TRIPLEX OXIDATION DITCH SYSTEM

USING

DRAFT TUBE CHANNEL TECHNOLOGY

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By T. F. Allen, D. H. Fredericks — French-Reneker-Associates, Fairfield, Iowa

A. L. Wilcox — Mixing Equipment Co.

Introduction

The City of Fairfield, Iowa, like many municipalities throughout the country, is faced with upgrading its wastewater treatment capabilities to meet stricter discharge effluent criteria.

Discharge limits, past and present, are as follows:

Figure #1

	Past Requirements		Present Requirements	
	30 Day Ave.	Max. Day	30 Day Ave.	Max. Day
BOD_5	30 ppm	45 ppm	10 ppm	15 ppm
SS	30 ppm	45 ppm	20 ppm	30 ppm
NH_3-N	---	---	2 ppm	5 ppm
pH	6.5 to 9.0		6.5 to 9.0	

Fairfield is a residential community of 9,000 people with a normal complement of light and medium industries. The industrial wastewater discharge does not impact significantly upon the quality of raw wastewater. Infiltration and inflow is expected to be a significant problem even after the rehabilitation work is completed.

The design parameters for the upgraded treatment plant are:

Figure #2

RAW WASTEWATER DESIGN PARAMETERS

	Average Daily	Maximum Daily	Maximum Hourly
Flow*	1.6 MGD	5.7 MGD	8.5 MGD
BOD	200 ppm/2,670#	---	---
SS	200 ppm/2,670#	---	---
NH_3-N	20 ppm/267#	---	---
pH	7.0 - 7.5	---	---

* Maximum flow rate after storm water equalization will be limited to 3.2 MGD.

The existing Fairfield sewage treatment plant was completed in 1968. It is a single stage trickling filter plant with anaerobic sludge digestion. The plant was designed for an average dry weather flow of 1.6 million gallons a day. Although the present treatment plant is operating very efficiently and is doing the treatment job that it was designed to do, the upgraded effluent criteria established by U. S. Environmental Protection Agency and Iowa Department of Environmental Quality require major renovations to the treatment facilities in order to meet these new guidelines of 10 ppm, 20 ppm, and 2 ppm.

The sizes and capacities of the individual treatment elements of the present Fairfield wastewater treatment plant are as follows.

Figure #3

EXISTING TREATMENT FACILITIES

	Element	Size	Capacity
1.	Grit collector	1 @ 1'-3" deep x 3'-0" wide	2.38 MGD @ 1'-3" deep
2.	Parshall flume	1 - 6"	1.87 MGD @ 1'-3" deep
3.	*Comminutor*	1 - 24" *drop discharge*	3.5 MGD
4.	Pump station	2 pumps @ 2,200 gpm ea.	3.1 MGD
5.	Primary clarifiers	2 @ 18' x 72'	3.88 MGD @ 1,500 gpd/ft^2
6.	Trickling filter	1 @ 160' dia.	N.A.
7.	Final clarifier	1 @ 50' dia.	1.60 MGD @ 800 gpd/ft^2
8.	Primary digester	1 @ 34,000 ft.^{3} (heated)	17,000 P.E. @ 2 ft^3/capita
9.	Secondary digester	1 @ 34,000 ft.^{3}	17,000 P.E. @ 2 ft^3/capita

Problems

The four primary design problems in upgrading the Fairfield treatment plant are:

1. Storm water flow equalization,
2. Improvement of BOD and SS removal,
3. Nitrification,
4. Providing any necessary increased secondary sludge treatment facilities.

The first problem, storm water flow equalization, is to be solved by the use of a side stream equalization pond.

The remaining three problems are the essentials of any treatment plant. BOD removal, SS removal, ammonia nitrogen oxidation and sludge treatment are where the major capital and operating dollars are spent and where the largest savings can be made.

Traditional Solutions

Traditional designs to meet the effluent criteria of 10 ppm of BOD, 20 ppm suspended solids and 2 ppm ammonia nitrogen, *would normally require one of the following standard treatment* schemes:

1. (Figure #4). Two stage activated sludge system with alkalinity adjustment followed by a rapid sand filter.

2. (Figure #5). Extended aeration system with alkalinity adjustment followed by rapid sand filters.

For both of these schemes the waste activated sludge is normally handled by:

1. Thickening with drying beds, or lime conditioning with sludge lagoons, before disposal on land or in a landfill,

2. Aerobic stabilization, thickening, chemical conditioning and dewatering before disposal on land or in a landfill.

Most design engineers are well aware of the costs, both capital and O & M, for such traditional designs.

Triplex Oxidation Ditch System

The Triplex Oxidation Ditch system is so called by us at French-Reneker-Associates because of the three treatment functions that can take place within a single treatment unit. These are:

1. Carbonacious BOD removal

2. Nitrification (NH_3-N to NO_3^-) and

3. Denitrification (NO_3^- to N_2 and O_2)

All three of these functions can be accomplished biologically in a single unit oxidation ditch <u>if</u> the designer is aware of the necessary parameters.

These characteristics are depicted on Figure #6 and include:

