

UNIVERSITY OF MINNESOTA

Twin Cities Campus

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November 28, 2000

Mr. Charlie Barebo
President & CEO, Otterbine Barebo, Inc.
3840 Main Road East
Emmaus, PA 18049

Reference: Letter Report No. 00-03(Revised)
By Julie Robinson and Chris Ellis
Prepared for Otterbine Barebo, Inc.

Subject: Aeration and Flowrate Analysis for Otterbine Barebo Fountain Aerators

Dear Mr. Barebo:

This letter is our report for the above referenced testing completed at St. Anthony Falls Laboratory during the period November 1999 - September 2000.

SUMMARY

Testing was conducted on two fountain aerators to determine the Standard Oxygen Transfer Rate (SOTR), the Standard Aerating Efficiency (SAE), and the flowrate for use by Otterbine Barebo, Inc. The laboratory testing indicates that the results for the Concept₃ 1 Hp High Volume and the Concept₃ 1 Hp Sunburst aerators are as follows:

Concept₃ 1 Hp High Volume			
SOTR (lb/hr)	Power (kW)	SAE (lb/kW-hr)	Flowrate (GPM)
3.28	1.51	2.17	921

Concept₃ 1 Hp Sunburst			
SOTR (lb/hr)	Power (kW)	SAE (lb/kW-hr)	Flowrate (GPM)
2.74	1.96	1.40	530

DISCLAIMER:

These tests were carried out under controlled laboratory conditions. The selection and installation of any of these products at any project site will of necessity incorporate site specific concerns, and therefore must be reviewed by and be the responsibility of a qualified, registered engineer on an individual project basis. Because it cannot control field installation, the St. Anthony Falls Laboratory, University of Minnesota, does not endorse the use of any specific product on which it has performed testing.



1. THEORY

1.1. Aeration

Aeration testing was performed in accordance with the ASCE Standard 2-91, "Measurement of Oxygen Transfer in Clean Water". The most important result of the test is the determination of the SOTR, which is the rate of oxygen transfer achieved by the device in water of zero oxygen concentration (as determined by the ASCE test procedure) adjusted to standard conditions (20°C, 1.00 atm pressure). SOTR is expressed in lb/hr. Additionally, the SAE gives the standard oxygen transfer rate per unit power of the aeration device. The power used to determine the SAE can either be electrical, mechanical, or hydraulic as long as it is clearly defined. In these tests, SAE is defined on the basis of electrical power and thus has the units lb/kW-hr.

1.2. Flowrate

The volumetric flow rate was calculated as the weight of water accumulated during a measured length of time, which can be described as:

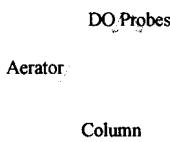
$$Q = \frac{W}{\gamma t}$$

where Q = volumetric flow rate (cfs)
 W = weight of accumulated water (lb)
 T = elapsed time (sec)
 γ = specific weight of water (lb/ft³)

2. TESTING

2.1. Aeration

A tank approximating an 8-foot tall, 30-foot diameter cylinder was constructed within one of the SAFL Volumetric Tanks. A plan view of the test tank is shown below. The tank geometry was carefully measured to provide the volume of the enclosed water necessary to the determination of the SOTR. Water depth at a reference location was measured before and after each test from which the water volume in the tank was calculated. The tank was filled with tap water from the City of Minneapolis.

