44    XTERM = XTERM * XI
45    YTERM = WEIGHT*YI
      DO 48 N=1, NTERMS
```

```
      SUMY(N)=SUMY(N) + YTERM
48    YTERM = YTERM *XI
49    CHISQ = CHISQ + WEIGHT*YI**2
50    CONTINUE
C
C     CONSTRUCT MATRICES AND CALCULATE COEFFICIENTS
C
51    DO 54 J=1, NTERMS
      DO 54 K=1, NTERMS
      N = J + K - 1
54    ARRAY(J,K) = SUMX(N)
      DELTA = DETERM (ARRAY,NTERMS)
      IF(DELTA) 61,57,61
57    CHISQR = 0.
      DO 59 J=1, NTERMS
59    A(IC,LC,J) = 0.
      GO TO 80
61    DO 70 L=1, NTERMS
62    DO 66 J=1, NTERMS
      DO 65 K=1,NTERMS
      N = J+K-1
65    ARRAY(J,K)=SUMX(N)
66    ARRAY(J,L)=SUMY(J)
70    A(IC,LC,L)=DETERM(ARRAY,NTERMS)/DELTA
C
C     CALCULATES CHI SQUARE
C
71    DO 75 J=1, NTERMS
      CHISQ = CHISQ - 2.*A(IC,LC,J)*SUMY(J)
      DO 75 K=1, NTERMS
      N=J+K-1
75    CHISQ=CHISQ+A(IC,LC,J)*A(IC,LC,K)*SUMX(N)
76    FREE=NPTS-NTERMS
77    CHISQR=CHISQ/FREE
      CALL TTEST(A,B,LAG,IC,LC,FREE,NPTS,X,Y)
80    RETURN
      END
```

```
      FUNCTION DETERM(ARRAY,NORDER)
C
C     EXTRACTED FROM: BEVINGTON,P. R., "DATA REDUCTION AND
C     ERROR ANALYSIS FOR THE PHYSICAL SCIEINCES",MCGRAW HILL,1969
C
C     FUNCTION DETERM
C
C     PURPOSE
C     CALCULATES THE DETERMINANT OF A SQUARE MATRIX
C
C     USAGE
C     DET = DETERM(ARRAY,NORDER)
C
C     DESCRIPTION OF PARAMETERS
C       ARRAY  -MATRIX
C       NORDER -ORDER OF DETERMINANT (DEGREE OF MATRIX)
C
C     SUBROUTINE AND FUNCTION SUBPROGRAMS REQUIRED
C     NONE
C
C     COMMENTS
C     THIS SUBPROGRAM DESTROYS THE INPUT MATRIX ARRAY
C
      DOUBLE PRECISION ARRAY,SAVE
      DIMENSION ARRAY(8,8)
10    DETERM =1.
11    DO 50 K=1, NORDER
C
C      INTERCHANGE COLUMNS IF DIAGNOL ELEMENT IS ZERO
C
      IF(ARRAY(K,K)) 41,21,41
21    DO 23 J=K, NORDER
      IF(ARRAY(K,J)) 31,23,31
23    CONTINUE
      DETERM = 0.
      GO TO 60
31    DO 34 I=K, NRODER
      SAVE = ARRAY(I,J)
      ARRAY(I,J)=ARRAY(I,K)
34    ARRAY(I,K)=SAVE
      DETERM = -DETERM
C
C     SUBTRACT ROW K FROM LOWER ROWS TO GET DIAGONAL MATRIX
C
41    DETERM = DETERM*ARRAY(K,K)
      IF(K - NORDER) 43,50,50
43    K1=K+1
      DO 46 I=K1, NORDER
      DO 46 J=K1,NORDER
46    ARRAY(I,J)=ARRAY(I,J)-ARRAY(I,K)*ARRAY(K,J)/ARRAY(K,K)
50    CONTINUE
60    RETURN
      END
```

```
      SUBROUTINE CORR(Y,ERROR,R,IC,LC,NP)
C
C ***************************************************************
C *                                                             *
C *       Subroutine CORR                                       *
C *       Purpose: To determin the quality of the fit of        *
C *                the data to the model for the zero           *
C *                order constants.                             *
C *                                                             *
C ***************************************************************
C
      DIMENSION Y(23),R(23,7)
      YT=0.0
      YS=0.0
      DO 10 I=1,NP
      YS=YS+Y(I)
      YT=YT+Y(I)**2
10    CONTINUE
      YMEAN=YS/NP
      DUM1=(YT/NP)-(YMEAN**2)
      R2=((DUM1-ERROR)/DUM1)
      R(IC,LC)=R2
      RETURN
      END
```

