ROBERT CLOUGH RIESS

BIOCHEMICAL OXYGEN DEMAND, DISSOLVED OXYGEN AND VELOCITY CHECKS ON AERATORS AT THE EAST LANSING, MICHIGAN SEWAGE TREATMENT PLANT

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

Robert C. Riess

1949

Biochemical Oxygen Demand, Dissolved Oxygen and Velocity Checks on Aerators at the East Lansing, Michigan Sewage Treatment Plant

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

Robert C. Riess

Candidate for the Degree of

Bachelor of Science

June 1949

Acknowledgements

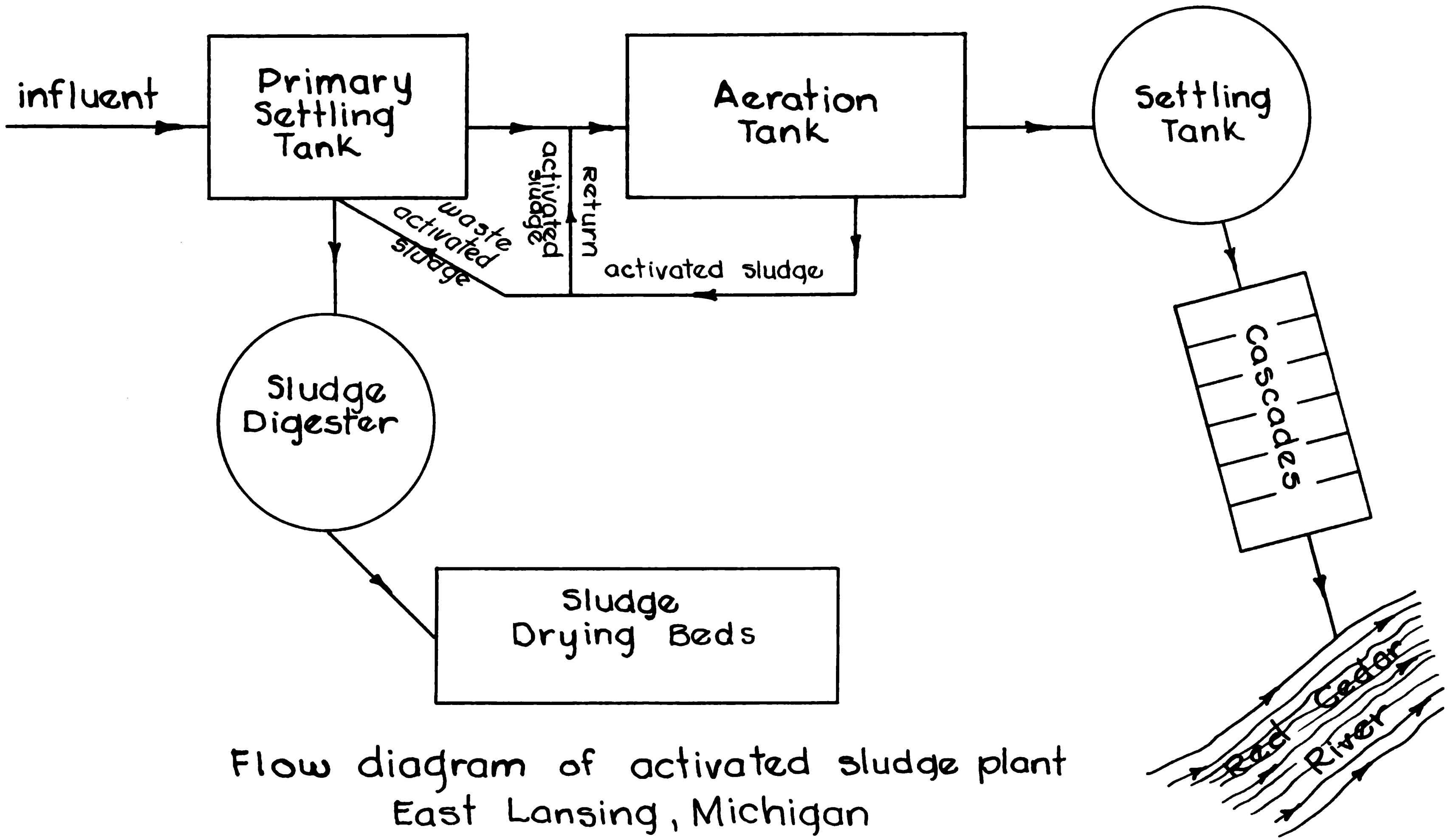
Professor Frank R. Theroux	- For his suggestion of the original idea and his help in getting the apparatus and material together.
Mr. Maurice Richman and Mr. Henry King	- For their help at the East Lansing plant in running the tests, use of materials, and general knowledge of the plant.
Patricia W. Riess	- My wife, who has helped me immensely on this paper and all others during my college years.