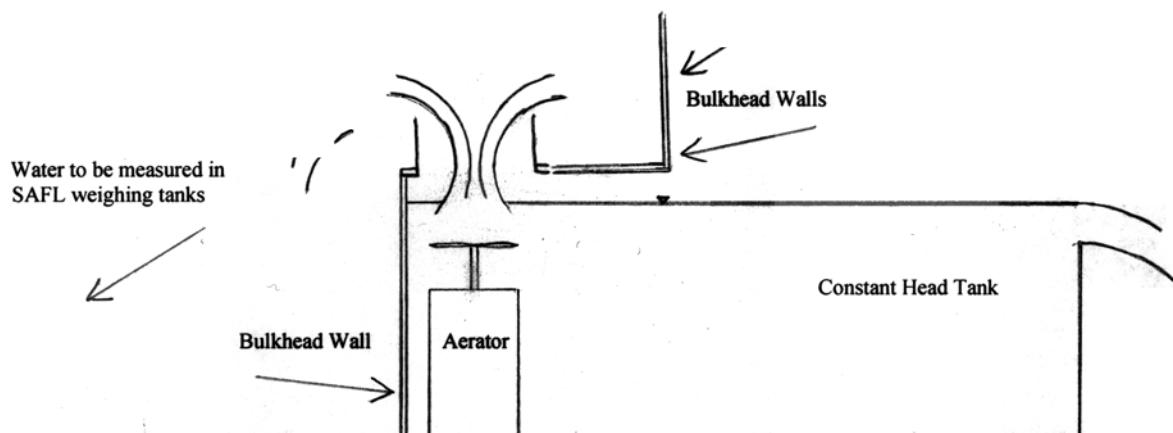


Three YSI dissolved oxygen (DO) probes connected to a Campbell Scientific CR10 datalogger measured oxygen concentration and water temperature. The probes were positioned at two locations along a common radius to take advantage of the axisymmetry of the flow and facility. The probes were placed at $\frac{1}{3}$ depth and $\frac{2}{3}$ depth at one location and at $\frac{1}{2}$ depth at the other location. The DO probes were calibrated before each test using the standard method of oxygen saturated air. The datalogger was programmed to record 1-second averages of the oxygen concentrations every minute.

All tests began by positioning and powering up the aerator, deoxygenating the tank with a sufficient amount of sodium sulfite as specified by the ASCE standard, calibrating and positioning the probes, and initiating datalogging. The tests concluded when the oxygen concentration in the tank reached at least 95% saturation.

2.2. Flowrate

The flow rate measurement was accomplished by placing a bulkhead in a 42" wide, 38" deep, rectangular channel. The channel was designed to separate the pump intake from the discharge and then divert the discharge to a pair of weighing tanks specifically designed for flow rate measurement. A schematic configuration is shown below.



With this setup, a fixed water surface elevation (setting the head on the pump) could be maintained upstream of the bulkhead while diverting the vertical discharge of the fountain to the downstream side of the bulkhead. This scheme was used instead of allowing the fountains to float freely in a tank of water (as would be the case in normal field use) for two reasons. First, the width of the available channel prevented easy use of the float. Second, the diversion of the fountain discharge to the downstream side of the bulkhead without causing backpressure on the pump required that the fountain be located very close to the bulkhead. The float would have prevented this. Ultimately, it is only the depth of submergence of the fountain pump that determines its discharge. The depth of submergence was set for the fountains by measuring the depth of submergence of the pump during normal operation.

Mr. Charlie Barebo
November 28, 2000
Page 4

3. TEST RESULTS

3.1.Aeration

The test data along with the water temperature, tank volume, and air pressure were used as input to software that accompanies the ASCE standard. Attachment 1 shows the ASCE program output for the individual runs. The final SOTR value for each aerator was then determined by taking the average of all of the individual run values. The final SAE value for each aerator is the average SOTR value divided by the average power used for each aerator. Attachment 2 shows the test conditions for the individual runs.

3.2.Flowrate

The water was allowed to accumulate for approximately 400 seconds for each flow rate test. The final flowrate value for each aerator was then determined by taking the average of six tests. Attachment 3 shows the test results for the individual runs.

If you have any questions regarding any of the information above please feel free to contact me at 612-627-1962 or tankx006@tc.umn.edu. It has been a pleasure working with you on this project and we look forward to working with you in the future.