```
      SUBROUTINE PLOT(TITLE,ISW,XS,YS,NP,IC,LAG,MODE,X,Y,XLABEL,.
     %RS,RLABEL,YLABEL)
C
C ***************************************************************
C *                                                             *
C *          Subroutine PLOT                                    *
C *                                                             *
C *          Purpose: To scale all the time an                  *
C *                   concentration data so that it will        *
C *                   fit within a 51x60 matrix                 *
C *                                                             *
C ***************************************************************
C
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION TITLE(23,20),X(23),Y(23),YLABEL(23,20),
     %XLABEL(23,20),RLABEL(23,20),IPICT(51,60)
      IF(ISW.GT.1) GO TO 9012
      CALL CLEAR(IPICT)
9012  IF(MODE)9011,17,9011
9011  IF(ISW.GT.1) GO TO 9010
      SCALE=YS/50.0
      GO TO 9040
9010  SCALE=RS/50.0
9040  DO 16 I=1,NP
      YT=Y(I)/SCALE
      IY=Y(I)/SCALE
      IF(IY.LE.SCALE) IY=0
      IF(Y(I).GT.(SCALE*50.0)) IY=51.0
      IF(YT-IY.GT.0.5) GO TO 9050
      GO TO 9015
9050  IY=IY+1
9015  XSCALE=XS/60.0
9060  XT=X(I)/XSCALE
      N=2
      NS=1
      IX=X(I)/XSCALE
      IF(X(I).LT.XSCALE) IX=1
      IF(X(I).GT.60*XSCALE) IX=60
      IF(XT-IX.GT.0.5) GO TO 9070
      GO TO 9080
9070  IX=IX+1
9080  IY=IY+1
      CALL POINT(IY,IX,IPICT,ISW)
16    CONTINUE
      IF(ISW.EQ.1) GO TO 17
      CALL DRAW(TITLE,IC,YS,XS,IPICT,XLABEL,YLABEL,RLABEL,RS)
17    RETURN
      END
```

```
      SUBROUTINE CLEAR(IPICT)
C
C       THIS SUBROUTINE CLEARS THE PICTURE SPACE
C
      DIMENSION IPICT(51,60)
      DATA NBLANK/' '/
      DO 2020 I=1,51
      DO 2010 J=1,60
      IPICT(I,J) = NBLANK
2010  CONTINUE
2020  CONTINUE
      RETURN
      END
```

```
      SUBROUTINE POINT(IY,IX,IPICT,ISW)
C
C ***************************************************************
C *                                                             *
C *          Subroutine POINT                                   *
C *                                                             *
C *          Purpose: To place the appropriate character        *
C *                   or blank in the matrix IPICT, in          *
C *                   order to set up the plot of data.         *
C *                                                             *
C ***************************************************************
      DIMENSION IPICT(51,60)
      DATA NCHAR/'+'/
      DATA NAXIS/'0'/
      IF(ISW.GT.1) GO TO 2040
2030  IPICT(IY,IX) = NAXIS
      GO TO 2050
2040  IPICT(IY,IX) = NCHAR
2050  RETURN
      END
```