In 1938, the City of East Lansing, Michigan, and Michigan State College at East Lansing deemed it necessary to construct a sewage treatment plant. At that time, the combined population totaled 10,000, of which 4,000 were students at the College. Up until the time of construction of the sewage plant, the sewage from the College was passed into an Imhoff tank which was, and still is, on the site of the present sewage treatment plant. The sewage from East Lansing was untreated.

An activated sludge type plant was decided upon and construction began on the sewage treatment plant in 1938; on August 21, 1939, the plant was in operation. The plant consisted of two primary settling tanks, nine aerators of the simplex downdraft mechanical type, two secondary or final settling tanks of the Dorr Squarex type, a sludge digestor, and ten sludge drying beds.

The plant operated successfully for a number of years treating an average of 1.7 million gallons of sewage per day.

By 1946, the combined populations of East Lansing and Michigan State College had increased to an estimated 30,000, and an addition to the existing sewage plant became a necessity. In 1946, enlargement began and by 1948, construction was completed. The new additions enlarged the plant to



Flow diagram of activated sludge plant
East Lansing, Michigan

Fig. 1

four primary settling tanks, seventeen aerators of the simplex downdraft mechanical type, four secondary settling tanks, two Dorr squarex types, three sludge digestors, and seventeen sludge drying beds. One of the sludge digestors in this case is the old Imhoff tank converted to use.

The aerators of the original plant were twenty-three feet, three inches square, and had an operating depth of thirteen feet, four inches. They were placed in three rows of three each, and flow could be regulated between aerators by means of a system of baffle gates in the concrete partitions.

The aerators were equipped with a 5 Hp motor that turned the impellers at 900 RPM, forcing the air down a twelve inch drawdown tube. The total capacity of these nine aerators is 488,000 gallons.

The new aerators are without baffles and measure twenty-seven feet wide and one hundred one feet long, with an operating depth of fourteen feet, seven inches. They were originally equipped with a twelve inch diameter drawdown tube, but they proved ineffective and, at the start of this test, were being replaced by fourteen inch diameter drawdown tubes.

These aerators are placed four in a row in two rows. They are aerated by a 5 Hp motor operating at 900 RPM, and carrying a total capacity of 528,760 gallons. This makes the combined capacity of the aerators 1,016,760 gallons.

During the aeration period, the pattern of the flow is outward from the drawdown tube or toward the edges of the aeration tank. At some outer points in the new aerators where the flow of the two aerators meet, whirlpools and eccentric currents are plentiful. In the old aerators, no such condition exists due to the boundaries of the concrete walls.

Several of the old aerators were equipped with four steel flutes, fourteen inches wide by ten inches deep and seven feet four inches long. These were placed so the bottoms of the flutes were seven inches below the surface of the sewage and arranged diagonally out from the drawdown tube. The flow pattern on those aerators equipped with the flutes was outward in the areas between the flutes and inward inside the flutes. Thus it may be seen that at the time the tests were run, four distinct arrangements of aerators were in use, i. e., aerators with baffles, aerators with baffles and flutes, aerators without baffles and twelve inch drawdown tubes, and aerators without baffles and fourteen inch aerators.

