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Cannery Wastewater Treatment with Rotating Biological Contactor and Extended Aeration

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CANNERY WASTEWATER TREATMENT WITH ROTATING BIOLOGICAL CONTACTOR AND EXTENDED AERATION

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ABSTRACT

Fruit and vegetable cannery wastewater was treated during two canning seasons by two pilot plants of the rotating biological contactor and extended aeration types.

The objective was to determine the feasibility of these biological treatments processes on cannery wastewater for the first time in the United States and to compare the two units under the same operating conditions. Economics were not included in this study since the project scope and resources were limited.

Nitrogen and phosphorus were added to the influent wastewater so the DOB:N:P ratio was kept above 100:5:1.

Both treatment units attained organic removals of over 90 percent. However, much less detention time was necessary in the RBC to obtain removals comparable to the extended aeration plant. Sludge produced by the RBC required additional treatment, but most of the sludge produced in the extended aeration plant was aerobically digested in the aeration tank.

Effluent quality from both units was about the same over the operating temperature range of 10-20°C, although the RBC appeared to recover more rapidly from organic shock loading. Neither unit produced an effluent that could be discharged to surface waters without further treatment.

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SECTION I

CONCLUSIONS

1. The Modified Extended Aeration (MEA) and Rotating Biological Contactor (RBC) are capable of removing over 90 percent of the organic matter at COD loadings of 3.1 to 19.1 lbs COD/day/1,000 cu ft of aeration tank volume for the MEA and 4.4 to 10.6 lbs COD/day/1,000 sq ft of disc surface area for the RBC. The upper loading limit for both units was due to inadequate oxygen addition equipment. Nutrient addition was made to insure a minimum influent BOD:N:P ratio of 100:5:1.

2. The RBC removed the same amount of organic matter as the MEA in a range of theoretical hydraulic detention times (THDT) from 0.17 to 0.42 days for the RBC compared to 7.3 to 75 days for the MEA.

3. Excluding mixed-liquor suspended solids remaining in the aeration tank at the end of the canning season, the MEA did not produce sludge that needed further treatment. The RBC produced sludge that would require separate digestion facilities.

4. Effluents from both units contained significant suspended solids. When operated properly, the MEA averaged 72 mg/l, and the RBC averaged 56 mg/l during the same time period. However, the variability of effluent suspended solids was larger for the RBC.

5. Power requirements for the RBC appeared less than for the MEA by about a 1:2 ratio. This may be altered considerably under full-scale operation.

6. The RBC appeared to recover from heavy organic shock loading in about one day, and the MEA did not appear to recover completely from the same shock loading for the rest of the study, which was about two weeks.

7. COD removal for both units was apparently not affected by mixed liquor temperature in the range of about 10-20°C. Meaningful data outside this range was not acquired.

8. Nitrification occurred in the MEA but not in the RBC.

9. Both units produced sludge that appeared to have good settling characteristics. However, limited data were gathered on the RBC.

10. Effluent characteristics were about the same for both units during good operation.

SECTION II

RECOMMENDATIONS

1. Since no economic analysis was planned for this study, many economic questions were left unanswered, however, both treatment units demonstrated their ability to treat cannery wastewater. These units are therefore recommended for use in situations where they are more economical than other methods of treatment. Cost data may be obtained concerning other applications of the RBC from Autotrol Corp.

2. In climates associated with driving rain or hail, the RBC should have a cover that would protect the biological slime and discs.

3. This study indicates these treatment processes should be used for pretreatment ahead of municipal or other treatment rather than for complete treatment.

SECTION III

INTRODUCTION

PROBLEM

Combined treatment of wastewater from industrial and domestic sources has generally been looked upon as the most economical approach to treatment of industrial wastes. Each situation warrants specific investigation to obtain all the facts necessary to make sound decisions concerning approach to treatment. Consideration of alternatives should include at least the following:

1. Combined treatment with the city.
2. Pre-treatment followed by combined treatment.
3. Complete treatment by industry.

Recently a Federal Government policy was established on grants for construction of domestic wastewater treatment plants. This policy provides the Environmental Protection Agency the authority to disapprove construction grant applications by cities that have not included provisions in their operation and maintenance schedules for acceptable industrial wastewater treatment assessment[(1)]. As a result of this policy, city officials will feel the need to evaluate more critically their industrial treatment assessments. Some industries may also find it necessary to reevaluate the alternatives in wastewater treatment.

Alternatives 2 and 3 require a detailed look at the treatment processes available. The following are some of the main points to be considered in selection of a treatment or pretreatment process:

1. Adequate operation on a seasonal basis.
2. Required operation time and operator skill.
3. Stability under shock hydraulic and organic loads.
4. Stability under widely varying temperature, pH, etc.
5. Available land.
6. Overall economics.
7. Public relations (aesthetic requirements, etc.).

Many of the wastewater treatment processes to be considered have adequate design information available, and comparisons can be made quite readily. There are more recent processes that do not have enough history of operation available. The Rotating Biological Contactor (RBC) is a process that does not have readily available operation and design data. For certain industrial wastes, another biological process is Modified Extended Aeration (MEA). This process is a modification of the normal extended aeration process because the detention is much longer and a relatively new settling device, the tube settler, is incorporated in the aeration tank thereby providing close to 100 percent sludge return.

The objective of this study was to determine the effectiveness of the MEA and RBC processes as means for complete treatment or pretreatment of cannery wastewater.

SECTION IV

STUDY PROCEDURES

DESCRIPTION

The study was conducted with two pilot plants which were located at a cannery owned by United Flav-R-Pac Growers, Inc. at Salem, Oregon, during the 1969 and 1970 canning seasons. The cannery processes canned and frozen vegetables and fruits on a seasonal basis running generally from June through December.

Wastewater for the pilot plants was taken from the cannery discharge flume just prior to discharge to the city sewage collection system. The wastewater did not include the initial-wash which contained large quantities of silt. Normal full-scale biological treatment processes would be operated in the same manner.

The wastewater was nutrient deficient so ammonium phosphate (9-30-0) and fertilizer grade urea were added in proportion to influent wastewater flow. Addition was accomplished in liquid form at a rate that provided nutrients in the weight ratio of 100:5:1 for BOD:N:P based on an assumed maximum BOD concentration of 2,000 mg/l.

The wastewater was then pumped to the pilot plants, at as constant a flow rate as possible, with helical rotor, positive displacement, variable speed pumps. Effluent from the pilot plants was discharged to the cannery sedimentation pond. Figure 1 shows the general layout.

The sedimentation pond is used for settling silt and other settleable solids from initial-wash operations. Discharge from the sedimentation pond goes to a manhole where city personnel measure flow and take samples for strength determinations to be used for assessment calculations. Table 1 shows averages of daily wastewater flow measured by the City of Salem at the sewer manhole that receives the total of discharges from the sedimentation pond and wastewater flume. The column for fruit and vegetables processed does not contain a listing of all items processed during the year indicated. Only the items processed during pilot plant operation are shown.

Modified Extended Aeration

Figures 2 and 3 show the layout of the MEA pilot plant. The materials used were:

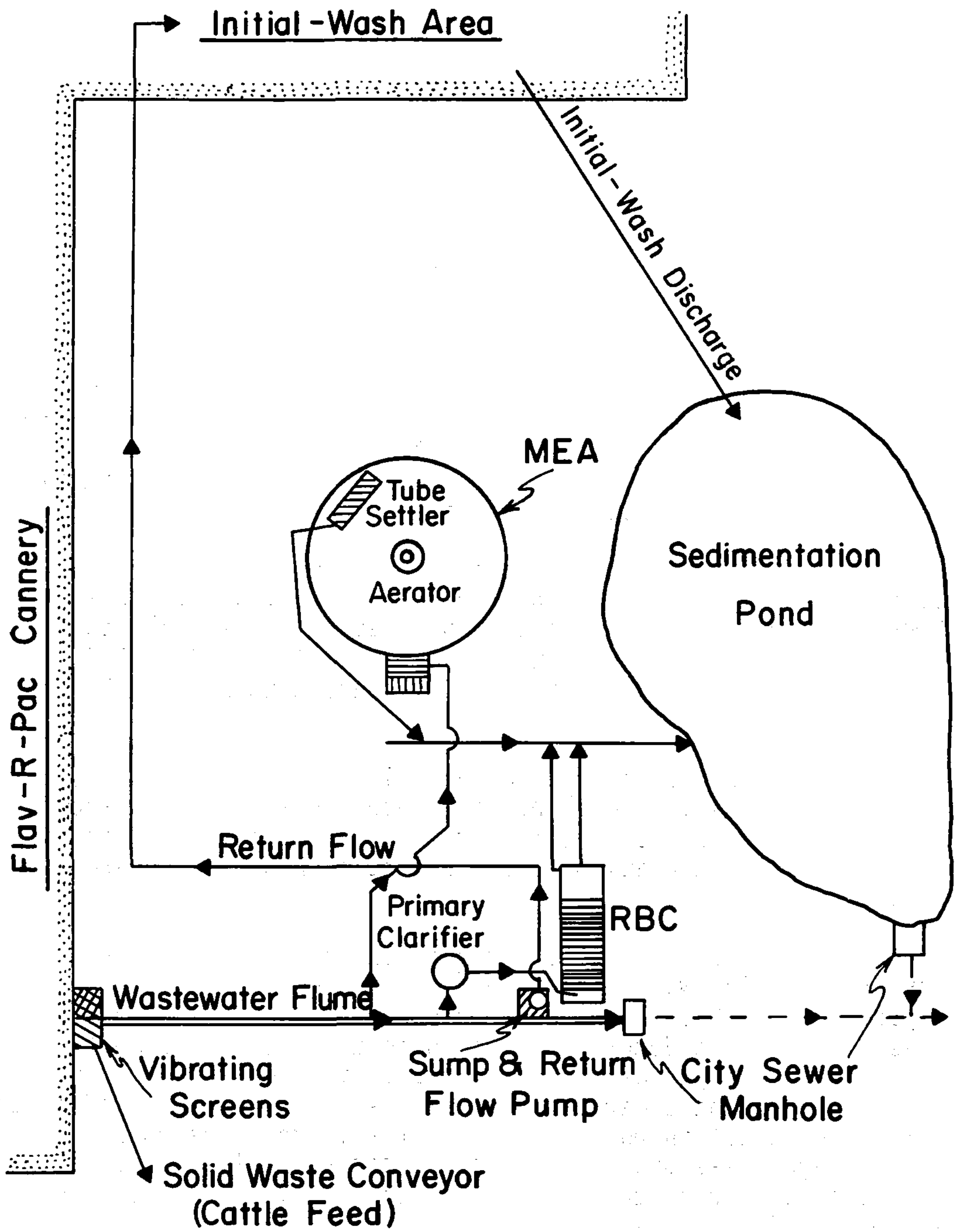

FIGURE 1. GENERAL PLAN VIEW OF CANNERY AND PILOT PLANTS

Table 1

PROCESSING AND WASTEWATER FLOW SUMMARY - FLAV-R-PAC CANNERY

Time Period	1969 Avg. Flow MGD	1969 Vegetable or Fruit Processed	1970 Avg. Flow MGD	1970 Vegetable or Fruit Processed
8/1-15	---	-----	0.750	Beans, Beets
8/16-31	---	-----	0.853	Beans, Beets, Corn
9/1-15	0.857	Corn	0.756	Beans, Beets, Corn
9/16-30	0.683	Corn, Prunes	0.686	Beets, Corn, Prunes, Squash
10/1-15	0.873	Corn, Beets	0.741	Corn, Squash, Carrots
10/16-31	0.774	Beets, Carrots	0.795	Corn, Squash, Carrots
11/1-15	1.036	Carrots	0.790	Squash, Carrots
11/16-30	1 062	Carrots	0.626	Potatos, Squash, Carrots
12/1-15	1.008	Carrots	---	-----
12/16-31	0.821	Carrots	---	-----