```
      SUBROUTINE DRAW(TITLE,IC,YS,XS,IPICT,XLABEL,YLABEL,RLABEL,RS)
C
C ***************************************************************
C *                                                             *
C *          Subroutine DRAW                                    *
C *                                                             *
C *          Purpose: To format the plot with labelled          *
C *                   and scaled axis.                          *
C *                                                             *
C ***************************************************************
C
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION TITLE(23,20),IPICT(51,60),IXB(7),XLABEL(23,20),
     %YLABEL(23,20),RLABEL(23,20)
      DATA NBLANK/' '/
      WRITE(6,4014)
4014  FORMAT('0','.single')
      WRITE(6,4012)
4012  FORMAT('0','.page')
      WRITE(6,4019)
4019  FORMAT('0','.asis')
      WRITE(6,3013)
3013  FORMAT(//)
      IFIG=IC
      WRITE(6,3030)IFIG
3030  FORMAT('1',5X,'FIGURE #',I2,'.'
     %,1X,'PLOT OF CONCENTRATION
     %'_____ VS. TIME')
      WRITE(6,3333)
3333  FORMAT('0','.SKIP3')
      WRITE(6,4019)
      IS=0.0
      YSCALE=YS
      RSCALE=RS
      YINT=YS/10.0
      RINT=RS/10.0
3025  DO 3040 I=1,51
      IF(I.EQ.51) GO TO 3060
      II=52-I
      III=I-1
      IF(III/5.EQ.FLOAT(III)/5) GO TO 3080
      IF((I.LT.5).OR.(I.GE.30)) GO TO 3065
3045  WRITE(6,3050)SUBST(IC,I-4),(IPICT(II,J), J=1,60),SUBST(IC,I-4)
      GO TO 3040
3065  IF(I.GE.30) GO TO 3073
      WRITE(6,3050)NBLANK,(IPICT(II,J), J=1,60),NBLANK
      GO TO 3040
3073  IF(I-29.GT.20) GO TO 3075
      WRITE(6,3050)YLABEL(1,I-29),(IPICT(II,J), J=1,60),RLABEL(1,I-29)
      GO TO 3040
3075  WRITE(6,3050)NBLANK,(IPICT(II,J), J=1,60),NBLANK
3050  FORMAT(' ',A1,6X,'|',60A1,'|',6X,A1)
      GO TO 3040
3080  IF((I.LT.5).OR.(I.GE.30)) GO TO 3072
      WRITE(6,3090)SUBST(IC,I-4), YSCALE,(IPICT(II,J), J=1,60),
     %RSCALE,SUBST(IC,I-4)
      GO TO 3049
3072  IF(I.GE.30) GO TO 3074
```

```
      WRITE(6,3090)NBLANK, YSCALE,(IPICT(II,J), J=1,60),
     %RSCALE,NBLANK
      GO TO 3049
3074  IF(I-29.GT.20) GO TO 3076
      WRITE(6,3090)YLABEL(1,I-29),YSCALE,(IPICT(II,J),J=1,60),
     %RSCALE,RLABEL(1,I-29)
      GO TO 3049
3076  WRITE(6,3090)NBLANK, YSCALE,(IPICT(II,J), J=1,60),
     %RSCALE,NBLANK
3090  FORMAT(' ',A1,F5.1,'-¦',60A1,'¦-',F5.1,A1)
3049  YSCALE=YSCALE-YINT
      RSCALE=RSCALE-RINT
3040  CONTINUE
3060  WRITE(6,3070)
3070  FORMAT(' ',7X,'+---------+---------+---------+'
     %'---------+---------+---------+')
      SCALE=XS/60.0
3057  IXB(1)=0.0
      DO 3130 I=2,7
      J=I-1
      IXB(I)=IXB(J)+SCALE*10.0
3130  CONTINUE
      WRITE(6,3140)(IXB(I),I=2,7)
3140  FORMAT(' '9X,8(I10))
      WRITE(6,3150)
3150  FORMAT('0',36X,'TIME/MIN')
      RETURN
      END
```

