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R. W. Raible
University of Arkansas, Fayetteville

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R. W. Raible
Principal Investigator

WATER RESOURCES RESEARCH CENTER

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R. W. Raible
Principal Investigator

ARKANSAS WATER RESOURCES RESEARCH CENTER
University of Arkansas
Fayetteville 72701

for work performed at

Department of Electronics and Instrumentation
University of Arkansas Graduate Institute of Technology
Little Rock 72203

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ABSTRACT

SURVIVAL AND GROWTH RATE OF CHANNEL CATFISH AS A FUNCTION OF DISSOLVED-OXYGEN CONCENTRATION

Channel catfish were raised in water-recirculating systems for several periods of about six months duration each. Initial stock was fingerling size fish (10 to 20 grams). At dissolved-oxygen levels below 2.5 parts per million, mortality was high. Fish raised in tanks held at dissolved-oxygen levels between 3.0 and 6.8 parts per million showed increased gains of weight for each increment of added oxygen. Weight gains were as much as 50 percent higher at 6.8 parts per million compared with weights at 3.0 parts per million. Feed conversion was good in all cases. When feeding was limited to demand, feed conversion was about the same at all oxygen levels, indicating that reduced oxygen levels resulted in reduced appetites for those fish at lower oxygen levels. Conclusions are that the dissolved-oxygen level should be held as close to saturation as circumstances allow for maximum gain rate.

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SURVIVAL AND GROWTH RATE OF CHANNEL CATFISH AS A FUNCTION OF DISSOLVED-OXYGEN CONCENTRATION

I. INTRODUCTION

The increasing importance of channel catfish (Ictalurus punctatus) as an agricultural commodity has generated interest in establishing controllable methods of fish cultivation. Unfortunately, there is a dearth of fundamental information about the environmental requirements of channel catfish for attaining maximum growth with minimum problems for the fish culturist. For all fish, health, growth, disease, and death are related to the amount of oxygen dissolved in the water that surrounds them. In the case of channel catfish, no useful figures on the minimum dissolved-oxygen concentrations necessary for survival, growth, or freedom from disease currently are available.

During a three-year research program, several batches of fingerling channel catfish were cultivated for approximately six months per batch in closed water-recirculating systems that incorporated biological filters. These controllable systems, designed and constructed specifically for this project, stabilized the variables affecting fish growth so that the effects of various concentrations of dissolved oxygen could be studied. The findings of these experiments are set forth in this report.

II. BACKGROUND

Interest in the cultivation of channel catfish as a source of protein for the human diet has increased during recent years. This relatively new agricultural product offers the farming community an additional source of income with the possibility of a relatively high yield per acre of land utilized. A survey[1] by the National Marine Fisheries Service showed farm production of catfish in the state of Arkansas to be approximately 9 million pounds (harvested from 5,276 acres) in 1973 with a total of 9,197 acres devoted to commercial catfish farming. Total United State production in 1973 was in excess of 49 million pounds (harvested from 29,942 acres) with a total of 54,633 commercial acres. Although no production figures have been released by the Fisheries Service for 1974, a recent survey[2] indicated that Arkansas catfish farmers had increased their total commercial acreage to 10,992 acres in 1974.

A. Controlled Culture Systems

Efforts have been underway for several years to determine the desirable characteristics for controlled systems for the cultivation of channel catfish. Examples of the improvements that could be attained in aquaculture through the use of such controlled systems may be found in the poultry industry, and similar progress is appearing in the swine and beef industries. However, at the present time, channel catfish generally are being cultivated in basically uncontrolled ponds where the fish are, for all intents and purposes, inaccessible for the major portion of their growth cycle. The resultant inability of the aquaculturist to observe his crop as it grows leads to difficulties in the detection of diseases and in the recording of growth rates. A second problem with the pond system arises at harvest, when large amounts of manual labor are required to seine the freely swimming, fully grown catfish from acres of water.

The poultry industry's success with caging hens for egg production and with raising broilers in houses with a high population density has led to attempts to develop similar methods of catfish culture. Two methods are under examination at the present time: (1) raceway or tank culture and (2) cage culture. In the case of raceway culture, the fish are confined in a narrow area, and water is pumped past them. In the case of cage culture, the fish are kept in cages that are immersed in a large body of water, and no artificial water circulation is used.

B. Problems Related to Dissolved Oxygen

One of the problems that arise when using either the raceway or the cage method is maintaining a sufficiently high concentration of dissolved oxygen so that there is no decrease of the natural growth rate nor damage to the catfish due to disease. The cost of the raceway method of catfish culture is very much affected by the cost of the power needed to pump the water past the fish. The amount of power consumed is partially dependent upon the necessity of aerating the water to keep the concentration of dissolved oxygen sufficiently high--often at concentration where the water is air saturated, approximately 8.0 parts per million (ppm) dissolved oxygen at 25° C (77° F). The determination of a minimum safe concentration for dissolved oxygen possibly could mean a reduction in power consumption. In cage culture, problems caused by oxygen deficiency in the area of the cages may arise if the cages are large and the population density of the fish is high. If an oxygen deficiency were to occur, air would have to be introduced artificially into the water. Once again, knowledge of a minimum safe concentration of dissolved oxygen could be used to determine the proper population density or to establish the proper aeration rate for the pond.

To date, no useful figures specifying the lower limit of oxygen requirements of channel catfish are available. Further, the effects of the dissolved-oxygen concentration on the survival rate, growth rate, feed conversion rate, and disease incidence for channel catfish are not known.

C. Project Objectives

The objectives of this research project were:

(1) To study the survival rate of channel catfish exposed to conditions of low concentrations of dissolved oxygen over extended periods of time;

(2) To relate feed conversion and growth rate of channel catfish to the continuous exposure of the fish to low concentrations of dissolved oxygen;

(3) To examine the susceptibility to disease of channel catfish whose biological systems are under stress from low concentrations of dissolved oxygen; and

(4) Ultimately, to attempt to estabilish a minimum dissolved-oxygen concentration and a temperature level at which channel catfish can be raised with the expectation of achieving optimum growth and survival rates.

III. RESEARCH PROCEDURE

The basic research procedure was established during the first year of this project. During that period, the major emphasis was directed toward designing and constructing a fish-cultivation tank and filter system that would permit precise control of the aquatic environment. A water-recirculating system employing a biological filter to purify the water was selected as the optimum controllable system. Eight of these systems (Figures 1 and 2) were constructed, and seven were stocked for each of the three experimental runs conducted during the remaining full-scale experimental period of the project.

Three stocking batches of fingerling channel catfish, each fish weighing 10-20 grams (less than an ounce), were cultured in the systems for periods of 165-188 days during the experimental period. Each of the stocking batches was divided into seven groups of approximately equal weight, and each of these seven groups was raised in one of the seven recirculating systems. The fish

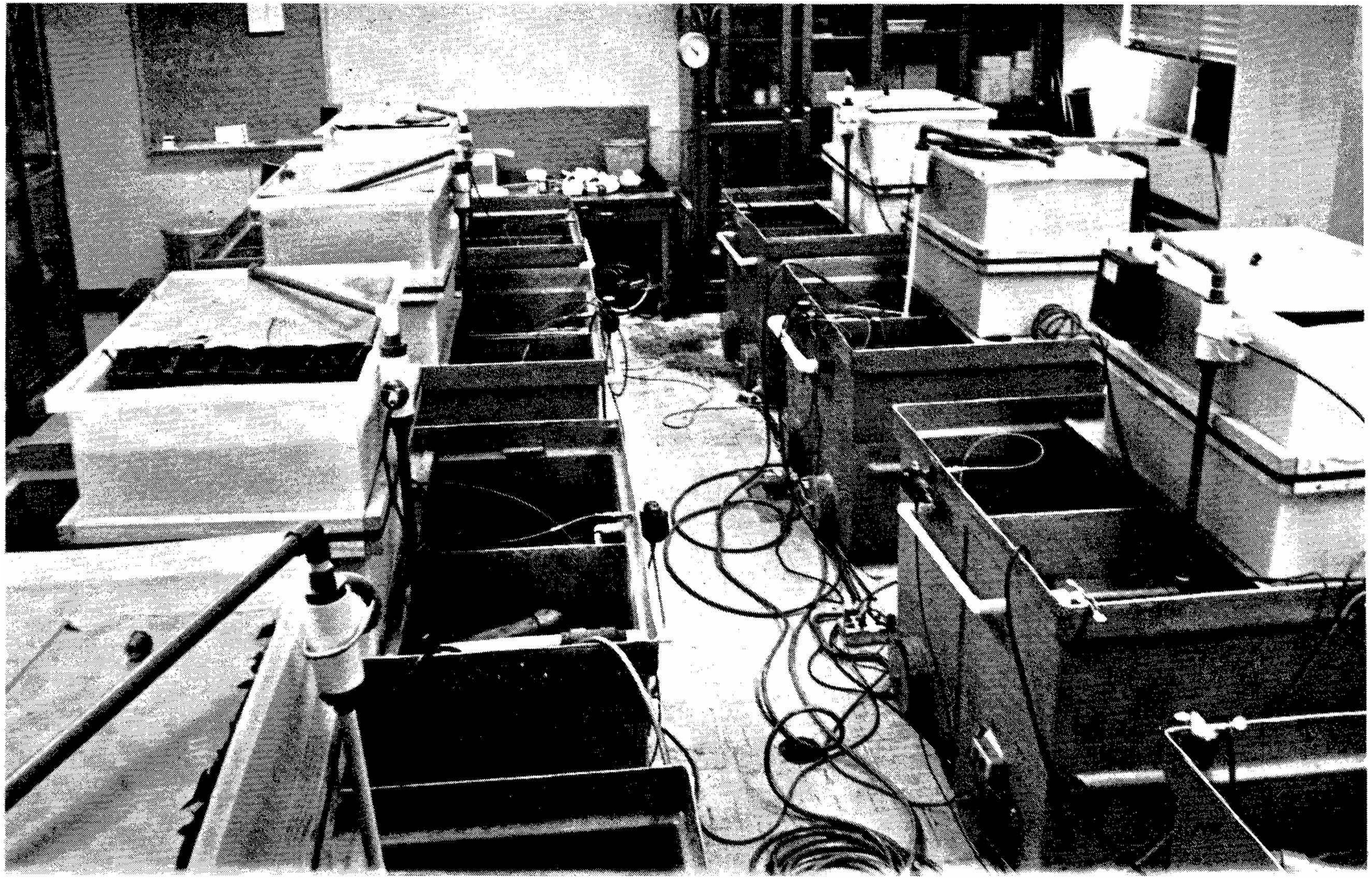

Fig. 1. Eight water-recirculating systems for raising catfish in a controlled environment. View of pump areas of systems.

