1975

# The Potential for Application of the Fluidized Bed in High Rate Waste Treatment

Bradley M. McClary
*Western Michigan University*

# THE POTENTIAL FOR APPLICATION OF THE FLUIDIZED BED IN HIGH RATE WASTE TREATMENT

by

Bradley M. McClary

Advisor:

Dr. Allen M. Springer

Faculty Advisor:

Dr. Stephen Kukolich

# A B S T R A C T

A feasibility study of fluidized bed high rate biological waste treatment was performed. Goals of the investigation were to demonstrate possible advantages of higher treatment rates and compaction of effective reactor volume, and to compare this system to conventional high rate treatment, in particular, activated sludge.

This system was found to be capable of achieving high rates of $BOD_5$ removal, producing a consistent low concentration effluent. Such treatment could be realized in one-fifth the reactor volume required for conventional activated sludge operating at an equivalent organic loading rate. Less sludge wasting occurred in this system operation than is common for activated sludge and the sludge exhibited good settling characteristics. Operation of the system was troublesome adding variability to the data obtained. Although the effects of shock loading per se were not observed the system stabilized rapidly to process upsets.

Thus, the fluidized bed system has demonstrated significant advantages in high rate treatment and should be considered seriously as the need for high rate systems becomes more critical.

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# I N T R O D U C T I O N

As effluent quality guidelines on pulp and paper mill waste discharges become more stringent, increasing emphasis on development of new or improved high rate biological treatment systems is underway. Such systems should provide more efficient treatment, be less affected by shock loadings and winter temperatures, require less capital and land area for installation and operation, and should operate with less difficulty than currently available methods of treatment.

Currently employed biological treatment systems are aerated ponds and lagoons, trickling filters, activated sludge and its modified processes, and the recently developed rotating biological surface units (RBS)[2]. Aerated ponds and lagoons require extensive land area and winter operation is ineffective[2]. Trickling filters require large volumes of solid medium for support of biological growths and periodic backwashing, and yield only fifty to sixty percent waste concentraction removal of pulp and paper mill effluents [2,3,8]. Activated sludge processes have very limited ability to adapt to influent changes and high capital and operating costs.

The development of the rotating biological surface marks a dramatic change in biological waste treatment technology

in the concept of a fixed biological growth for substrate utilization offering a large surface area for treatment in a relatively small reactor volume. Perhaps the furthest extent to which this concept can be applied is in the fluidized bed process utilizing many small carrier particles the surfaces of which become residences of biological growth. In the confines of a column type reactor the effluent stream is pumped to cause fluidization of the carrier particles and subsequent mixing and assimilation of organic wastes occurs. This fluidized bed system for high rate waste treatment therefore poses advantages of greater treatment efficiency, minimal land area requirements, no excessive biomass build-up, less sensitivity to shock loading and less operating costs (i.e. power consumption).

# B A C K G R O U N D

The earliest uses of fluidized bed systems for wastewater treatment were as anaerobic filters for treating organic wastes with treatment efficiency comparable to commonly available treatment systems[3,4]. However, it has since been demonstrated aerobic treatment operation is advantageous and worth the expense and difficulty involved.

The medium for biological growth and treatment has received much attention in previous experimental work. Sand, rigid and nonrigid polyvinyl chloride, polyvinyl acetate particles, and activated carbon have been the most commonly used mediums. PVC and PVAC have been demonstrated to be a useful medium although the materials require more pressure head to fluidize than does sand[2,9]. The cost of these synthetic mediums makes them less desirable than sand but their lower density could allow for less massive tower construction. Sand has been shown to be the best performing fluidized bed medium due to the small particle size, availability, and low cost. Activated carbon has an advantage over other mediums in its ability to assimilate waste and has been used to achieve BOD and COD reduction and denitrification in

fluidized bed applications[2,6,8]. The use of activated carbon has been limited due to the high cost of replacement caused by depletion of the material.

The fluidized bed columns used in most previous research shared many of the same design parameters. The main construction material used was plexiglass due to its convenience to work with. Column diameter was kept as small as possible to reduce fluid flow dispersion problems at the feed end of the column (bottom). Effective column height, the height of the fluidized bed, was determined to be a variable having a significant effect in treatment efficiency[1,3,8]. Changing the effective column height was a method of changing the loading rate without changing the feed flow rate. For a fluidized bed system, more effective control of loading rate could be obtained by changing the flow rate rather than changing bed height and thereby increasing head loss. In previous experimental work the installation of a flow manifold near the feed entrance to the column was beneficial to flow dispersion throughout the bed of carrier particles[1,3,8]. In one study concerning a model for an activated sludge tower process sieve plates were installed at regular intervals to redisperse the waste and entrained oxygen and create a multistaging effect[1]. In a fluidized bed system such sieve plates would not enhance the excellent mixing properties of the process and would only serve to increase head loss through the column.

One drawback to many of the studies done using fluidized beds was the use of low organic strength (in terms of BOD and COD) waste[2,3]. If a high strength waste were to be used, the effects of the process variables would be more pronounced, enabling more correct interpretation of the experimental results. Also, a high strength waste is more typical of effluents from pulp and paper mills (i.e. kraft mill effluent). One drawback to the use of high strength wastes would be the large volumes of waste which would be needed for a laboratory scale process. This problem could be solved by limiting the fluidized bed volume so the desired loading rates would not neccessitate large flow rates of raw waste.

In all the previous experimentation with the fluidized bed process, seeding the bed with organisms acclimated to the waste to be treated was necessary to promote a rapid microbiological growth on the particle surfaces and accordingly, a faster attainment of maximum treatment efficiency[2,3,8]. Also, nutrients were required to supplement the food source for the biomass. Commonly used nutrients for BOD removal of pulp and paper mill wastes were ammonium chloride and potassium dihydrogen phosphate[8].

One recent study demonstrated the effect of temperature on treatment efficiency as being directly proportional and dramatic[8]. For a laboratory scale

process such as the one to be incorporated into this senior thesis study, to determine the effect of temperature on BOD removal would be beyond the scope of the study.

The literature put little emphasis on pH as a variable. In several studies pH was maintained at neutral so as to not interfere with the operating variables.

It was common practice in previous experimentation to combine an aeration cell with the fluidized bed column using a recycling of some process fluid to provide a saturated level of dissolved oxygen and to achieve further effluent treatment[2].

EXPERIMENTAL APPROACH

Parameters considered important to any biological waste treatment operation were pH, temperature, nutrients (type and concentration), dissolved oxygen concentration, organic loading rate, hydraulic detention time, food to microorganism ratio and sludge age (mean cell residence time). Organic loading rate was chosen as the process controlling variable consequently affecting hydraulic detention time, food to microorganism ratio and sludge age. The equipment to be used in the study was designed after previous fluidized bed work[2] and sized larger to facilitate a pilot scale operation however restrained in capacity by limited availability of effluent.

The effluent used was a bleached kraft combined mill effluent (350 TPD, CEHD bleaching, 20 MGD total effluent discharge) ranging in pH from 5.6 to 6.6 Since the pH was in a sufficiently narrow range no control was put on it.

The sand bed used in the study was a pure silica grade which was fractionated in 30 and 40 mesh laboratory hand sieves. The sand particles passing through the 30 mesh and retained on the 40 mesh was the sand fraction chosen for use in the system on the basis of a compromise between smaller

particle size for larger surface area and fluidization and plugging problems which might have occurred with a very small particle size bed. This fraction represented a mean particle diameter of 0.512 mm. A 400 $cm^3$ volume of sand was chosen for the bed size as good flow dispersion and fluidization using this volume of sand made use of all available space in the column. This volume represented 50 $m^2$ surface area.

The system was seeded with municipal sewage at a concentration of 214 mg/l in the presence of a high concentration of nitrogen and phosphorus nutrients and kraft mill effluent at a flux rate within the column of 50 cm/min for a one week duration, in which time a substantial growth of organisms appeared on the sand particles. At this point the first and lowest of three organic loading rates was started and nutrients were supplied at a ratio of at least 53 parts BOD per 2 parts nitrogen per 1 part phosphorus which fairly satisfied the conventional requirement of 100/5/1. This was done to ensure nutrients would not be the limiting factor in cell growth. Samples were taken daily of the feed source, aeration cell, and effluent from the system and determinations of $BOD_5$ and COD were made to establish treatment efficiency. The system was in a recycle mode of operation without a clarifier at this time (see system diagram in appendix).

It was decided a one pass mode of operation would be used rather than recycling which was considered a drawback to a high rate system. Such operation resulted in plugging

due to biomass build up in the static bed and a conversion to an anaerobic biological population due to rapid exhaustion of dissolved oxygen in the lower extremity of the bed. Such anaerobic activity was considered detrimental to the high rate treatment concept since such populations grow more slowly than aerobic populations and also are slower to recover from shock loadings.

Another problem in operation up to this point was plugging in the feed lines due to suspended solids build up. Also, the need for a means to recover wasted sludge from the effluent was to be met. A constant head, pump fed feed device (see system diagram in appendix) was built which made that part of the process far less erratic. A clarifier was built and sized based on a conventional requirement of 500 gal/ft$^2$/day (0.7 ft$^2$ was needed for 1 liter per minute flow rates).

With the addition of this new equipment more data was obtained at various loading rates, at room temperature (20 - 22°C) and complete saturation of process fluid with dissolved oxygen. In addition to determinations of $BOD_5$ and COD, suspended solids in the effluent and volatile solids accumulated in the clarifier were measured.

Biochemical oxygen demand (BOD) of the samples was measured by the method given in the 13th Edition _Standard Methods for the Examination of Water and Wastewater_, (1971). The procedure involved a five day incubation period and measurement of dissolved oxygen by a YSI Model 54 D. O. meter.

Chemical oxygen demand (COD) was measured by the method given in the same reference[7]. Suspended solids was measured by filtration through glass fiber filters on a volume basis. Due to small amounts of volatile solids generated and recovered in the clarifier this quantity was measured in three to five day intervals. The sludge was recovered and thickened by gravity thickening and decantation. The quantity was measured by volumetric suspended solids analysis.