```
      SUBROUTINE RESULT(A,R,TITLE,RUN,IC,LC)
C
C ***************************************************************
C *                                                             *
C *          Subroutine RESULT                                  *
C *                                                             *
C *          Purpose: To give a summary of the                  *
C *                   constants of intergration for each        *
C *                   model in each set of data.                *
C *                                                             *
C ***************************************************************
C
      COMMON TEMP(23,15),CONC(23,15),DATE(23,15),SUBST(23,25)
      DIMENSION A(23,7,7),R(23,7),TITLE(23,20),RUN(23,15)
      DO 7030 L=1,LC
      WRITE(6,4023)
4023  FORMAT('0',',double')
      WRITE(6,4013)
4013  FORMAT('0',',page')
      WRITE(6,4020)
4020  FORMAT('0',',asis')
      WRITE(6,7010)(SUBST(IC,I),I=1,25)
7010  FORMAT('1',5X,'SUMMARY OF RESULTS FOR THE SUBSTRATE ',25A1)
      WRITE(6,7020)
7020  FORMAT('0',10X,'MEDIA',12X,'RUN',15X,'INITIAL',
     %5X,'RATE',9X,'CORR')
      DO 7050 IR=1,IC,1
      IF(L.GT.1) GO TO 7031
      WRITE(6,7000)(TITLE(IR,I),I=1,20),(RUN(IR,J),J=1,15),A(IR,L,1),
     %A(IR,L,2),R(IR,L)
      GO TO 7050
7031  IF(L.GT.2) GO TO 7032
      WRITE(6,7001)(TITLE(IR,I),I=1,20),(RUN(IR,J),J=1,15),A(IR,L,1),
     %A(IR,L,2),R(IR,L)
      GO TO 7050
7032  WRITE(6,7002)(TITLE(IR,I),I=1,20),(RUN(IR,J),J=1,15),A(IR,L,1),
     %A(IR,L,2),A(IR,L,3),R(IR,L)
7050  CONTINUE
7030  CONTINUE
      RETURN
7000  FORMAT('0',5X,20A1,2X,15A1,2X,F9.4,2X,F9.4,2X,F9.4)
7001  FORMAT('0',5X,20A1,2X,15A1,2X,F9.4,2X,F9.4,2X,F9.4,2X,F9.4)
7002  FORMAT('0',5X,20A1,2X,15A1,2X,F9.4,2X,F9.4,2X,F9.4,2X,F9.4,
     %2X,F9.4)
      END
```

```
      SUBROUTINE TTEST(A,B,LAG,IC,LC,FREE,NP,X,Y)
C
C ***************************************************************
C *                                                             *
C *          Subroutine TTEST                                   *
C *          Purpose: To perform a student t-test on            *
C *                   the data used with the zero order         *
C *                   model in order to estimate the error      *
C *                   in the constants with 95% certainty       *
C *                                                             *
C ***************************************************************
C
      DIMENSION X(23),Y(23),SUMY(23),SUMX(23),SUMXY(23),
     $A(23,7,7),B(23,10,10),T95(23)
      DATA T95(1),T95(2),T95(3),T95(4)/12.706,4.303,3.182,2.776/
      DATA T95(5),T95(6),T95(7),T95(8)/2.565,2.447,2.365,2.306/
      DATA T95(9),T95(10),T95(11)/2.262,2.228,2.201/
      DATA T95(12),T95(13),T95(14)/2.179,2.160,2.145/
      DATA T95(15),T95(16),T95(17)/2.131,2.120,2.110/
      DATA T95(18),T95(19),T95(23)/2.101,2.093,2.086/
      DO 990 L=1,NP
      SUMX(L)=0.0
      SUMY(L)=0.0
      SUMXY(L)=0.0
990   CONTINUE
      NPT=NP+1
      LL=LAG+1
      DO 1000 L=LL,NPT,1
      J=L-1.0
      I=J
      SUMY(L)=SUMY(J)+(Y(I))
      SUMX(L)=SUMX(J)+(X(I))
      SUMY(J)=SUMY(L)
      SUMX(J)=SUMX(L)
1000  CONTINUE
      YSUM=SUMY(J)/NP
      XSUM=SUMX(J)/NP
      XS=0
      YT=0.0
      YS=0.0
      DO 1010 J=1,NP
      YS=YS+((YSUM-Y(J))**2)
      YT=YT+((YSUM-Y(J))*(XSUM-X(J)))
      XS=XS+((XSUM-X(J))**2)
1010  CONTINUE
      S=((YS-(A(IC,LC,2)*YT))/FREE)
      S2=S/XS
      S3=S/NP
      B(IC,LC,1)=T95(FREE)*(SQRT(((1.0/NP)+(XSUM/XS))*S))
      B(IC,LC,2)=T95(FREE)*(SQRT(S2))
      RETURN
      END
```