Fig. 2. Siphon and settling basin areas of recirculating systems.

were observed throughout the growth cycle for abnormalities. However, they were disturbed as little as possible and were taken from their tanks only for monthly weighings.

Initial experiments rapidly demonstrated that channel catfish subjected to dissolved-oxygen concentrations of 1 ppm or less either died or were stressed to the point that any additional slight stress, such as being removed from the water for weighing, caused death. In fact, difficulty was encountered in maintaining the catfish for extended periods of time at dissolved-oxygen concentrations less than approximately 2.5 ppm. In view of this mortality, values of 3.0, 3.6, 4.2, 4.8, 5.4, 6.0, and 6.8 were selected as the dissolved-oxygen concentrations for the series of seven tanks utilized for the full-scale experimental runs. Earlier experimenters have demonstrated that around 27^{0} C (80.6^{0} F) is an optimum temperature for cultivating catfish. Further, it was determined to be necessary to maintain the ambient temperature of the room containing the culture systems at 27^{0} C in order to hold the water temperature at the same level over an extended period of time.

A. General System Design

Each of the water-recirculating systems was constructed around a double fiberglass tank, each half of which was 30 in. deep, 24 in. wide, and 72 in. long. Each half was watertight, permitting cultivation of the catfish in one tank with no cross-over to the filtration system in the other tank. A smaller tank (24 in. X 36 in. X 24 in.) was positioned above the double tank to provide an auxiliary filtration area. Total system water capacity was approximately 450 gal, with the fish-cultivation half of the main tank being maintained constantly at 180 gal.

The design of the system can best be described by tracing the circular path of the water from the cultivation area through the filters and back.

Water was drawn from cultivation tank by a 4-in.-diameter polyvinyl chloride siphon that was screened with half-inch mesh to prevent passage of the catfish. The mesh was coated with silicone rubber to prevent oxidation. The siphon was positioned at one end of the system (Figure 3) with its opening sufficiently far below the surface of the water (18 in.) to maximize its ability to remove the detritus and waste food products from the fish-culture tank. The siphon emptied into a settling basin (24 in. X 24 in. X 12 in.) in the filtration tank. The large-diameter siphon was chosen to produce a low water velocity, permitting the waste products to settle on the bottom of the basin and remain there with little disturbance.

The water then flowed over a partition between the settling basin and the main filter area. A pump at the bottom of the opposite end of the main filter tank drew the water, at a rate of 24 gal/min, through a biological filter and returned it to the fish-culture tank or forced the water up to the auxiliary filter in the smaller tank, which drained back into the main filter. The water in the system made three circuits per hour.

To permit accurate monitoring of the dissolved-oxygen concentration in the fish-cultivation tank, an electrode was positioned in the pump's output pipe. The electrode was connected to a metering system that automatically controlled the air-inlet valve. When the concentration of dissolved oxygen in the output pipe was below the selected level for the system, the metering system would open the valve, permitting pressurized air to mix with the water as it was returned to the cultivation tank.

The smaller tank positioned above the double tank contained an auxiliary biological filter that drained by gravity back into the main filter. This auxiliary filter was added when it was determined that the main filter was too small to accommodate the fish at the end of the approximately six-month growth period. However, the auxiliary filter was operated continuously, regardless

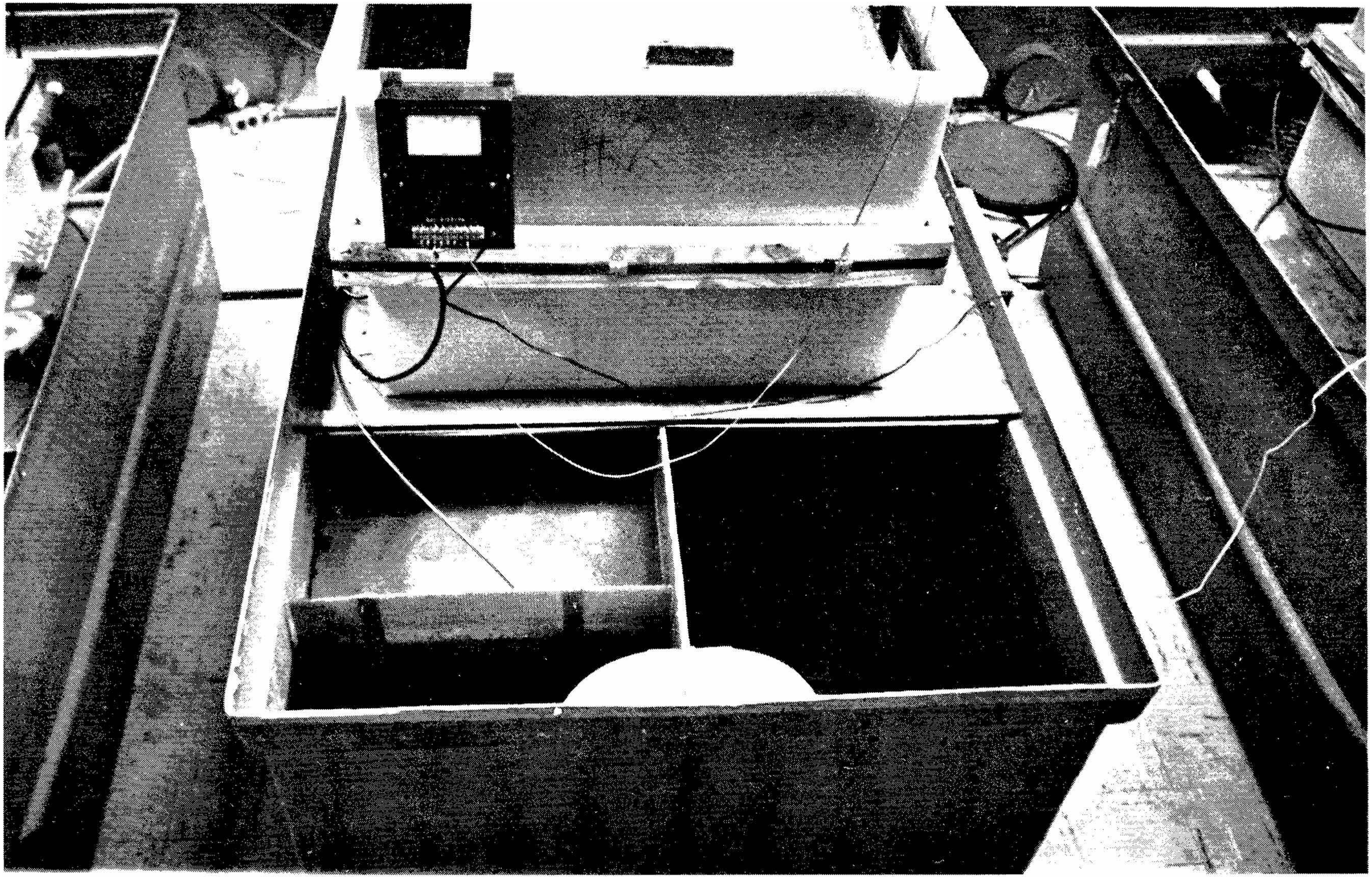

Fig. 3. PVC siphon connecting fish-cultivation tank with settling basin.

of the size of the fish in the system.

Figures 4-6 are schematic diagrams of the water-recirculating systems.

B. Filtration

The culture systems designed for this project incorporated biological filters that cleansed the water by utilizing the nitrogen cycle described by Spotte.[3] Initial attempts to construct a filter bed with materials described in the literature were disappointing because of rapid plugging of the filter by slime and finely divided waste products. The filter elements ultimately used in the systems were made of a polyvinyl chloride material called Flocor,[4] chosen because of its light weight, large surface area, and large passageways.

Naturally occurring bacteria, Nitrosomonas and Nitrobacter, attached themselves to the filter elements within three weeks after initial stocking of the cultivation tanks. These bacteria converted the ammonia generated in the systems into nitrites and nitrates and were able to keep the ammonia levels at approximately 1 ppm. To ensure that these aerobic bacterial had a sufficient supply of oxygen, air could be injected into the water as it flowed from the settling basin with no effect on the cultivation tank.