The calculations used in this study are demonstrated below:

$$\text{Organic loading rate} = \frac{(BOD_F)(Q)}{V_E} =$$

$$\frac{0.2 \text{ g BOD/l} \times 1 \text{ lb/454 g} \times 0.04 \text{ l/min} \times 1440 \text{ min/day} \times 1000}{2.8 \text{ l} \times 1 \text{ cu ft/28 l} \times 1000}$$

$$= 230 \text{ lb BOD/1000 cu ft/day}$$

in which $BOD_F$ is the feed BOD, Q is the volumetric feed flow rate, $V_E$ is the effective reactor volume (fluidized bed volume).

$$\text{Percent Removal} = \frac{BOD_F - BOD_E}{BOD_F} \times 100$$

$$\text{" \quad "} = \frac{COD_F - COD_E}{COD_F} \times 100$$

in which $BOD_E$ is effluent BOD and $COD_E$ is effluent COD.

Detention Time = $\frac{V}{Q}$ in which V is total system volume.

Sludge Generation = $\frac{VSS}{(BOD_F - BOD_E)Q}$ in which VSS is the quantity of volatile suspended solids collected per day.

An example:

$$\frac{2 \text{ g/day}}{(0.175 - 0.035) \text{ g/l/day} \times 0.015 \text{ l/min} \times 1440 \text{ min/day}} =$$

$$0.66 \ \frac{\text{lb VSS}}{\text{lb BOD}} \text{ Removed}$$

$$\text{Average Sludge Age} = \frac{\text{MLVSS}}{\text{VSS}} = \frac{2.2 \text{ g}}{1.1 \text{ g/day}} = 2 \text{ days}$$

in which MLVSS is the quantity of volatile solids within the the fluidized bed and VSS is the average value of volatile suspended solids collected per day.

Average Food to Microorganism Ratio =

$$\frac{BOD_F \times Q}{\text{MLVSS}} = \frac{0.16 \text{ g/l} \times 0.03 \text{ l/min} \times \frac{1440 \text{ min}}{\text{day}}}{2.2 \text{ g}} = 3$$

in which $BOD_F$ and Q are median values.

Power Requirements (neglecting air supply) =

$$\frac{\text{Total HP}}{\text{Volume delivered/day}} \text{ which was } \frac{0.06 \text{ HP}}{9\text{GPM}} \doteq 4.4 \text{ HP/MGD}$$

## DISCUSSION OF RESULTS

The control chart of infulent and effluent $BOD_5$ (figure 2) shows a high degree of variability and fairly rapid system response to influent concentration. However upon comparison to actual mill data[11] (figure 3) for activated sludge treatment a similar range of variability (maximums are roughly four times greater than the minimums) is noted. Apparently this variability is a common trait in high rate biological treatment and system response to influent variability should be noted as an important factor in evaluating this type of system. For this system no lingering ill effects of influent variation are evident.

The control chart of influent and effluent COD (figure 4) shows less variability than the $BOD_5$ data and shows a general downward trend in influent concentration, which was not related to the mill operation. However chemical oxygen cemand does not accurately reflect biological changes in a waste source so this data just reflects the general reduction in influent concentration through the course of the study.

Figure 5 shows treatment efficiency response to changing loading over the operating period. Less variability

in COD removals than in $BOD_5$ removals is evident, presumably due to the insensitivity of the COD analysis to biological changes, the variability inherent in the $BOD_5$ analysis, and the sensitivity of the $BOD_5$ analysis to biological changes. Again, loading rate fluctuations are quickly reflected in $BOD_5$ and COD and no lingering effects of biomass upsets are observed.

The least squares plot of BOD removal vs. organic loading rate (figure 6) shows a substantial decrease in removal efficiency as loading rate increases. This relationship was desirable in that previous work indicated no limit to removal efficiency, presumably due to lower loading rates applied[2]. Since 85% removal is the lowest performance tolerable in conventional activated sludge, placing such a limit on this relationship indicates 200 lb BOD/1000 $ft^3$/day loading is an acceptable operating condition. This loading rate is five times greater than the 40 lb BOD/1000 $ft^3$/day loading commonly used in conventional activated sludge[10]. Thus based on organic loading rate performance equivalent treatment can be achieved in one fifth the reactor volume of activated sludge.

The least squares plot of COD removal efficiency (figure 7) shows far more scatter in the data than in the $BOD_5$ removal efficiency plot indicating far less correlation of COD removal with organic loading rate. The slight slope indicates this poor correlation which is best explained by again referring to the inherent insensitivity of the analysis

to biological changes. In comparison to previous fluidized bed treatment work the COD removal efficiency obtained in this study was nearly twice as high (32% average in previous work at 80 lb BOD/1000 $ft^3$/day compared to 60% removal at 270 lb BOD/1000 $ft^3$/day)[2].

The least squares plot of $BOD_5$ removal versus dentention (figure 8) indicates this relationship is not as critical to system performance as is organic loading rate. Thus this represents another advantage of this system's high rate performance capabilities. It should be noted the minimum 85% $BOD_5$ removal requirement for activated sludge comparison is met at a minimum detention time of 3.5 hours which is slightly less than the four hour requirement for activated sludge[10]. The maximum detention time commonly observed in conventional activated sludge operation is eight hours which for this system corresponds to 87% $BOD_5$ removal[10], so this system can meet the same detention time restrictions as activated sludge.

The least squares plot of %-COD removal versus detention time (figure 9) describes an unlikely relationship of decreasing performance with increasing detention. This poor correlation can be attributed to the nature of the COD analysis.

A good correlation was shown to exist between effluent concentration and organic loading rate (figure 10) in a direct proportion as expected. This relationship followed a similar slope for both $BOD_5$ and COD (figure 11),

thus helping to alleviate the uncertainty in the results obtained despite the variability of the data. The dotted line on the effluent BOD versus loading plot (least squares) at 30 mg/l represents the commonly observed minimum acceptable effluent quality for high rate treatment and is met at a maximum loading rate of 160 lb BOD/$10^3$ $ft^3$/day.

The probability plot of effluent BOD for actual mill activated sludge data and the fluidized bed system (figure 12) indicates greater variability in performance of the fluidized bed systems (indicated by greater slope) which is expected since the applied loading rate is much higher[10]. In addition the minimum acceptable effluent quality of 30 mg/l can be obtained more consistently in this system (83% probability) than in activated sludge (37% probability) and also is the case for a wide range of effluent $BOD_5$. This relationship is more a point of importance in terms of process variability and effluent discharge guidelines than the data presented earlier.

The probability plot of effluent COD for two loading rates (figure 13) demonstrates the higher process variability associated with higher applied loading rates. Also, a comparison of these two slopes with the previously discussed effluent $BOD_5$ probability plot indicates less COD variability, again attributed to the nature of the analysis of COD which does not accurately reflect biological changes in wastewater.

The final graphical presentation (figure 14) is the

least squares plot of volatile settleable solids production or sludge generation versus organic loading rate. This relationship is unlikely since these two variables should be in direct proportion as theorized by greater biological growth supported by an increased food source. The important point here is significantly less sludge wasting occurs in this system than in conventional activated sludge (which commonly generates 0.5 lb VSS/lb BOD removed per day) and is an advantage in terms of less requirements for sludge thickening and deposition. The average sludge generation was 0.20 $\pm$ 0.05 lb VSS/lb BOD removed.

A result not graphically presented is effluent suspended solids concentration which did not correlate to organic loading rate. The effluent suspended solids was 18.8 $\pm$ 3.8 mg/l, a low level which contributes to the overall high effluent quality achievable in this system.

Sludge age or mean organism lifetime within the system (cell retention time) and food to microorganism (F/M) ratio were calculated to point out the high rate conditions within this system. Average sludge age was 2.0 days compared to 5 to 15 days for conventional activated sludge. Average F/M ratio was 3 for the fluidized bed compared to 0.4 for activated sludge. These factors demonstrate higher rates of biological activity for this system than for conventional activated sludge.

Fluidization power requirements were calculated for this system to be 4.4 HP/MGD and did not take air

transferring power into account. When the quantity of sand bed was increased under fluidization conditions no significant increase in pressure head supplied by the pump was required to maintain fluidization. It was evident the sand particles could be fluidized easily with a low pressure head and large bed expansion occurred with small increases in head.

# C O N C L U S I O N S

This fluidized bed system can achieve high BOD removal rates producing an effluent of good consistent quality. This system requires one fifth the reactor volume of conventional activated sludge to achieve comparable loading rate performance. Less sludge generation occurs in this system than in activated sludge and the sludge seems to exhibit good settling characteristics. Operation of the system was troublesome, adding variability to the data obtained. Although the effects of shock loading per se were not observed, stabilization to process upsets occurred rapidly.

# R E C O M M E N D A T I O N S

The effects of changes in bed surface area should be investigated. The effects of shock loading should be more fully explored. Elimination of recycling mode of operation in favor of multistaging should be investigated. Apply a more efficient method of air dispersion to the system. Apply more effective process control to the system.