Sincerely,

Julie Robinson
Engineer

Chris Ellis
Research Associate

Mr. Charlie Barebo

November 28, 2000

Page 5

Attachments

- 1 ASCE Program Output
 - a) Concept₃ 1 Hp High Volume Aerator
 - b) Concept₃ 1 Hp Sunburst Aerator
2. Summary of Aeration Test Conditions
3. Individual Flowrate Test Results

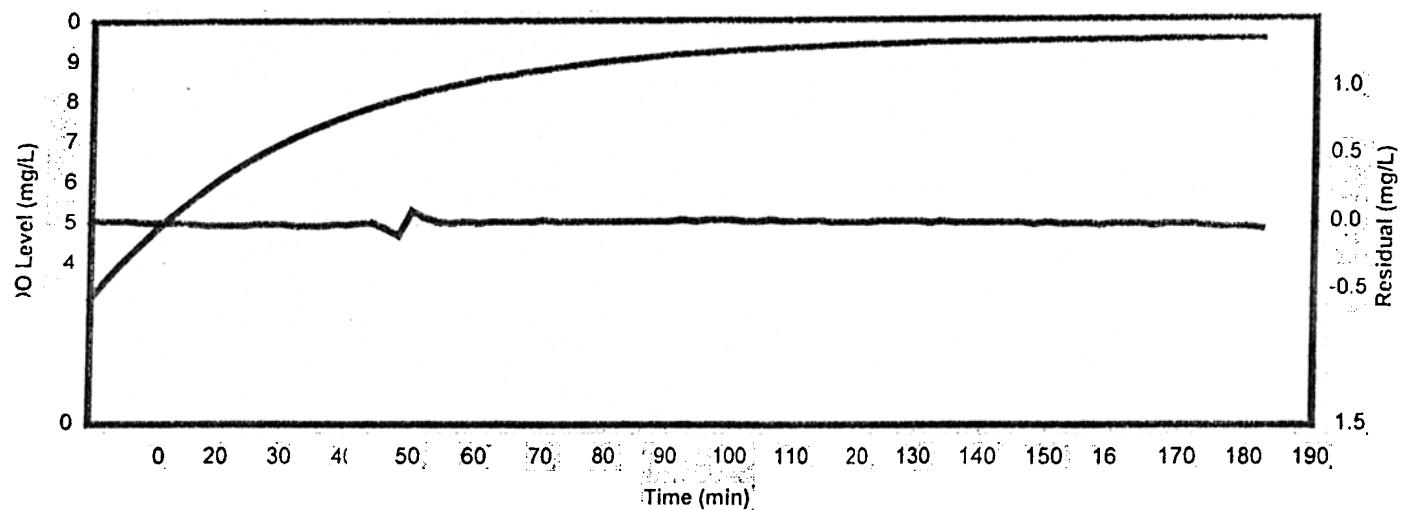
1Hp_HighVolume.xls

Run1 ASCE Output

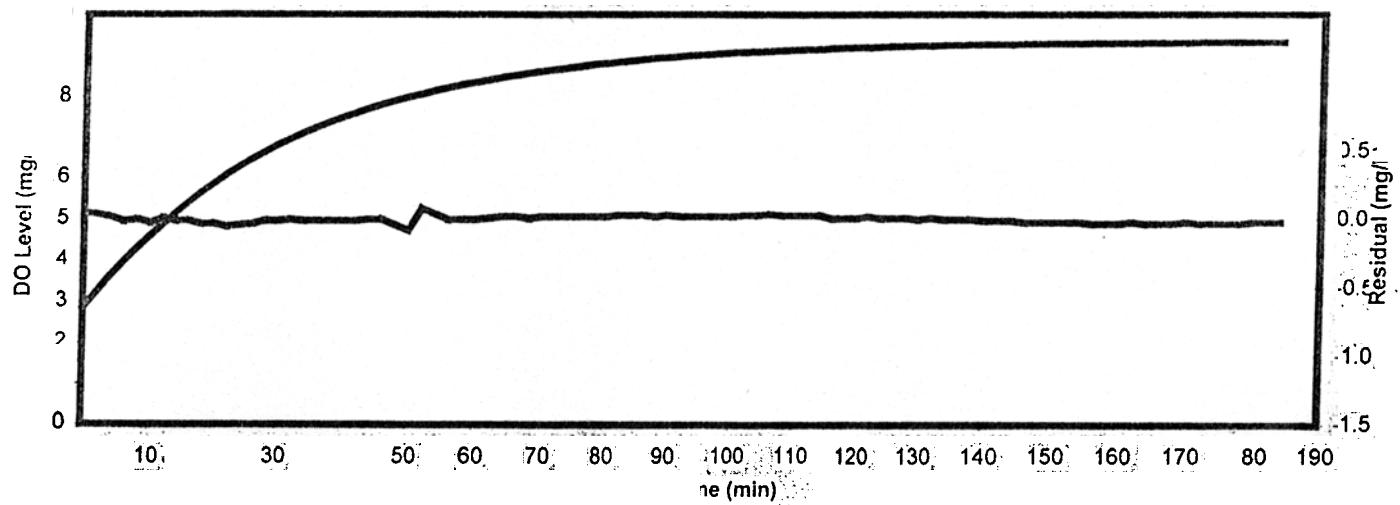
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132.0	9.43	9.43	0.00	132.0	9.25	9.24	0.01	132.0	9.04	9.04	0.00
134.0	9.44	9.43	0.01	134.0	9.25	9.25	0.00	134.0	9.05	9.05	0.00
136.0	9.44	9.44	0.00	136.0	9.25	9.25	0.00	136.0	9.05	9.06	-0.01
138.0	9.44	9.44	0.00	138.0	9.26	9.26	0.00	138.0	9.06	9.06	0.00
140.0	9.45	9.45	0.00	140.0	9.26	9.27	-0.01	140.0	9.06	9.07	-0.01
142.0	9.45	9.45	0.00	142.0	9.26	9.27	-0.01	142.0	9.07	9.07	0.00
144.0	9.46	9.46	0.00	144.0	9.26	9.27	-0.01	144.0	9.07	9.07	0.00
146.0	9.46	9.46	0.00	146.0	9.26	9.28	-0.02	146.0	9.08	9.08	0.00
148.0	9.46	9.47	-0.01	148.0	9.26	9.28	-0.02	148.0	9.08	9.08	0.00
150.0	9.47	9.47	0.00	150.0	9.27	9.29	-0.02	150.0	9.09	9.09	0.00