The maximum difficulty in generating a viable filter occurred when new materials, fresh water, and clean filter elements were used to construct a system. Under such circumstances, the ammonia-conversion process of the nitrogen cycle required a period of up to three weeks to become active. During this period, it was found advisable to place a small number of fish (in comparison with total carrying capacity) in each tank and to monitor the ammonia concentration in the water. The concentration of ammonia generally rose to 3-10 ppm, depending upon the number of fish in the system; then it decreased suddenly, dropping to approximately 0.2-0.3 ppm within 48-72 hr. At this concentration

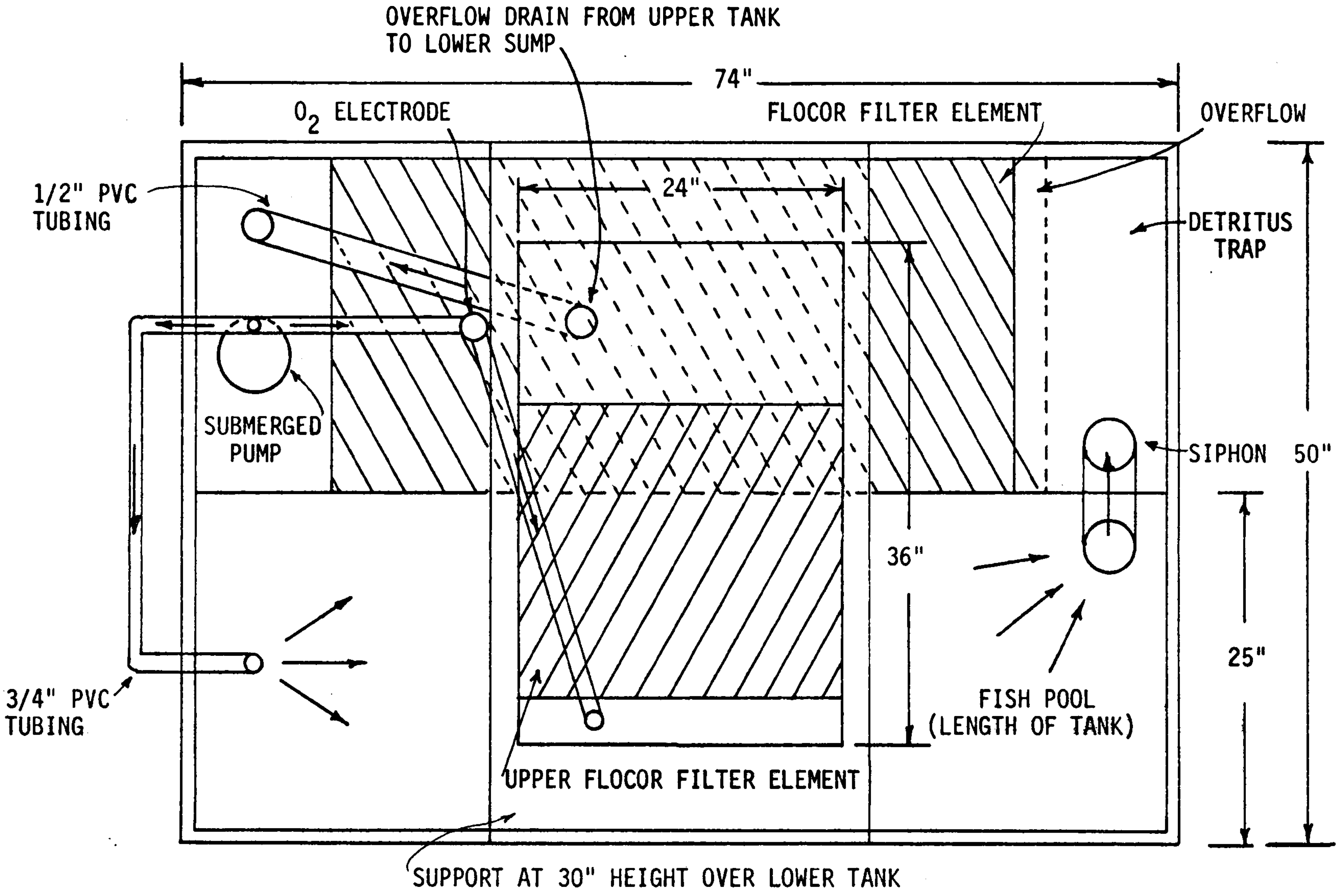

Fig. 4. Schematic diagram of recirculating system, top view.

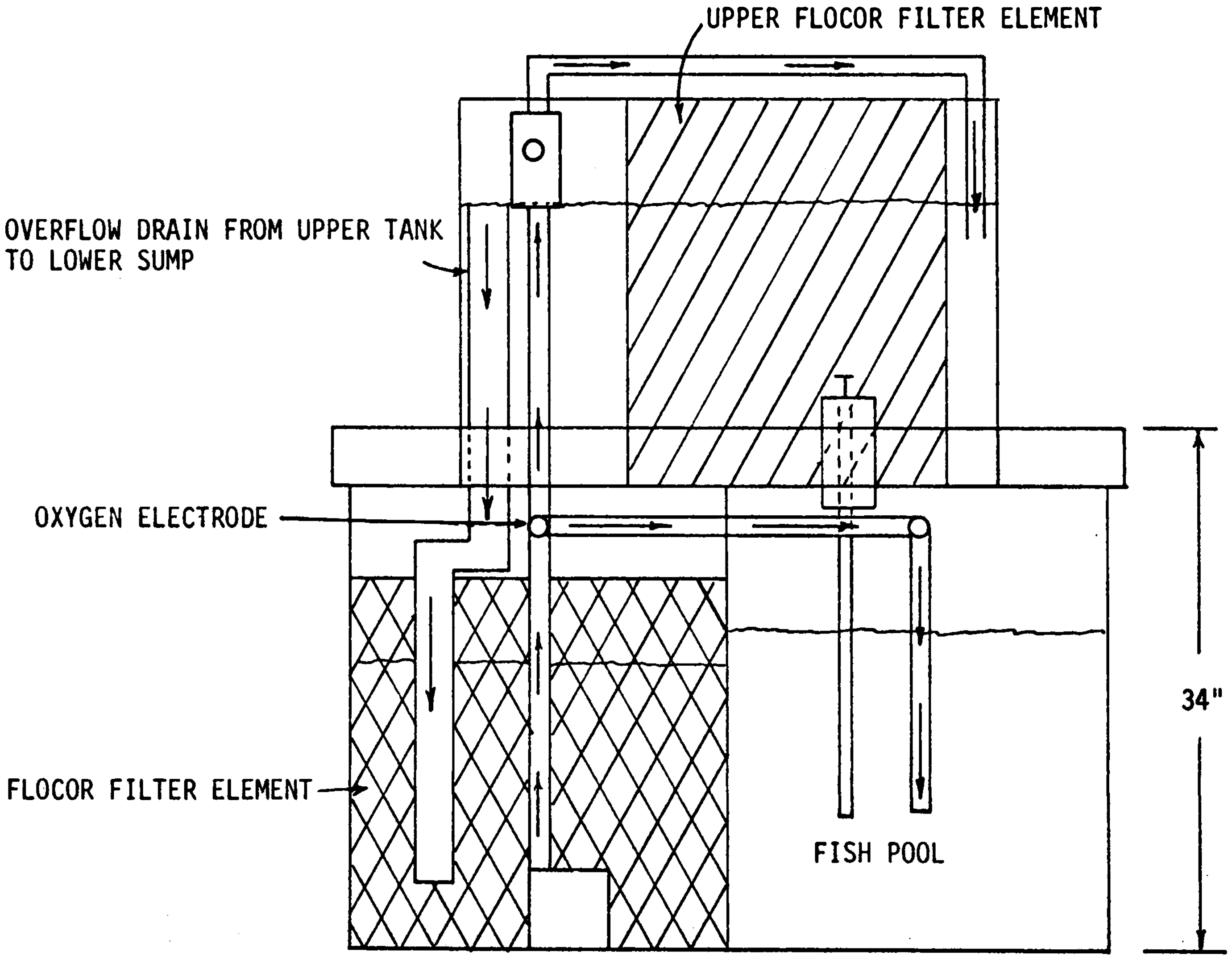

Fig. 5. Schematic diagram of recirculating system, front view.