1. Autotrophic nitrification, a completely mixed high D.O. zone with limited BOD for nitrification.

2. A completely mixed oxic zone for BOD removal by substrate metabolism and endogenous respiration.

3. A completely mixed anoxic zone for denitrifying bacteria.

FIGURE 4: TWO STAGE ACTIVATED SLUDGE SYSTEM

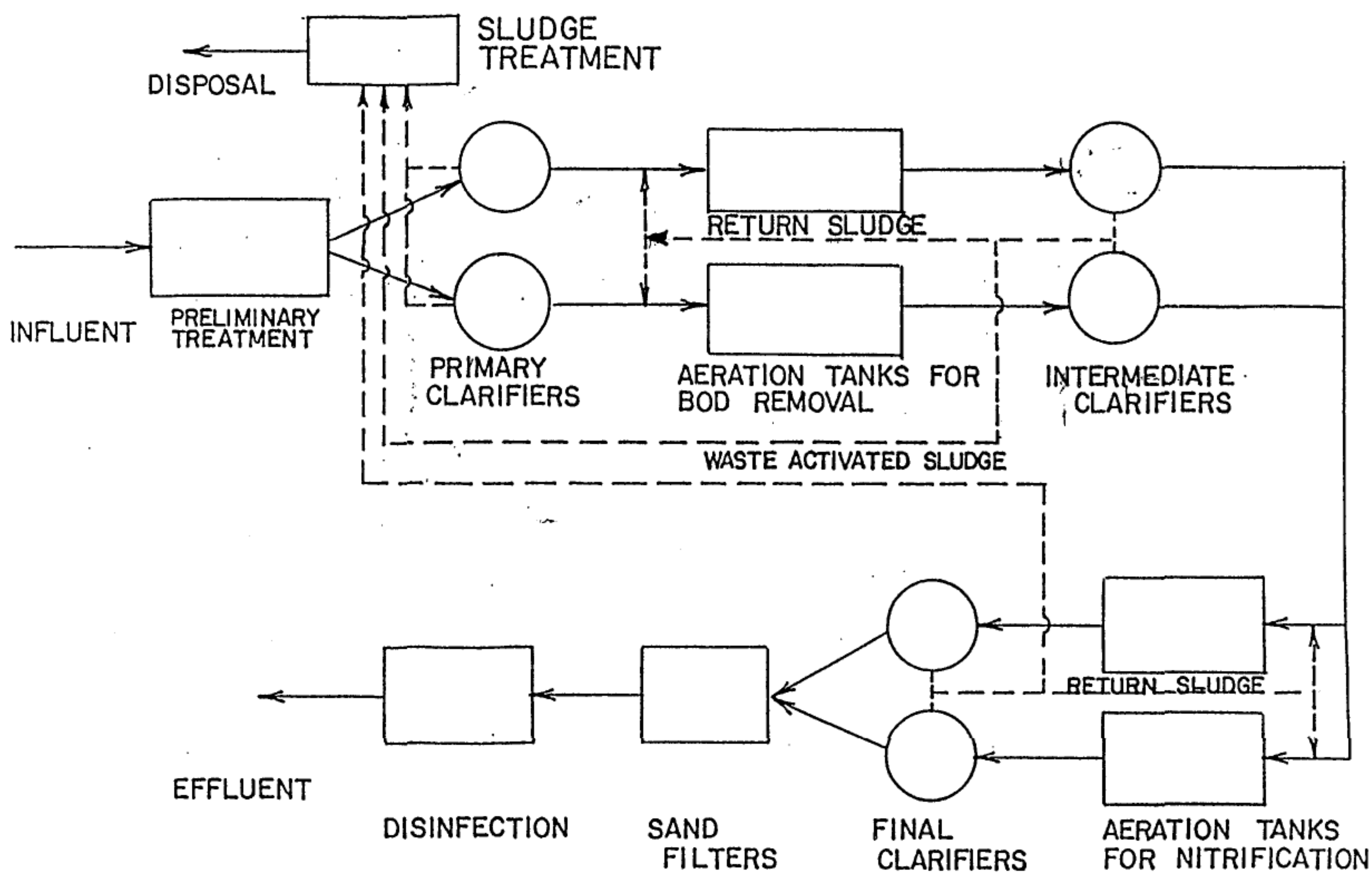


FIGURE 5: EXTENDED AERATION SYSTEM

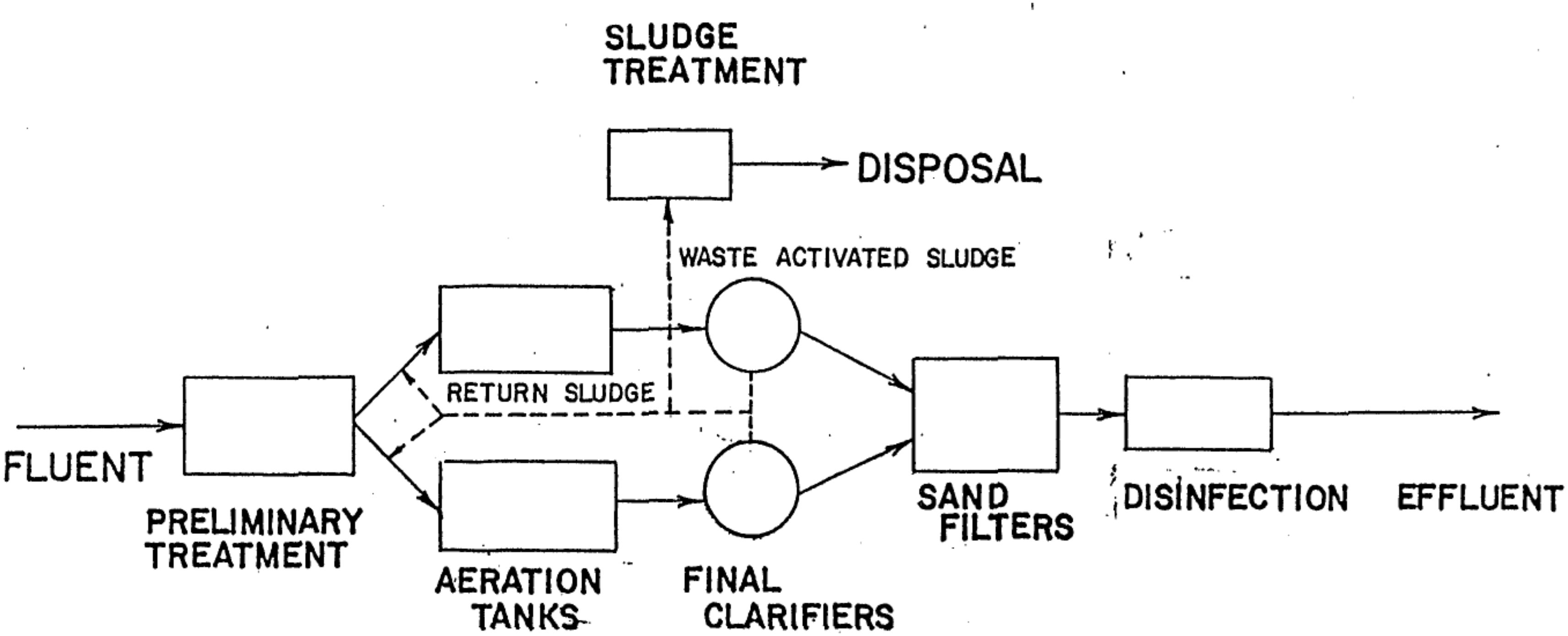
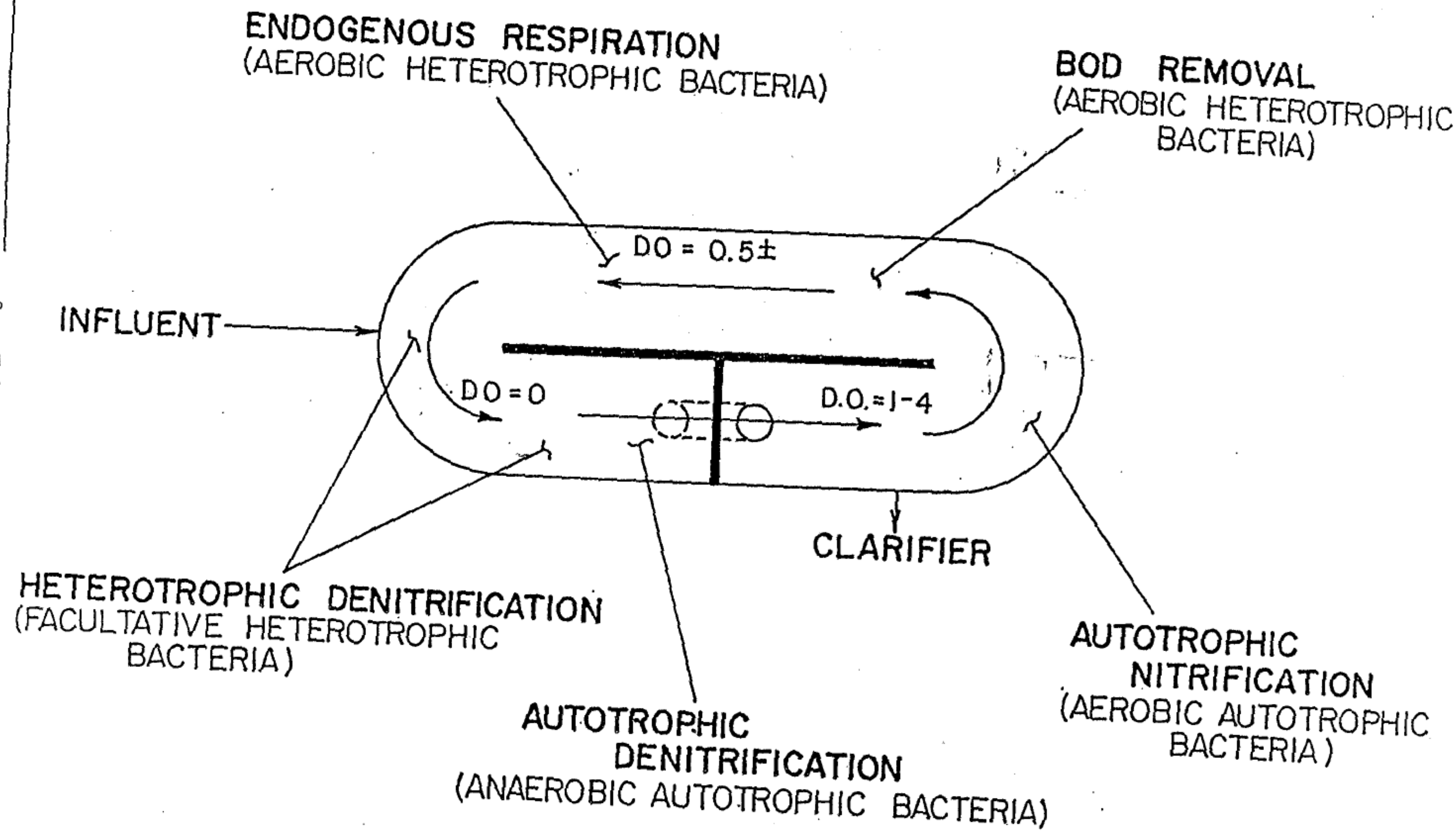