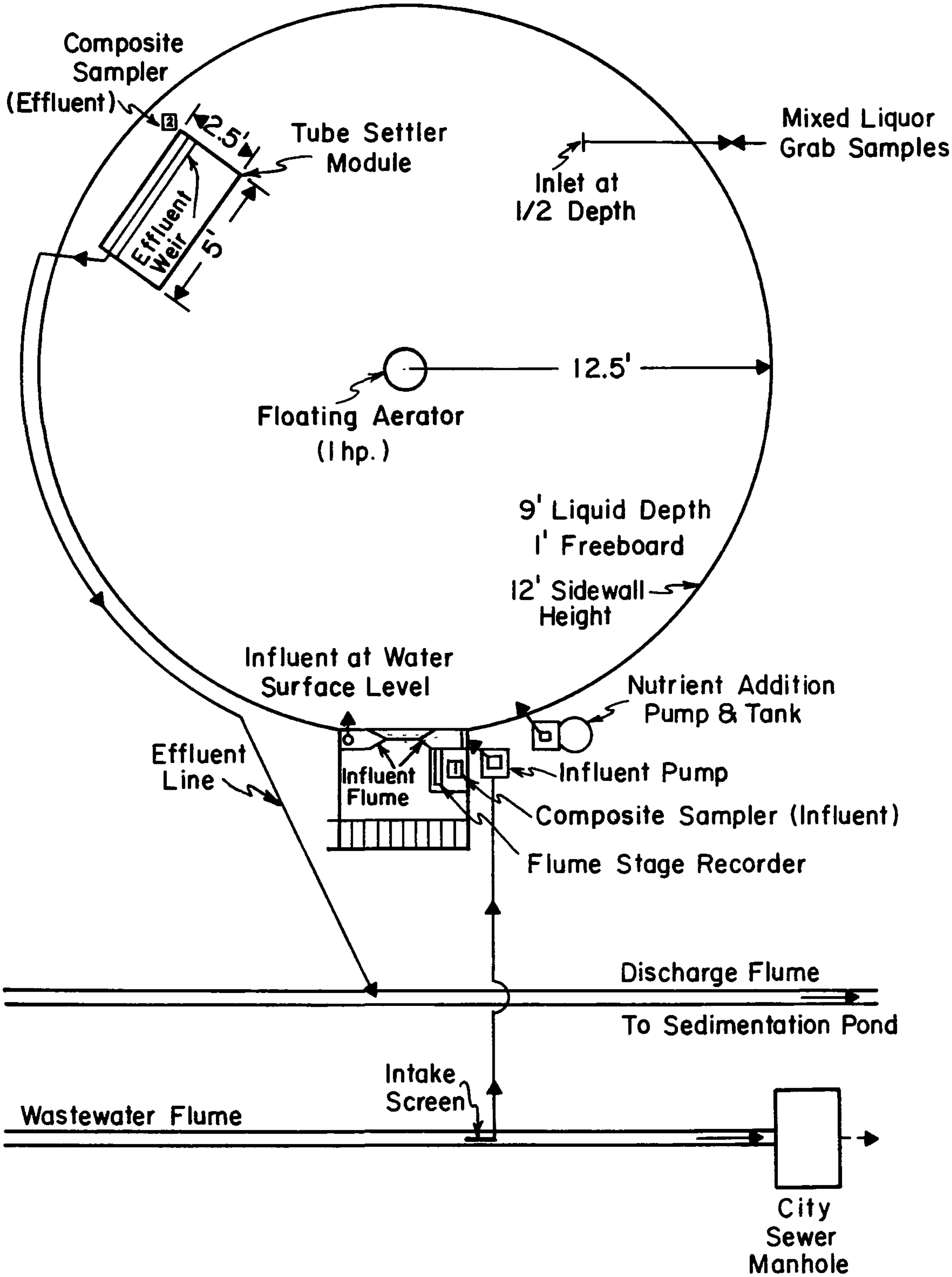

FIGURE 2. MEA PLAN VIEW

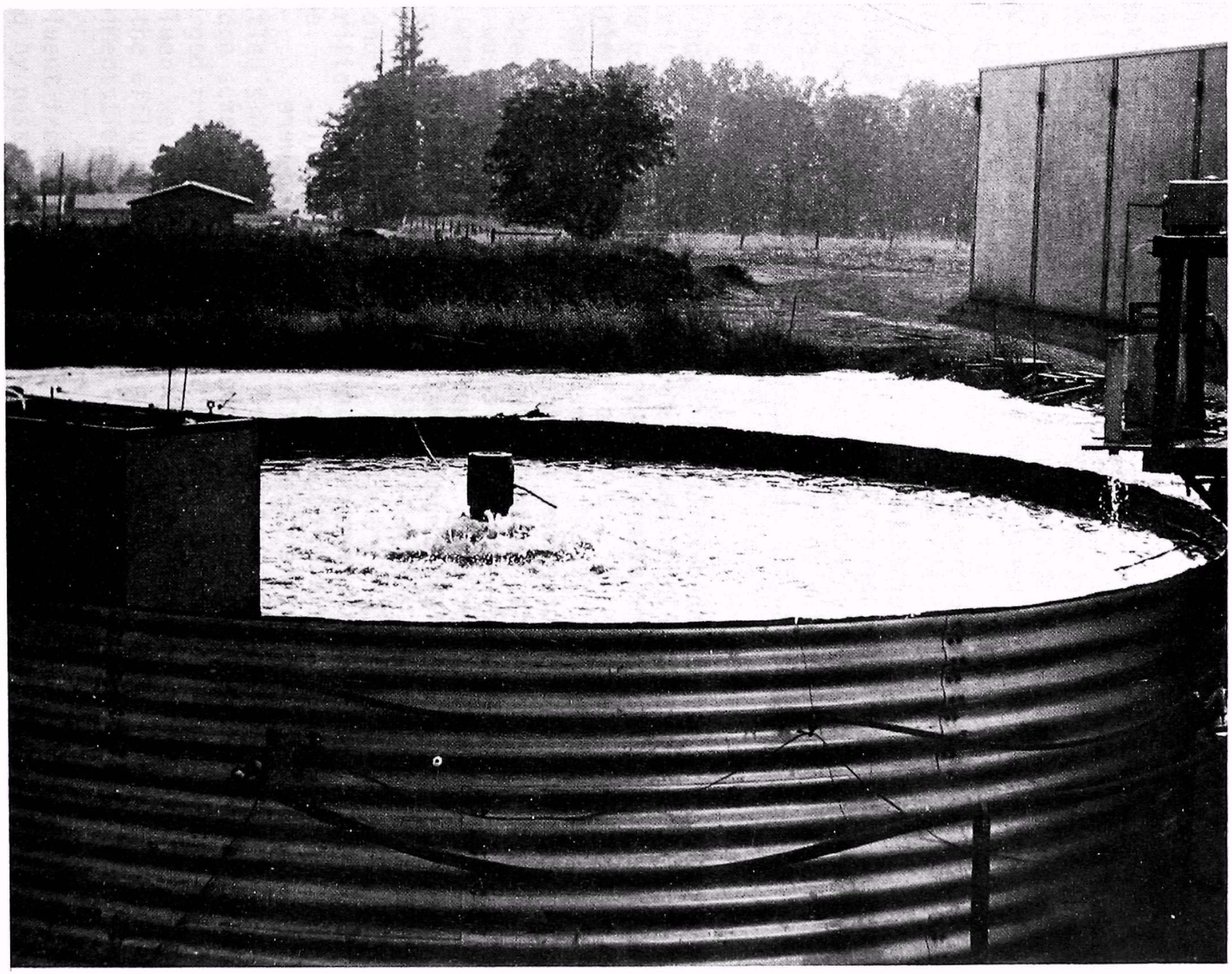

FIGURE 3. MEA PHOTOGRAPH

Tank - bolted 14 Ga. aluminum corrugated plates.

Tank liner - 1/16" thick butyl rubber

Settling unit - Neptune Microfloc tube settler - 2' depth x 2-1/2' width x 5' length module; tube inclined 60° to horizontal plane.

Aerator - 1 Hp. Welles floating aerator.

The aeration tank was placed with 2 feet of the aluminum sidewalls below ground level.

Flow to the MEA was controlled by adjusting the speed of the influent pump until the desired flow was obtained in the inlet flume or by changing the overflow weir height in the influent flume and allowing the excess influent to be bypassed to the sedimentation pond. The actual stage in the flume was recorded continuously with a Type F Stevens water level recorder. The intake on the pump suction line was a 1-1/2" diameter PVC plastic pipe section 2 feet long. The pipe was perforated by drilling 3/16" holes at about 1" spacing. Flow in the cannery wastewater flume was intermittent due to equipment breakdown and shutdown on weekends. To insure automatic influent pump operation in response to wastewater flow on an "on-off" basis, a float switch was installed in the pump control circuit.

Nutrient addition was accomplished in liquid form with a chemical proportioning pump and a 50 gallon mixture tank. Feed rate was manually changed except for automatic shutoff when wastewater flow ceased.

Aeration was provided by a 1 horsepower floating aerator that was designed to keep suspended solids in the tank in suspension as well as provide the oxygen needed for biological treatment of the wastewater. The aerator was operated continuously except for a few shutdowns with a maximum of 30 minute duration due to overloaded electrical control circuits.

Sludge settling and return to the aeration tank were accomplished as the mixed liquor passed upward through the tube settler module. The settleable solids slid down the tube settler surfaces and were swept back into the aeration tank by the mixed liquor flow past the bottom of the module. Clarified liquid continued to the water surface level of the module, where it entered the effluent line by passing over two multiple v-notch weir plates each of which was 5' long.

Rotating Biological Contactor

Figure 4 shows the layout of the RBC pilot plant. Figure 5 shows a photograph, from Autotrol Corp., of the type of RBC that was used. However, the unit used in this study had a fiberglass canopy for protection of the biological mass on the discs from driving rain. The RBC was built and provided by Autotrol Corporation, Milwaukee, Wisc., as a pilot plant model.

Flow of wastewater was controlled by adjusting the speed of the influent pump until the desired stage was obtained on the influent v-notch weir. The wastewater was taken in through the same type intake as used in the MEA, and then it was pumped to the primary clarifier. Effluent from the primary clarifier flowed by gravity to the RBC where measurement of flow was made with a Type F Stevens level recorder mounted behind the influent v-notch weir. Automatic pump control was provided by the same float switch as used for the MEA.

Primary clarification of the wastewater was provided on the recommendation of Autotrol Corp. representatives. This was accomplished with a 2'-diameter upflow clarifier. The surface over-flow rate was 920 gal/sq ft/day at a wastewater flow of 2 gpm, and the THDT was 51 minutes, which is based on an overall clarifier volume of 12.3 cu ft. The THDT was usually much less than 51 minutes because of the volume occupied by settled solids.

The nutrient addition mixture was the same as for the MEA. However, gravity flow was used from an elevated, constant-head, tank with a 30 gallon capacity. The flow was manually controlled, and the nutrient addition was made in proportion to influent flow. Addition was made just ahead of the inlet to the RBC influent chamber.

As the flow entered the influent chamber, rotating cups elevated the wastewater and nutrient mixture to the influent channel to the first disc stage. The flow entered on one side of the first stage and left on the diagonal corner to the influent channel of the second stage. The same flow pattern was repeated through the second stage to the secondary clarifier. Flow into the secondary clarifier was dampened by a baffle over the end of the influent pipe.

Settled sludge was picked up in the secondary clarifier by a rotating sludge scraper operated at about 4 revolutions per hour. The scraper emerged from the clarifier on the side of the RBC opposite the effluent weir which minimized the carry over of settled sludge in the effluent. The sludge then flowed by gravity to the cannery sedimentation pond.

Effluent from the secondary clarifier was discharged to the sedimentation pond by passing over a multiple v-notch weir plate that was the same length as the secondary clarifier.