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FLUIDIZED BED WASTE TREATMENT SYSTEM

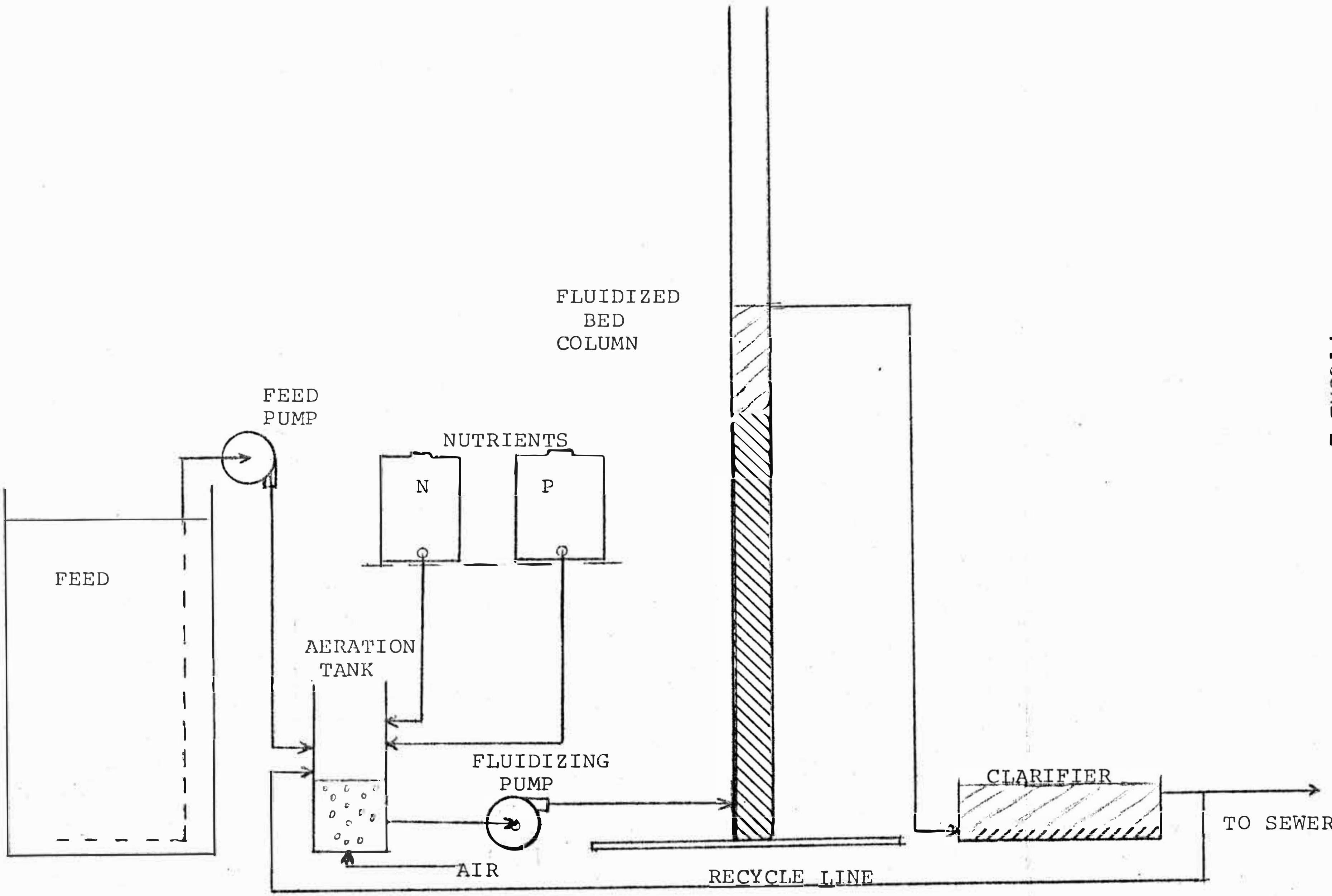



FIGURE 1

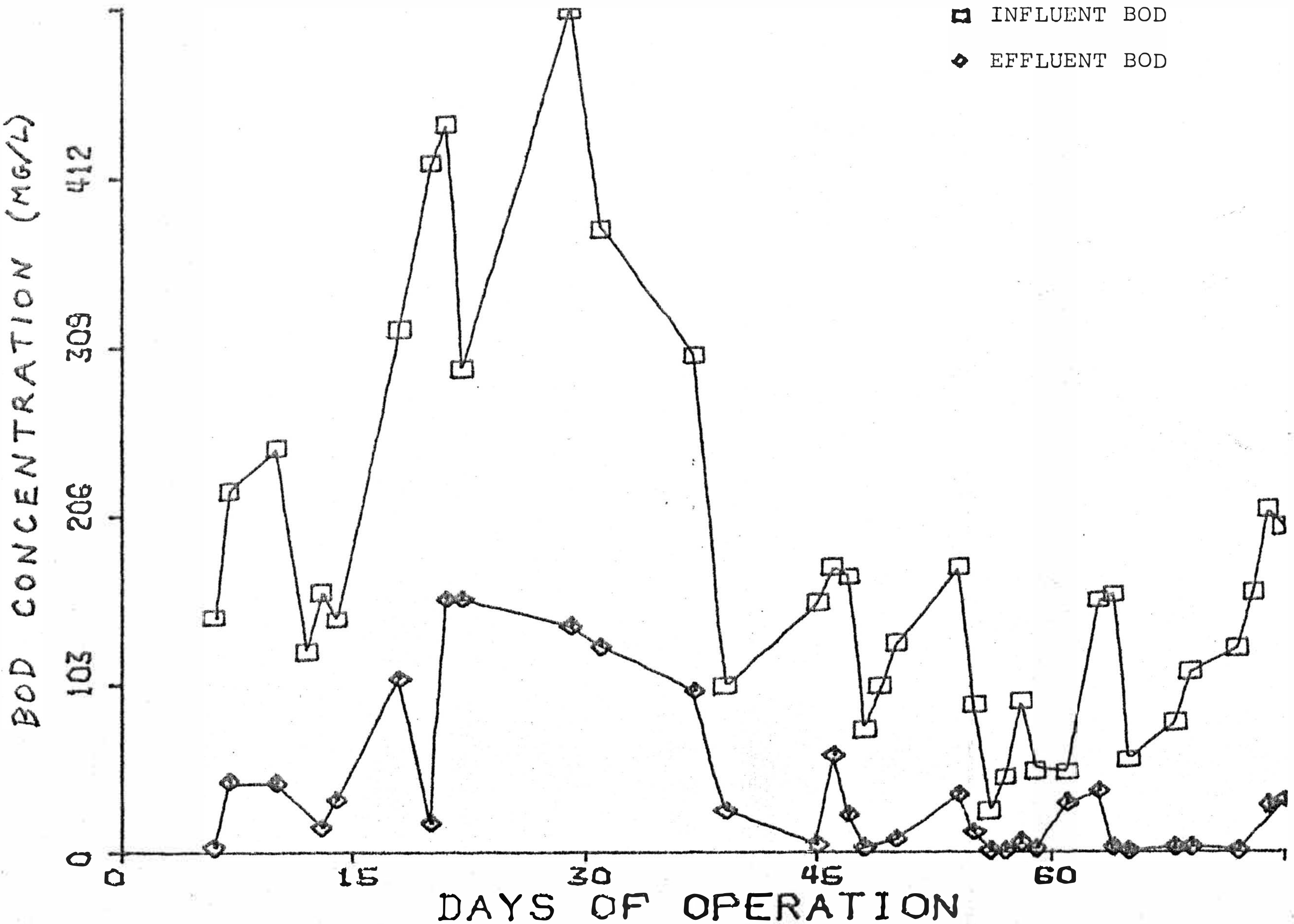