```
      SUBROUTINE MONOD(TIME,PPM,NP,IC,LC,A,B,R,YCAL,DELTAY,ERROR)
C
C ***************************************************************
C *                                                             *
C *          Subroutine MONOD                                   *
C *                                                             *
C *          Purpose: To set up an augmented matrix for         *
C *                   each data set to solve the Monod          *
C *                   desgradation equation for it's            *
C *                   constants by Gaussian reduction           *
C *                                                             *
C ***************************************************************
C
      REAL*8 G
      DIMENSION TIME(23),PPM(23),Y(23),X(23),YCAL(23),S(100),
     %G(2,3),A(23,7,7),B(23,7,7),R(23,7),F(23,100),DELTAY(23)
      TLAG=TIME(1)
       DUM1=0.0
       DUM2=0.0
       DUM3=0.0
       DUM4=0.0
      DUM7=0.0
      TLAG=TIME(1)
       DO 10 I=1,NP
      TIME(I)=TIME(I)-TIME(1)
      Y(I)=ALOG(PPM(1)/PPM(I))
      X(I)=PPM(1)-PPM(I)
      DUM1=DUM1+(Y(I)*TIME(I))
      DUM2=DUM2+(TIME(I)**2)
      DUM3=DUM3+(X(I)*TIME(I))
      DUM4=DUM4+(X(I)**2)
      DUM7=DUM7+(X(I)*Y(I))
10    CONTINUE
      G(1,1)=DUM2*(-1.0)
      G(1,2)=DUM3
      G(1,3)=DUM1
      G(2,1)=DUM3*(-1.0)
      G(2,2)=DUM4
      G(2,3)=DUM7
      ND=2
      NCOL=3
      N=2
      NS=1
      CALL GAUSL(ND,NCOL,N,NS,G)
      G(1,3)=(G(1,3)*(-1.0))
      G(2,3)=(G(2,3)*(-1.0))
      C1=(G(1,3)/G(2,3))
      C2=(1.0/G(2,3))
      DO 20 I=1,NP
      S(1)=PPM(I)
      S(2)=PPM(I)+1.0
      L=1
30    F(I,L)=(C2*(ALOG(PPM(1)/S(L)))+(PPM(1)-S(L))-(C1*TIME(I)))
      IF (L.LT.2) GO TO 40
      GO TO 50
40    L=L+1
      GO TO 30
50    CALL SECANT(S,SNEW,F,I,L)
```

```
      DIFF=(S(L)-SNEW)
      IF((ABS(DIFF)).LT.0.0001) GO TO 25
      S(L+1)=SNEW
      L=L+1
      IF(L.GT.99) GO TO 25
      GO TO 30
25    DELTAY(I)=PPM(I)-SNEW
      YCAL(I)=SNEW
20    CONTINUE
      DO 60 I=1,NP
      TIME(I)=TIME(I)+TLAG
60    CONTINUE
      A(IC,LC,2)=C1
      A(IC,LC,1)=C2
      ERROR=0.0
      DO 21 I=1,NP
      ERROR=ERROR+(DELTAY(I)**2)
21    CONTINUE
      ERROR=ERROR/NP
      CALL CORR(Y,ERROR,R,IC,LC,NP)
      RETURN
      END
```

```
      SUBROUTINE SECANT(S,SNEW,F,I,L)
C
C ***************************************************************
C *                                                             *
C *          Subroutine SECANT                                  *
C *                                                             *
C *          Purpose: To perform abounded iterative             *
C *                   calculation to find a theoretical         *
C *                   substrate concentration knowing the       *
C *                   kinetic constants of either the           *
C *                   Monod or Haldane equation at a            *
C *                   time t.                                   *
C *                                                             *
C ***************************************************************
C
      DIMENSION S(100),F(23,100)
      AMAX=5000.0
      AMIN=0.0001
      IF(F(I,L).NE.F(I,L-1)) GO TO 301
      SNEW=(S(L)+S(L-1))/2.0
      GO TO 310
301    SLOPE=(S(L-1)-S(L))/(F(I,L)-F(I,L-1))
      DELTAC=F(I,L)*SLOPE
305    SNEW=S(L)+DELTAC
      IF((SNEW.GE.AMIN).AND.(SNEW.LT.AMAX)) GO TO 310
      DELTAC=DELTAC*0.9
      GO TO 305
310   RETURN
      END
```