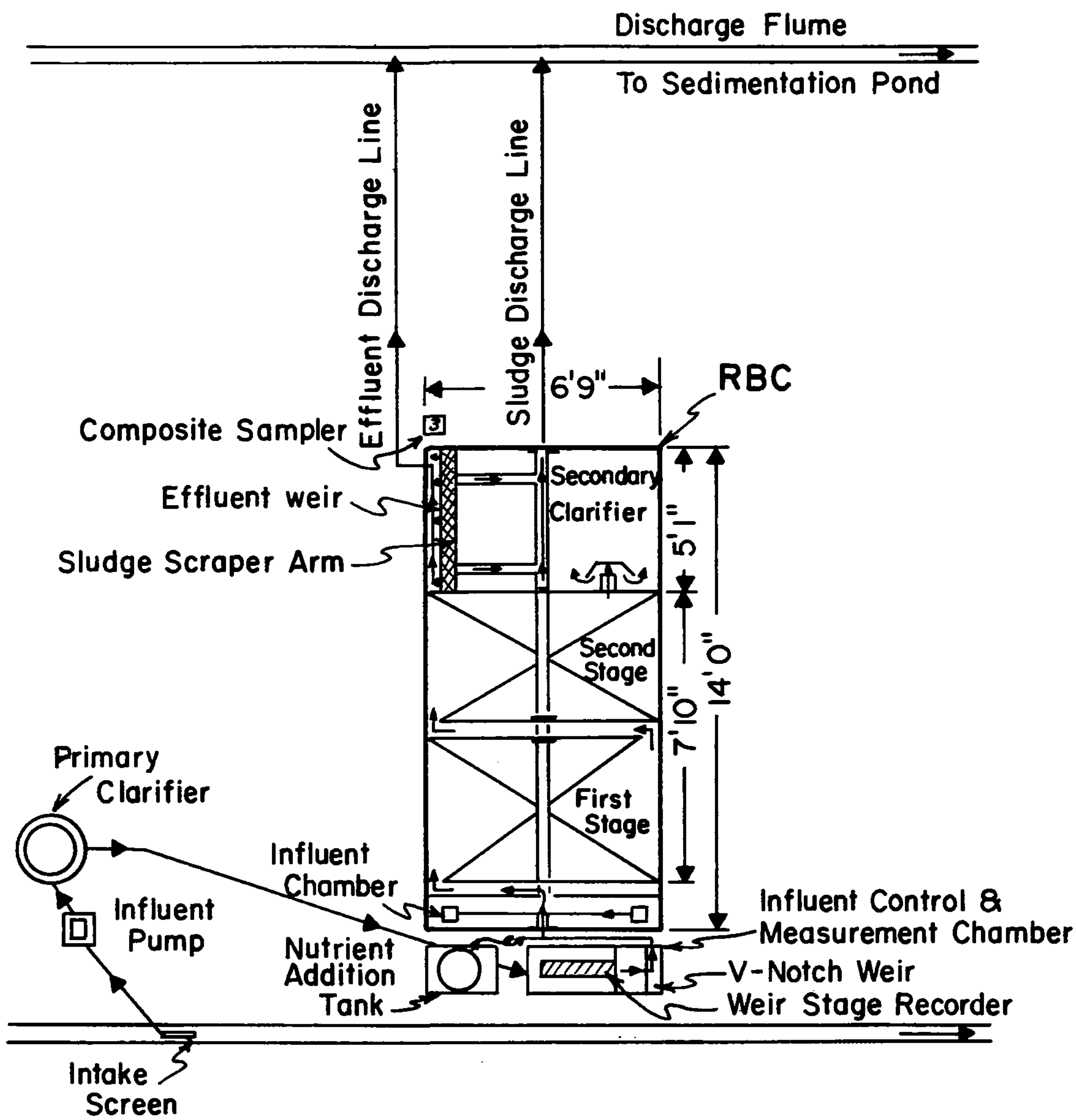

FIGURE 4. RBC PLAN VIEW

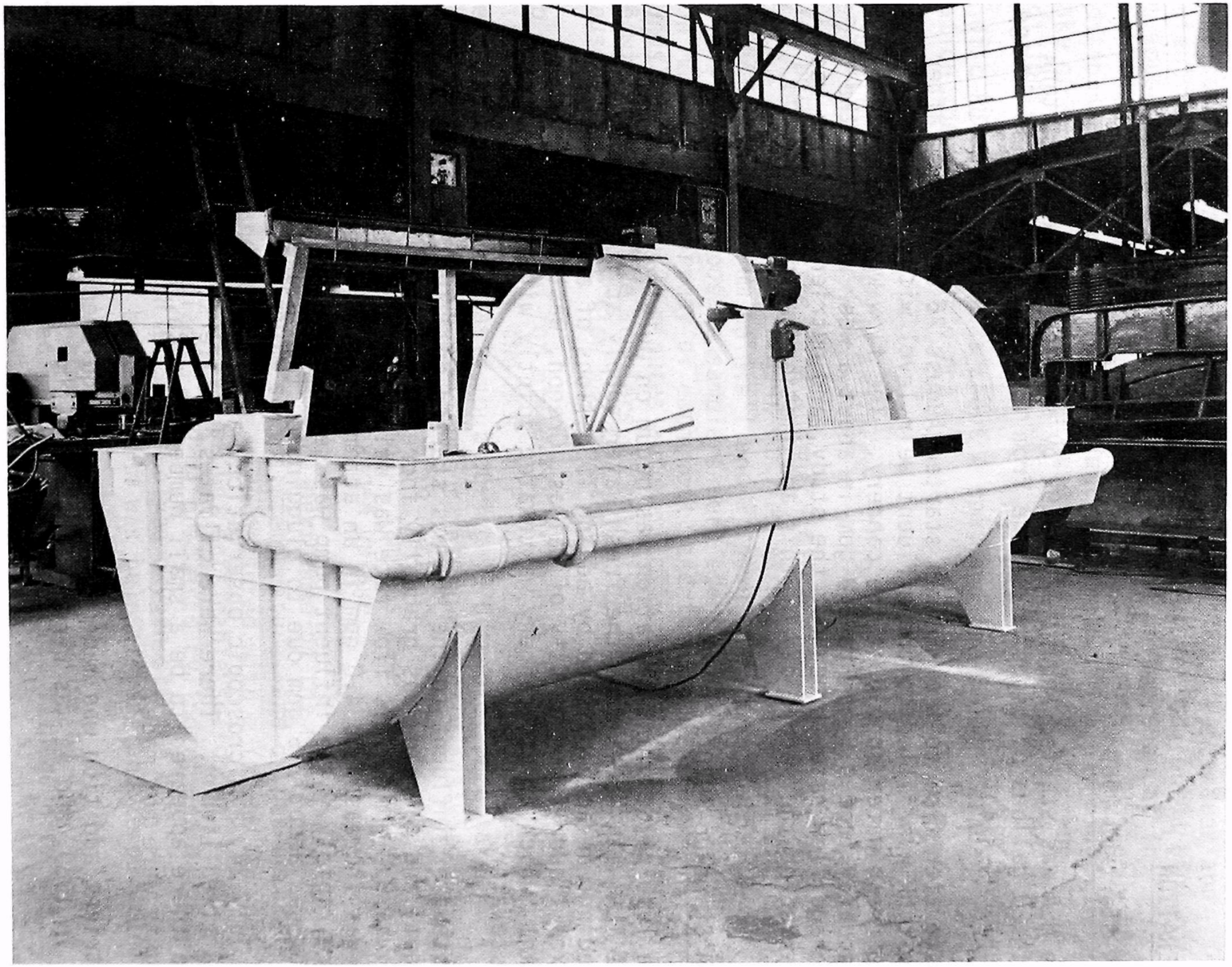

FIGURE 5. RBC PHOTOGRAPH

Aeration in the two disc stages was directly related to the rotation speed of the discs which was fixed at about 4 rpm. There were a total of 91 discs in the two stages. Each disc was 7/16" thick and 5.35' in diameter. The discs were made of molded polystyrene supported by radial metal braces. Without any growth on the discs, the total disc surface area was 4,670 sq ft. The total submerged surface area was about 1,500 sq ft, depending on flow rate through the unit.

OPERATION

MEA Start-up-1969

The MEA was started August 22, 1969, by seeding the aeration tank with 20 gallons of digestor sludge from the City of Corvallis Sewage Treatment Plant.

Wastewater flow to the MEA was started August 26 at 0.5 gpm after the tank was filled to the effluent weir level with water from the fresh water supply at the cannery. The flow was increased gradually from 0.5 gpm to 2.0 gpm in about a week which was the average flow rate throughout the study, and nutrient addition was started on the second day of this acclimation period.

MEA Start-up-1970

The 1970 pilot plant operation was begun on July 13, by filling the MEA with water from the fresh water supply at the cannery. Seeding was accomplished by adding 15 gallons of activated sludge mixed liquor from the City of Dallas, Oregon, wastewater treatment plant, which treats cannery wastewater jointly with the domestic wastewater.

Wastewater influent to the MEA was started on July 13, at about 1 gpm, and the flow was gradually increased until July 18, when it was 2.0 gpm. This flow rate was maintained until July 24, when it was increased to 4.0 gpm in an attempt to increase the MLSS more rapidly. The influent pump was set for 4.0 gpm but actual flow was about 2.5 gpm due to plugging of the intake.

On July 24, a microscopic observation was made on a sample of the MEA mixed liquor. There were ciliates, rotifers, and motile bacteria, and there appeared to be a small number of each, although actual counts were not made.

Nutrient addition was made with the same equipment and feed rates as in 1969, and it was begun at the same time as the seed addition.

RBC Start-up-1970

The RBC did not arrive on the site until August 24 and all supporting equipment was not operating properly until about September 10.

No seed was applied to the RBC before adding wastewater. Flow of wastewater was started to the empty unit on August 26, at a rate of about 2 gpm. Nutrient addition was started on August 28, at the same concentration and rate as to the MEA. Wastewater and nutrient flow was unsteady during the start-up period, but a biological mass appeared on the discs by August 31, and an improvement in the physical appearance of the effluent was also noted. Unsteady conditions resulted from intermittent wastewater flow and plugged intake on several occasions. Because of the unsteady start-up conditions, sampling on the RBC was not begun until September 14.

The disc rotation speed was about 4 rpm, and the sludge scraper rotation speed was about 4 rph.

MEA Sampling Procedure and Analyses - 1969 and 1970

During both seasons, the same approach to sampling was used on the MEA. Influent and effluent samples were taken by automatic composite samplers from points 1 and 2 shown on Figure 2 on a 24-hour basis. The composite samplers were started at about 9:00 am on Monday and Thursday of each week, and they sampled about 10 seconds out of every 20 minutes automatically for 24 hours. Pumping rate with the composite samplers on any given sample day was constant because the wastewater flow was constant.

Grab samples were taken for mixed liquor analysis from the point indicated on the side of the MEA in Figure 2. During 1969 samples were taken on a random basis, but during 1970 samples were taken each day except on weekends. These samples were only analyzed for settleable solids on a volumetric basis on Monday, Wednesday, and Thursday. On Tuesday and Friday, samples were analyzed for settleable solids, SS, VSS, and oxygen uptake.

The following on-site analyses were performed on the mixed liquor: dissolved oxygen, settleable solids, temperature, and oxygen uptake. Dissolved oxygen and temperature were measured with a Yellow Springs Instrument Co. dissolved oxygen probe; settleable solids was measured volumetrically with a glass 1,000 ml graduated cylinder; and oxygen uptake was measured with a YSI dissolved oxygen stirrer combination probe inserted in a BOD bottle which was held at constant temperature.

At the Pacific Northwest Water Laboratory the following analyses were performed on the mixed liquor grab samples: suspended solids, volatile suspended solids, pH, total alkalinity, oxygen uptake, and filtered and unfiltered COD during the endogenous phase of plant operation.

Composited MEA influent and effluent samples were analyzed for the following at the Pacific Northwest Water Laboratory: filtered and unfiltered BOD and COD, suspended solids, volatile suspended solids, pH, total alkalinity, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total Kjeldahl nitrogen, total phosphorus and ortho-phosphates.

RBC Sampling Procedures and Analyses -1970

Influent samples for the RBC were the same samples as taken for the MEA. Effluent samples were taken each week from the RBC by automatic composite samplers on a 24-hour basis, from about 9:00 am Monday to 9:00 am Tuesday and from about the same time Thursday to Friday. As with the MEA, the sampler was set to pump at a constant rate on any given sample date.

Grab samples were taken from the mixed liquor of the first and second disc stages on Tuesday and Friday. The samples were taken by inserting a siphon hose (1/2" inside diameter) about 18" below the water level along the side of each stage between the rotating discs and tank side. The hose was moved the entire length of the stage during the siphoning in an attempt to get representative samples.

The slime thickness and texture were so variable on the discs that the only attempt to determine the amount of biomass was an overall visual estimation of average slime thickness for each stage of discs. Samples of sludge from the secondary clarifier were obtained by diverting sludge flow from the removal scraper to a 35 gallon tank. This capacity tank allowed about a 1 hour continuous sample to be taken. The tank contents were thoroughly mixed by gently hand stirring, and two 1,000 ml samples were taken for analysis.

On-site analyses for the RBC were as follows: dissolved oxygen, temperature, and slime thickness. Slime thickness was obtained by visual estimation based on only a few random measurements each day. Dissolved oxygen and temperature were obtained in the mixed liquor of the disc stages and the secondary clarifier by measurement with a YSI dissolved oxygen probe.

The same analyses were made on the RBC effluent in the Water Laboratory as for the MEA influent and effluent.

Disc stage mixed liquor grab samples were analyzed for suspended solids and volatile suspended solids after the samples were homogenized in a blender.

Secondary clarifier sludge samples were also homogenized and analyzed for suspended solids and volatile suspended solids. Settleable solids were run on unblended samples at the laboratory using a 1,000 ml graduated cylinder and gravimetric suspended solids analysis. Settleable solids were run on unblended samples.

MEA and RBC - Methods of Analysis

Analyses were performed according to Standard Methods[2] with the exceptions of ammonia, nitrate, nitrite, total Kjeldahl nitrogen, total phosphorus, orthophosphates, and suspended and settleable solids which were all analyzed according to FWPCA[3] methods.

MEA and RBC - Sample Preservation

All samples for laboratory analysis were collected in insulated and iced containers and were transported under the same conditions. At the laboratory, samples were split into portions to be analyzed, preserved with mercuric chloride solution or sulfuric acid and then stored at 4°C, according to FWPCA[3] preservation methods. Samples that were not to be preserved were stored at 4°C until they were analyzed, which was the same day as sampling for about 95 percent of the samples.

SECTION V

RESULTS

MEA-1969

Summaries of data for the MEA during 1969 are presented in Tables 2 and 3, and ranges for the same parameters are shown in Table 4.

All values shown in Tables 2, 3, and 4 are in mg/l unless otherwise noted. Theoretical hydraulic detention time is calculated by using influent flow and an aeration tank volume of 32,500 gallons.

The influent values shown in Tables 2, 3, and 4 are based on samples of wastewater pumped from the cannery wastewater flume shown in Figure 1. Until the latter part of October, 1969, the initial-wash wastewater was not included in this flume because it was discharged directly to the sedimentation pond. At the end of October, however, the initial-wash wastewater was routed through the flume to the city sewer because the sedimentation pond was filled with silt. As a result, influent SS values and other parameters reflected the effect of the silt-laden initial-wash wastewater during the latter part of the season.

Sludge volume index was run on the MEA during 1969, but all values exceeded 300.

Nutrients were added ahead of the influent sampling point so all influent nutrient data in Table 2 were combined concentrations of wastewater and nutrients added.

The tube settler SS removal efficiency ranged from 6.6 to 84.8 percent with an average of 55 percent, and for VSS the range was 7.0 to 85.4 and the average was 55 percent.