FIGURE 6: DRAFT TUBE CHANNEL BIOCHEMICAL REACTIONS



The oxidation ditch configuration offers the potential of providing these three zones in a single tank.

Traditionally, oxidation ditches have not been an attractive alternative in northern climates due to the cooling effect of the aeration equipment available. Until recently, the aerators have been limited to horizontal brushes or surface aerators. Both devices cool the wastewater and effectively limit the ditch depth because of mixing constraints. Cold winter conditions cause ice formation from aerator spray and cooling through the large exposed surface area. The cooling limits biological activity. These traditional surface aeration devices provide only induced flow with questionable channel velocity gradients. With surface aeration devices the resulting channel velocities are tied directly to oxygen transfer rate. Only recently, with the development of the Down Draft Tube Aerator, has equipment been available that overcomes both of these disadvantages

In its simplest form (Figure #7) the draft tube aerator is a vertical pumping device with provisions for introducing air below an impeller at shallow depth. The impeller forces the air-liquid mixture down to a region of higher pressure before releasing this mixture to the basin. Pumping capacity remains relatively constant, while oxygen supply can be varied at will. Pumping capacities as high as 4,000 gpm per horsepower are easily attainable with the high specific speed, high flow, low head impellers developed for these draft tubes. Thus, mixing is independent of the oxygen transfer and a consistant dissolved oxygen profile can be obtained, with a variable BOD input. Therefore, solids can be suspended in a uniform manner regardless of oxygen demand without wasting blower horsepower.

For any aeration system, the oxygen stripping efficiency is a function of four major parameters:

1. Bubble size
2. Bubble retention time
3. The D.O. differential driving force
4. The hydrostatic pressure

Bubble Size:

The bubble size for the draft tube system is controlled by the shearing force of the water passing the air diffuser.

Any large bubbles are suspended by the countering forces of buoyancy and the downward water velocity until they are sheared to a small enough size so they can be driven down the tube by the moving water. Much research has been done on the advantages of small bubble vs. large bubble aeration systems. The smaller the bubble, the greater the interfacial area for oxygen transfer.