152.0	9.47	9.48	-0.01	152.0	9.27	9.29	-0.02	152.0	9.09	9.09	0.00
154.0	9.47	9.48	-0.01	154.0	9.27	9.29	-0.02	154.0	9.09	9.09	0.00
156.0	9.47	9.48	-0.01	156.0	9.27	9.30	-0.03	156.0	9.10	9.10	0.00
158.0	9.47	9.49	-0.02	158.0	9.27	9.30	-0.03	158.0	9.10	9.10	0.00
160.0	9.48	9.49	-0.01	160.0	9.27	9.30	-0.03	160.0	9.10	9.10	0.00
162.0	9.48	9.49	-0.01	162.0	9.28	9.30	-0.02	162.0	9.10	9.10	0.00
164.0	9.48	9.49	-0.01	164.0	9.28	9.31	-0.03	164.0	9.10	9.11	-0.01
166.0	9.48	9.50	-0.02	166.0	9.28	9.31	-0.03	166.0	9.10	9.11	-0.01
168.0	9.49	9.50	-0.01	168.0	9.28	9.31	-0.03	168.0	9.10	9.11	-0.01
170.0	9.49	9.50	-0.01	170.0	9.29	9.31	-0.02	170.0	9.10	9.11	-0.01
172.0	9.49	9.50	-0.01	172.0	9.29	9.32	-0.03	172.0	9.10	9.12	-0.02
174.0	9.48	9.50	-0.02	174.0	9.29	9.32	-0.03	174.0	9.10	9.12	-0.02
176.0	9.48	9.51	-0.03	176.0	9.29	9.32	-0.03	176.0	9.10	9.12	-0.02
178.0	9.48	9.51	-0.03	178.0	9.29	9.32	-0.03	178.0	9.10	9.12	-0.02
180.0	9.48	9.51	-0.03	180.0	9.30	9.32	-0.02	180.0	9.10	9.12	-0.02
182.0	9.47	9.51	-0.04	182.0	9.30	9.32	-0.02	182.0	9.10	9.12	-0.02
				184.0	9.30	9.32	-0.02	184.0	9.10	9.13	-0.03
				186.0	9.30			186.0	9.10		