MEA-1970

Summaries of data for the MEA during 1970 are presented in Tables 5 and 6, and ranges are presented in Table 7.

All values shown in Tables 5, 6, and 7 are in mg/l unless otherwise noted. Theoretical hydraulic detention time was calculated in the same manner as in 1969. The values shown for December are for endogenous respiration since influent flow was stopped on November 24, which was essentially the end of the canning season.

Table 2

AVERAGE INFLUENT AND EFFLUENT CHARACTERISTICS - 1969 MEA

Time Period	Flow gpm	D. T. days	Temp.* °C	BOD (3) Inf.	BOD (3) Eff.	COD (Total) (3) Inf.	COD (Total) (3) Eff.	COD (Soluble) (3) Inf.	COD (Soluble) (3) Eff.	SS (3) Inf.	SS (3) Eff.	VSS (3) Inf.	VSS (3) Eff.	pH (1) Inf.	pH (1) Eff.	AlK (2) Inf.	AlK (2) Eff.
9/1-15	2.1	10.8	16.0	---	---	2390	210	--	170	430	100	400	90	6.2	6.9	17	78
9/16-30	1.2	18.9	14.0	---	50	1360	180	--	90	260	190	240	150	4.4	7.2	41	141
10/1-15	2.2	10.3	10.5	620	150	1090	530	--	100	140	340	130	320	5.6	6.6	32	83
10/16-31	2.9	7.8	11.5	470	130	720	280	--	90	450	270	130	190	6.2	6.6	33	113
11/1-15	2.6	8.7	11.5	---	---	320	290	--	70	340	150	40	60	6.5	7.4	47	215
11/16-31	---	----	10.0	650	40	980	150	--	70	740	190	170	70	6.1	7.5	69	395
12/1-15	---	----	9.0	520	20	820	100	--	50	---	---	---	---	6.9	7.6	66	521
12/16-31	---	----	7.0	720	---	1040	---	--	---	---	---	---	---	7.7	8.2	336	654

* Mixed liquor temp.
(1) Median value
(2) As calcium carbonate, mg/l
(3) Concentration in mg/l

Table 2 (Continued)[6]

Time Period	(4) TKN		(4) Ammonia-N		(4) Nitrate-N		(4) Nitrite-N		(5) Total-P		(5) Ortho-P	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
9/1-15	96.8	18.2	7.2	3.8	0.12	0.12	0.04	0.03	15.5	3.2	6.70	1.70
9/16-30	47.9	53.6	7.0	22.4	0.12	0.06	0.01	0.02	13.5	8.3	8.35	7.05
10/1-15	55.5	55.6	1.0	12.8	----	0.53	----	0.89	6.0	10.0	2.25	3.85
10/16-31	47.2	46.0	6.4	5.4	----	0.65	----	0.21	48.6	4.9	48.7	1.58
11/1-15	60.4	94.0	----	70.4	----	0.12	----	1.44	9.1	14.3	51.4	11.30
11/16-30	188	140	40.0	100	----	1.10	----	4.60	55.7	16.7	13.8	15.6
12/1-15	42.0	130	280	124	----	----	----	1.76	13.7	18.8	270	18.4
12/16-31	300	170	48.4	156	----	0.28	----	3.52	10.3	27.0	4.74	25.8

(4) As nitrogen, mg/l
(5) As phosphorus, mg/l
(6) Nutrient addition made before influent sampling point

Table 3

DATA SUMMARY - 1969 MEA

Time Period	Mixed Liquor (3) MLSS	(3) MLVSS	(1) pH	(2) AlK	Temp. °C	(3) DO	Loading #COD/Day/#MLVSS	#COD/Day/1000 Cu. Ft.	Ratios and Removals Inf. BOD/COD_T	% BOD Removal	% COD_T Removal	% SS Removal	% VSS Removal
9/1-15	144	136	6.8	560	16.0	5.0	----	---	----	--	91	77	77
9/16-30	508	462	7.2	150	14 0	5.0	0.20	4.8	----	--	87	27	27
10/1-15	360	302	6.4	80	10.5	5.5	0.33	7.1	0.57	73	51	Increase	Increase
10/16-31	543	340	6.5	117	11.5	5.0	0.29	7.0	0.65	72	61	40	Increase
11/1-15	492	208	7.3	265	11.5	8.0	----	--	----	--	9	56	Increase
11/16-30	1020	345	7.6	413	10.0	6.0	----	--	0.66	94	85	74	59
12/1-15	618	277	7.7	525	9.0	8.0	----	--	0.63	96	88	--	--
12/16-31	633	322	8.2	625	7.0	7.5	----	--	0.69	--	--	--	--
1/1-15	536	250	8.2	540	6.0	8.0	----	--	----	--	--	--	--
1/16-30	592	247	7.6	280	6.0	8.0	----	--	----	--	--	--	--

(1) Median value
(2) As calcium carbonate, mg/l
(3) Concentration in mg/l

Table 4

RANGE OF PARAMETERS 1969 MEA

Parameter	Inf.	Eff.	Mixed Liquor	Removal (%)
BOD	12-1640	9-264	---	40.6-99.9
COD (Total)	43-2760	57-628	---	10.0-93.8
COD (Soluble)	---	15-222	---	---
SS	69-2140	24-516	18-818	0-77
VSS	16-448	24-464	13-786	0-77
pH	3.9-7.7	6.3-8.2	6.2-8.3	---
AlK	1-336	41-654	40-668	---
TKN	1.9-1390	15.9-170	---	---
Ammonia-N	0.52-280	0.28-156	---	---
Nitrate-N	0.12*	0.03-1.1	---	---
Nitrite-N	0.01*	0.008-4.6	---	---
Total-P	1.8-170	2.6-27.0	---	---
Ortho-P	1.2-270	0.23-25.8	---	---
Flow (gpm)	0-6.0	---	---	---
D.T. (days)	$\geq$ -3.7	---	---	---
BOD/COD_T	0.19-0.73	---	---	---
DO	---	---	3.5-8.5	---
Temp. °C	---	---	6-18	---
#COD/Day/#MLVSS	---	---	0.003-1.80	---
#COD/Day/1000 Cu.Ft.	---	---	0.06-18.4	---

* (only data)
Units in mg/l except where otherwise indicated

Table 5

AVERAGE INFLUENT AND EFFLUENT CHARACTERISTICS - 1970 MEA

Time Period	Flow gpm	D.T. days	Temp.* °C	(3) BOD		(3) COD (Total)		(3) COD (Soluble)		(3) SS		(3) VSS		(1) pH		(2) AlK	
				Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
8/1-15	2.0	11.5	20.0	----	---	770	60	----	---	150	60	80	40	6.8	6.3	40	25
8/16-31	2.4	9.3	18.5	1290	90	1510	160	1230	100	170	50	160	45	5.6	6.5	25	40
9/1-15	1.4	16.4	16.0	1090	80	1800	130	1220	90	460	70	420	55	5.7	5.8	41	18
9/16-30	1.7	13.3	15.0	1100	150	1200	140	840	80	230	70	200	65	6.5	5.8	70	17
10/1-15	2.4	9.5	13.5	1050	100	1580	110	1050	70	480	80	410	70	6.1	6.1	48	25
10/16-31	2.0	11.3	10.0	750	80	1550	120	810	70	790	70	540	60	6.0	5.8	40	15
11/1-15	1.5	15.6	11.0	750	60	1060	270	800	150	300	180	210	150	5.9	6.4	30	60
11/16-30	1.3	17.1	8.0	810	200	1630	510	1330	250	330	360	180	300	5.5	6.7	43	60
12/1-15	---	----	5.5	----	---	----	---	----	---	---	---	---	---	---	---	--	--
12/16-31	---	----	3.0														

* Mixed liquor
(1) Median value
(2) As calcium carbonate, mg/l
(3) Concentration in mg/l

Table 5 (Continued)(6)

Time Period	(4) TNK Inf.	Eff.	(4) Ammonia-N Inf.	Eff.	(4) Nitrate-N Inf.	Eff.	(4) Nitrite-N Inf.	Eff.	(5) Total-P Inf.	Eff.	(5) Ortho-P Inf.	Eff.
8/1-15	16.8	50.6	0.8	45.5	0.26	3.90	0.04	42.00	2.1	20.7	1.07	17.8
8/16-30	27.1	24.9	1.7	15.0	0.97	3.22	0.04	14.45	5.7	20.0	4.85	18.0
9/1-15	38.4	18.2	1.8	16.7	0.71	0.93	0.14	6.85	5.3	32.3	4.48	30.3
9/16-30	21.6	36.2	0.8	22.5	0.17	7.73	0.01	9.30	3.9	43.5	3.30	43.3
10/1-15	25.4	31.8	0.9	7.9	0.37	0.08	0.08	2.35	2.9	36.9	3.45	36.3
10/16-31	28.5	18.3	1.2	7.3	0.17	1.14	0.03	10.98	3.3	35.5	2.40	37.1
11/1-15	17.4	34.2	1.1	15.6	0.28	1.21	0.05	6.90	2.3	29.9	1.29	24.5
11/16-30	24.3	105.7	2.9	71.5	0.57	----	0.07	-----	11.5	53.2	6.61	47.3

(4) As nitrogen, mg/l

(5) As phosphorus, mg/l

(6) Nutrient addition made after influent sampling point

Table 6

DATA SUMMARY - 1970 MEA

	Mixed Liquor						Loading		Ratios and Removals					
Time Period	(3) MLSS	(3) MLVSS	(1) pH	(2) AlK	Temp. °C	(3) DO	#COD Day / #MLVSS	#COD Day / 1000 Cu Ft	Inf. BOD / COD_T	% BOD Removal	% COD_T Removal	% COD_S Removal	% SS Removal	% VSS Removal
8/1-15	320	210	---	--	20.0	3.1	0.328	6.62	----	--	92	--	60	50
8/16-31	670	490	6.6	64	18.5	2.7	0.215	8.25	0.85	93	89	92	71	72
9/1-15	1070	880	5.5	37	16.0	3.4	0.144	8.93	0.61	93	93	93	85	87
9/16-30	1230	1060	6.2	27	15.0	3.4	0.084	6.23	0.92	86	88	90	70	68
10/1-15	1920	1850	5.7	22	13.5	1.8	0.102	12.25	0.66	91	93	93	83	83
10/16-31	2300	2000	6.3	20	10.0	4.0	0.090	9.74	0.48	89	92	91	91	88
11/1-15	2170	1890	6.6	91	11.0	1.8	0.040	5.19	0.71	92	75	81	40	29
11/16-30	1280	1020	6.6	63	8.0	3.9	0.082	6.49	0.51	75	69	81	Increase	Increase
12/1-15	1090	810	6.4	43	5.5	8.3	-----	----	----	--	--	--	--	--
12/16-31	860	610	6.0	33	3.0	7.7	-----	----	----	--	--	--	--	--

(1) Median value
(2) As calcium carbonate, mg/l
(3) Concentration in mg/l

Table 7

RANGE OF PARAMETERS - 1970 MEA

Parameter	Inf.	Eff.	Mixed Liquor	Removal (%)
BOD	371-1740	57-198	---	76-96
COD (Total)	636-3000	80-708	---	47-97
COD (Soluble)	419-1950	41-324	---	---
SS	85-2400	32-505	204-2560	40-91
VSS	60-1560	22-385	132-2210	29-88
pH	5.0-6.8	5.6-6.8	5.5 7.0	---
AlK	21-62	8-102	14-168	---
TKN	10.7-58.0	9.4-120	---	---
Ammonia-N	0.16-5.1	0.13-117	---	---
Nitrate-N	0.042-1.68	0.008-20.2	---	---
Nitrite-N	0.002-0.20	0.018-43.5	---	---
Total-P	1.38-21.6	16.0-60.0	---	---
Ortho-P	0.3-10.9	1.6-48.4	---	---
Flow (gpm)	0.3-3.1	---	---	---
D.T. (days)	75.0-7.3	---	---	---
BOD/COD_T	0.56-0.90	---	---	---
DO	---	---	0.2-6.8	---
Temp. °C	---	---	2.0-20.0	---
#COD/Day/#MLVSS	---	---	0.03-0.69	---
#COD/Day/1000 Cu.Ft.	---	---	3.1-19.1	---

Units in mg/l except where otherwise indicated

The influent data shown in Tables 5 through 10 are based on samples taken from the cannery wastewater flume shown in Figure 1. Since the wastewater from the initial-wash area never passed through this flume during the 1970 season, the samples are representative of actual operating conditions that would be encountered by full-scale biological treatment plants. The silt-laden wastewater from initial-wash would considerably change the concentration of suspended solids and other parameters of the overall wastewater as it did during the latter part of the 1969 season.

Sludge volume index ranged between 19 and 179 with a median value of 81.

Influent nutrient data in Table 5 were actual wastewater characteristics before nutrient addition. Nitrogen and phosphorus are covered in more detail in the Discussion section.

SS tube settler efficiency ranged from 61-97 percent and averaged 90 percent and for VSS the range was 62-97 percent with an average of 90 percent.

RBC-1970

Summaries of data for the RBC during 1970 are presented in Tables 8 and 9, and ranges are presented in Table 10.