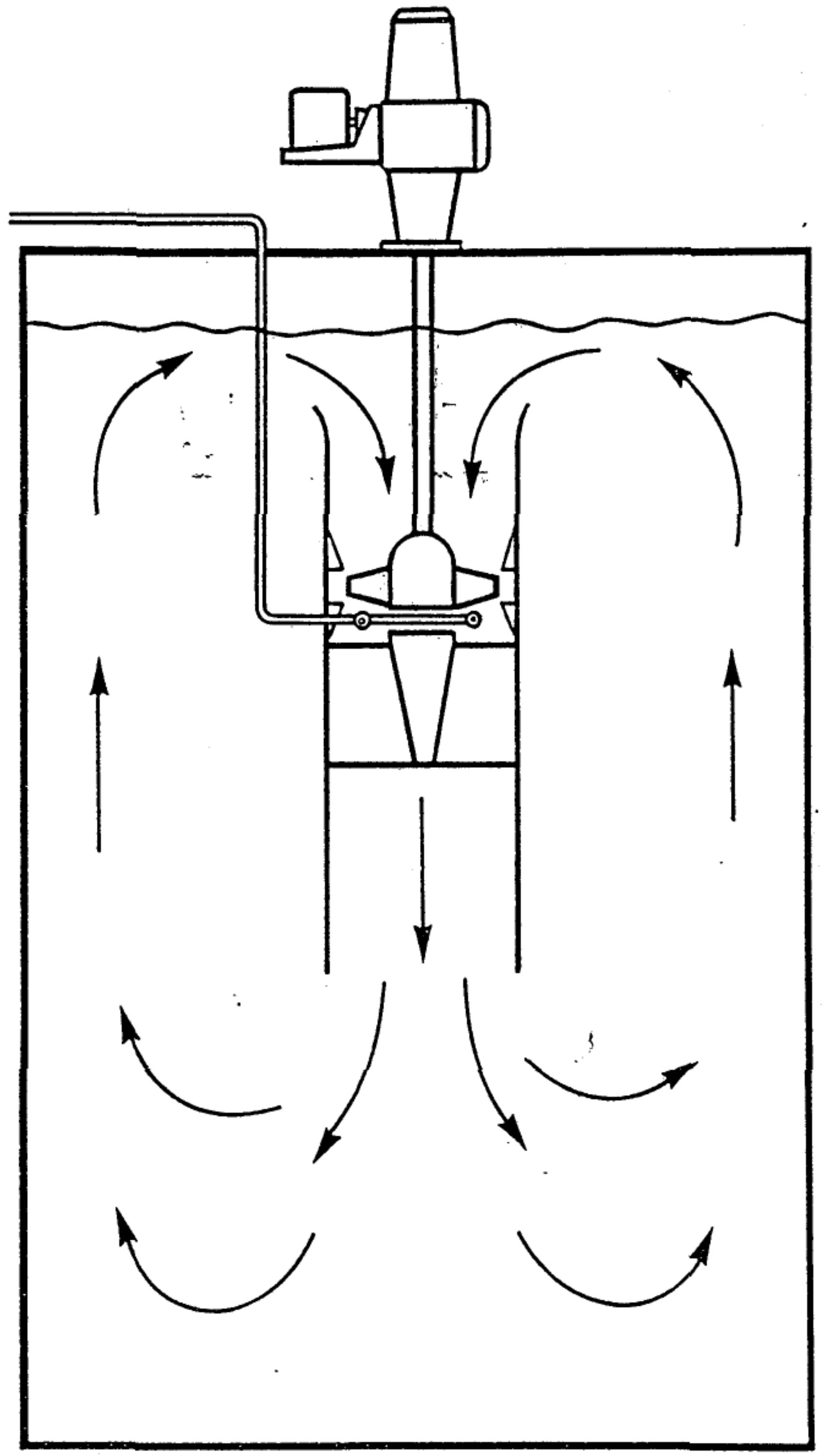


FIGURE 7

Retention Time:

Bubble retention time is also a well defined parameter affecting oxygen transfer efficiency. "The longer the retention time, the greater the efficiency." The downward path that the bubbles must travel from the air diffuser to the discharge of the draft tube insures a controlled detention time that is several times longer than traditional diffused aeration systems.

Driving Force:

In a traditional completely mixed basin designed for nitrification, D.O. levels are normally maintained at 2-3 ppm. This reduces the driving force available for mass transfer. If a zero D.O. level could be "seen" by the aerator, the efficiency would show a significant improvement as illustrated by Figure 8.

Pressure:

The hydrostatic pressure influence upon oxygen transfer is also well documented. Most engineers have been exposed to the "deep shaft" system which takes maximum advantage of this parameter.

"The greater the pressure, the higher the oxygen transfer." By forcing the air bubbles down the draft tube, as in the "deep shaft" system, the hydrostatic pressure can be dramatically increased without an increase in blower horsepower.

Since its introduction a few years ago, the draft tube aerator has attained wide acceptance. Many units are in operation in complete mixed basins handling wastes from municipal sewage to high carbohydrate corn milling effluent. However, it was not until 2-1/2 years ago that Reid Engineering Co. in Virginia applied this technique to an oxidation ditch.

In cooperation with the equipment manufacturer, Mr. Reid found that by constructing a barrier across an oxidation ditch (Figure 9) he could accomplish six goals simultaneously:

1. Positive pumping capacity - thus a controlled ditch velocity, independent of oxygen demand.

2. In essence a completely mixed - plug flow system. All contents of the ditch must pass through the aerator once every cycle.

3. Maximum driving force for oxygen transfer. The D.O. level at the aerator entrance could be designed for 0 ppm, rather than the 2.0 to 3.0 ppm generally necessary in a completely mixed basin. By comparison, if a surface aerator