```
      SUBROUTINE REPORT(ID,K1,NP,TIME,PPM,COD,PH,NH,MLSS,TITLE,RUN,
     %CL,A,B,R,YCAL,DELTAY,IC,LC,ERROR)
C
C ***************************************************************
C *                                                             *
C *           Subroutine REPORT                                 *
C *                                                             *
C *           Purpose: To format each set of input and          *
C *                    output data for use in the report        *
C *                    of the regression results.               *
C *                                                             *
C ***************************************************************
C
      COMMON TEMP(23,8),CONC(23,8),DATE(23,8),SUBST(23,25)
      DIMENSION RUN(23,15),NH(23),TITLE(23,20),A(23,7,7),R(23,7),
     %YCAL(23),TIME(23),PPM(23),COD(23),PH(23),MLSS(23),
     %CL(23),B(23,7,7),DELTAY(23)
1     WRITE(6,4015)
      WRITE(6,4011)
      WRITE(6,4100)
4100  FORMAT('0','.center')
      WRITE(6,4101)IC,ID
4101  FORMAT('0','TABLE ',I2,'-',I1)
      IF (ID.GT.1)GO TO 4105
      WRITE (6,4102)
4102  FORMAT('0','A SUMMARY OF THE EXPERIMENTAL DATA OBTAINED'
     %'FOR THE DEGRADATION OF')
      WRITE(6,4103)(SUBST(IC,I),I=1,25),(TITLE(IC,I),I=1,20)
4103  FORMAT('0',25A1,'IN THE MEDIA ',20A1)
      GO TO 4125
4105  IF(ID.GT.2) GO TO  4107
      WRITE(6,4311)(SUBST(IC,I),I=1,25)
4311  FORMAT('0','THE REGRESSION OF THE ',25A1,'CONCENTRATION'
     %' VERSUS TIME TO ')
      WRITE(6,4312)(TITLE(IC,I),I=1,20)
4312  FORMAT('0',' FIT THE ZERO ORDER MODEL IN THE MEDIA ',20A1)
      GO TO 4125
4107  IF(ID.GT.3) GO TO 4110
      WRITE(6,4211)(SUBST(IC,I),I=1,25)
4211  FORMAT('0','THE REGRESSION OF THE ',25A1,'CONCENTRATION'
     %' VERSUS TIME TO ')
      WRITE(6,4212)(TITLE(IC,I),I=1,20)
4212  FORMAT('0',' FIT THE MONOD MODEL IN THE MEDIA ',20A1)
      GO TO 4125
4110  WRITE(6,4111)(SUBST(IC,I),I=1,25)
4111  FORMAT('0','THE REGRESSION OF THE ',25A1,'CONCENTRATION'
     %' VERSUS TIME TO ')
      WRITE(6,4112)(TITLE(IC,I),I=1,20)
4112  FORMAT('0',' FIT THE HALDANE MODEL IN THE MEDIA ',20A1)
4125  WRITE(6,4027)
      WRITE(6,4018)
      WRITE(6,9021)(SUBST(IC,I),I=1,25)
9021  FORMAT('1',5X,'SUBSTRATE    :',25A1)
      WRITE(6,9005)(TITLE(IC,I),I=1,20)
9005  FORMAT('0',5X,'MEDIA        :',20A1)
      WRITE(6,9022)(CONC(IC,I),I=1,8)
9022  FORMAT('0',5X,'CONCENTRATION:',8A1,'NOMINAL')
      WRITE(6,9014)(DATE(IC,I),I=1,8)
```