FIGURE 2 - BOD CONTROL CHART

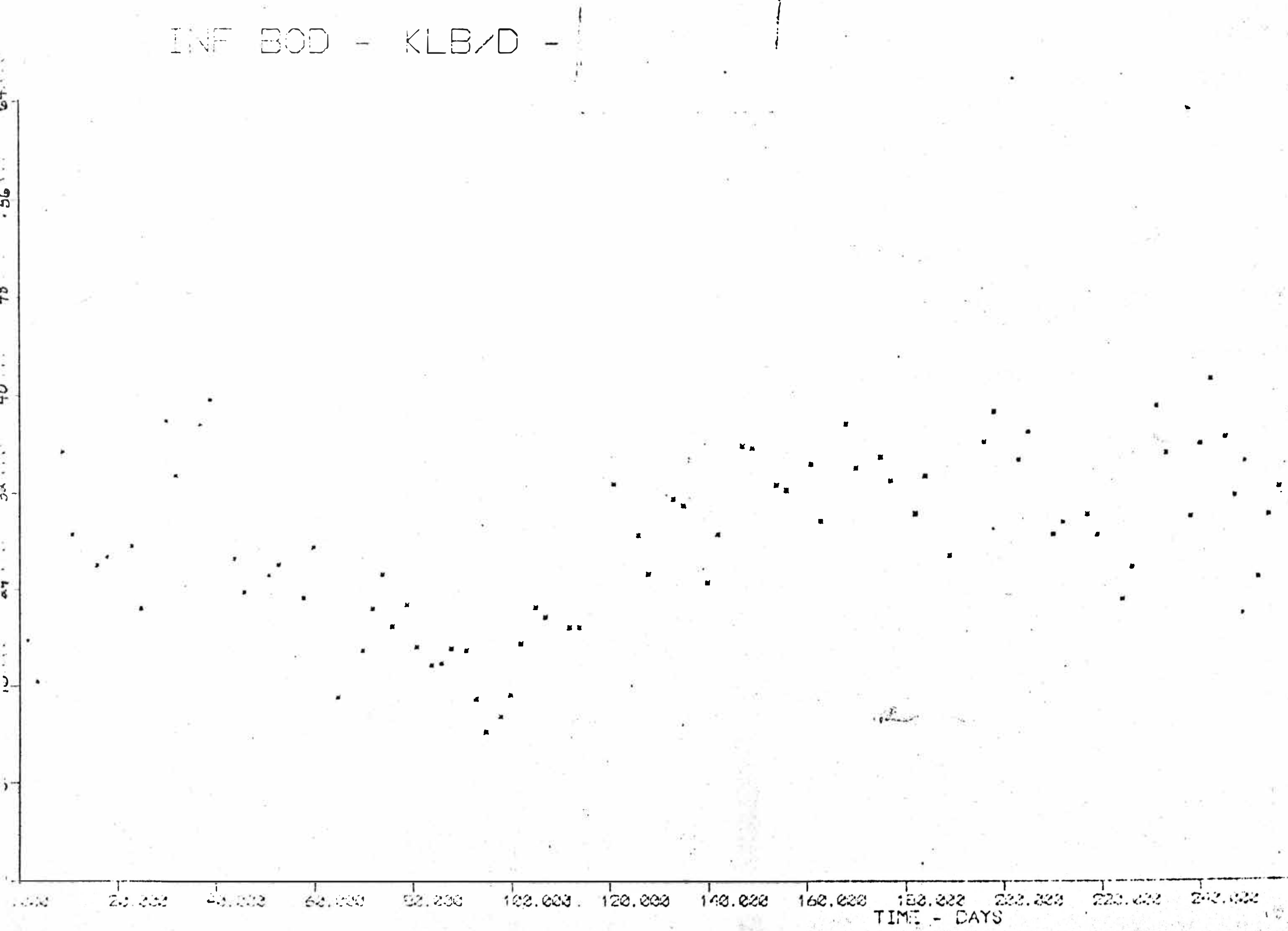



FIGURE 3 - ACTIVATED SLUDGE CONTROL CHART

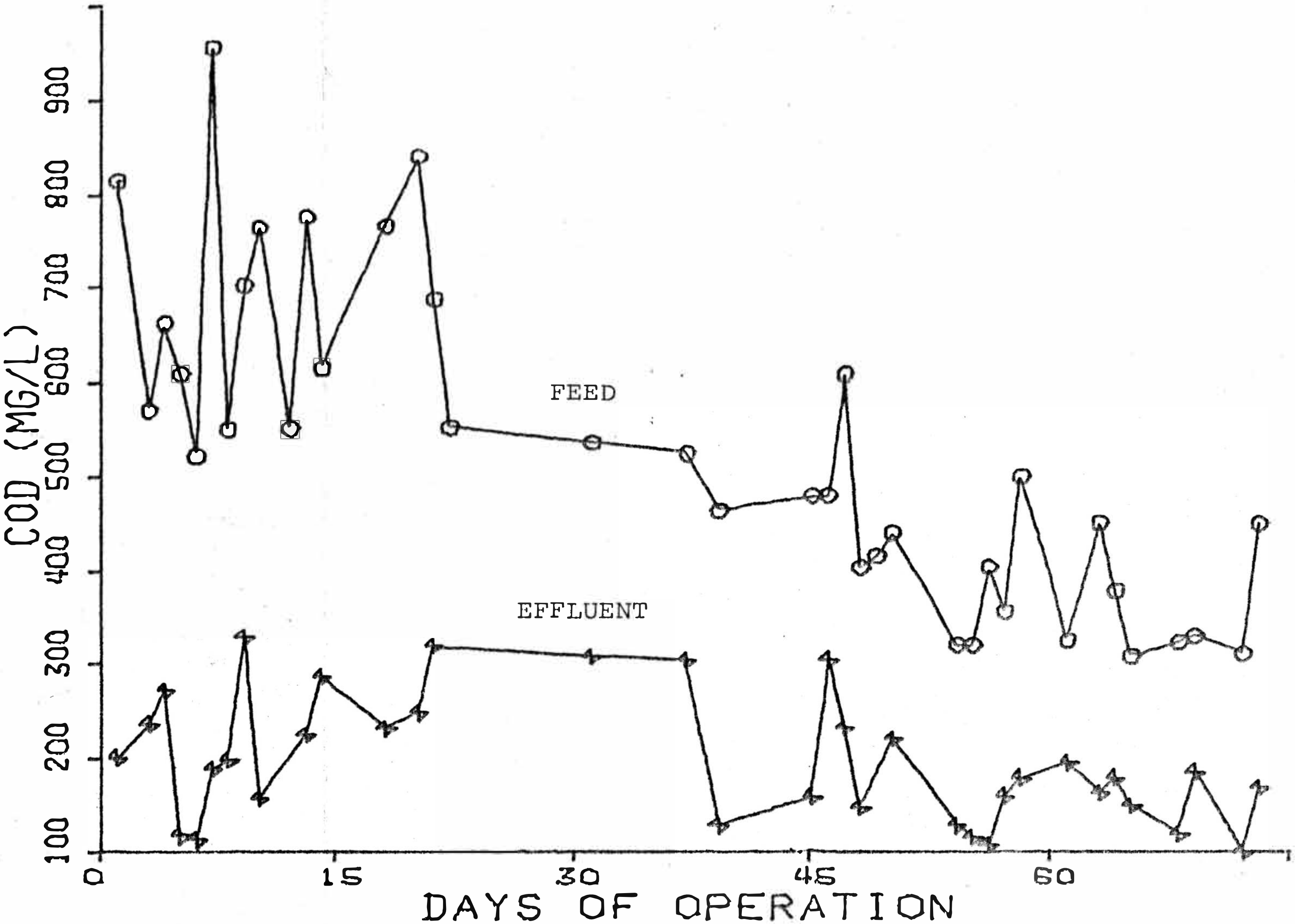



FIGURE 4 - COD CONTROL CHART