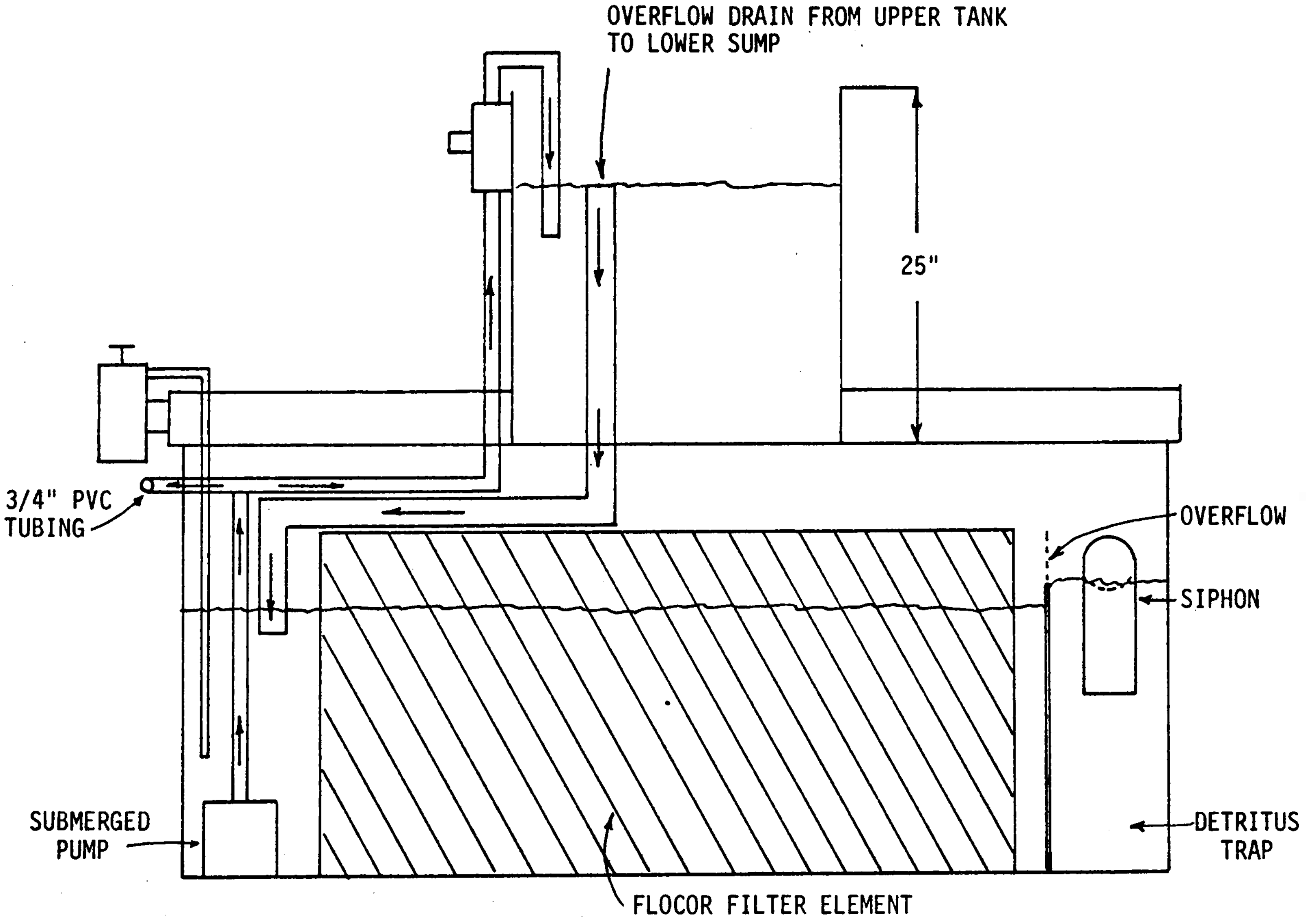

Fig. 6. Schematic diagram of recirculating system, side view.

of ammonia, a larger number of fish were introduced into the system, and the filter continued to function.

Once the ammonia-conversion cycle had been initiated, the fish could be removed at the end of their growth period and the systems left empty for approximately two weeks without harming the ability of the filters to return to full operation when a new batch of fish was introduced into the systems. However, when any of the systems was devoid of fish for more than two weeks, it was considered advisable to add ammonium hydroxide to the water every few days to prevent the filter from dying completely. The ammonium hydroxide supplied the ammonia needed in the life cycle of the bacteria.

It was found that a drop in the concentration of dissolved oxygen to an extremely low level with a resultant increase in the ammonia concentration would cause the system to fail catastrophically, sometimes within a period as brief as 24 hr. Since the ammonia-conversion bacteria require oxygen to maintain their life cycle, a severe drop in the dissolved-oxygen concentration would slow the rate of ammonia conversion. The increase in ammonia would cause the fish to begin dying, adding a very high biological oxygen demand. That, in turn, would further reduce the available oxygen, causing a spontaneous failure of the entire system.

C. Chemical Treatment of Culture Water

Precautions that were observed in the initial filling of the tanks included the addition of sodium thiosulfate to counteract any chlorine present in treated city water. Approximately one teaspoonful of sodium thiosulfate crystals was used to treat 200 gal of water. Once the systems were filled, fresh water was added only to compensate for evaporation (about 5 cuft per week). Any chlorine in these small amounts of compensation water caused no observable problems. Occasionally, it was found necessary to drain a tank (e.g., when the nitrate concentration rose to excessive levels) and refill it with fresh water. Sodium thiosulfate was then added to the fresh water.

During early stages of the experiments, the fish were found to thrive better, to be more comfortable, and to be less prone to disease when the water had been treated with hardening chemicals. As an added benefit, no Sphaerolitus growth, which had been a problem, was noted after the water-hardening chemicals had been added. It has not been determined absolutely that all the chemicals in Table I are necessary. The use of the proportions listed in the table was successful; therefore, no experimentation with additions or deletions was attempted.

Table I

Water-Hardening Chemicals

Chemicals	Grams per 180 gal water
Sodium carbonate (Na_2CO_3)	270
Calcium sulfate ($CaSO_4$)	130
Magnesium sulfate ($MgSO_4$)	190
Potassium chloride (KCl)	10

Fine limestone was added periodically to maintain the pH of the water in a basic state (between 7 and 8). The fish appeared to be less comfortable and more susceptible to disease when the water became acid.

The pH level of the water was unstable because one of the conversion products of the biological filter was nitric acid. When the fish were large, causing heavy loading of the system in terms of pounds per gallon, the acid production was very great, and considerable care was required to maintain a basic condition. Other authors (Burrows and Combs, 1968, and Kramer, Chin, and Mayo, 1972)[5,6] have suggested that ground oyster shell, used as part of the filter, is sufficient as a buffer. In the present study, slime and finely divided waste products tended to cover the granules of the oyster shell, making it ineffective as a buffering agent for the fish-loading levels attained.

Initially, a partial-flow charcoal filter was used in the system. This filter was found to require considerable maintenance and was subject to the same slime formation as the oyster shell, which made it ineffective as a filtering medium. The charcoal filter was removed from the system, and no detrimental effects were observed. The only noticable change was that the color of the water deepened, making observation of the fish slightly more difficult. However, the fish apparently were not disturbed by the presence of the water-darkening agent and, in fact, seemed to prefer the added concealment.

D. Dissolved-Oxygen Control System

The heart of the experimental tank was the control system designed to maintain a selected dissolved-oxygen concentration at all times. The control system was an outgrowth of previous studies performed by the Department of Electronics and Instrumentation,[7] University of Arkansas Graduate Institute of Technology, for the Arkansas Water Resources Research Center. That study involved consideration of the lifetime and temperature compensation of dissolved-oxygen electrodes.

The electrode used in the control system was the Beckman Model 191605 because previous work had shown that its lifetime is long relative to that of other electrodes and that the large cathode area makes it less sensitive to fouling. In addition, this electrode is constructed in such a manner that it will fit into a standard 2-in.-diameter polyvinyl chloride pipe tee using only O-rings as seals. The connector and wiring that carry the signal from the electrode thus can be kept dry.

The circuit used with the electrode is shown in Figure 7. Amplifier A-1 is used to generate the polarizing potential for the electrode. The stability of the voltage is dependent upon a regulated +15 V supply. Amplifier A-1 presents a low output impedance for providing current to the electrode.

Amplifier A-2, which is used to amplify the current produced by the electrode, is connected as a current-to-voltage converter. The gain of amplifier A-2 is adjustable by means of the 100 kΩ potentiometer in the feedback loop.

Amplifier A-3 is used as a unity-gain amplifier. It samples a composite signal made up of the output of amplifier A-2 as modified by the network that includes the 3 kΩ thermistor designated T-1. Thermistor T-1 is part of the Beckman electrode.

Amplifier A-4 is connected as a gain stage, with further temperature compensation being provided by thermistor T-2, also a part of the Beckman probe. The signal levels in the early stages are intentionally kept at low values in order to reduce the self-heating of thermistor T-2.

Amplifier A-5 is used as a gain stage with a gain of approximately 5 in order to make its output have a value of 10 V. The meter that is connected to amplifier A-5 is normally adjusted for a full-scale reading of 10 ppm dissolved-oxygen concentration. The procedure for setting the amplifier is:

(1) With the probe disconnected, the offset potentiometer is adjusted to yield zero output at the meter.

(2) The electrode is connected, and the 100 kΩ adjustable-gain resistor is used to set the meter reading to the known value of dissolved-