The tests were run almost exclusively on the latter two aerator types as the primary object of the tests was to determine if the new aerators were operating to capacity and as desired. However, at some times during the research, the new aerators were not operating and so several tests were run on the old aerators for a comparison and the results from those tests are included in this report for added information.

During the course of these tests, the usual plant operating procedures were not always followed due to an unusual amount of breakdown of equipment and misfortunes.

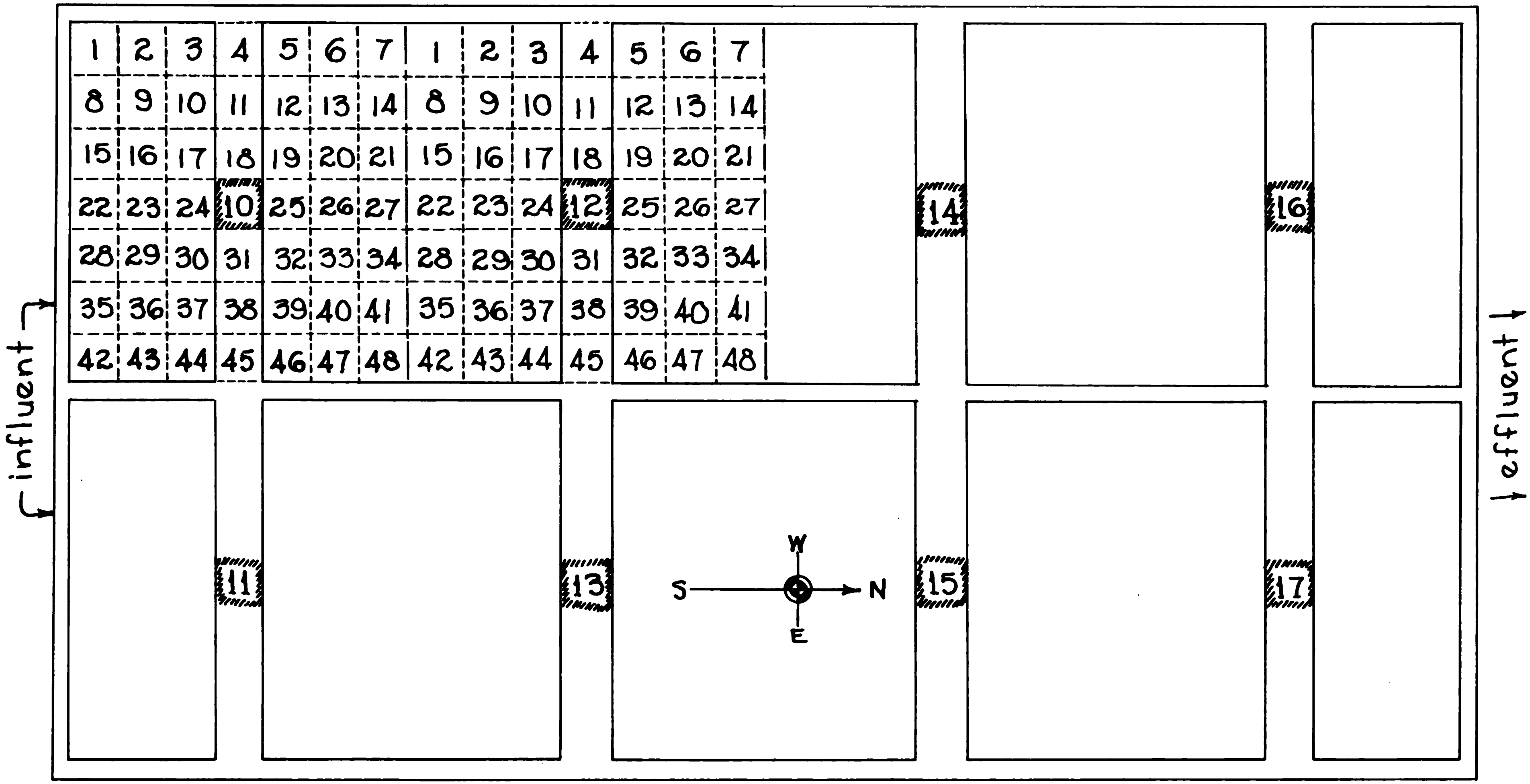
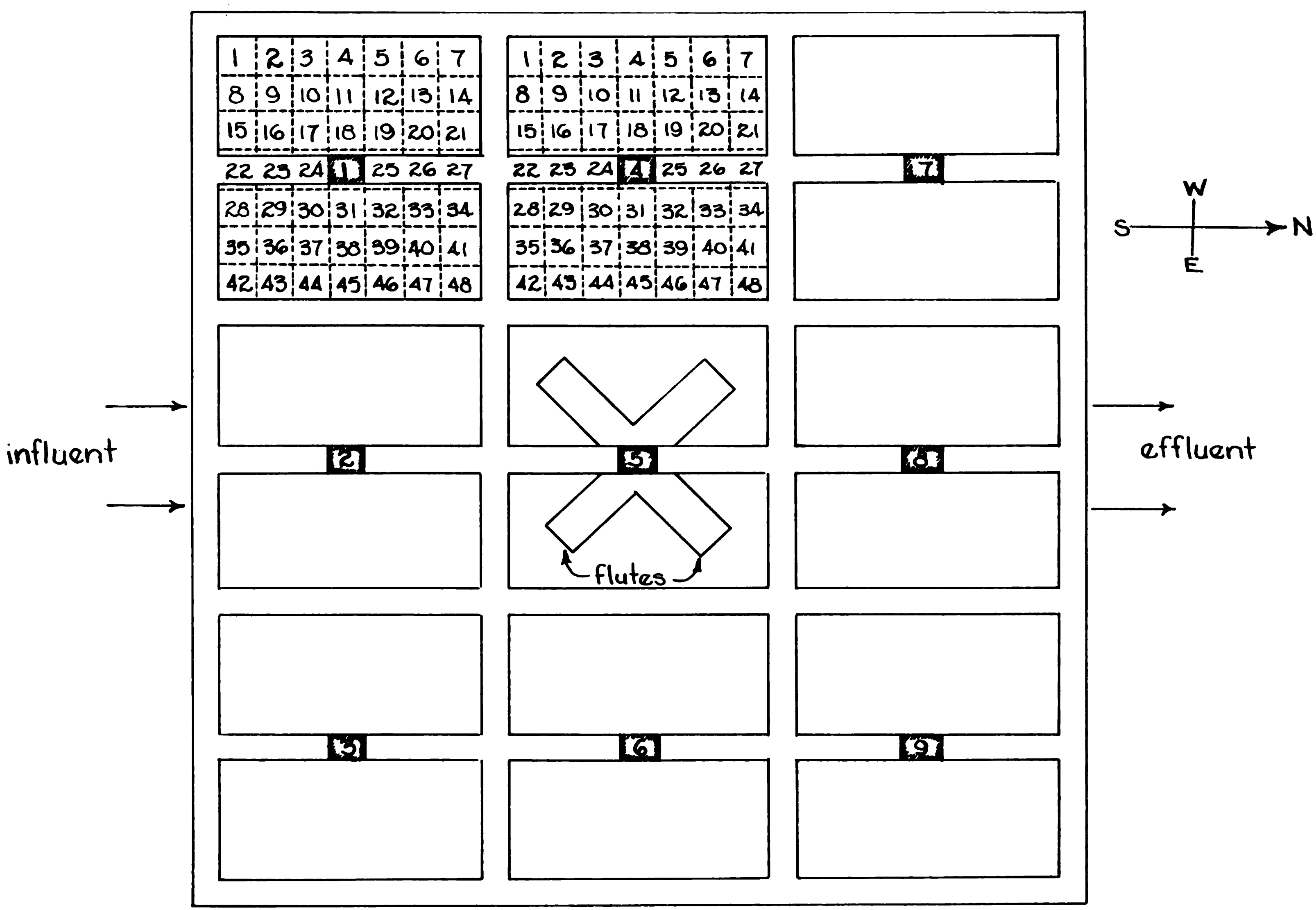