All values shown in Tables 8, 9, and 10 are in mg/l unless otherwise indicated. Detention time shown was based on theoretical figures furnished by Autotrol Corporation, although check calculations were made so any large errors would be eliminated. The detention times included the effect of wastewater displacement by the various thicknesses of the disc slime layer and the volume of the secondary clarifier. Detention time in the disc stages ranged from 1/3 to 1/2 of total detention time through the RBC. Dissolved oxygen in the secondary clarifier was usually zero as a result of the length of detention time in this portion of the unit.

Average disc slime thickness was 3/16" with the exception of the time periods 9-1 to 9-15-71 and 10-1 to 10-15-71, when the average thickness was 1/8". These values are approximate since only visual observation was considered practical due to the slime variability.

Loading was based on total COD applied per 1,000 square feet of disc surface.

No attempt was made to estimate the quantity of sludge synthesized because of the need for a much more rigorous sampling program, which was beyond the limitations of this study. The solids values presented in Table 9 are intended for use in rough solids production calculations only.

Table 8

AVERAGE INFLUENT AND EFFLUENT CHARACTERISTICS - RBC

Time Period	Flow gpm	D.T.* days	Temp.# °C	(3) BOD Inf.	Eff.	(3) COD (Total) Inf.	Eff.	(3) COD (Soluble) Inf.	Eff.	(3) SS Inf.	Eff.	(3) VSS Inf.	Eff.	(1) pH Inf.	Eff.	(2) AlK Inf.	Eff.
9/1-15	2.0	0.20	----	1090	---	1800	130	1220	130	460	10	420	10	5.7	8.0	41	372
9/16-30	2.0	0.20	15.0	1100	65	1200	160	840	100	230	40	200	40	6.5	8.0	70	705
10/1-15	1.6	0.28	13.5	1050	165	1580	230	1050	160	480	100	410	70	6.1	8.0	48	400
10/16-31	1.9	0.23	11.0	750	240	1550	310	810	250	790	80	540	75	6.0	7.8	40	240
11/1-15	2.1	0.19	10.5	750	100	1060	120	800	100	300	35	210	32	5.9	7.7	30	250
11/16-30	1.6	0.28	12.0	810	240	1630	320	1330	210	330	90	180	85	5.5	7.7	43	268

* DT for entire RBC including secondary clarifier
\# Average for both disc stages
(1) Median value
(2) As calcium carbonate, mg/l
(3) Concentrations in mg/l

Table 8 (Continued)(6)

Time Period	(4) TKN Inf.	(4) TKN Eff.	(4) Ammonia-N Inf.	(4) Ammonia-N Eff.	(4) Nitrate-N Inf.	(4) Nitrate-N Eff.	(4) Nitrite-N Inf.	(4) Nitrite-N Eff.	(5) Total-P Inf.	(5) Total-P Eff.	(5) Ortho-P Inf.	(5) Ortho-P Eff.
9/1-15	38.4	145	1.8	6.4	0.71	0.11	0.14	0.02	5.3	44.0	4.48	46.2
9/16-30	21.6	239	0.8	161	0.17	0.13	0.01	0.01	3.9	41.6	3.30	50.0
10/1-15	25.4	98.3	0.9	82.3	0.37	0.10	0.08	1.39	2.9	31.6	3.45	30.2
10/16-31	28.5	73.2	1.2	52.6	0.17	0.14	0.03	0.01	3.3	16.9	2.40	20.2
11/1-15	17.4	70.5	1.1	55.7	0.28	0.04	0.05	0.01	2.3	16.0	1.29	14.8
11/16-30	24.3	71.9	2.9	72.0	0.57	0.05	0.07	0.02	11.5	18.8	6.61	18.0

(4) As nitrogen, mg/l
(5) As phosphorus, mg/l
(6) Nutrient addition made after influent sampling station

Table 9

DATA SUMMARY - RBC

	Secondary Clarifier Sludge			Mixed Liquor				Loading	Ratios and Removals					
Time Period	(1) SS	(1) VSS	% Sett. Solids	DO*	Temp.# °C	1st Stage MLVSS	2nd Stage MLVSS	#COD / Day / 1000 Sq. Ft.	Inf. BOD / COD_T	% BOD Removal	% COD_T Removal	% COD_S Removal	% SS Removal	% VSS Removal
9/1-15	----	----	--	5.0	----	----	----	7.20	0.61	--	93	89	98	98
9/16-30	1240	1140	19	3.2	15.0	----	----	6.00	0.92	94	87	88	83	80
10/1-15	1040	920	14	1.9	13.5	800	1960	6.10	0.67	84	85	85	79	83
10/16-31	1640	1540	30	2.3	11.0	482	1030	7.10	0.48	68	80	69	90	86
11/1-15	1500	1290	25	2.5	10.5	775	740	5.70	0.71	87	89	87	88	85
11/16-30	3600	2770	54	2.0	12.0	1420	1100	8.10	0.50	70	80	94	73	53

* Average DO for both disc stages, mg/l
# Average temperature for both disc stages
(1) Concentration in mg/l

Table 10

RANGE OF PARAMETERS - RBC

Parameter	Inf.	Eff.	Mixed Liquor	Clarifier Sludge	Removal (%)
BOD	371-1330	65-405	--	--	71-92
COD (Total)	636-3000	59-898	--	--	64-98
COD (Soluble)	419-1950	46-806	--	--	--
% Settleable Solids	--	--	--	4.0-78.0	--
SS	153-2400	12-145	--	150-4850	56-99
VSS	100-1560	11-130	170-1460*	380-3800	56-98
MLVSS-2nd Disc Stage	--	--	410-1960	--	--
pH	5.0-6.8	6.4-8.6	--	--	--
AlK	22-62	132-1040	--	--	--
TKN	10.7-58.0	19.5-560	--	--	--
Ammonia-N	0.6-5.1	6.4-220	--	--	--
Nitrate-N	0.04-0.80	0.03-0.25	--	--	--
Nitrite-N	0.002-0.16	0.001-0.029	--	--	--
Total-P	1.38-21.6	12.0-60.0	--	--	--
Ortho-P	0.48-10.9	7.56-57.8	--	--	--
Flow (gpm)	0.8-2.5	--	--	--	--
D.T. (days)	0.42-0.17	--	--	--	--
BOD/COD_T	0.56-0.83	--	--	--	--
DO	--	--	0.6-5.0	--	--
Temp. °C	--	--	10.0-19.0	--	--
#COD/Day/1000 Sq. Ft.	--	--	4.4-10.6	--	--

* 1st Disc Stage
Concentrations in mg/l unless otherwise indicated

The dissolved oxygen and temperature values in Tables 8 and 9 are combined average values for the mixed liquor of both disc stages.

Influent nutrient data in Table 8 were actual wastewater characteristics before nutrient addition.

SECTION VI

DISCUSSION

MEA

Various attempts were made to use existing kinetic equations for the MEA. The first attempt was made using the relationship for reaction rate as expressed by Monod[4] in equation (1):

$$R = \frac{FL_e}{C+L_e} \qquad (1)$$

where reaction rate is determined by equation (2):

$$R = \frac{L_o-L_e}{S_a t} \qquad (2)$$

R = reaction rate = rate of waste utilization per unit of time and biological mass. (#COD Removed/#MLVSS/Day)

F = maximum possible reaction rate (at high waste concentration).

C = soluble waste concentration (BOD or COD) at 1/2 F.

L_e = substrate concentration = effluent soluble BOD or COD (for a completely mixed system).

L_o = substrate added = influent total COD or BOD (if all suspended volatile matter is assumed biodegradeable).

S_a = mixed liquor suspended volatile solids (assumed to be directly proportional to active biological mass).

t = hydraulic detention time.

Equation (1) was intended for systems with any range of effluent substrate concentrations relative to C. For this reason the first attempt at kinetic evaluation was made with this approach. Soluble COD levels were as high as 125 mg/l during this study.

The Monod approach involved the following steps:

1. The basic Monod equation was rearranged and a temperature correction applied to form the following equation:

$$\frac{(F_{20})(\theta^{T-20})L_e}{R} = C + L_e \qquad (3)$$

where:

F_{20} = F at 20° C

θ = temperature correction coefficient.

T = aeration tank temperature in °C.

Equation (3) was further modified to:

$$\frac{L_e}{R(\theta^{20-T})} = (\frac{1}{F_{20}})L_e + \frac{C}{F_{20}} \qquad (4)$$

which can be plotted as a straight line equation of the form $y = mx + b$.

2. Analytical measurements and calculations gave L_e, R, and T for the various sampling days.

3. θ values between 1.0 and 1.40 were assumed and, with the use of a computer, least square lines and correlation coefficients were calculated using the L_e, R, and T values together with the various assumed θ values.

4. The optimum correlation coefficient was determined to be 0.66 and the corresponding θ value was 1.130.

5. F_{20} and C were then determined by using the θ value of 1.130 and equation (4).

F_{20} was found to be 0.3 which does not seem to be a reasonable value based on a range of 4 to 24 LBS COD removed/LB MLVSS-Day reported by McCarty.(5) There may be several factors contributing to such a low value for F_{20} in this study, but the largest factor is probably the large sludge age, which is about 200 to 300 days. Active biological mass would undoubtedly be only a small percentage of MLVSS at these sludge ages. And if true values for active mass were used in equation (2) for calculating reaction rate, larger values of F_{20} would result.

A second attempt at kinetic evaluation involved another approach that has been used often in the past. Despite the relatively high observed L_e values, L_e was assumed to be much less than C so that $(C + L_e)$ in the denominator of the right hand side of equation (1) was essentially equal to C and the following equation resulted:

$$R = \frac{F}{C} L_e = KL_e \qquad (5)$$

where

K = a constant

Equation (5) was then modified to include a temperature correction factor:

$$\frac{R}{L_e} = K_{20}\theta^{T-20} \qquad (6)$$

where

K_{20} = K at 20°C = a constant

θ = temperature correction coefficient.

Figure 6 is a semi-log plot of R/L_e against aeration tank temperature. A least square line was calculated for the data points shown, and a K_{20} of 0.00276 and a temperature coefficient of 1.107 were obtained. These values were reasonable, but the correlation coefficient was 0.51 so confidence in this approach was not very great.

The third evaluation approach of the MEA involved a simple comparison, as shown in Figure 7, of influent COD loading and COD removal. Total influent COD minus soluble effluent COD was used for calculation of removal rate. The least square line in Figure 7 shows the removal rate as a function of influent COD rather than effluent soluble COD, as is more often the case.

The data were gathered over a range of 6°C, and the high correlation coefficient suggests a temperature coefficient of 1.0 in this range. Detention time varied from 8.7 to 17.4 days while mixed liquor suspended solids increased from 400 to 2,000 mg/l during the period shown.

In view of the wide range of variables, the excellent correlation is very encouraging. Restriction in aeration capacity prohibited higher loading rates so the point of nonlinear relationship between removal rate and loading was not determined.

Sludge production and endogenous respiration coefficients were determined for the MEA by the following procedure:

1. All influent VSS were assumed to be biodegradeable and therefore, to have no influence on changes in MLVSS concentration.

2. The change in quantity of VSS in the aeration tank between sampling days was assumed to be due to sludge synthesis, endogenous respiration, and solids wash-out in the effluent.