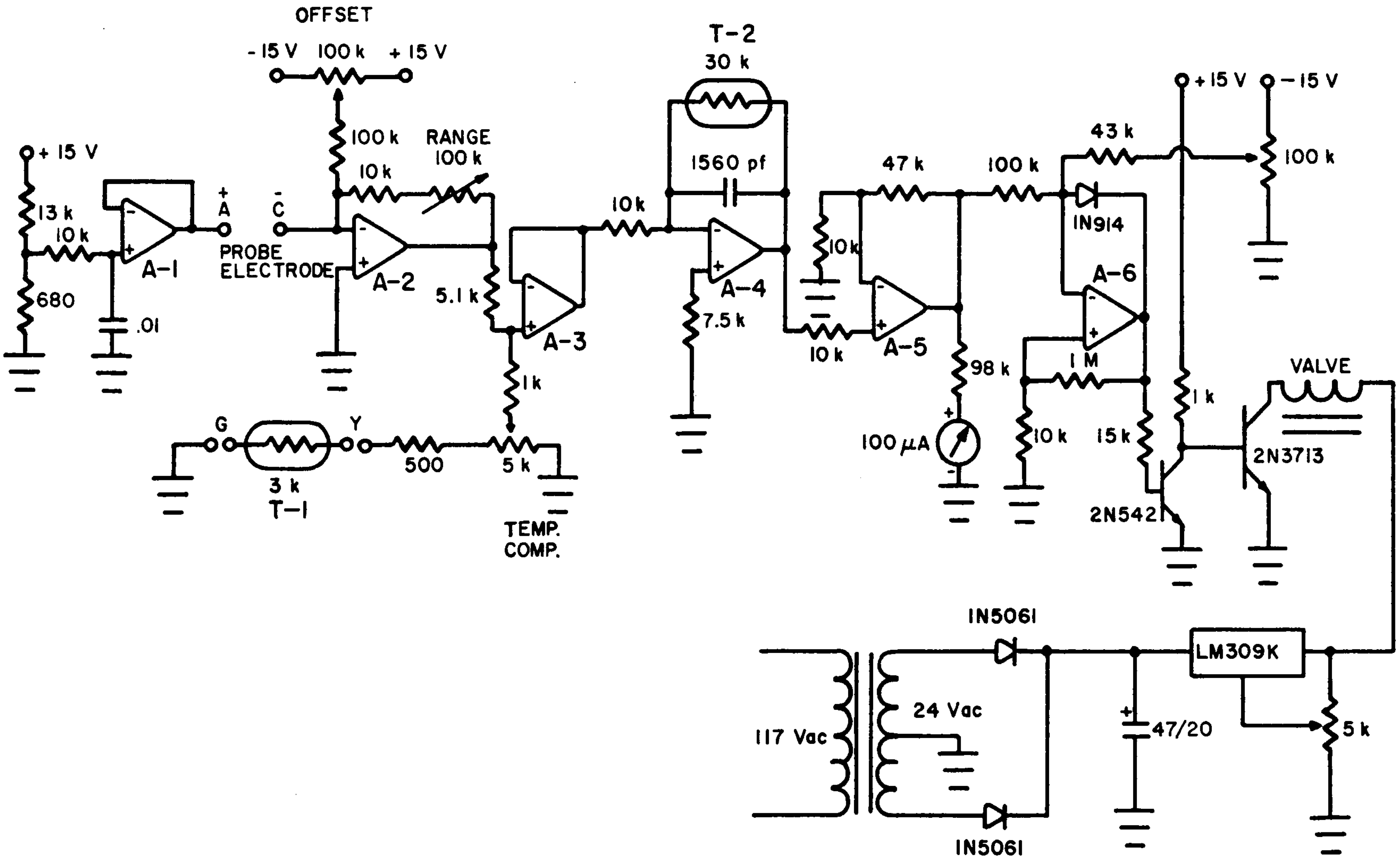

Fig. 7. Schematic diagram of dissolved-oxygen controller.

oxygen concentration. Normally, this is done by exposing the electrode to air and making the proper corrections for barometric pressure and humidty.

(Verification of the calibration of the electrode was performed at frequent intervals, using either a master meter that had been freshly calibrated or by making a Winkler analysis for each electrode.)

Amplifier A-6 is used as a comparator with a small amount of hysteresis to prevent chattering of the air-control valve. The signal output from amplifier A-5 is balanced against the signal taken from the 100 kΩ potentiometer that is connected to the -15 V supply. When the dissolved-oxygen concentration drops below the previously chosen value, the input to amplifier A-6 goes negative, driving the output of A-6 high. This turns on transistor Q-1, which turns off transistor Q-2. The air-control valve passes air only when power is not applied to its coil (i.e., when Q-2 is off), making possible fail-safe operation. Adjustable air pressure is applied to the valve so that approximately equal on and off times are produced. The air is then introduced into the system's pumping system so that it is driven into the tank containing the fish. The system controls the concentration of dissolved oxygen to better than 0.1 ppm. Figure 8 is a photograph of the electrode installation and meter.

IV. RESULTS FOR DIFFERENT STOCKING BATCHES

It was decided to raise fish from the 4-6-in. stocking size (Figure 9) to much larger sizes (Figure 10) to represent the conditions faced by the commercial grower, rather than to concentrate on the much smaller fish generally used for laboratory and experimental purposes. The two classes of culture--the raising of small fish for stocking purposes and the growing of fish to marketable size--commonly are separated in the catfish industry, and it was

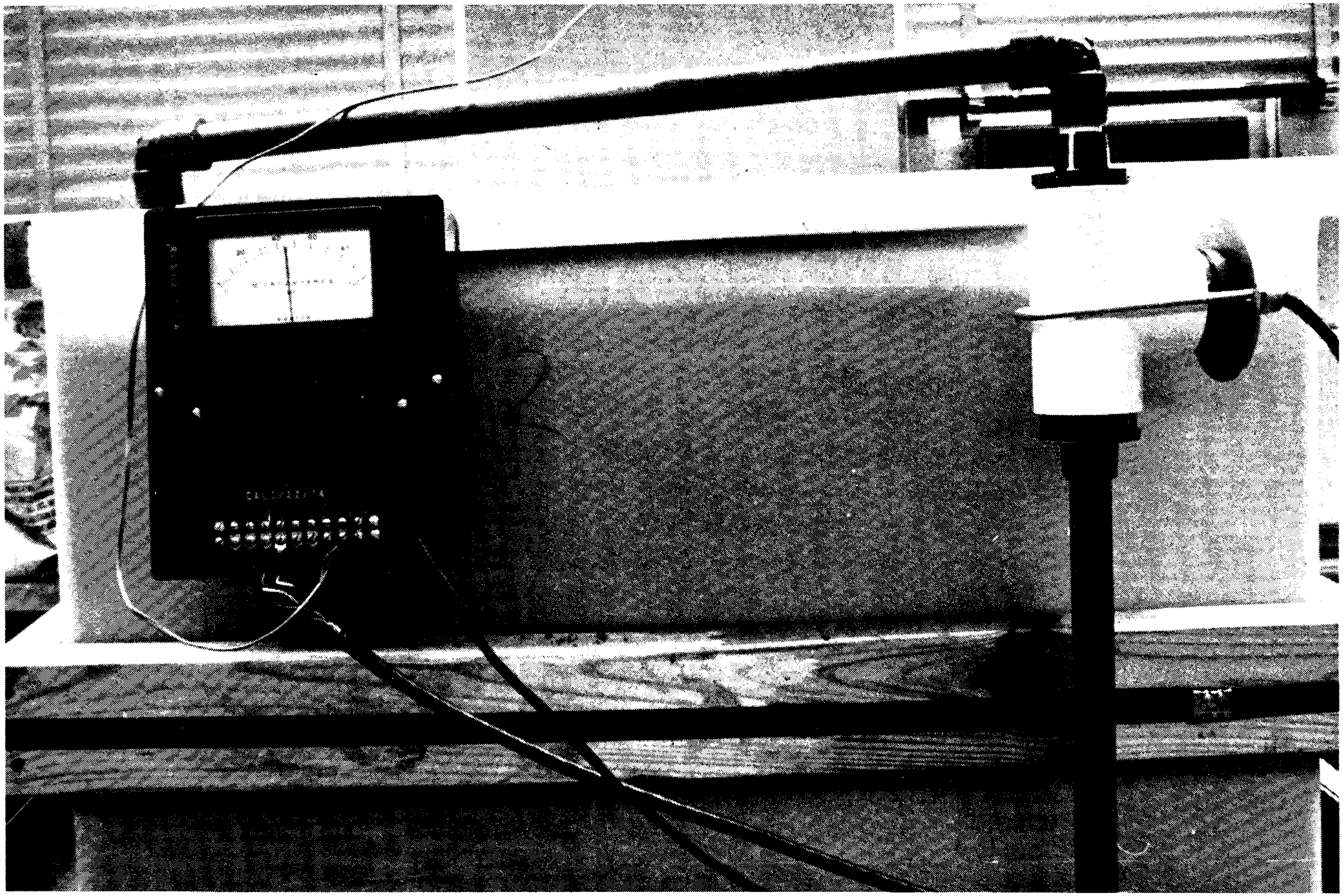

Fig. 8. Meter (left) and electrode installation for automatic control of dissolved-oxygen concentration.