Illustration of how sample positions were numbered and the numbering of the new aerators

Fig. 2



Numbering of positions of old aerators

Fig. 3

Consequently, the results obtained may present an untrue picture of the plant when it is operating at full capacity and under design conditions.

At the beginning of the tests run, the twelve inch drawdown tubes in aerators 10, 12, 14, and 16 were being replaced with the fourteen inch drawdown tubes, and so the tests were run on aerators 11, 13, 15, and 17, with their twelve inch drawdown tubes. It was hoped to thus be able to run a set of tests on the latter aerators with their twelve inch drawdown tubes and to run the same tests on them after being replaced with fourteen inch drawdown tubes. Unfortunately, the fourteen inch tubes were not in place when the tests were terminated.

Before the results of the tests are examined, a word or two must be said about them and how they were conducted. The dissolved oxygen tests (D. O.) were all run using Winkler's method and two samples run of each position. The biochemical oxygen demand tests (B. O. D.) were also run according to Winkler's method after their five day incubation period. The velocity tests were run by use of a stream gage at various depths and the time in seconds noted when ten clicks or ten revolutions had sounded in the earphones. This was changed to velocity in feet per second by a chart in the carrying case of the stream gage.

In all cases the results given are an average as the results obtained were sometimes very erratic, especially in the velocity tests. Sometimes on two successive trials at the same depth in the same aerator area and position, the time for ten revolutions varied by as much as thirty seconds. This is probably due to a reversal of the gage such as might be caused by whirlpool interference.

In examining the results, it will be useful to know that aerator 16 is equipped with a fourteen inch drawdown tube and no baffles; aerator 15 has a twelve inch drawdown tube and no baffles; aerator 4 has a twelve inch drawdown tube and baffles, while aerator 5 has a twelve inch drawdown tube, baffles, and flutes.

Taking each aerator individually and analyzing its performance, it will be noted that in aerator 15 (Table 1), the area nearest the aerator drawdown tube has the lowest B. O. D., but that the B. O. D. is not the same on a locus around the drawdown tube. This indicates that the amount of oxygen rising along the outside of the shaft is not uniform throughout the aerator. The D. O. and velocity tests bear this out.

The velocity tests at the various depths for this aerator show that a diagonal line through positions 19, 30, and 42 have their highest velocities at the three feet, two inch level of the water, while a diagonal through 1, 17, and 32 shows that the highest velocities recorded are at the seven feet, three inch depth.

In aerator 4, (Table 2) the D. O. test was run several times with no results obtained while the B. O. D.

Aerator Number 15

Test	D.O. p.p.m.			B.O.D. p.p.m.			Velocity			feet per second					
Depth	Surface			Surface			3 feet 2 inch			7 feet 3 inch			10 feet 0 inch		
Position	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.
1	1.00	0.50	0.82	7.2	6.6	6.85	0.38	0.30	0.34	0.43	0.35	0.39	0.40	0.31	0.35
17	0.60	0.30	0.41	7.0	5.0	6.25	0.40	0.36	0.38	0.45	0.41	0.42	0.38	0.38	0.38
19	0.80	0.60	0.70	6.8	5.2	6.40	0.47	0.37	0.42	0.39	0.39	0.39	0.47	0.22	0.39
30	0.75	0.60	0.66	6.8	6.4	6.65	0.58	0.39	0.48	0.45	0.40	0.43	0.36	0.36	0.36
32	0.80	0.40	0.60	6.8	6.6	6.75	0.54	0.30	0.42	0.57	0.39	0.48	0.35	0.31	0.33
42	0.80	0.40	0.60	8.4	6.4	6.95	0.45	0.45	0.45	0.30	0.30	0.30	0.28	0.28	0.28
46							0.28	0.28	0.28	0.27	0.27	0.27	0.27	0.31	0.31
Aerator Avg.	0.79	0.47	0.63	7.34	6.20	6.64	0.46	0.35	0.39	0.48	0.36	0.38	0.36	0.31	0.34
Influent*				2.4	1.4	1.9									
Effluent*				5.4	5.2	5.3									