FIGURE 8
INFLUENCE OF AERATION ZONE
D. O. LEVEL ON OXTGEN TRANSFER RATE

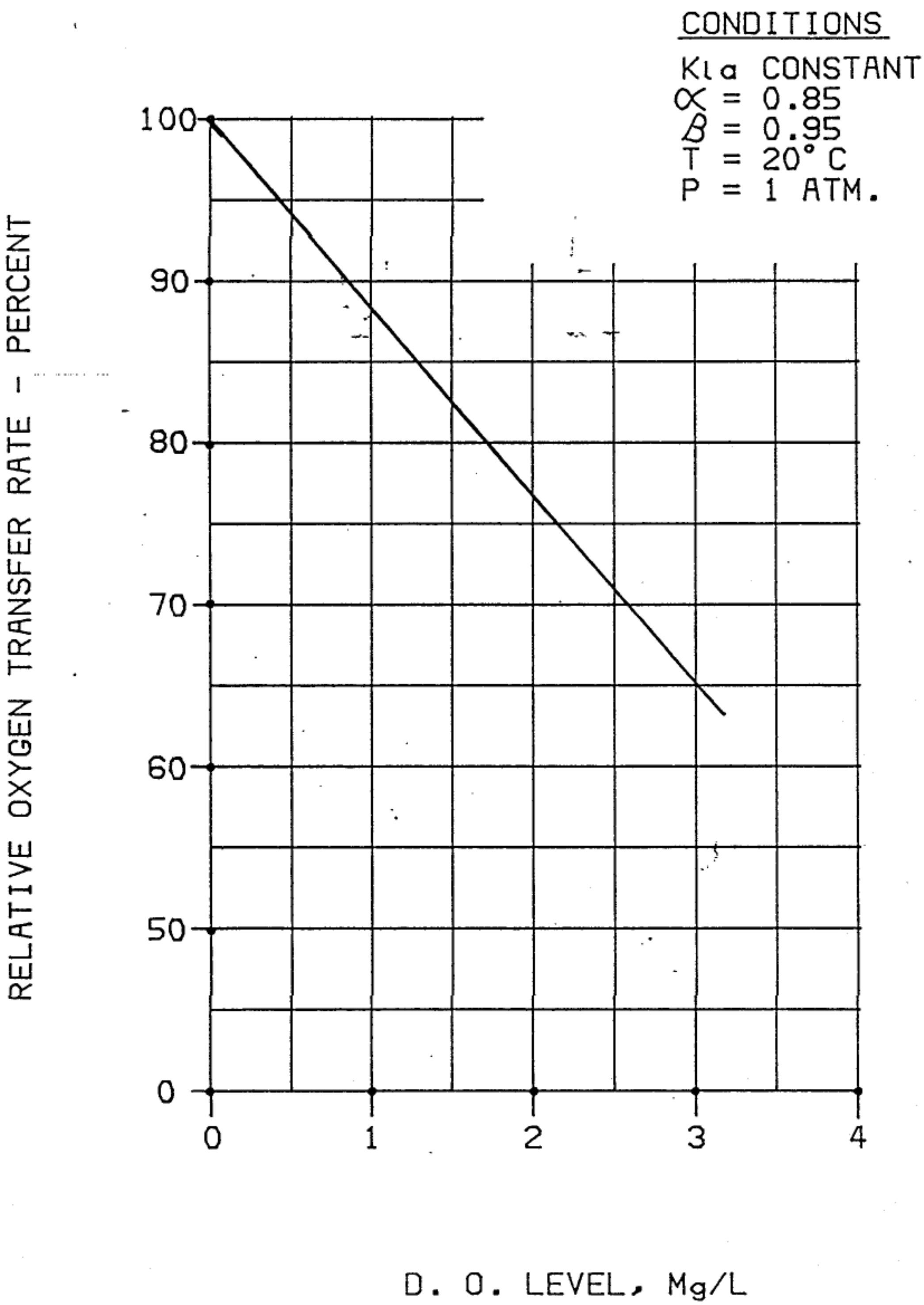
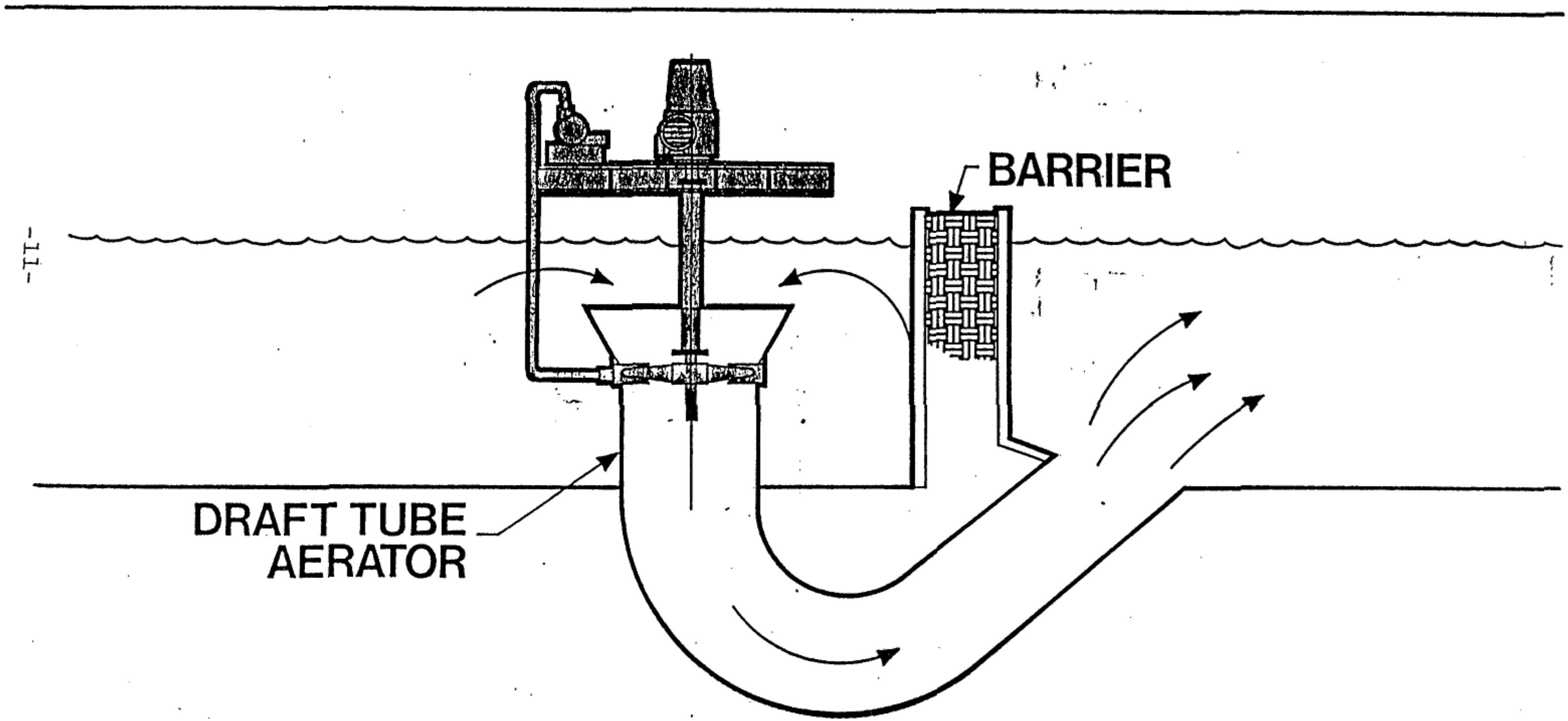


FIGURE 9

CROSS SECTION OF DRAFT TUBE CHANNEL



were used in an oxidation ditch to provide both aeration and pumping requirements, a design based on an aeration zone inlet D.O. of at least 1.0 ppm would be necessary to compensate for the back mixing of the impeller. In addition, the draft tube depth could be optimized to make maximum use of the benefit of hydrostatic pressure on oxygen transfer as outlined above. This results in a more energy efficient system as illustrated in Figure 10. The draft tube design permits use of increased depth without the usual increases in energy and blower costs.

4. A controlled D.O. profile can be designed by merely adjusting the air supply and the ditch length (Figure #11.)

5. All of the biological reactions which could be achieved with controlled retention times in separate basins of various D.O. levels could be accomplished in one basin. For example, carbonaceous removal, nitrification, and denitrification reactions could easily be achieved over wide fluctuations of input BOD (Figure 6.) Note that by adding the raw waste in the proper location, a convenient carbon source can be obtained for denitrification. Also because the draft tube pumping capacity is independent of the oxygen transfer, a controlled oxygen profile can be maintained over wide ranges of carbonaceous demand by simply adjusting the air supply.

6. Several co-existing and viable micro-organism colonies can be grown, each with sufficient residence time under optimum growth conditions, but passing through hostile zones rapidly enough to prevent substantial inhibition. As a resul this system becomes very defensive against biological shock loads. The storage volume in the oxidation ditch also provides enough volume to minimize the effects of other types of shock loads.

Since the introduction of this technique, "Barrier Oxidation Ditches", or "Draft Tube Channels", or "Triplex Oxidation Ditches" have proven quite cost effective for high up-take industrial wastes containing ammonia. But the dramatic power savings potentially available on domestic sewage have received little attention. This is probably because nitrification has not been required by regulation for a large segment of domestic waste waters. At Fairfield, we need nitrification and are very interested in power savings.

The flexible geometry available in oxidation ditches has been known for some time. Simple "race tracks" have been replaced on many occasions by more complex layouts. This flexibility presents very convenient possibilities for retrofitting existing ditches. For example, we are aware of a recent industrial installation in which six brush aerators were replaced with a single down draft tube aerator providing a positive flow and positive D.O. profile for a large chicken house wastewater oxidation ditch. (Figure 12.) However, we know of no retrofitting to-date on a municipal plant, using a draft tube aerator for an oxidation ditch system.

At Fairfield, the 160 foot diameter trickling filter basin offers distinct retrofit possibilities. "Why not", we asked, "use this approach (Figure 13) to convert this structure to an oxidation

FIGURE 10
EFFECT OF DRAFT TUBE DEPTH ON OXYGEN TRANSFER EFFICIENCY DRAFT TUBE OXIDATION CHANNELS

<u>BASIS</u>

4000mg/l MLSS 80 SVI
20°C, 100 FT. ELEVATION
200 LBS./HR. ACTUAL O_2 REQUIRED
$\alpha = 0.85$, $\beta = 0.95$
CONSTANT CHANNEL CROSS SECTION AREA
MINIMUM CHANNEL VELOCITY = 1 FT./SEC.