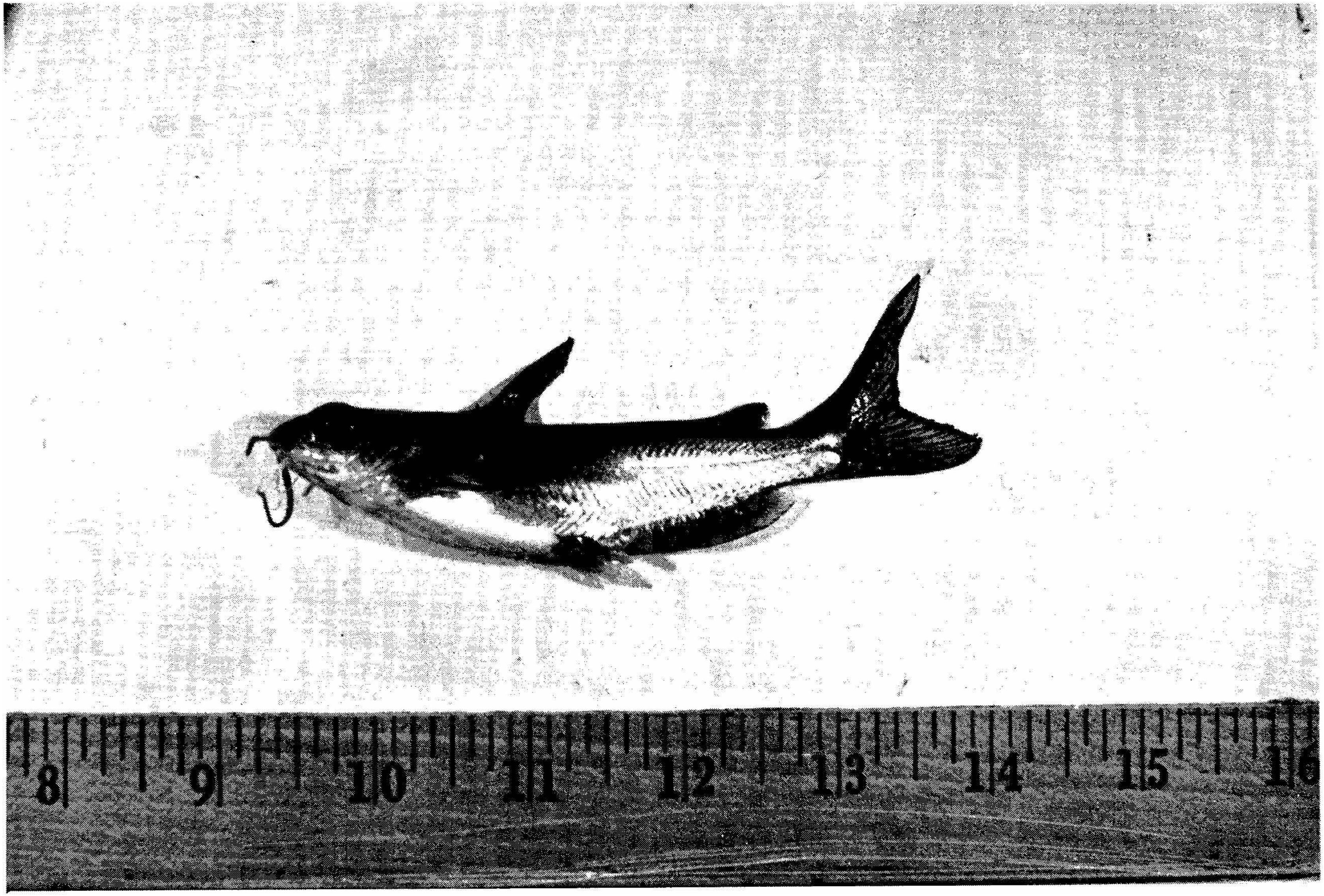

Fig. 9. Stocking-sized catfish, average length 4.5 in., average weight 13 grams.

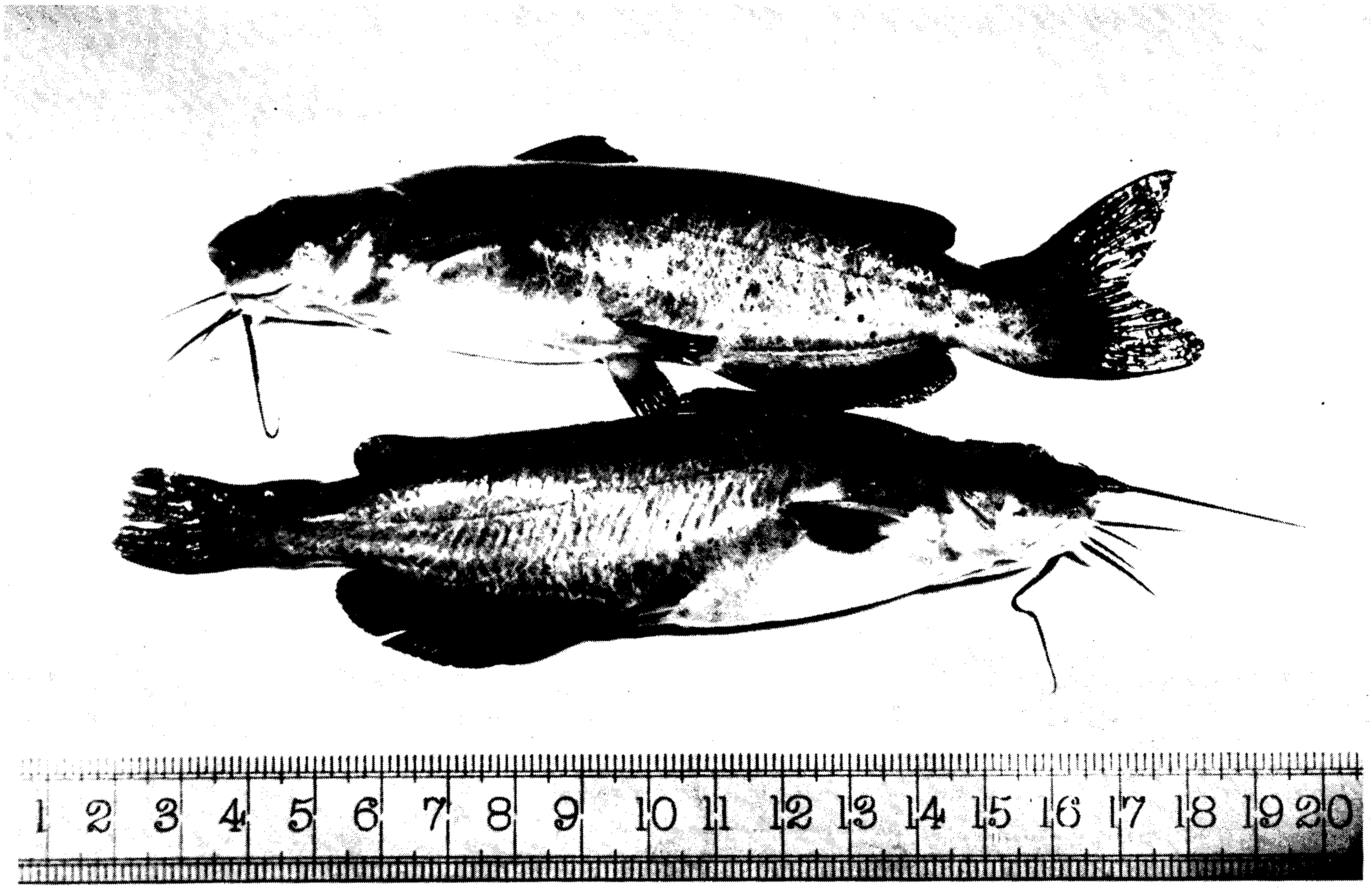

Fig. 10. Harvested catfish, large specimens, length approximately 16 in.

apparent that more problems would occur for this project during the growing period of the larger fish since a greater volume of waste products would be introduced into the systems.

Problems occurred with certain batches of specimens placed in the tanks. Diseases seemed to be more prevalent in specimens obtained from sources where fish had been raised for stocking purposes for many years. Early in the project, two batches of 3-year-old specimens were obtained inadvertently because their stunted growth made them appear to be of suitable stocking size. Unfortunately, the 3-year-old fish, although small, were sexually mature. The specimens fought constantly, producing lesions and damage to each other. Subsequently, by being certain that the stocking fish were young specimens, such damage was eliminated.

A. Run 1

The first of the three batches of fish cultivated in the recirculating systems during the full-scale experimental period of this project was held in the systems for 188 days, from September 26, 1973, to April 1, 1974. No attempt was made to maintain low concentrations of dissolved oxygen; all the systems of Run 1 were held constant at a dissolved-oxygen concentration of 6.8 ppm throughout the 188-day growth period to provide comparison data on weight gain when the systems were maintained at various dissolved-oxygen concentrations.

The concentrations of ammonia, nitrite nitrogen, and nitrate nitrogen in the systems 26 days before the Run 1 fish were removed are shown in Table II. Values are shown for only six of the seven systems originally stocked for Run 1 because one tank had been lost when its pump failed. The higher concentrations indicated in the table did not appear to cause specific distress to the catfish. However, during most of the growth cycle, the concentrations of ammonia generally were not as high as shown by this set of data; the ammonia concentrations generally were below 1 ppm. The higher concentrations shown in Table II are an indication that the loading limit of the filter system, in terms of weight of fish versus volume of filter, had been attained.

Table II

Concentrations of Ammonia, Nitrite Nitrogen, and Nitrate Nitrogen on March 8, 1974

Tank No.	Ammonia (ppm)	Nitrite Nitrogen (mg/1)	Nitrate Nitrogen (ppm)
1	7.5	0.30	105
2	1.5	0.14	27
3	5.5	1.90	135
4	6.8	0.25	95
5	1.0	0.42	28
6	1.2	0.04	34

This batch of fish weighed 20.5 lb per 1000 when stocked on Sept. 26. The batch was divided into seven groups so that the average weight of fish in each group was 10.3 grams. The Run 1 fish started with clean tanks and fresh water, and charcoal filters were used in addition to the biological filters. The fish were fed Purina Trout Chow at 3 percent of body weight per day, six days each week. The fish were weighed monthly, and the feed rations were adjusted accordingly. On April 1, 1974, after a growth period of 188 days, the fish were removed from the systems. The average weight per fish was 290 grams (approximately 10 oz) for a total average weight gain of approximately 3000 percent. A total of 400 lb of fish was raised in five tanks (two had been lost due to pump failure before the end of the growth period), or approximately 80 lb of fish per tank. Table III shows the percentage of weight gain per fish for the period, and Figure 11 is a graphic representation of weight-gain data.

Table III

Percent of Weight Gain per Fish for 188-Day Period for Run 1

Tank No.	Concentration of Dissolved Oxygen (ppm)	No. of Fish per Tank	Sept. 26 Weight (g/fish)	April 1 Weight (g/fish)	Percent Gain per Fish (%)
1	6.8	132	10.3	227.2	2770
2	6.8	133	10.3	257.2	2570
3	6.8	140	10.3	284.6	2870
4	6.8	109	10.3	320.6	3210
5	6.8	105	10.3	322.3	3220

The largest specimens of this batch of fish weighed 1 lb, 5 oz; and the smallest weighed 4 oz. This variance in the weight of fish raised under controlled conditions suggests that much work is needed on the breeding of catfish to produce specimens that will grow at a uniform rate (an achievement of the broiler industry). Improvements in feed conversion and growth rate should be possible if the necessary breeding experiments are carried out.