* Refers to influent and effluent of the aerators

Table No. 1

Aerator Number 4

Test	D.O. p.p.m.			B.O.D. p.p.m.			Velocity feet per second								
Depth	Surface			Surface			3 feet 2 inch			7 feet 3 inch			10 feet 0 inch		
Position	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.
17	0	0	0	3.8	3.6	3.7	0.58	0.58	0.58	0.66	0.66	0.66	0.52	0.52	0.52
19	0	0	0	5.0	4.6	4.8	0.58	0.58	0.58	0.52	0.52	0.52	0.58	0.58	0.58
30	0	0	0	3.0	3.0	3.0	0.43	0.43	0.43	0.43	0.43	0.43	0.37	0.37	0.37
32	0	0	0	4.6	3.6	4.1	0.58	0.58	0.58	0.66	0.66	0.66			
42	0	0	0	4.4	4.2	4.3									
48	0	0	0	6.0	5.0	5.5									
Aerator Avg.	0	0	0	4.4	4.0	4.2	0.54	0.54	0.54	0.57	0.57	0.57	0.49	0.49	0.49
Influent*				2.0	1.6	1.8									
Effluent*				4.0	4.0	4.0									

* Refers to influent and effluent of the aerators

Table No. 2

Aerator Number 5

Test	D. O. p.p.m.			B.O.D. p.p.m.			Velocity feet per second								
Depth	Surface			Surface			3 feet 2 inch			7 feet 3 inch			10 feet 0 inch		
Position	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.
33	0	0	0	3.3	3.2	3.25									
31	0	0	0	5.6	3.8	4.70	0.22	0.22	0.22	0.26	0.26	0.26			
30							0.23	0.23	0.23	0.30	0.30	0.30	0.40	0.40	0.40
29	0	0	0	5.2	2.4	3.80									
20							0.43	0.43	0.43	0.40	0.40	0.40	0.39	0.39	0.39
18	0	0	0	5.8	5.6	5.70	0.91	0.91	0.91	0.58	0.58	0.58	0.46	0.46	0.46
17							0.26	0.26	0.26	0.31	0.31	0.31	0.34	0.34	0.34
16															
7	0	0	0	6.4	5.6	6.00									
42	0	0	0	6.0	5.8	5.90									
Aerator Avg.	0	0	0	5.2	4.4	4.90	0.41	0.41	0.41	0.37	0.37	0.37	0.39	0.39	0.39
Influent *				4.2	3.8	4.00									
Effluent *				5.8	4.8	5.30									