```
9014  FORMAT('0',5X,'DATE          :',8A1)
      WRITE(6,9008)(RUN(IC,I),I=1,15)
9008  FORMAT('0',5X,'RUN           :',15A1)
      WRITE(6,9017)(TEMP(IC,I),I=1,8)
9017  FORMAT('0',5X,'TEMPERATURE   :',8A1)
      IF((LC.EQ.1).AND.(ID.EQ.1)) GO TO 101
      WRITE(6,4027)
      WRITE(6,4018)
      WRITE(6,100)
100   FORMAT('0',6X,'TIME (MIN)',3X,'PPMEXP',6X,'PPMCAL',8X,'DY')
      GO TO 149
101   WRITE(6,102)
102   FORMAT('0',8X,'TIME',5X,'CONC.',4X,'COD',4X,'PH'
     %,3X,'MLSS',3X,'NH4+',6X,'CL-')
      WRITE(6,103)
103   FORMAT('0',8X,'MINS',5X,' PPM ',4X,'PPM',4X,'   '
     %,3X,'mg/l',3X,'PPM ',6X,'PPM')
      WRITE(6,4027)
      DO 148 I=1,NP
      WRITE(6,4018)
      WRITE(6,104)TIME(I),PPM(I),COD(I),PH(I),MLSS(I),NH(I),CL(I)
104   FORMAT('0',5X,F7.1,2X,F7.1,2X,F7.1,2X,F4.1,2X,I4,2X,I4,5X,F5.1)
148   CONTINUE
      ID=ID+1
      GO TO 1
149   WRITE(6,4028)
4028  FORMAT('0',',skip1')
      WRITE(6,4014)
4014  FORMAT('0',',single')
      WRITE(6,4018)
      DO 201 J=1,NP
150   WRITE(6,200)TIME(J),PPM(J),YCAL(J),DELTAY(J)
200   FORMAT('0',5X,4G12.5)
201   CONTINUE
      WRITE(6,4027)
      WRITE(6,4024)
4024  FORMAT('0',',double')
      WRITE(6,500)
500   FORMAT(/,5X,'KINETIC CONSTANTS')
      A(IC,LC,2)=A(IC,LC,2)*60.0
      IF(LC.GT.0) GO TO 319
      B(IC,LC,2)=B(IC,LC,2)*60.0
319   GO TO (321,322,323),LC
321    WRITE(6,324)
324   FORMAT('0',5X,'ZERO ORDER MODEL')
      GO TO 331
322   WRITE(6,326)
326   FORMAT('0',5X,'MONOD MODEL')
      GO TO 331
323   WRITE(6,327)
327   FORMAT('0',5X,'HALDANE MODEL')
331   DO 20 I=1,K1
      IF(I.GT.1) GO TO 252
      WRITE(6,250)I,A(IC,LC,I),B(IC,LC,I)
250   FORMAT(/,5X,'K',I1,'=',F9.3,' ±',F5.2,3X,'mg/l')
      GO TO 20
252   IF(I.GT.2) GO TO 253
      WRITE(6,251)I,A(IC,LC,I),B(IC,LC,I)
```

```
251   FORMAT(/,5X,'K',I1,'=',F9.3,' ±',F5.2,3X,'mg/l.hr')
      GO TO 20
253   WRITE(6,254)I,A(IC,LC,I),B(IC,LC,I)
254   FORMAT(/,5X,'K',I1,'=',F9.3,' ±',F5.2,3X,'l/mg')
20    CONTINUE
      WRITE(6,375) R(IC,LC)
375   FORMAT('0',5X,'THE CORRELATION COEFFICIENT = ',G12.5)
      RESID=(SQRT(ERROR*NP))/NP
      WRITE(6,300)RESID
300   FORMAT(/,6X,'THE ABSOLUTE AVERAGE RESIDUAL = ',G12.5)
      ID=ID+1
4015  FORMAT('0',',double')
4011  FORMAT('0',',page')
4018  FORMAT('0',',asis')
4027  FORMAT('0',',skip3')
      RETURN
      END
```

```
C     *       SUBROUTINE GAUSL(ND,NCOL,N,NS,G)
C     *
C     ************************************************************
C
C
C     SUBROUTINE GAUSL SOLVES N LINEAR EQUATIONS BY GAUSS
C     ELIMINATION WITH ROW PIVOTING.
C     TO SOLVE THE PROBLEM QX=U, WHERE Q IS A NXN MATRIX AND IS
C     NXNS, ONE PLACES Q IN THE FIRST N COLUMNS OF A ND U IS PLACED
C     IN THE FOLLOWING NS COLUMNS.
C     THE PROGRAM RETURNS X=Q**(-1)*U AT THE PREVIOS
C     POSITION OF U.
C     ***********
C     ND IS THE ROW DIMENSION AND NCOL IN THE COLUMN DIMENSION OF A.
C     BOTH MUST BE TRANSFERRED TO THE SUBROUTINE.
C     **********************
C
      SUBROUTINE GAUSL(ND,NCOL,N,NS,G)
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION G(ND,NCOL)
      N1=N+1
      NT=N+NS
      IF(N .EQ. 1) GO TO 50
C
C     START ELIMINATION
C
      DO 10 I=2,N
      IP=I-1
      I1=IP
      X=DABS(G(I1,I1))
      DO 11 J=I,N
      IF(DABS(G(J,I1)) .LT. X) GO TO 11
      X=DABS(G(J,I1))
      IP=J
11    CONTINUE
      IF(IP .EQ. I1) GO TO 13
C
C     ROW INTERCHANGE
C
      DO 12 J=I1,NT
      X=G(I1,J)
      G(I1,J)=G(IP,J)
12    G(IP,J)=X
13    DO 10 J=I,N
      X=G(J,I1)/G(I1,I1)
      DO 10 K=I,NT
10    G(J,K)=G(J,K)-X*G(I1,K)
C
C
C     ELIMINATION FINISHED, NOW BACKSUBSTITION
C
50    DO 20 IP=1,N
      I=N1-IP
      DO 20 K=N1,NT
      G(I,K)=G(I,K)/G(I,I)
      IF(I .EQ. 1) GO TO 20
      I1=I-1
```