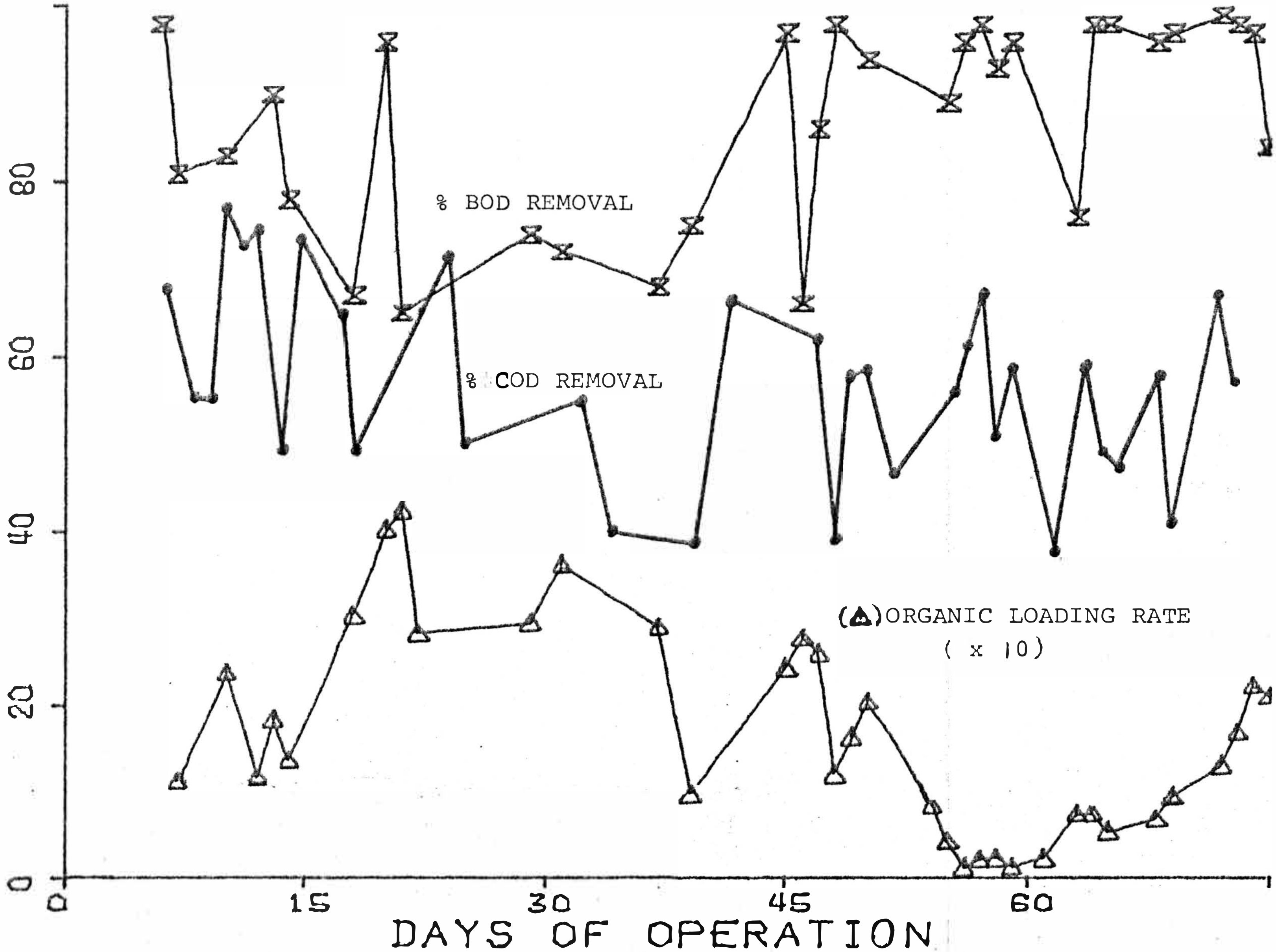



FIGURE 5 - CONTROL CHART

FIGURE 6 - BOD REMOVAL EFFICIENCY

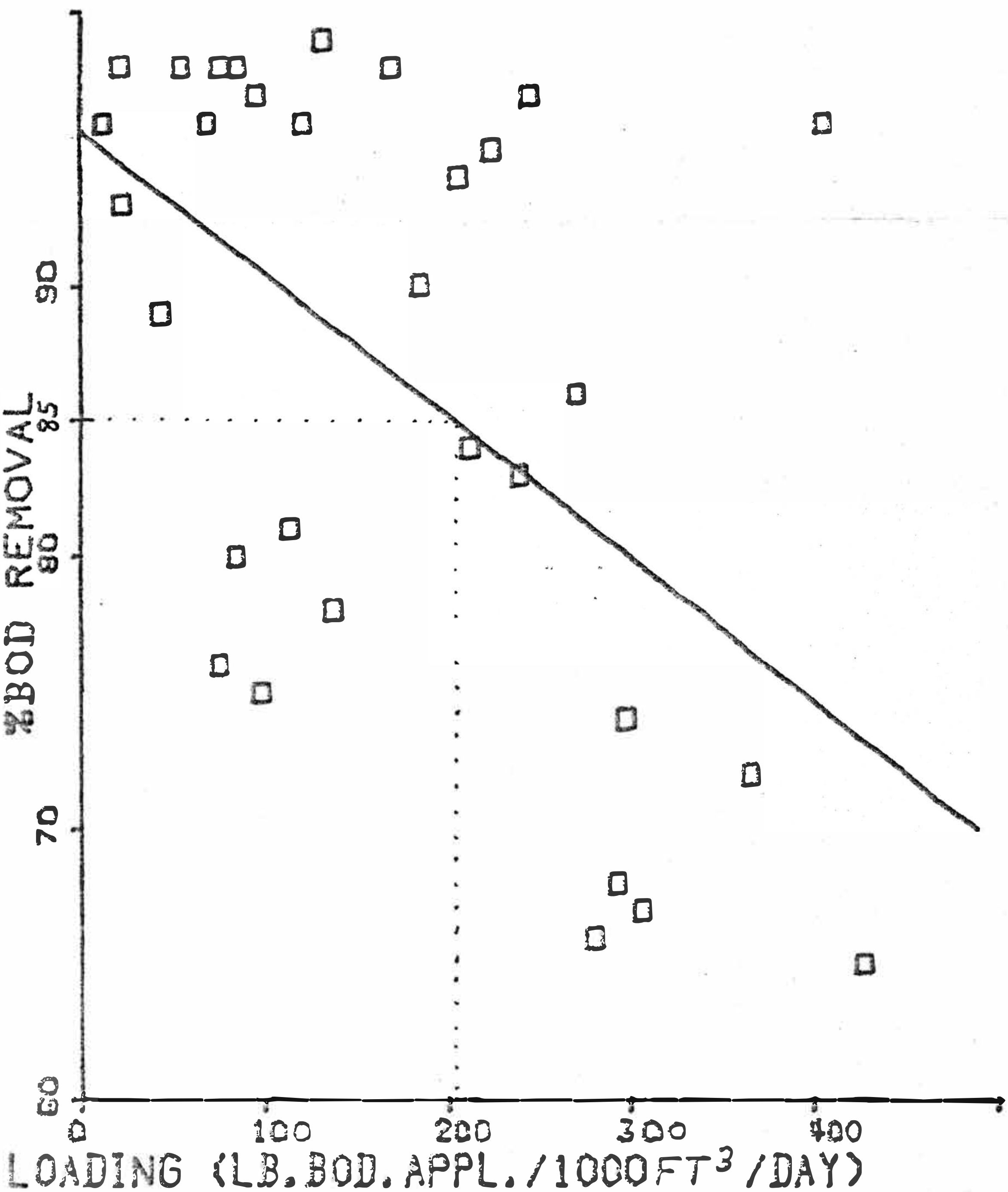
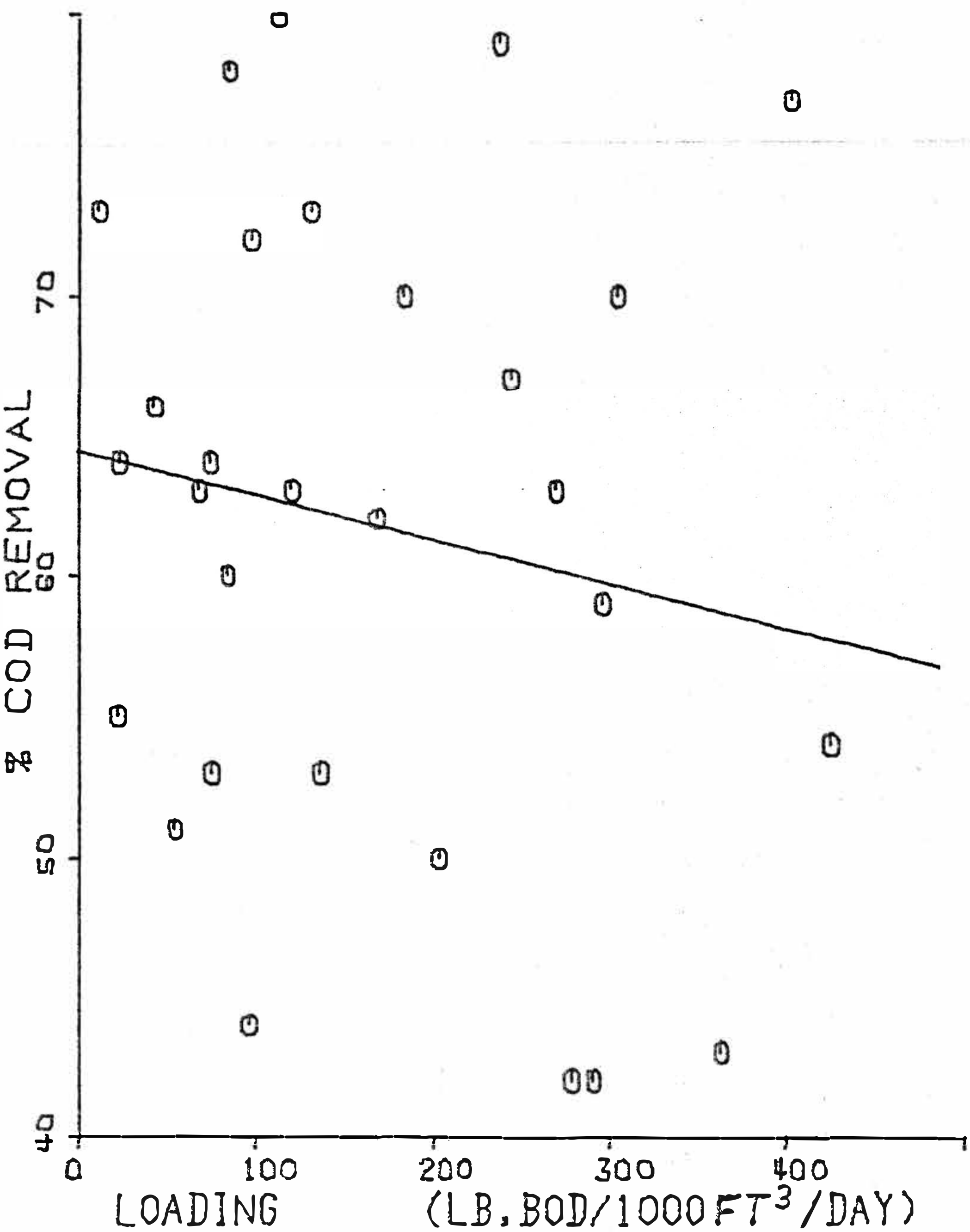