At one point during the 188 days, a sudden failure of the biological filters caused by an unknown poisoning agent made it necessary to reduce feed levels to very low rates for 30 days in order to reduce the loading on the

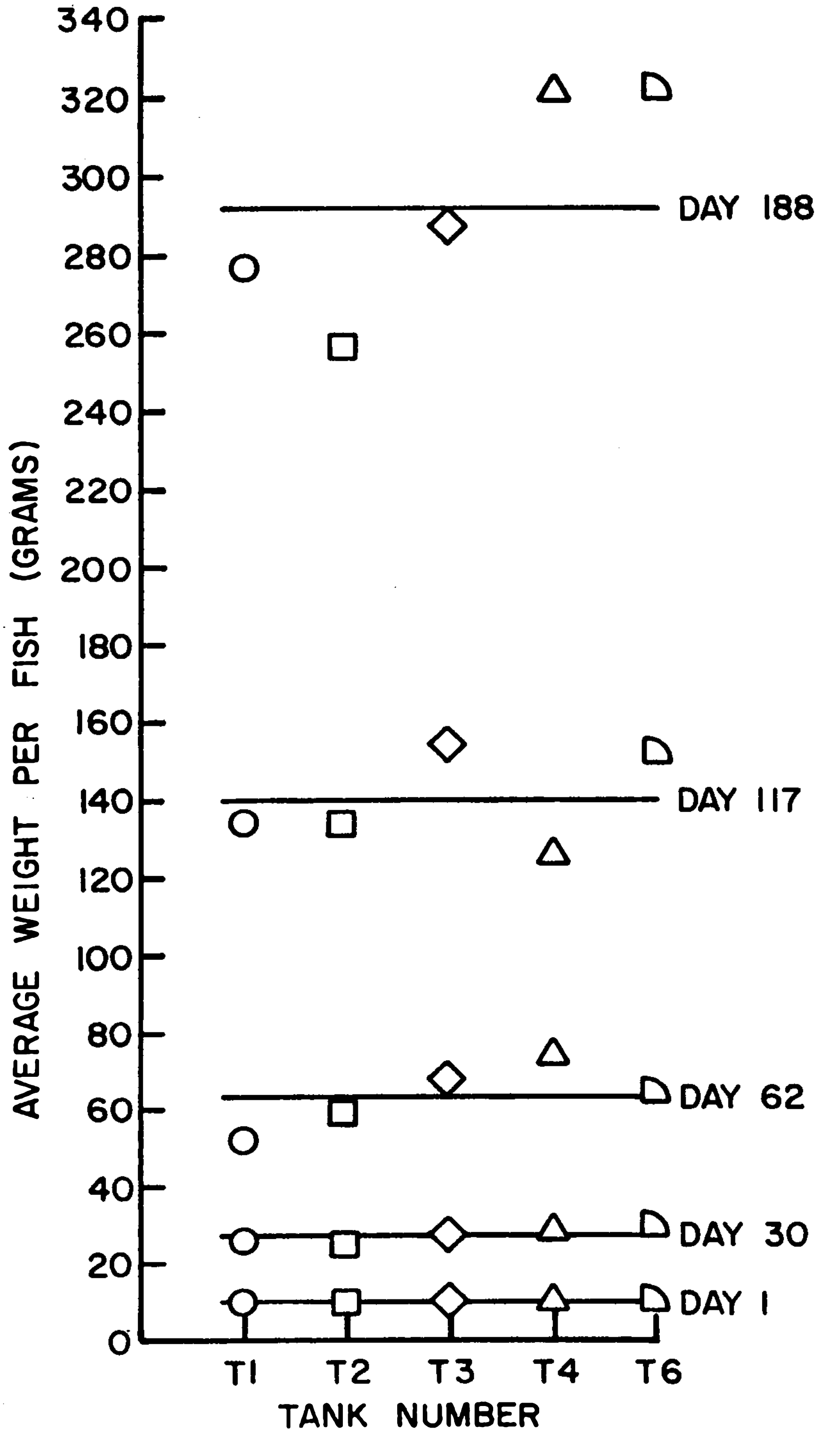

Fig. 11. Weight gain versus time for Run 1 with dissolved-oxygen concentration maintained at 6.8 ppm in all tanks.

filters. The final growth-rate figures should have been considerably higher had this interruption not occurred.

B. Run 2

A new batch of stocking specimens was received on May 3, 1974, and was grown for a 165-day period. The charcoal filters were removed before Run 2 was initiated, but the systems were not otherwise altered. The feeding schedule for Run 2 was maintained at 3 percent of body weight, six days each week, with Purina Trout Chow. However, for this run the series of seven systems was maintained at the various selected concentrations of dissolved oxygen. Table IV shows the percentage gain of weight for the fish over the 165-day period. Only four of the seven systems initially stocked for Run 2 are listed in this table due to incomplete results on three tanks caused by pump failure or power losses. Figure 12 is a graph of the average weight per fish versus time as a function of dissolved-oxygen concentration.

Table IV

Percent of Weight Gain per Fish for 165-Day Period for Run 2

Tank No.	Concentration of Dissolved Oxygen (ppm)	No. of Fish per Tank	May 3 Weight (g/fish)	Oct. 15 Weight (g/fish)	Percent Gain per fish (%)
1	3.6	51	19.3	243.4	1261
2	4.5	50	22.0	261.8	1190
3	5.1	55	20.0	277.2	1386
4	6.0	53	20.8	296.7	1587

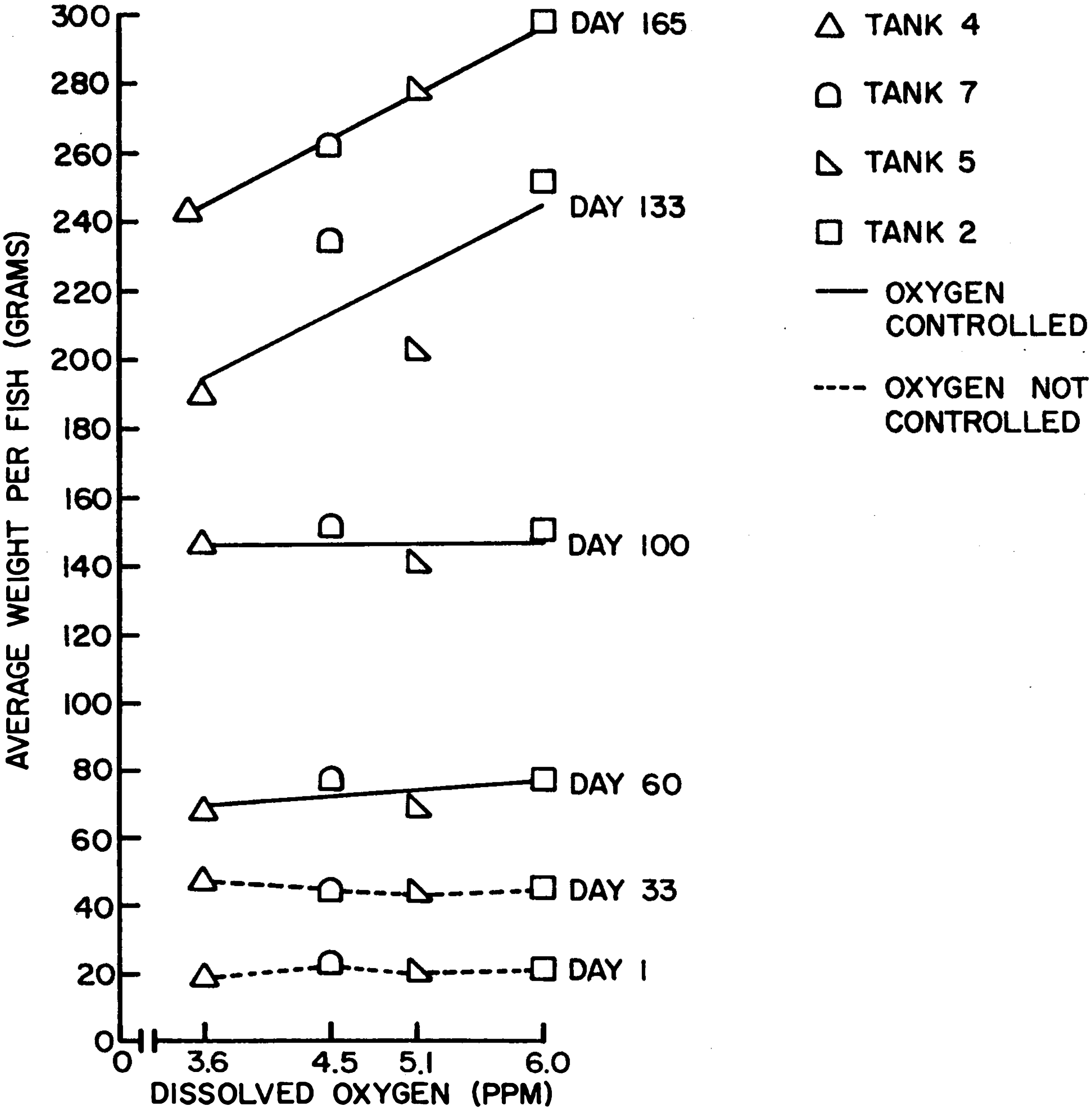

Fig. 12. Weight gain versus time as a function of dissolved-oxygen concentrations for Run 2.