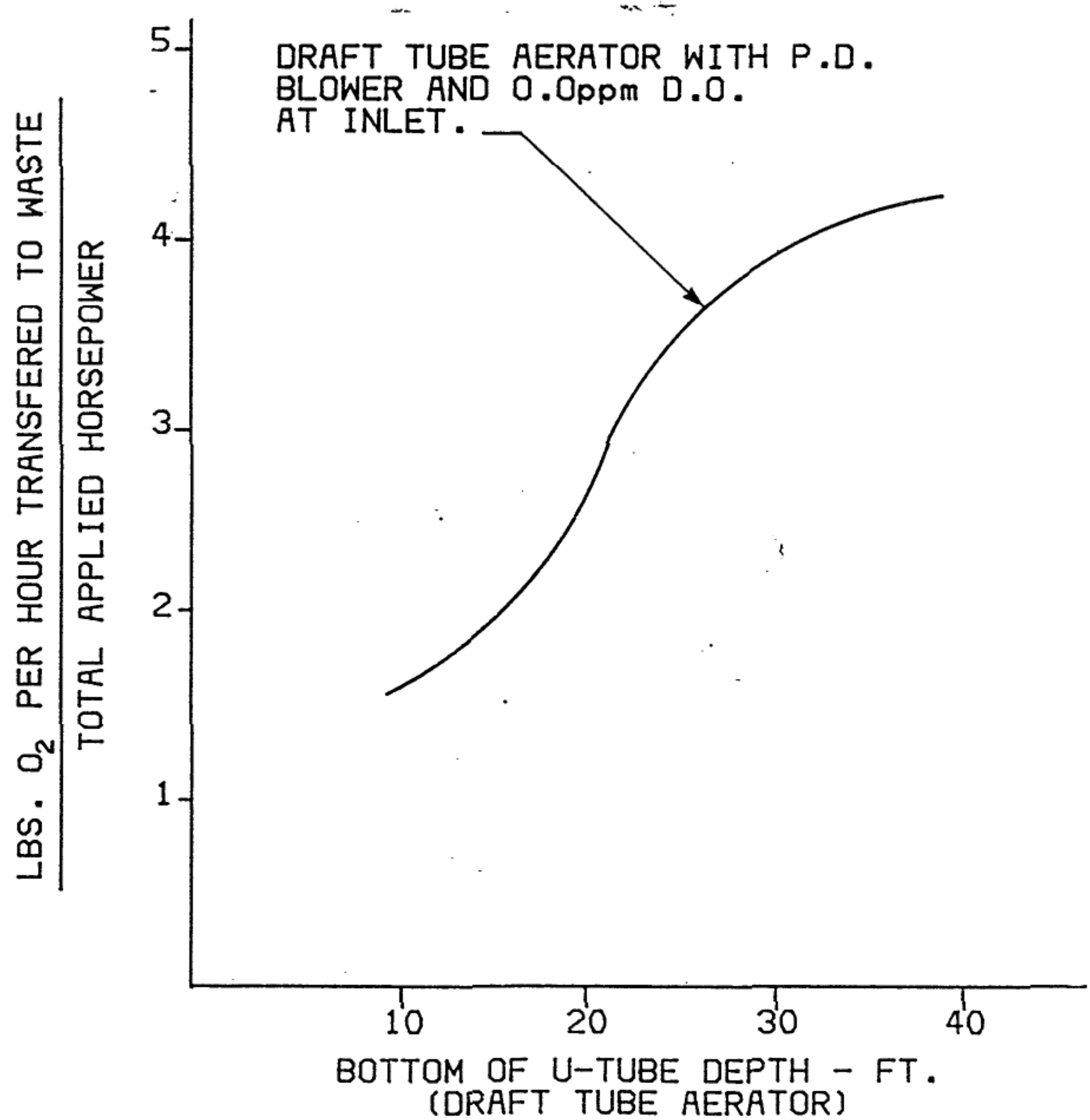
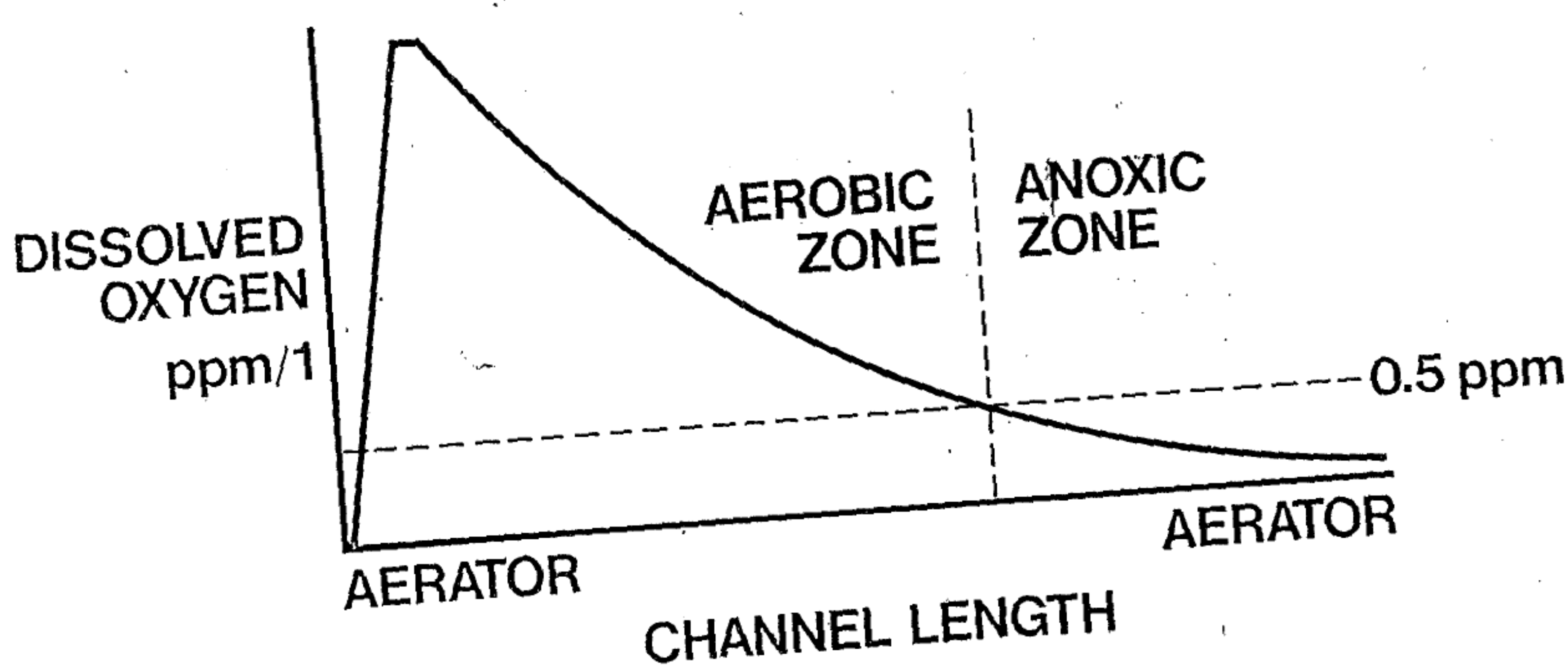