FIGURE 7 - COD REMOVAL EFFICIENCY



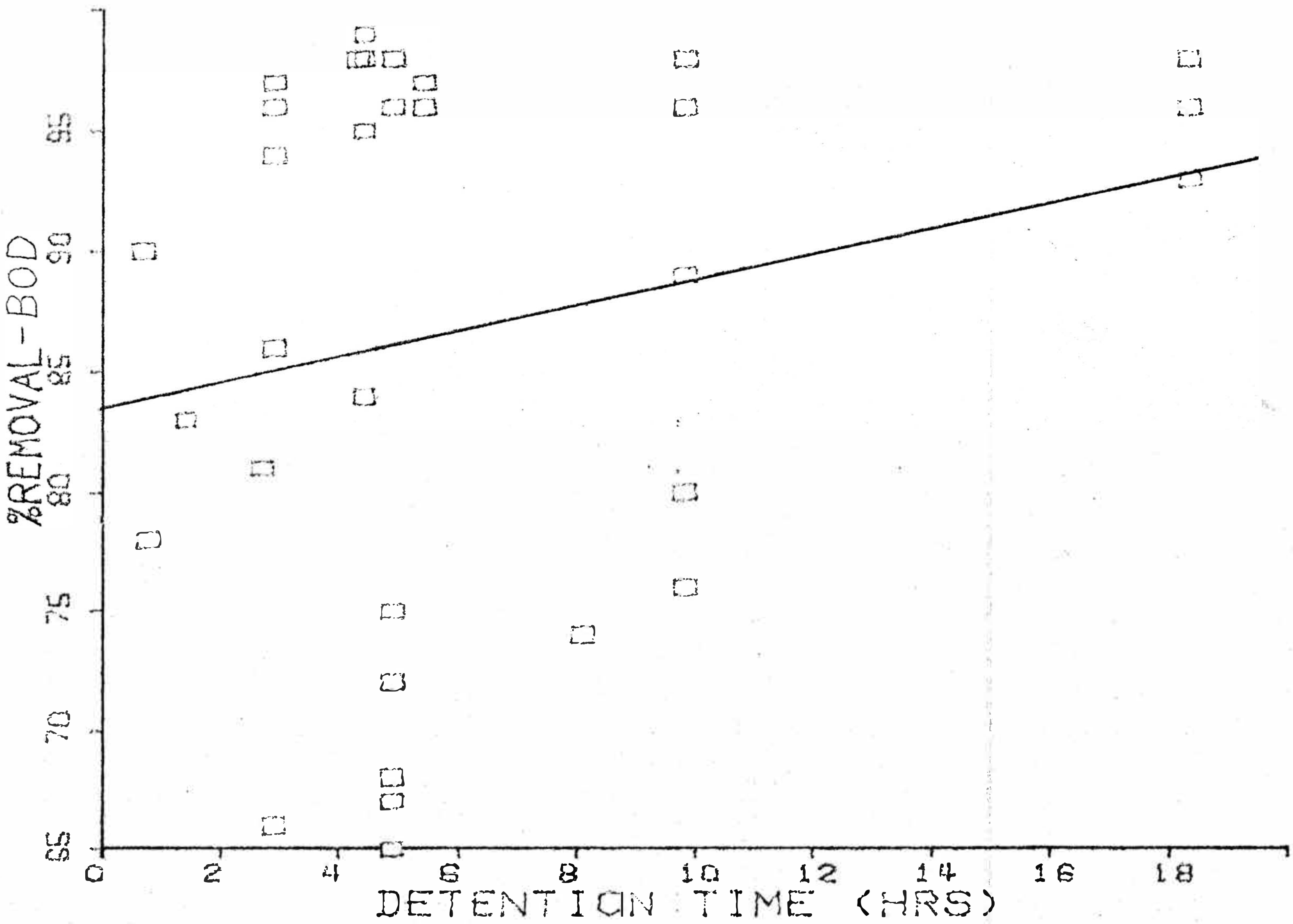



FIGURE 8 - EFFECT OF DETENTION OF BOD REMOVAL

FIGURE 9 - EFFECT OF DETENTION OF COD REMOVAL

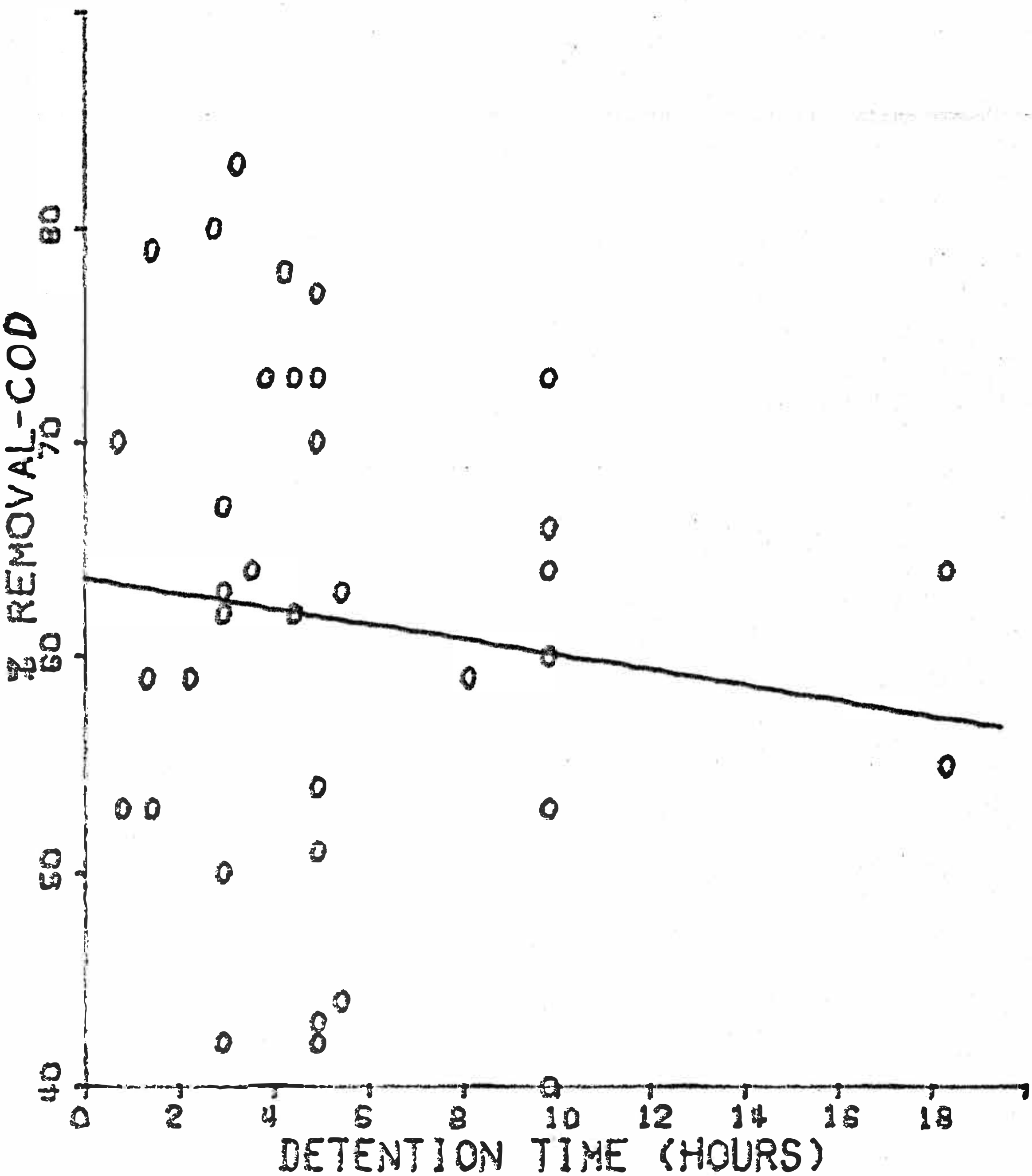


FIGURE 10 - EFFECT OF ORGANIC LOADING ON EFFLUENT BOD

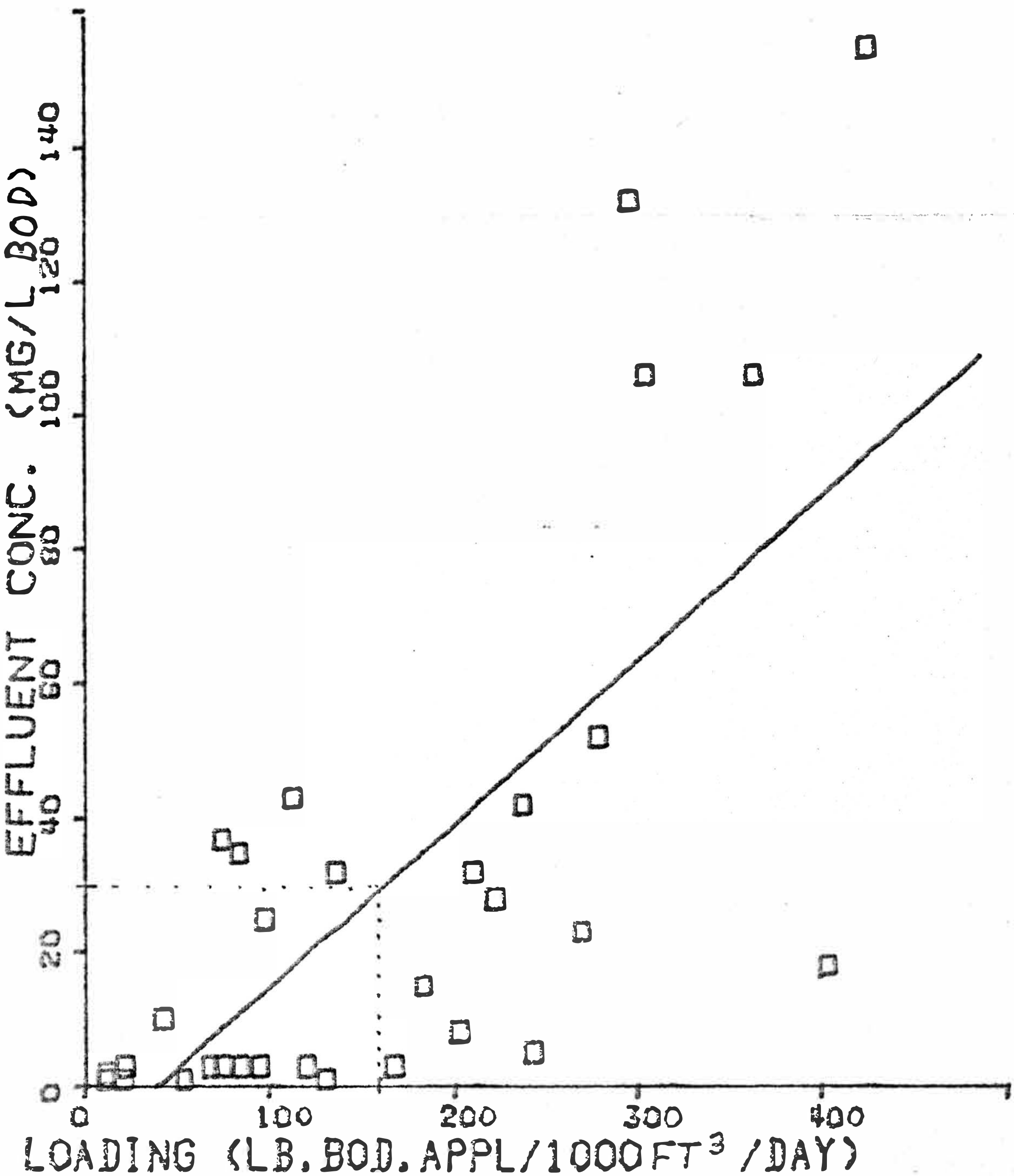
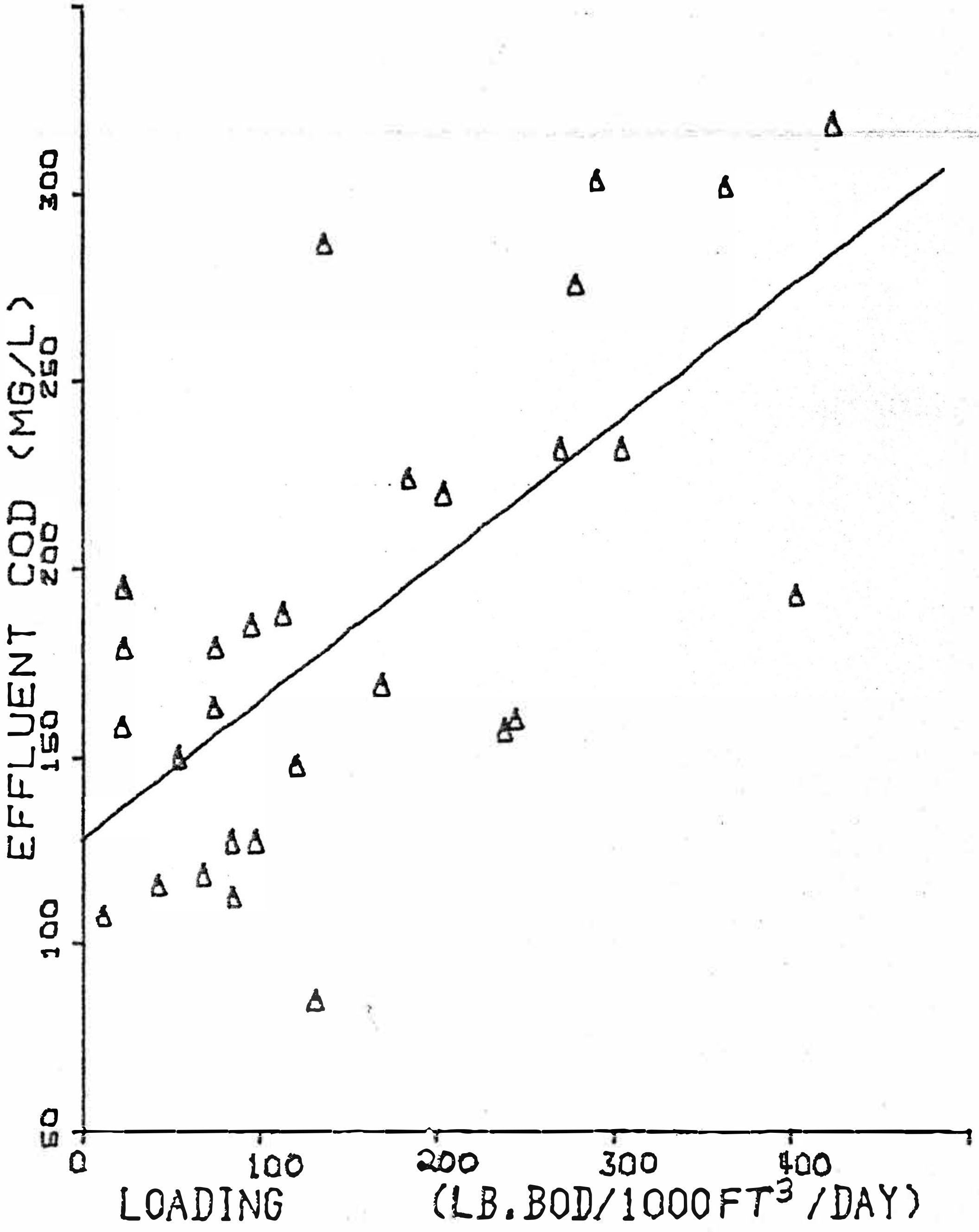