1Hp_HighVolume.xls
Run1 ASCE Output

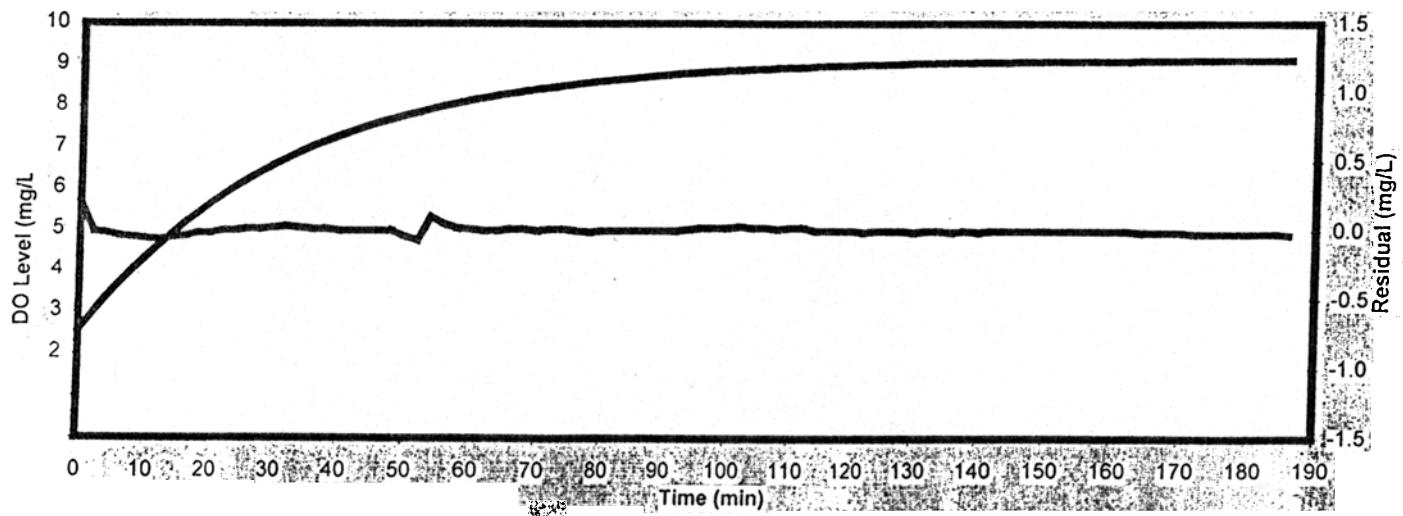
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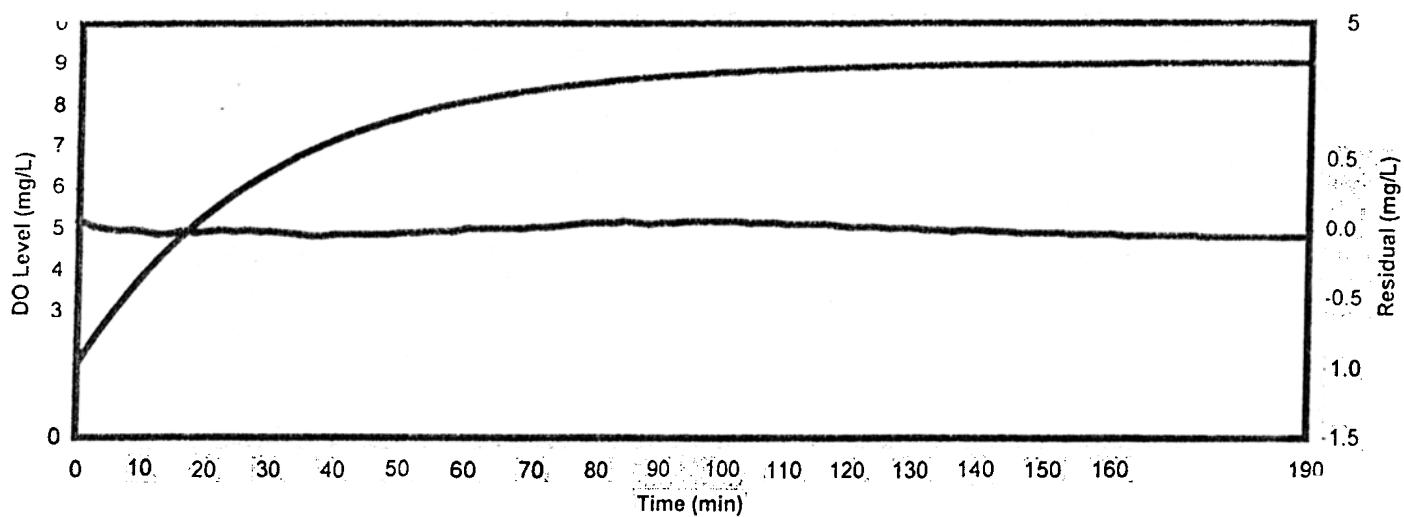