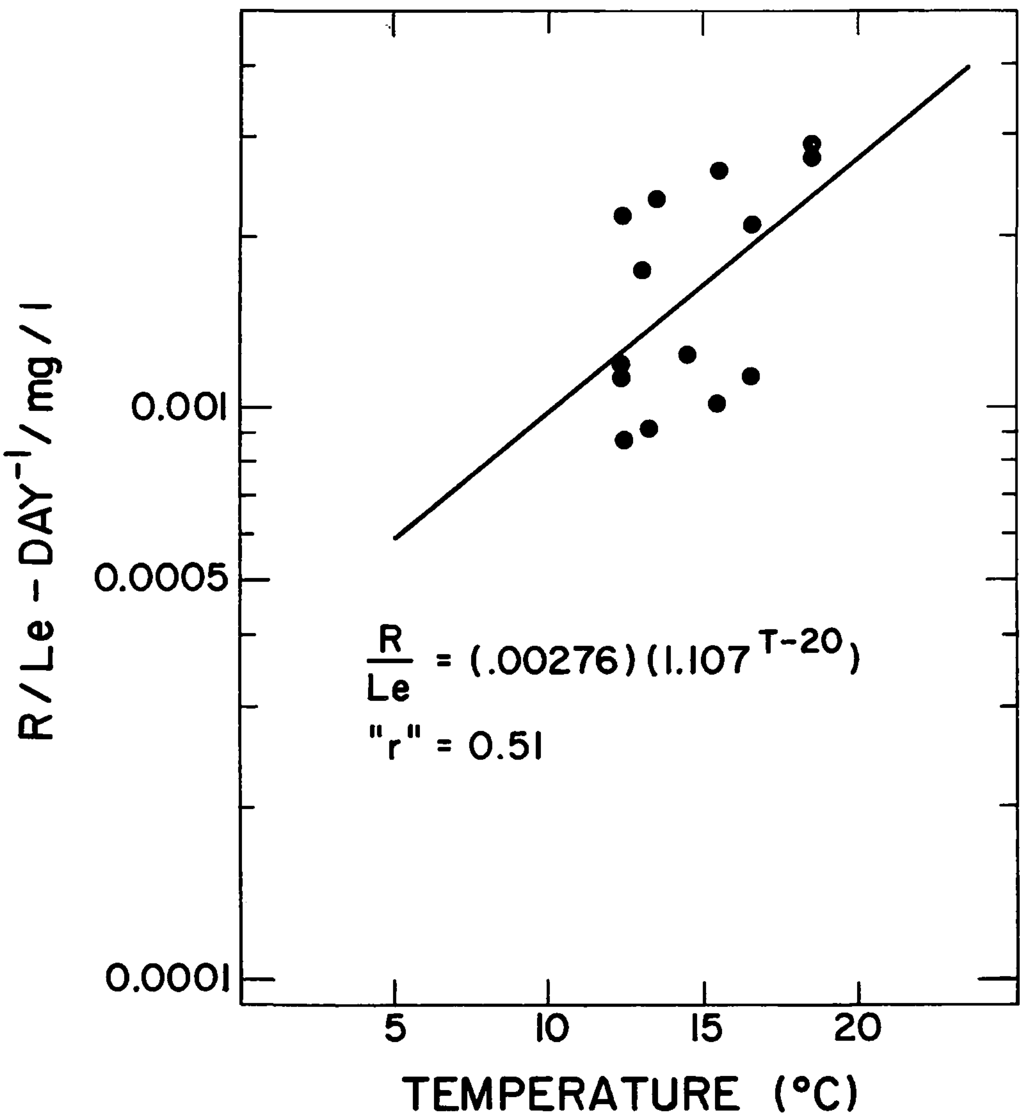

FIGURE 6. MEA R/L_e VS TEMPERATURE - 1970

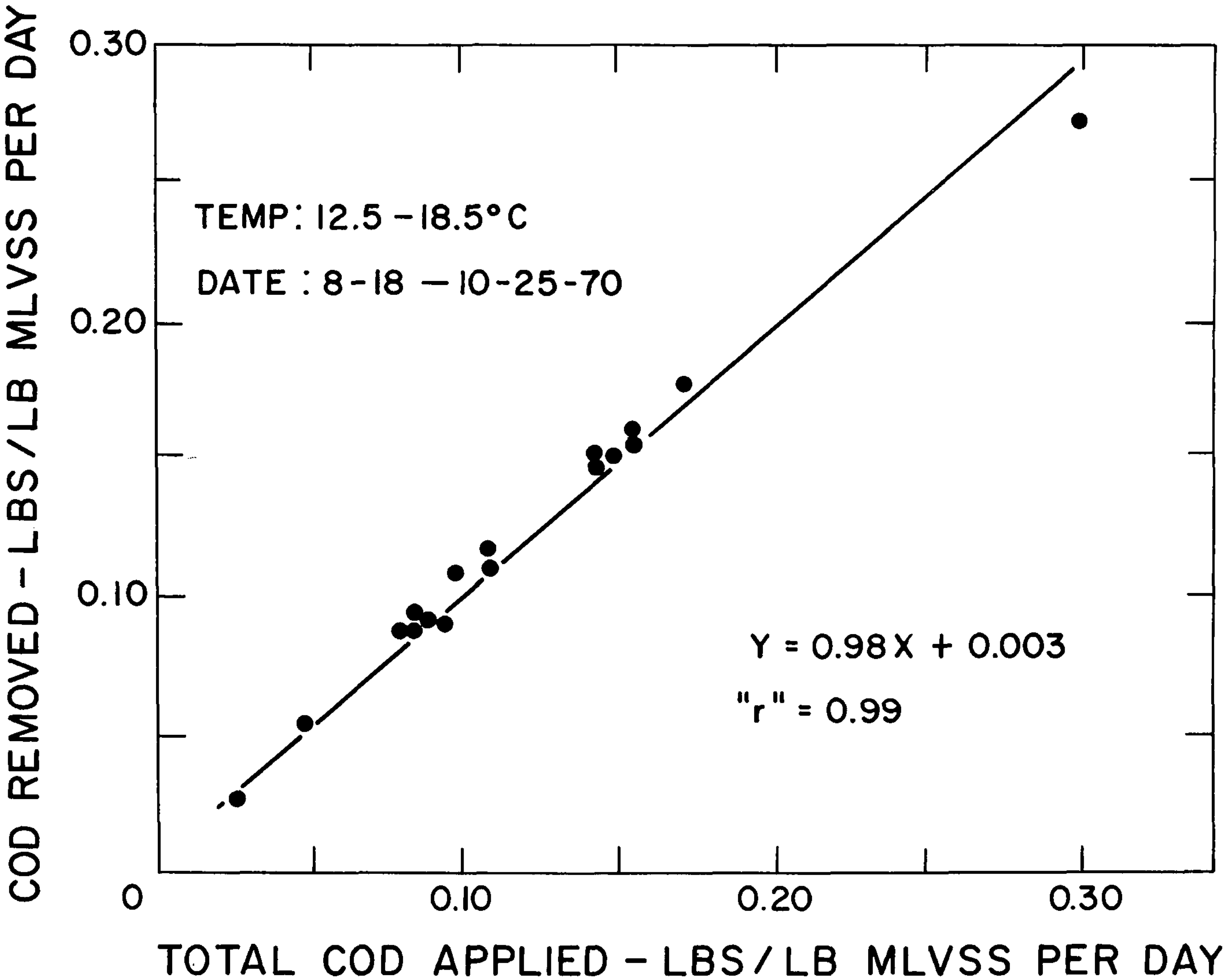

FIGURE 7. MEA REMOVAL CHARACTERTISTICS - 1970

3. Measured values for daily sludge production were plotted against daily COD removal as shown in Figure 8.

4. A least square line was calculated and plotted and "a", which is the sludge synthesis coefficient, equals 0.30 and "b", which is the endogenous respiration coefficient, equals 0.01 (Day^{-1}) were obtained.

The values for "a" and "b" are reasonable according to ranges of 0.3 to 1.0 for "a" and 0.014 to 0.35 for "b" reported for various industrial wastes by McCarty[5] and Eckenfelder.[6] Values for "a" and "b" may be only approximate when obtained in this way because all influent VSS may not be biodegradeable.

The values for "a" and "b" were then used to obtain coefficients a' and b' for the theoretical oxygen requirements of the biological solids in the aeration tank. This was done by using relationships given by Eckenfelder:[7]

$$"a" + a' = 1 \qquad (7)$$

$$b' = 1.5"b" \qquad (8)$$

where

"a" and "b" are as defined earlier.

a' = unit weight of oxygen required per unit weight of COD removed.

b' = unit weight of oxygen required per unit weight of VSS destroyed by endogenous respiration.

1.5 = oxygen equivalent of MLVSS

From equations (7) and (8), a' = 0.70 and b' = 0.015. These values were then used for calculation of total theoretical oxygen requirement using equation (9):[7]

$$O_2 = a'(L_o-L_e) + b'S_a \qquad (9)$$

In addition, an approximate method was used to account for oxygen requirement for nitrification. In this method, the percentage of oxygen required for nitrification was estimated by making an ultimate BOD analysis and nitrification analysis on a sample of influent wastewater. The results of the analyses indicated that about 28 percent of the oxygen required in 20 days was utilized by nitrifying organisms.

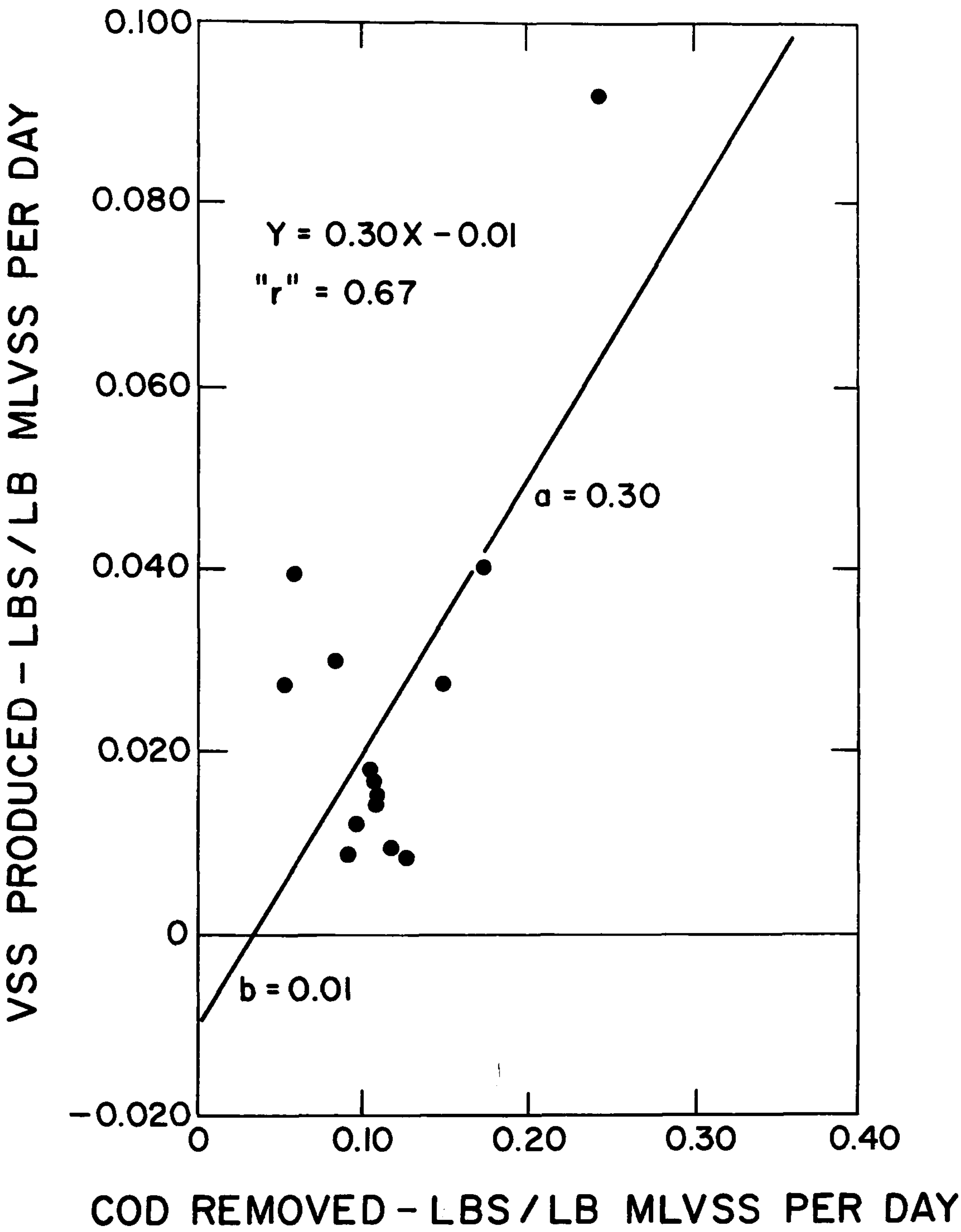

FIGURE 8. MEA SYNTHESIS AND ENDOGENOUS RESPIRATION COEFFICIENTS - 1970

The average theoretical oxygen requirement that resulted was 29.4 pounds per day compared to 26.4 pounds per day for the measured oxygen requirement as determined by oxygen uptake measurements. These values were based on the entire aeration tank mixed liquor volume, an average MLVSS concentration of 1,750 mg/l, and an average loading rate of 0.05 pound of COD per pound of MLVSS.

The data that were used for calculation of the average theoretical oxygen requirements were taken over the time interval 10-23-70 to 11-20-70. The same interval was used for measured oxygen uptake so the two values could be compared. In addition, there were no reliable oxygen uptake data earlier in the season.

The difference between theoretical and measured oxygen requirement values may be primarily due to variation of the food to microorganism ratio in the aeration tank (0.03 to 0.10) which may cause wide variation in the measured oxygen uptake rate.[8]

Data for aerator evaluation were not obtained during this study, however, calculations were made by using practical values for $\propto$ and θ in the following equation:[8] [9]

$$N = N_o \times \frac{C_{SW} - C_L}{C_{20}} \times \theta^{T-20} \times \propto \qquad (10)$$

where

N = # oxygen transferred per hp-hr in field operation

N_o = # oxygen transferred per hp-hr in water at 20°C and zero DO

= 2.0 from a previous study using the same aerator and aeration tank and the same liquid volume.

C_{SW} = DO saturation at aeration tank temp. (mg/l)

C_L = DO in aeration tank at aeration tank temp. (mg/l)

C_{20} = DO of tap water at 20°C = 9.17 (mg/l)

θ = temp. correction coefficient (assumed at 1.02)

T = temp. in °C of aeration tank mixed liquor

$\propto$ = relative oxygen transfer factor (assumed 0.85)

Since no data were obtained on dissolved oxygen concentration at saturation at various temperatures, C_{SW} was assumed to equal the DO concentration of tap water, i.e., $C_{SW} = C_{20}$ at 20°C. This assumption was in keeping with the others in this analysis which was intended to show only relative magnitude of oxygen parameters, theoretical, measured, and added.