FIGURE 11 - EFFECT OF ORGANIC LOADING ON EFFLUENT COD



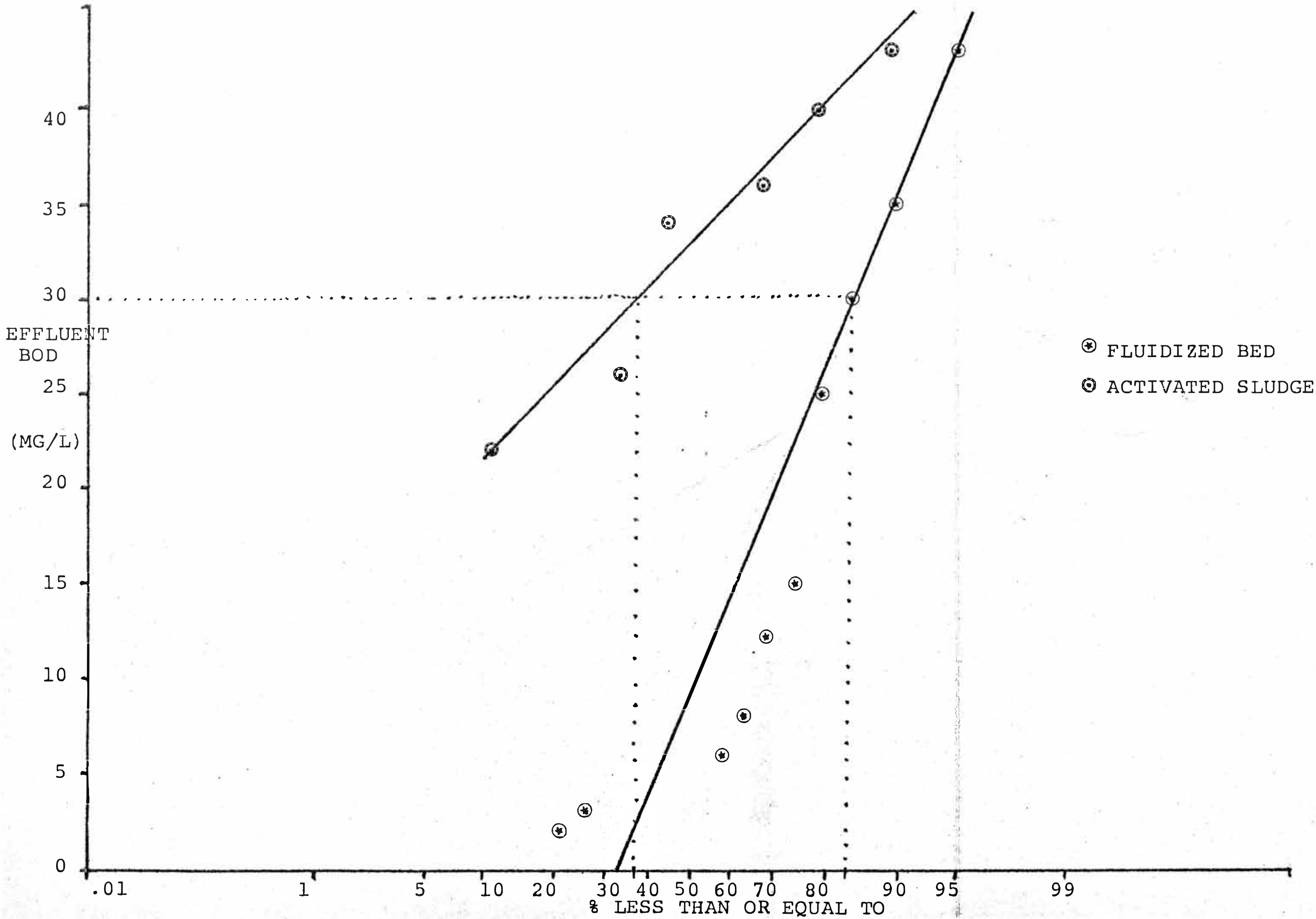



FIGURE 12 - EFFLUENT BOD PROBABILITY COMPARISON

FIGURE 13 - EFFLUENT COD PROBABILITY AND LOADING RATE COMPARISON

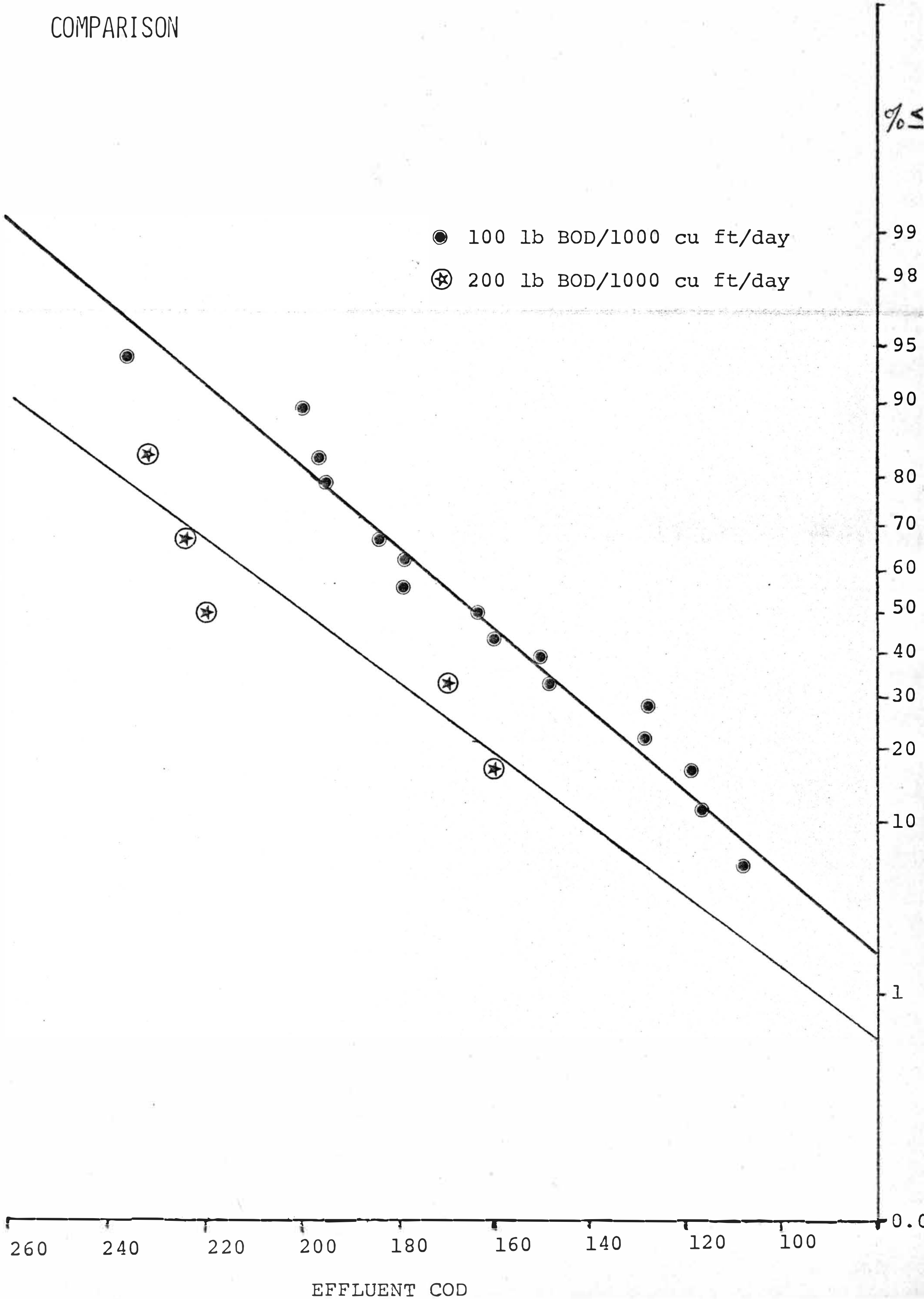
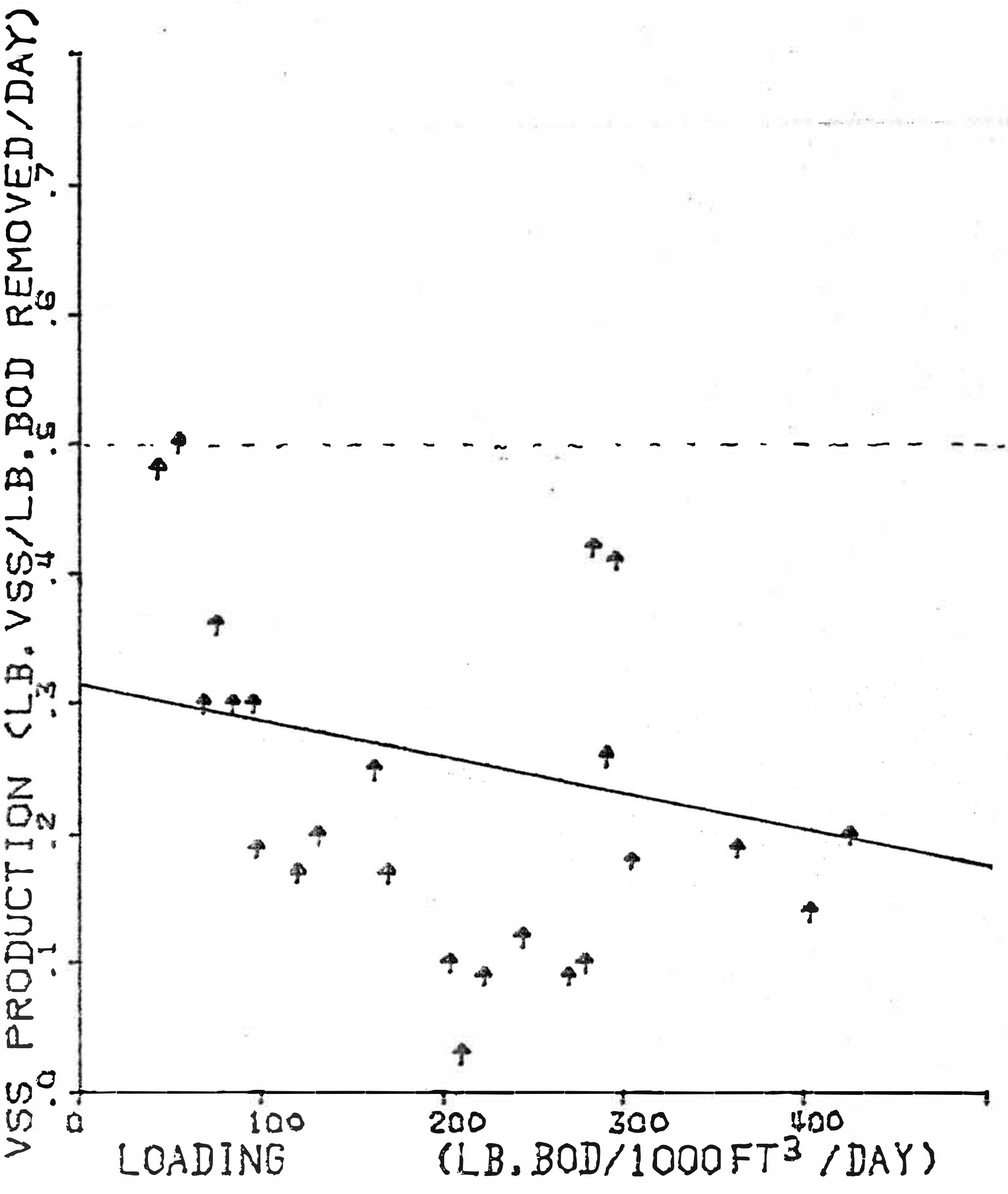