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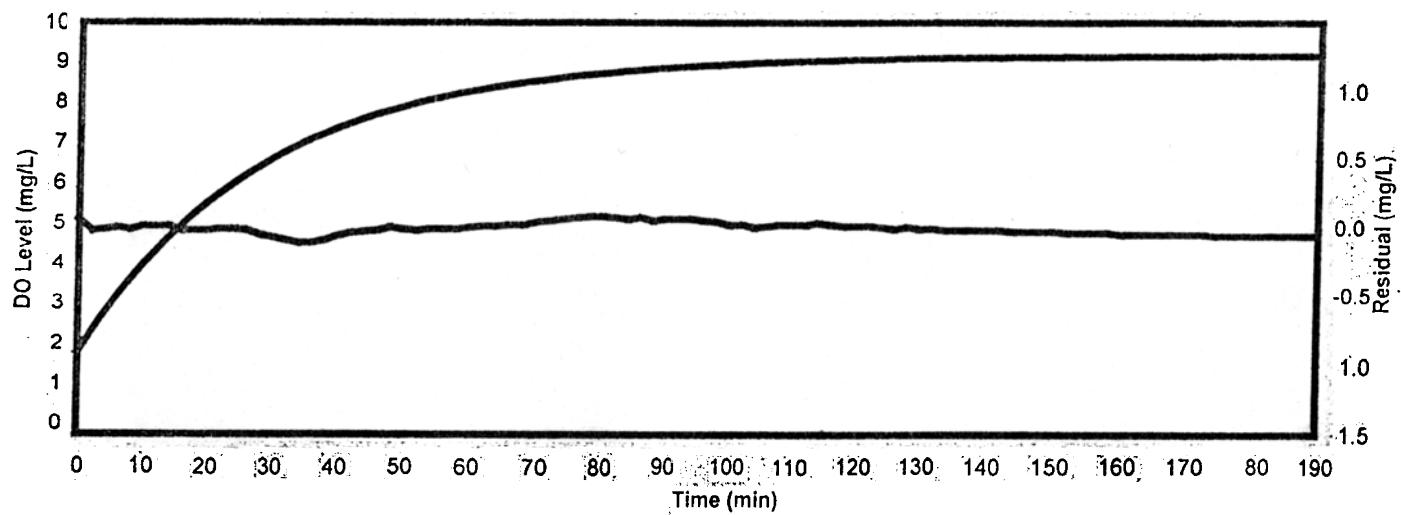
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Probe #1