Data used for the calculations were taken from the same period of operation as the data used for measured and theoretical oxygen requirement values. The average was 24 lbs oxygen per day for the 1 horsepower aerator used in this study. This value compares favorably with the average theoretical oxygen requirement of 29.4 lbs oxygen per day if consideration is given to additional oxygen tranferred at the air-water interface. Through this process, a check has also been indirectly applied on the magnitude of "a", "b", a', and b'.

Nitrogen and phosphorus data for 1969 and 1970 were not extensive enough for use in making accurate nitrogen and phosphorus balances. Table 2 did not contain sufficient data to indicate nitrification in 1969, but data in Table 5 indicated there was nitrification during 1970. The MEA and RBC Comparison section covers nutrient relationships further.

RBC

A major problem in the kinetic evaluation of the RBC was the inability to determine the amount of active biological mass in the system. The thickness of the slime on the discs was quite variable on any given disc and from the first disc to the last disc in the direction of flow. There was also continuous sloughing of slime which complicated the problem, and there was no assurance that slime on the inner part of the discs was similar to that on the visible portion of the discs.

An attempt was made to evaluate the RBC by using disc surface area instead of biomass to develop a relationship between removal rate and effluent soluble COD concentration similar to that presented in Figure 6 for the MEA, but no meaningful relationship was apparent.

A comparision of influent total COD and COD removed per 1000 square feet of disc surface was attempted, and the relationship shown in Figure 9 resulted. COD removed was calculated by subtracting effluent soluble COD from influent total COD. The removal rate uniformity over the 10-17°C temperature range indicated θ was close to 1.0 under the conditions of operation. Even though the temperature varied over a range of 10-17°C, it was also shown in Figure 9 as average temperature because the temperatures of the two disc stages

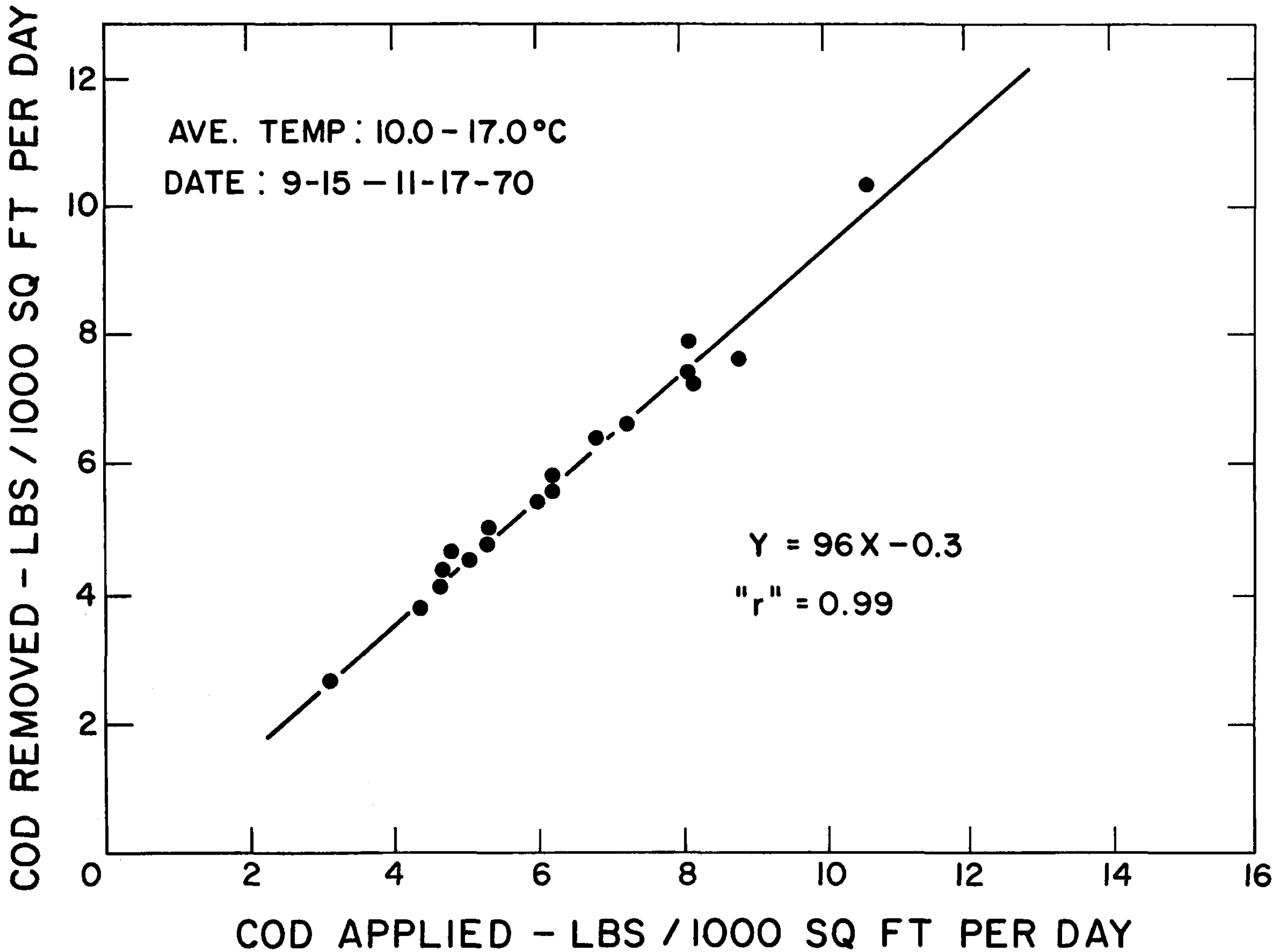

FIGURE 9. RBC REMOVAL CHARACTERISTICS

were averaged. Detention time during the data gathering period varied from 4.1 to 10.0 hours, and influent total COD concentration varied from 975 to 3,000 mg/l. Variation of active biomass was unknown.

Even in view of a variation of 7°C in temperature, a 300 percent change in influent total COD concentration, and a 250 percent change in detention time, the removal rate appeared to be dependent only upon the amount of COD applied. This relationship holds at least to 10.5 pounds of total COD per 1,000 square feet of disc surface, which was the highest loading rate used.

COMPARISON OF MEA AND RBC

One objective of this study was to compare these two methods of cannery wastewater treatment. During the study, certain characteristics of the two units were revealed which are best covered in this section of the report.

Detention Time vs COD Removal

Minimum theoretical hydraulic detention time attained on both units was dependent upon the DO limitations mentioned earlier in the report. As a result, the minimum THDT for the MEA was 8.7 days based on an average flow of 2.6 gpm. Minimum for the RBC was 4.1 hours at an average flow of 2.4 gpm. Calculation of detention time for the RBC in Figure 10 is total detention time as discussed earlier.

Figure 10 is presented to show variation of total COD removed in relation to detention time. The amount of COD removed per day shows an inverse relationship with detention time in the MEA. This same trend is less pronounced in the RBC. The most significant fact evident in the figure is the much larger detention time necessary in the MEA to achieve the same COD removal rate as the RBC. Total COD removed in Figure 10 was calculated in the same manner for both units, effluent total COD was substracted from influent total COD.

COD Removal per Horsepower - day

COD loadings to both units were in the same range throughout the study, and removals were also comparable although a much longer detention time was required by the MEA, as mentioned previously.

Figure 11 relates the COD applied to the power required to remove the COD. Since both units removed similar amounts of COD at similar loadings, the two least square lines shown actually approximate

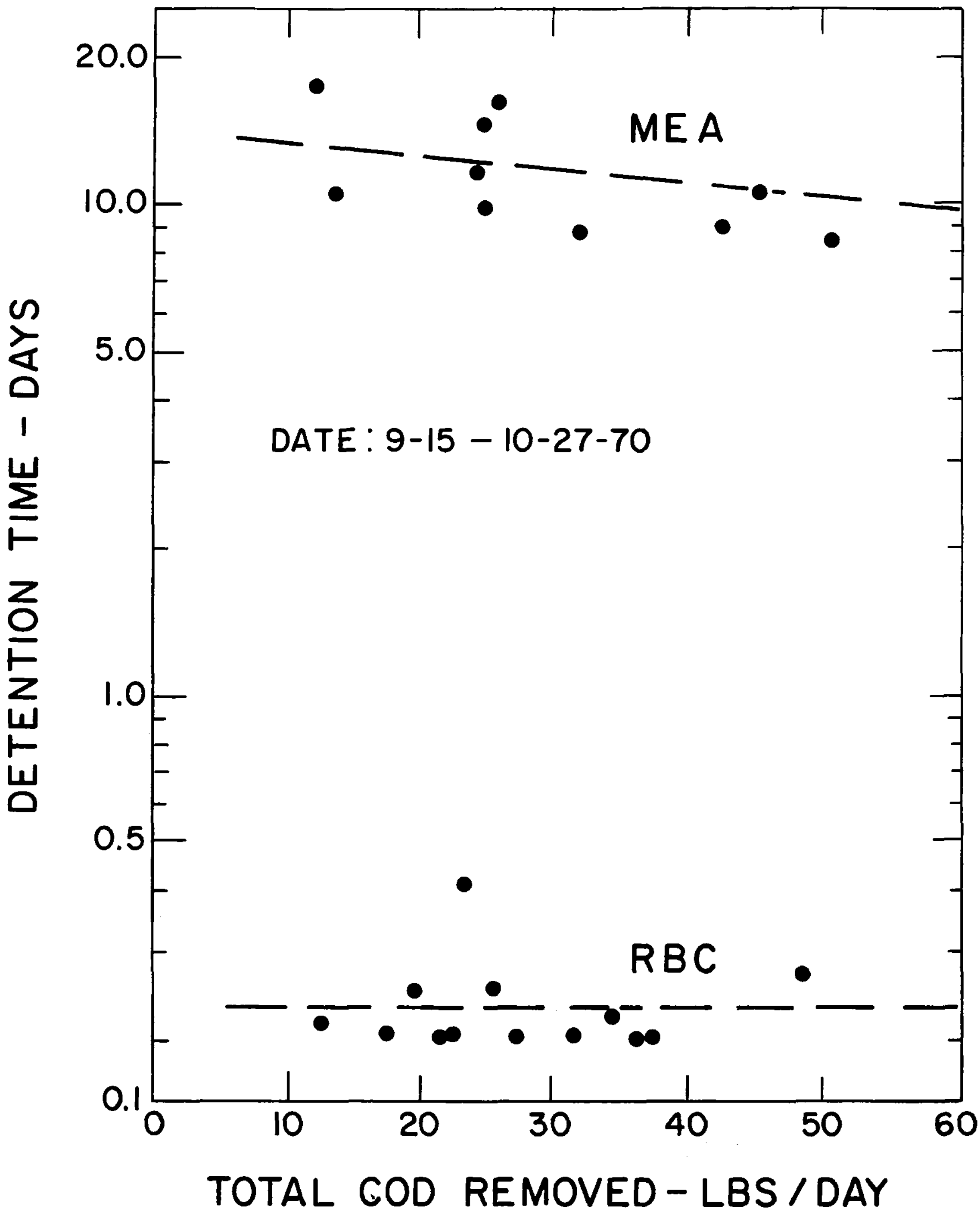

FIGURE 10. RBC AND MEA DETENTION TIME VS COD REMOVAL

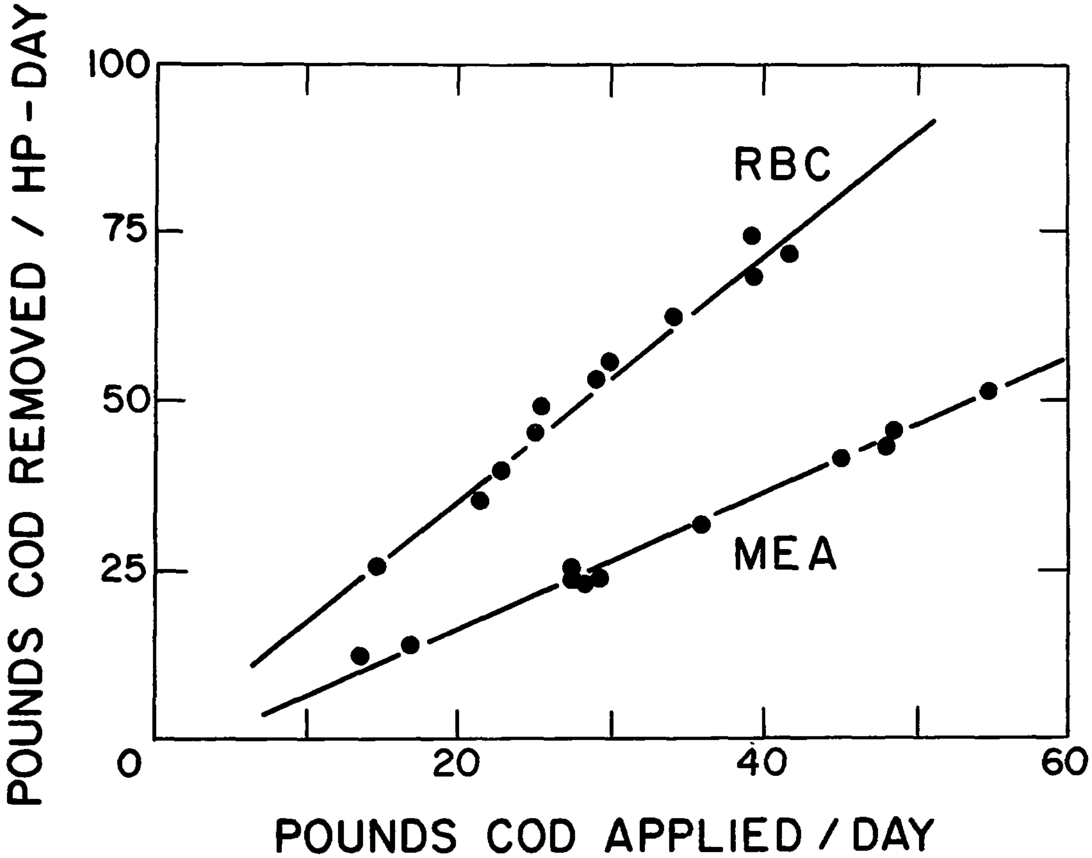

FIGURE 11. MEA AND RBC COD ADDED VS COD REMOVED/HP-DAY

the 2:1 horsepower requirement ratio for the two units, i.e., 1 horsepower aerator for the MEA and about 1/2 horsepower total requirement for the RBC disc drive and sludge scraper motors.