The greatest percentage gain of weight per fish was just under 1600 percent. The fingerling stocker catfish weighed an average of 20.5 grams per fish. The grown fish had an average weight of 269 grams per fish. Using as a baseline the data from the culture system maintained at a dissolved-oxygen concentration of 3.0 ppm, Run 2 catfish showed an increase in weight gained of 13 percent for each part-per-million increase in the dissolved-oxygen concentration. Data for Run 2 indicated an almost 1-to-1 feed conversion ration (Table V). It is possible that personnel involved in the feeding process may have been careless in measurement of feed quantity. The feed conversion ratio for Run II must be viewed with suspicion.

Table V

Feed Conversion for Run 2

Tank No.	Feed (lb)	Fish (lb)	Conversion Ratio (lb feed/lb fish)
1	32.98	32.33	1.02
2	32.98	25.5	1.29
3	32.98	31.35	1.05
4	32.98	26	1.27

C. Run 3

A third batch of fish was stocked on Oct. 30, 1975, and was cultured in the systems for 177 days. Although the systems remained unchanged, a new feeding program was used for Run 3: The fish were fed as much Purina Trout Chow as they would eat in 15 minutes once each day, seven days a week. The tank containing fish maintained at a dissolved-oxygen concentration of 4.8 ppm was lost as a result of pump failure. Table VI shows the weight-gain data for the fish of Run 3, and Figure 13 is a graph of the data. The highest percentage gain of weight per fish for Run 3 was just over 1200 percent.

Table VI

Percent of Weight Gain per Fish for 177-Day Period for Run 3

Tank No.	Concentration of Dissolved Oxygen (ppm)	No. of Fish per Tank	Oct. 30 Weight (g/fish)	April 22 Weight (g/fish)	Percent Gain per fish (%)
1	3.0	103	18.0	127.0	706
2	3.6	107	17.7	144.0	814
3	4.2	102	18.6	152.0	817
4	5.4	103	18.7	178.0	952
5	6.0	97	18.0	217.7	1210
6	6.8	96	18.3	171.2	936

The Run 3 catfish (average weight of 18.2 grams per fingerling) weighed an average of 164 grams per fish at the end of the 177-day growth period. Again using the system maintained at 3.0 ppm dissolved oxygen as a baseline, the Run 3 fish had an increase in weight gained of 10 percent for each part-per-million increase of the concentration of dissolved oxygen. Run 3 data also indicated a high ratio of feed conversion (Table VII).

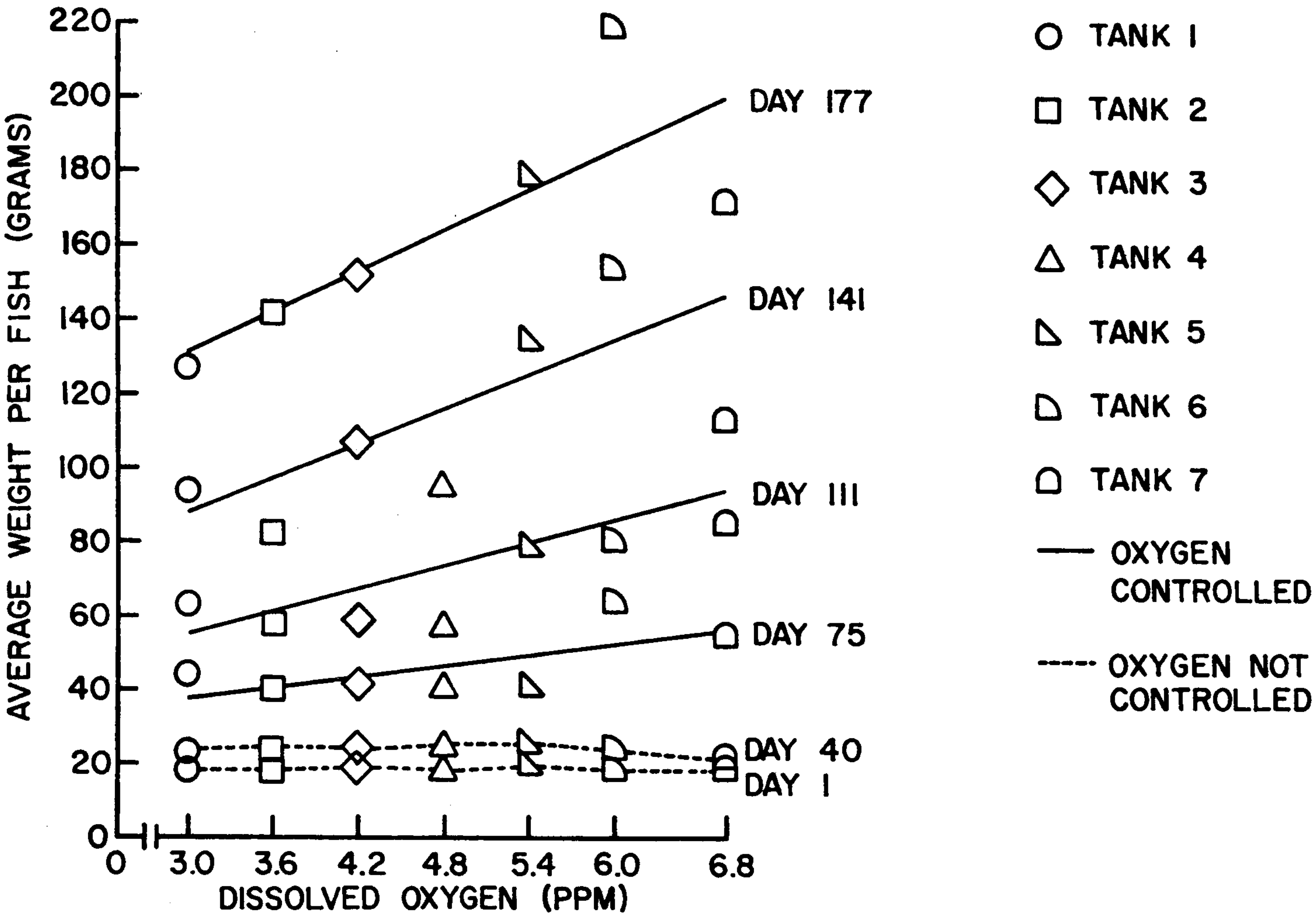

Fig. 13. Weight gain versus time as a function of dissolved-oxygen concentrations for Run 3.

Table VII

Feed Conversion for Run 3

Tank No.	Feed (lb)	Fish (lb)	Conversion (lb feed/lb fish)
1	44.75	28.84	1.552
2	44.875	33.97	1.32
3	44.625	34.17	1.30
4	54.125	40.43	1.34
5	54	46.56	1.16
6	53.94	36.24	1.48

V. CONCLUSIONS

At low concentrations of dissolved oxygen (i.e., less than approximately 2.5 ppm), difficulty was encountered in maintaining channel catfish for extended periods of time. Mortality was high as a direct result of the low level of dissolved oxygen, and fish that managed to survive were stressed to the point where any additional slight stress caused death. Low dissolved-oxygen concentrations also had an adverse effect on the ability of the biological filter to convert ammonia to nitrites and nitrates at a rate sufficient to maintain operation of the cultivation system. In fact, extremely low concentrations of dissolved oxygen could trigger the spontaneous failure of the entire cultivation system.

Channel catfish maintained at such low concentrations of dissolved oxygen were also weakened to the point where they were highly susceptible to disease. Mortality due to disease was high in the early experiments for this research project. The high incidence of death and disease at dissolved-oxygen concentrations of 2.5 ppm and below dictated the establishment of 3.0 ppm dissolved oxygen as the lowest concentration for the experimental runs made during the last year of the project.

It also was found that treatment of the water in the cultivation systems to a hardness of 200 to 300 grains and maintenance of the water in a slightly basic state--a pH between 7 and 8--reduced disease mortality to negligible levels. Also, growth of Sphaerolitus was a problem in early phases of this project. However, no Sphaerolitus growth was noted after the addition of the water-hardening chemicals.

Serious injury to the catfish and some mortality occurred during two early experiments when the fish matured sexually during their growth periods in the cultivation systems. It is necessary to know the age of the stocking fish being used since the maturity of the fish is not necessarily related to size.

The full-scale experimental runs made for this project with the levels of dissolved oxygen precisely controlled indicate that the dissolved-oxygen concentration should be maintained as high as possible, up to air saturation. The rate of weight gain appeared to be directly related to the concentration of dissolved oxygen up to 6.8 ppm, which was the highest level maintained in these experiments. The weight gain for one run was 50 percent higher at 6.8 ppm than at 3.0 ppm dissolved oxygen. For another run, the weight gain was 25 percent higher at 6.0 ppm than at 3.6 ppm. Further, increases of weight gained ranged from 10 to 13 percent for each part-per-million increase of the dissolved-oxygen concentration.

In view of the present energy situation and higher costs of energy, the necessity of maintaining a high dissolved-oxygen concentration may mean that closed systems are not feasible for commercial catfish cultivation. However, some of the cost may be balanced by the high feed conversion ratios that apparently are possible in closed systems. From an experimental standpoint, however, the closed system developed for this project would seem desirable. The system is compact, easily controlled, and virtually maintenance free. The major problem encountered was pump failure. Choice of a dependable, long-life pump is mandatory to prevent catastrophic failure of the system. Pumped aeration with an air-injected backup could reduce losses from pump failure.

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