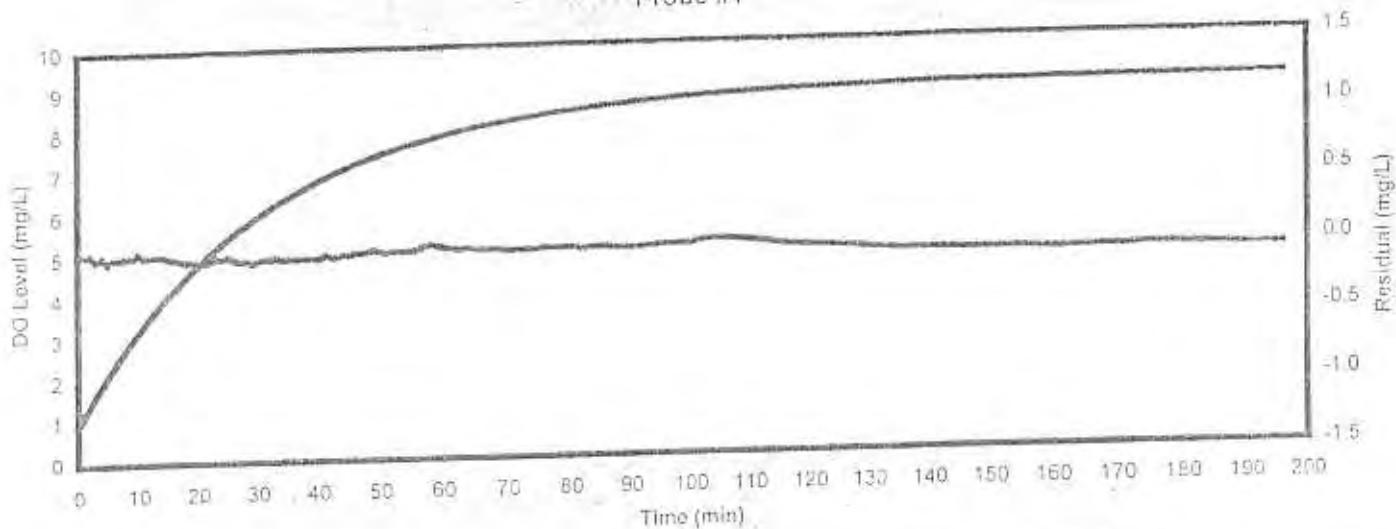
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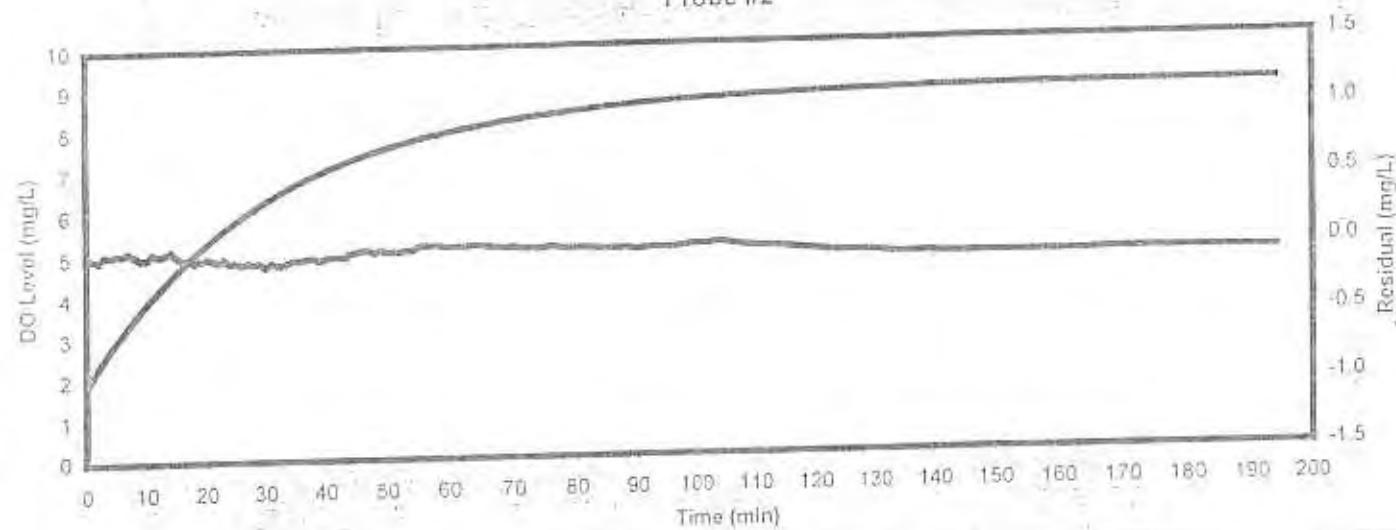