FIGURE II

DRAFT TUBE CHANNEL
(DISSOLVED OXYGEN PROFILE)



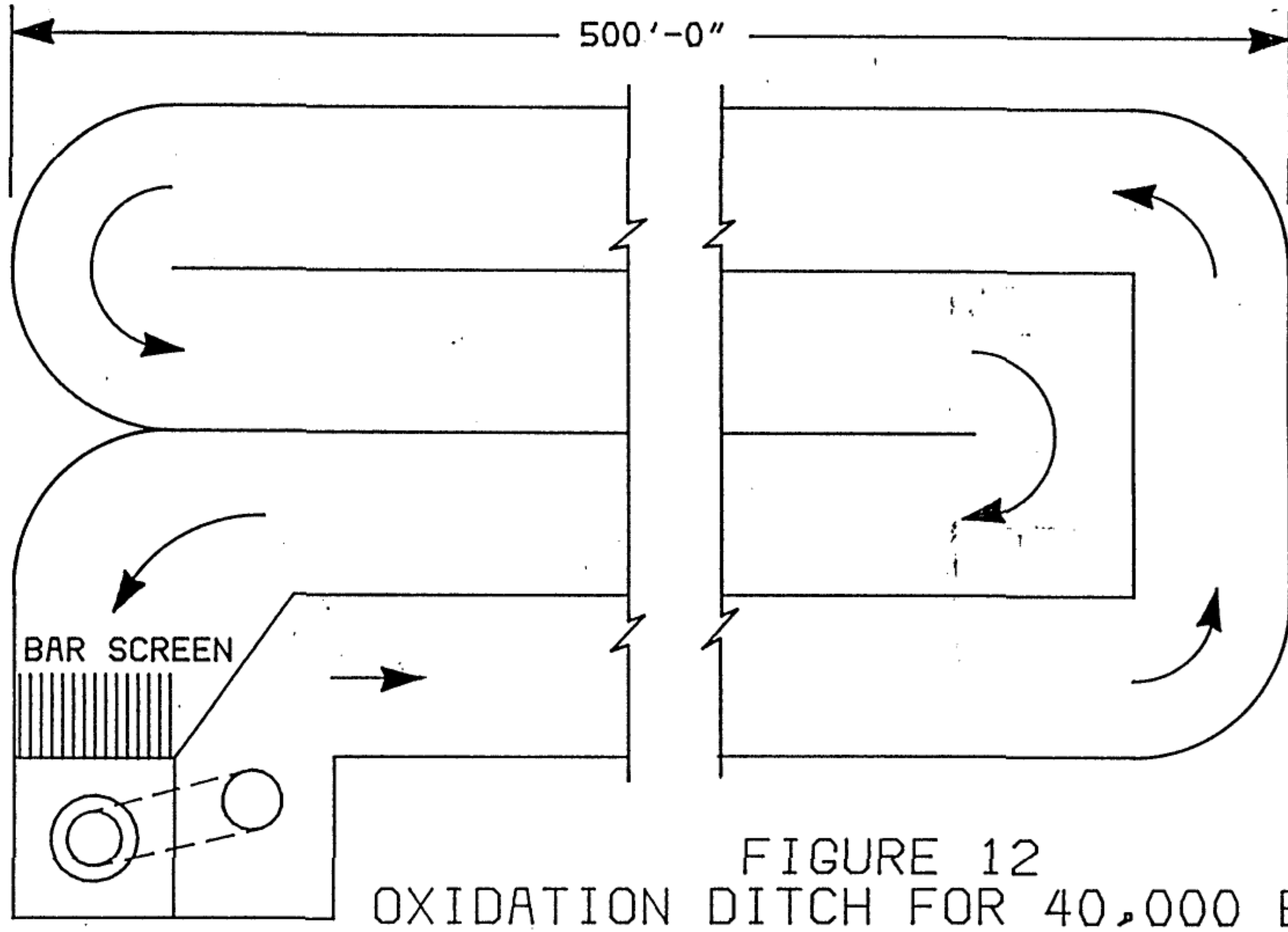


FIGURE 12
OXIDATION DITCH FOR 40,000 BIRD
CHICKEN HOUSE WASTEWATER
60 H.P. DRAFT TUBE AERATOR-CIRCULATOR,
15 H.P. BLOWER

ditch, and at the same time take advantage of the Draft Tube Aerator?" We found that, indeed, this innovative approach was not only mechanically feasible but economically attractive, and the longer we studied this concept, the more attractive it became.

A major factor contributing to our enthusiasm was the ability of this system not only to do the required nitrification job, but also to provide for denitrification with a significant side benefit: the annual operating cost was reduced below that of a system which would simply meet the discharge requirements.

We found that the denitrification cycle is possible because of the planned oxidation ditch configuration (Figure 13) and because the draft tube device provides for:

1. Absolute assurance of completely mixing the total basin contents once every cycle.

2. The D. O. level at various points around the ditch could be controlled to provide the anoxic zone needed. (This is not convenient with any other system.)

By simply designing the travel path long enough, we provided Fairfield a denitrification cycle having four major advantages:

1. A high percentage (50%-60%) of the oxygen required for nitrification is recovered from the nitrates by the bacteria under anoxic conditions, thus reducing the total air and power requirements.

2. 50% of the alkalinity destroyed in the nitrification process is recovered in the denitrification cycle, thus eliminating the need to add lime or sodium bicarbonate to the treatment process.