```
      DO 25 J=1,I1
25    G(J,K)=G(J,K)-G(I,K)*G(J,I)
20    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE HALDAN(TIME,PPM,NP,IC,LC,A,B,R,YCAL,DELTAY,ERROR
C
C ***************************************************************
C *                                                             *
C *          Subroutine HALDAN                                  *
C *                                                             *
C *          Purpose: To set up an augmented matrix for         *
C *                   each data set to solve the Haldane        *
C *                   degradation equation for it's             *
C *                   constants by Gaussian reduction           *
C *                                                             *
C ***************************************************************
C
      REAL*8 G
      DIMENSION TIME(23),PPM(23),Y(23),X(23),YCAL(23),S(50),
     %G(3,4),A(23,7,7),B(23,7,7),R(23,7),F(23,50),DELTAY(23)
     %,Z(23)
      DUM1=0.0
      DUM2=0.0
      DUM3=0.0
      DUM4=0.0
      DUM5=0.0
      DUM6=0.0
      DUM7=0.0
      DUM8=0.0
      DUM9=0.0
      DUM10=0.0
       DO 10 I=1,NP
      Y(I)=PPM(I)
      X(I)=ALOG(PPM(I))
      Z(I)=(PPM(I)**2)
      DUM1=DUM1+(Y(I)*TIME(I))
      DUM2=DUM2+(TIME(I)**2)
      DUM3=DUM3+(X(I)*TIME(I))
      DUM4=DUM4+(X(I)**2)
      DUM5=DUM5+(Y(I)**2)
      DUM6=DUM6+X(I)
      DUM7=DUM7+(X(I)*Y(I))
      DUM8=DUM8+(Z(I)*X(I))
      DUM9=DUM9+(Y(I)*Z(I))
      DUM10=DUM10+(Z(I)**2)
10    CONTINUE
      G(1,1)=DUM2*(-1.0)
      G(1,2)=DUM3
      G(1,3)=DUM6
      G(1,4)=DUM1
      G(2,1)=DUM3*(-1.0)
      G(2,2)=DUM4
      G(2,3)=DUM8
      G(2,4)=DUM7
      G(3,1)=DUM6*(-1.0)
      G(3,2)=DUM8
      G(3,3)=DUM10
      G(3,4)=DUM9
      ND=3
      NCOL=4
      N=3
      NS=1
```

```
      CALL GAUSL(ND,NCOL,N,NS,G)
      G(1,4)=(G(1,4)*(-1.0))
      G(2,4)=(G(2,4)*(-1.0))
      G(3,4)=(G(3,4)*(-1.0))
      C1=G(1,4)
      C2=G(2,4)
      C3=G(3,4)
      DO 20 I=1,NP
      S(1)=PPM(I)
      S(2)=PPM(I)+1.0
      L=1
30    F(I,L)=((C1*TIME(I))-(C2*ALOG(S(L)))-S(L)-(C3*(S(L)**2)))
      IF (L.LT.2) GO TO 40
      GO TO 50
40    L=L+1
      GO TO 30
50    CALL SECANT(S,SNEW,F,I,L)
      DIFF=(S(L)-SNEW)
      IF((ABS(DIFF)).LT.0.0001) GO TO 25
      S(L+1)=SNEW
      L=L+1
      IF(L.GT.49) GO TO 25
      GO TO 30
25    DELTAY(I)=PPM(I)-SNEW
      YCAL(I)=SNEW
20    CONTINUE
      A(IC,LC,1)=G(2,4)*(-1.0)
      A(IC,LC,2)=G(1,4)*(-1.0)
      A(IC,LC,3)=G(3,4)*(-1.0)
      ERROR=0.0
      DO 21 I=1,NP
      ERROR=ERROR+(DELTAY(I)**2)
21    CONTINUE
      ERROR=ERROR/NP
      CALL CORR(Y,ERROR,R,IC,LC,NP)
      RETURN
      END
```