Figure 11 presents actual field data, but it does not present an entirely accurate picture of power requirements for the following reasons:

1. Data from Autotrol Corporation indicates the 1/2 horsepower disc drive motor does not operate at capacity until the discs are rotated in excess of 6 rpm. Rotation during the study was about 4 rpm and Autotrol data indicate this speed can be maintained with a power input of 0.1 horsepower.

2. The 1-horsepower aerator in the MEA delivers 2 pounds of oxygen per hour at standard conditions. Aerators above 5 horsepower capacity will deliver between 3 and 4 pounds of oxygen per horsepower-hour under standard conditions.

In view of the above reasons, both units would probably remove considerably larger amounts of COD per horsepower-day in full-scale treatment plants.

Sludge Production

In an ideal situation, none of the sludge synthesized would be intentionally discharged from the MEA during the canning season, and most of the excess would then be digested by endogenous respiration at the end of the season. However, in actual operation, some loss of suspended matter will usually occur in the effluent. This was the case with the MEA during the 1970 season. Most of the sludge was nevertheless held in the tank until an upset period during the weekend of November 7 and 8, the details of which are covered in the Organic Overloads Section. This was evidenced by constantly increasing mixed liquor suspended solids and relatively constant effluent suspended solids concentration of less than 100 mg/l. The MEA did operate from August through October as an efficient COD removal system without producing an immediate sludge disposal problem.

In contrast, the RBC continually produced sludge, which on a larger scale operation would have to be given further treatment and disposal. The quantity and other characteristics of the RBC sludge were not determined in this study. Some volumetric settleable solids analyses were run on the sludge, and they indicated the sludge settled readily. The amount of settleable solids data is limited, and therefore, may not be representative of the highly dynamic sludge sloughing and synthesis.

Effluent Suspended Solids

Both units had secondary clarifiers with adequate settling capacity to handle the flows encountered. The tube settler module in the MEA had an overflow rate of 230 gpd/sq ft at 2 gpm of flow, and the RBC final clarifier had an overflow rate of 190 gpd/sq ft at 2 gpm.

Table 11 give average effluent suspended and volatile suspended solids values for the two units during their operation. The level of suspended matter in the MEA effluent was fairly steady throughout the period from September 15 to November 6. The overall average suspended solids concentration was 72 mg/l. Then on November 7 an upset occurred and large amounts of solids passed through the tube settler for the remaining two weeks of the season.

The level of suspended matter in the RBC effluent was more dynamic, as indicated by the larger standard deviation, and an overall average suspended solids of 56 mg/l was observed.

On a few occasions, both effluents were quite clear with only very small diameter particulate matter visible, but generally, they did not exhibit the clarity associated with a well designed and operated activated sludge plant. The effluents from both units would not meet many present or probably future water quality and effluent standards on suspended solids concentration for discharge to receiving waters, but they would undoubtedly be acceptable for discharge into a municipal sewage system.

Temperature Effects

Figures 7 and 9 indicate both units are not significantly sensitive to temperature change within the relatively small range in which they were operated. No meaningful data were gathered in the 0-10°C range, but substrate removal rates would probably be lower in this range.

Sub-freezing temperatures would hamper the operation of the RBC to the point that it would probably have to be insulated unless the source of wastewater was steady and warm enough to prevent freezing. Even if the liquid in the RBC tank would not freeze, the slime may be unable to metabolize substrate efficiently due to the magnitude of temperature change with each disc rotation, i.e., sub-freezing air temperature above the liquid level and above-freezing liquid temperature.

Table 11

RBC AND MEA EFFLUENT SOLIDS CONCENTRATIONS

Period	Susp. Solids						Vol. Susp. Solids					
	RBC			MEA			RBC			MEA		
(1970)	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
9/15-9/30	38	31	5	70	16	5	36	28	5	65	16	5
10/1-10/16	93	46	5	72	19	5	65	30	5	63	15	4
10/17-11/7	36	16	5	75	13	3	38	--	2	70	9	3
11/8-11/21	56	45	4	325	143	4	92	--	1	260	104	4

$\bar{x}$ = mean (mg/l)
s = standard dev. (mg/l)
n = No. of analyses

Organic Overloads

A short term organic shock loading would be expected to cause reduction in substrate removal efficiency of the RBC to a greater degree than in the MEA because of the shorter detention time in the RBC. No short term overloads were detected in the analytical results so unit response to such overloads was not determined.

On the weekend of November 7-8 there was apparently a relatively long term organic overload applied to both units. No analyses were taken during the weekend, but on Monday morning the following was observed:

1. Effluents from both units were very turbid and the DO was lower than the previous week.

2. The RBC had a very strong unpleasant odor.

3. There was foam on the aeration tank that had never been observed before.

4. A representative from the cannery said there was very little wash down water used over the weekend, and only squash was processed continuously for both days which probably resulted in a wastewater of high organic content.

On Tuesday, November 10, conditions in the units were as shown in Table 12. There was no odor observed from the MEA, and there never had been in the past. Odor from the RBC was only slight, which could be called normal because the RBC generally exhibited a slightly unpleasant odor at least during squash processing. In general, the routine samples and observations taken on November 10, showed that the RBC was functioning as well as ever. The MEA continued to discharge solids, and the substrate removal efficiency decreased for the rest of the season. Mixed liquor suspended solids concentration in the MEA decreased from 2310 mg/l on Nov. 6 to 1210 on November 24, while the sludge volume index went from 80 to 103, despite the fact the unit was receiving wastewater, and all other environmenal conditions were kept at proper levels.

Nitrogen and Phosphorus

Comparison of the MEA and RBC on nitrogen and phosphorus removal efficiency and requirements for treatment was not made due to the limited number of samples taken and lack of control of some of the variables involved.

Table 12

ORGANIC OVERLOAD RECOVERY OBSERVATIONS - NOV. 10, 1970

Parameter	MEA	RBC
DO	back to normal	back to normal
Odor	non	slight
Effluent Appearance	very turbid	slightly turbid
Effluent S.S.	up 200% of average	less than usual (about 30 mg/l)
% COD Removal	73	92

The ratio of total influent BOD to total nitrogen added to total phosphorus added during the 1970 season was 100:15:2.2 which does not include any nitrogen or phosphorus present in the influent wastewater before nutrient addition. This ratio was not calculated for the RBC because the influent wastewater and nutrient addition were the same as for the MEA.

Constant nutrient addition, and the fact that influent BOD never exceeded the assumed maximum of 2,000 mg/l upon which nutrient addition rate was based, support the assumption that there were no nutrient deficient periods during the 1970 season.

Nitrification in the MEA in 1969 was not demonstrated by the results. There was insufficient data in 1969 to demonstrate nitrification in the MEA. In 1970 there was adequate data to show evidence of nitrification in the MEA. There was no evidence of nitrification in the RBC which seems reasonable because the maximum hydraulic detention time was only 10 hours. However, the biomass detention time on the discs is probably much longer, and nitrification could occur even at relatively low hydraulic detention times if all other conditions for nitrification were met.

For both units nutrient addition was made on the basis of an assumed maximum BOD of 2,000 mg/l and a BOD:N:P ratio of 100:5:1. For the purpose of this study, this was an adequate approach, but on full scale treatment plants it would be necessary to keep nutrient addition at the minimum rate consistent with maximum cell synthesis and endogenous respiration so nutrient cost would be minimized and excess effluent nutrients would not add to problems associated with eutrophication of receiving waters.

Effluent Comparison

Table 13 compares the effluents from the MEA and RBC for the 1970 season. Values shown are for the same time period, September 15, through November 20, and for very closely the same influent wastewater flow volume, characteristics, and nutrient feed rates.

The effluents have characteristics similar to domestic wastes so there would probably be no surcharge cost applied if these effluents were discharged to municipal sewers unless such a surcharge was based on flow volume only. Surcharge is intended to mean an additional assessment for wastewater quantity or quality that is above what is considered normal for a cannery.[10] Also, consideration should be given to the fact that the remaining COD is probably less biologically degradeable because the more readily metabolizable portion of the COD has been removed.

Table 13

COMPARISON OF EFFLUENTS - 1970

	MEA		RBC	
	Average	Range	Average	Range
Total* BOD	112	57-198	148	65-239
Total* COD	207	80-708	180	59-420
Total BOD/COD	0.54	0.38-0.95	0.82	0.42-0.90
Soluble* BOD	57	23-110	110	43-200
Soluble* COD	113	36-324	128	46-291
Soluble BOD/COD	0.50	0.33-1.34	0.86	0.40-0.86
% Soluble BOD	51	34-77	74	51-86
% Soluble COD	55	45-86	71	45-100
BOD:N	5.1:1	7.6:1-2.4:1	1.1:1	6.1:1-0.1:1
BOD:P	3.1:1	5.8:1-1.9:1	6.1:1	23.8:1-0.5:1

*Concentrations in mg/l

SECTION VII

ACKNOWLEDGMENTS

The personnel of United Flav-R-Pac Growers, Inc. are thanked for providing a study site and cooperation. Also, Autotrol Corporation employees are thanked for providing the RBC.

Gratitude is extended to the Oregon State University, Department of Civil Engineering and Pacific Northwest Water Laboratory staff for their technical and administrative roles in this study.

SECTION VIII

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SECTION IX

GLOSSARY

BOD	5-day, 20°C biochemical oxygen demand, mg/l
BOD_S	Soluble BOD, mg/l (0.45 μ filtrate)
COD	Chemical oxygen demand = COD (Total) = COD_T, mg/l
COD_S	Soluble COD, mg/l (0.45 μ filtrate)
SS	Suspended solids, mg/l
VSS	Volatile suspended solids, mg/l
MLSS	Mixed liquor volatile suspended solids, mg/l
MLVSS	Mixed liquor volatile suspended solids, mg/l
TKN	Total Kjeldahl nitrogen, mg/l as nitrogen
Ammonia-N	Ammonia nitrogen, mg/l as nitrogen
Nitrate-N	Nitrate nitrogen, mg/l as nitrogen
Nitrite-N	Nitrite nitrogen, mg/l as nitrogen
Total-P	Total phosphorus, mg/l as phosphorus
Ortho-P	Orthophosphates, mg/l as phosphorus
ALK	Total alkalinity, mg/l as calcium carbonate
DO	Dissolved oxygen, mg/l
D.T. or THDT	Theoretical hydraulic detention time, calculated from flow and volume data (Minutes, Hours, or Days)
Cu ft	Cubic feet
Sq ft	Square feet
lb or #	Pound(s)
"r"	Correlation Coefficient
hp	Horsepower

gpd/sq ft	Gallons per day per square foot
rpm	Revolutions per minute
rph	Revolutions per hour
gpm	Gallons per minute
mgd	Million gallons per day
mg/l	Milligrams per liter

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8. Performing Organization Report No.

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16. Abstract

Fruit and vegetable cannery wastewater was treated during two canning seasons by two pilot plants of the rotating biological contactor and extended aeration types.

The objective was to determine the effectiveness of these biological treatments processes on cannery wastewater and to compare the two units under the same operating conditions.

Nitrogen and phosphorus were added to the influent wastewater so the BOD:N:P ratio was kept above 100:5:1.

Both treatment units attained organic removals of over 90%. However, much less detention time was necessary in the RBC to obtain removals comparable to the extended aeration plant. Sludge produced by the RBC required additional treatment, but most of the sludge produced in the extended aeration plant was aerobically digested in the aeration tank.

Effluent quality from both units was about the same over the operating temperature range of 10-20°C, although the RBC appeared to recover more rapidly from organic shock loading. Neither unit produced an effluent that could be discharged to surface waters without further treatment.

17a. Descriptors

*Waste Water Treatment, *Water Pollution Control, *Industrial Wastes, Canneries, Biological Treatment, Aerobic Treatment

17b. Identifiers

Extended Aeration, Rotating Biological Contactor

17c. COWRR Field & Group

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

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