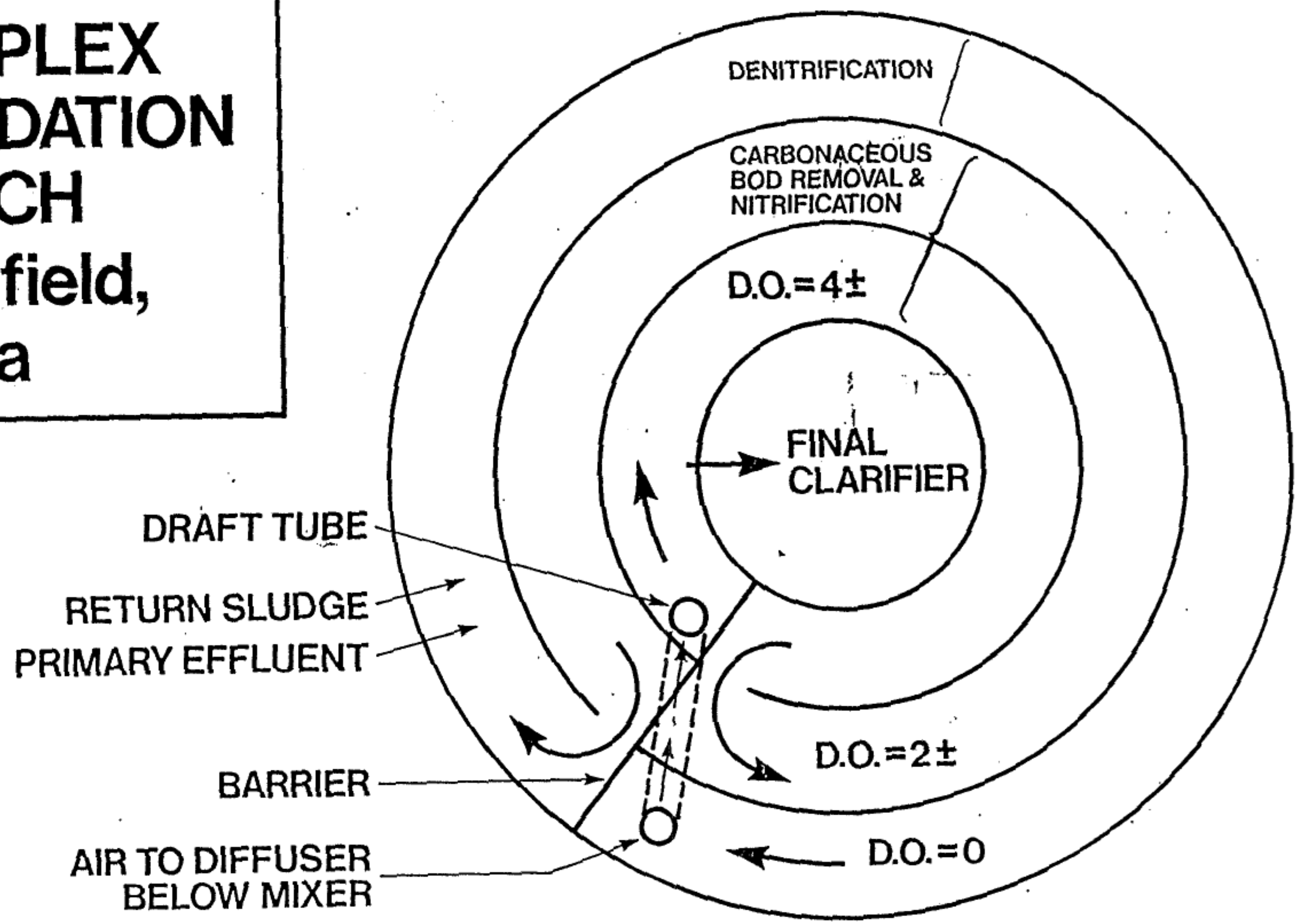
3. A high degree of denitrification enhances sludge settling characteristics.

4. The carbon contained in the raw waste stream can be used to satisfy the denitrification requirements, rather than having to add methanol as in traditional denitrification systems.

In the normal design sequence of a Draft Tube Channel, we would first establish the necessary volume in the carbonaceous removal zone using high SRT values for nitrification. We would then establish the necessary time under anoxic conditions, based on the well-known denitrification rates for domestic waste. The initial D.O. level in the carbonaceous removal zone would be based on nitrification requirements. Velocities would be established to maintain solids in suspension. All of this information, coupled with oxygen depletion rates in the aerobic zone would give the required ditch length. This information would then be

FIGURE 13

TRIPLEX OXIDATION DITCH Fairfield, Iowa



translated into the required ditch geometry, aerator pumping capacity, and air requirements.

In Fairfield's case we had an existing trickling filter basin that seemed worthwhile using. We worked from the dimensions of this physical tank to arrive at a trial ditch configuration. Fortunately, the dimensions met our requirements, and the ditch shown in Figure 13 resulted. The channels are 14' wide and 9' deep, with the draft tube submerged to about 20' below the bottom of the ditch.

We plan to use a simple variable speed drive on each blower to give us control of the initial D.O., and thus the length of the anoxic zone.

Because most of the inert material will be removed in the primary clarifiers, we are designing for a ditch velocity of 0.8 ft./sec. to keep biological solids in suspension.

Other Design Features

Waste Secondary Sludge:

We expect the waste secondary sludge to be less than 200 pounds per day. This sludge will have a long SRT and will be highly stabilized. We plan to discharge this sludge periodically from the oxidation ditch directly to the storm water flow equalization basins to undergo facultative decomposition. A layer of oxygenated water over the sludge will eliminate potential odor problems in these basins. Primary sludge will continue to be treated by the anaerobic digesters prior to land disposal.

Final Clarifiers:

To insure against the loss of suspended solids during peak flow conditions, the final clarifiers are being designed with:

1. An average overflow rate of 300 gpd/ft.^{2}
2. Polymer addition facilities ahead of the final clarifiers for emergency use only.

Effluent Polishing and Dechlorination:

To insure that the effluent requirements are met, particularly in the winter, a polishing pond will be provided downstream of the chlorine contact chamber. This polishing pond will have a 2 day retention time at design flow with a depth of 10 feet. The BOD and SS removal through the polishing pond is expected to be in the range of 40%.

The 2 days retention time has been shown to be a maximum if algae problems are to be controlled.

A side benefit of this polishing pond is that it will also provide for dechlorination.

Conclusions

A. Life cycle costs for the triplex oxidation ditch system is estimated to be less than the next most cost effective conventional system (extended aeration).

B. Except for chlorine, and stand-by polymer for emergency use, no chemicals are expected to be used.

C. Secondary sludge disposal costs will be limited to pumping of the waste activated sludge to the storm water equalization basins.

D. Effluent polishing will require no O & M costs.

E. The big story, however, is the power savings. The total draw horsepower required downstream of the primary clarifiers is expected to be:

Figure #14

2 final clarifiers	=	2 Hp
non-potable water pump	=	1 Hp
2 draft tube aerators @ 11.5 Hp	=	23 Hp
2 blowers @ 7.5 Hp	=	15 Hp
2 sludge return pumps @ 2 Hp	=	4 Hp
2 waste sludge pumps @ 0.5 Hp (ave.)	=	1 Hp
Total		45 Hp

This amounts to 28 Hp per million gallons. By comparison, a complete mixed extended aeration basin alone would require a minimum of 64 Hp./million gallons.

The treatment through the Triplex Oxidation Ditch system will produce a higher quality effluent than the limits required by the NPDES Permit at less life cycle costs than any "traditional system" which we could have used at Fairfield.

Further, our studies of the Draft Tube Channel Triplex Oxidation Ditch would indicate that inclusion of a denitrification cycle for any treatment system which requires nitrification, will improve effluent quality; provide a more stable treatment system; and eliminate chemical costs. Additionally all of these benefits are obtained at substantially reduced power requirements.

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