* Refers to influent and effluent of the aerators

Table No. 3

Aerator Number 16

Test	D.O. p.p.m.			B.O.D. p.p.m.			Velocity feet per second								
Depth	Surface			Surface			3 feet 2 inch			7 feet 3 inch			10 feet 0 inch		
Position	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.	High	Low	Avg.
1				6.8	6.6	6.7	0.31	0.31	0.31	0.22	0.22	0.22	0.49	0.49	0.49
3	0.8	0.8	0.8				0.26	0.22	0.24	0.26	0.24	0.25	0.31	0.29	0.30
17	1.0	1.0	1.0	7.2	5.2	6.1	1.03	1.03	1.03	0.82	0.79	0.81	0.64	0.60	0.62
19	1.2	1.2	1.2	7.0	6.1	6.5	0.82	0.53	0.67	0.74	0.66	0.70	0.91	0.56	0.73
27				4.2	2.8	3.5	0.64	0.64	0.64						
30	1.0	1.0	1.0	7.6	5.6	6.6	0.62	0.38	0.50	0.44	0.36	0.40	0.57	0.47	0.52
32	0.8	0.8	0.8	6.8	6.8	6.8	0.49	0.36	0.42	0.56	0.46	0.51	0.68	0.66	0.67
41	1.2	1.2	1.2	7.6	7.4	7.5									
Aerator Avg.	1.0	1.0	1.0	6.9	5.8	6.3	0.59	0.49	0.54	0.50	0.45	0.48	0.60	0.51	0.56
Influent *	1.2	1.2	1.2	2.6	2.4	2.5									
Effluent *	1.4	1.4	1.4	5.2	4.0	4.6									

* Refers to influent and effluent of the aerators.

Table No. 4

test again indicates that the lowest B. O. D. is nearest the drawdown tube and not uniform in value at those positions.

The velocities again seem to follow a pattern like that of aerator 15 with a diagonal through positions 17 and 32, having the highest velocities at the seven feet, three inch depth and the highest velocities at the three feet, two inch on a diagonal through 19 and 30.

In aerator 5 (Table 3), as with aerator 4, no results for D. O. were obtained and, due to the flutes being present, the usual testing positions were not available in all cases. Due to that situation, the results are a little more difficult to analyze.

The B. O. D. test seems to indicate, however, that the greatest B. O. D. is at the extremities (positions 7 and 42), while directly around the aerator the next highest B. O. D. is obtained. This means that the lowest B. O. D. would be in between these positions, and the results obtained bear this out.

In aerator 16 (Table 4), the velocities again form a pattern of sorts as the highest velocities are on a diagonal line through 19 and 30 at a depth of ten feet, zero inches. However, no pattern is found through positions 17 and 32, as position 17 has its highest velocity at the two feet, three inch level, and position 32 has its highest velocity at the ten feet, zero inch level.

The B. O. D. tests show some uniformity near the drawdown tube as the four positions (17, 19, 30 and 32) only vary by 0.7 ppm from the highest to lowest B. O. D.

The D. O. tests show results similar to the B. O. D. as the most uniform and greatest D. O. results were obtained at positions nearest the drawdown tube. The D. O. at these positions (17, 19, 30 and 32) varied by only 0.4 ppm from the highest to lowest values.

Before the tests were run, it was assumed that the velocity was greatest near the bottom of the aerator and at a locus nearest the drawdown tube. The obtained results indicate that the highest velocities are obtained near the drawdown tube, but not necessarily at a point near the bottom. In a number of cases, the highest velocity was at the seven foot, three inch level, and, in some cases, at the three feet, two inch level.

It was also thought that the air released at the bottom of the drawdown tube surged upward too vertically, and thus did not aerate the entire surface area but only that immediately around the drawdown tube. For the most part, the results indicate this to be true, but also show that the next highest D. O. tests are obtained at the extremities of the aerators, leaving a locus of low D. O. between the drawdown tube and aerator extremities.

The results taken as a whole seem to indicate that the aerators are functioning as designed, but no definite conclusions can be drawn from the tests run for several reasons. One of the main reasons is that during the period the tests were run, the plant was not functioning properly and so the results are not indicative of a plant running at full capacity or design capacity.

Another item against the results obtained is that the time to run the tests was so limited that a complete analysis could not be made. To be complete, more tests would have to be run of each position, of more positions, and of more aerators.

Another item that would make the results more valuable would be to run the B. O. D., D. O., and velocity tests on the aerator positions at as nearly possible the same time for an aerator. The results of this report for the tests mentioned some times were run as far apart as a week's time, due to necessity.