FIGURE 14 - EFFECT OF ORGANIC LOADING ON SLUDGE GENERATION



| DATE | DAY OF OPERATION | FLOW RATE ml/min | FEED COD mg/l | CELL COD mg/l | EFFLUENT COD mg/l | FEED BOD mg/l | CELL BOD mg/l | EFFLUENT BOD mg/l | EFFLUENT SS mg/l | VSS PROD $\frac{\text{lb VSS}}{\text{lb BOD}}$ | % COD REMOVAL | % BOD REMOVAL | DETENTION (HOURS) | ORGANIC LOADING $\frac{\text{lb BOD}}{1000\ ft^3/day}$ | FLUID BED FLUX cm/min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/10 | 1 | 11 | 814 | 220 | 200 | | | | | | 73 | | 3.8 | | 44 |
| 1/13 | 3 | 31 | 570 | 271 | 236 | | | | | | 59 | | 1.3 | | 49 |
| 1/14 | 4 | 19 | 661 | 362 | 271 | | | | | | 59 | | 2.2 | | 41 |
| 1/15 | 5 | 13 | 608 | 105 | 117 | | | | | | 83 | | 3.2 | | 40 |
| 1/16 | 6 | 10 | 521 | 128 | 113 | 144 | | 3 | | | 78 | 98 | 4.2 | 85 | 42 |
| 1/17 | 7 | 16 | 955 | 237 | 188 | 222 | 63 | 43 | | | 80 | 81 | 2.7 | 113 | 49 |
| 1/18 | 8 | 12 | 550 | 252 | 197 | | | | | | 64 | | 3.5 | | 54 |
| 1/19 | 9 | 30 | 702 | 329 | 329 | | | | | | 53 | | 1.4 | | 54 |
| 1/20 | 10 | 30 | 764 | 189 | 157 | 248 | 82 | 42 | | | 79 | 83 | 1.4 | 237 | 57 |
| 1/22 | 12 | 30 | 551 | | 398 | 123 | | 74 | | | 28 | 40 | 0.8 | 117 | 1.5 |
| 1/23 | 13 | 36 | 775 | 735 | 224 | 160 | 20 | 15 | | | 70 | 90 | 0.7 | 183 | 1.8 |
| 1/24 | 14 | 30 | 614 | 425 | 287 | 143 | 68 | 32 | | | 53 | 78 | 0.8 | 136 | 1.5 |
| 1/28 | 18 | 30 | 766 | 433 | 232 | 320 | | 106 | | .18 | 70 | 67 | 4.9 | 304 | 65 |
| 1/30 | 20 | 30 | 840 | 193 | 248 | 422 | 116 | 18 | | .14 | 77 | 96 | 419 | 403 | 65 |
| 1/31 | 21 | 30 | 687 | 374 | 319 | 445 | 166 | 155 | | .20 | 54 | 65 | 4.9 | 425 | 65 |
| 2/1 | 22 | 30 | 552 | | 352 | 296 | 168 | 155 | | .42 | 36 | 48 | 4.9 | 283 | 65 |
| 2/8 | 29 | 18 | 1320 | 547 | 547 | 515 | 132 | 138 | | .41 | 59 | 74 | 8.1 | 295 | 65 |
| 2/10 | 31 | 30 | 536 | 296 | 308 | 381 | 106 | 125 | | .19 | 43 | 72 | 4.9 | 363 | 65 |
| 2/16 | 37 | 30 | 524 | | 304 | 304 | | 98 | | .26 | 42 | 68 | 4.9 | 290 | 65 |
| 2/18 | 39 | 30 | 464 | 212 | 128 | 102 | 63 | 25 | | .39 | 72 | 75 | 4.9 | 97 | 65 |
| 2/24 | 45 | 50 | 480 | 184 | 160 | 153 | 9 | 5 | | .12 | 67 | 97 | 2.9 | 243 | 45 |
| 2/25 | 46 | 50 | 480 | 276 | 304 | 175 | 52 | 59 | | .10 | 42 | 66 | 2.9 | 278 | 45 |
| 2/26 | 47 | 50 | 608 | 260 | 232 | 169 | | 23 | | .09 | 62 | 86 | 2.9 | 269 | 45 |
| 2/27 | 48 | 50 | 404 | | 148 | 75 | | 3 | | .27 | 63 | 96 | 2.9 | 120 | 45 |
| 2/28 | 49 | 50 | 416 | | 304 | 102 | | 52 | | .25 | 27 | 49 | 2.9 | 162 | 45 |
| 2/29 | 50 | 50 | 440 | | 220 | 128 | | 8 | | .10 | 50 | 94 | 2.9 | 203 | 45 |
| 3/4 | 54 | 15 | 320 | | 128 | 175 | 35 | 35 | | .30 | 60 | 80 | 9.8 | 84 | 45 |
| 3/5 | 55 | 15 | 344 | | 116 | 90 | 10 | 12 | | .48 | 66 | 89 | 9.8 | 43 | 45 |
| 3/6 | 56 | 15 | 404 | 124 | 108 | 26 | 0 | 1 | | 1.46 | 73 | 96 | 9.8 | 12 | 45 |
| 3/7 | 57 | 8 | 356 | 156 | 160 | 46 | 35 | 1 | | 1.54 | 55 | 98 | 18.3 | 22 | 45 |
| 3/8 | 58 | 8 | 500 | | 179 | 92 | 3 | 6 | 34 | .78 | 64 | 93 | 18.3 | 23 | 45 |
| 3/9 | 59 | 8 | | | | 50 | 13 | 2 | 38 | 1.45 | | 96 | 18.3 | 13 | 45 |
| 3/11 | 61 | 15 | 325 | | 195 | 49 | | 30 | 126 | | 40 | | 9.8 | 23 | 45 |
| 3/13 | 65 | 30 | 451 | | 163 | 155 | | 37 | 56 | | 64 | 76 | 9.8 | 74 | 45 |
| 3/14 | 68 | 27 | 378 | | 179 | 158 | | 3 | 24 | .36 | 53 | 98 | 9.8 | 75 | 45 |
| 3/15 | 69 | 27 | 308 | | 150 | 57 | | 1 | 8 | .50 | 51 | 98 | 4.9 | 54 | 45 |
| 3/18 | 72 | 33 | 323 | | 119 | 79 | | 3 | 34 | .30 | 63 | 96 | 5.4 | 68 | 45 |
| 3/19 | 73 | 33 | 330 | | 185 | 111 | | 3 | 20 | .30 | 44 | 97 | 5.4 | 95 | 45 |
| 3/22 | 72 | 33 | 311 | | 85 | 125 | | 1 | 8 | .2 | 73 | 99 | 4.4 | 131 | 45 |
| 3/23 | 73 | 33 | 450 | | 169 | 160 | | 3 | 0 | .17 | 62 | 98 | 4.4 | 168 | 45 |
| 3/24 | 74 | 33 | | | | 211 | 10 | 29 | 20 | .09 | | 95 | 4.4 | 222 | 45 |
| 3/25 | 75 | 33 | | | | 200 | | 32 | 16 | .03 | | 84 | 4.4 | 210 | 45 |

TABULATED DATA