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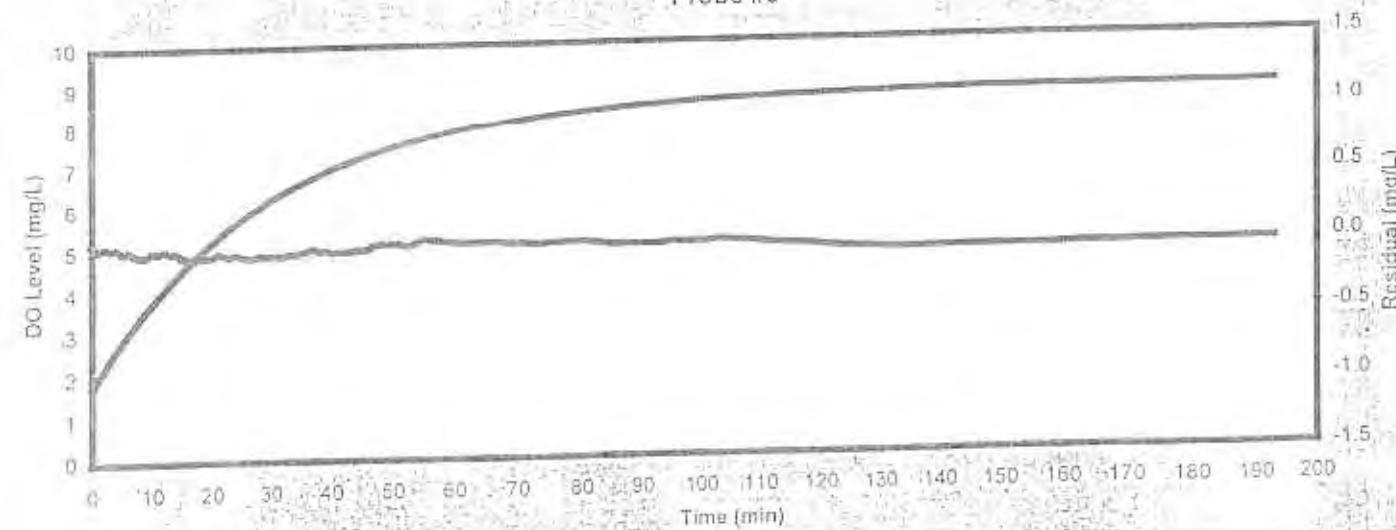
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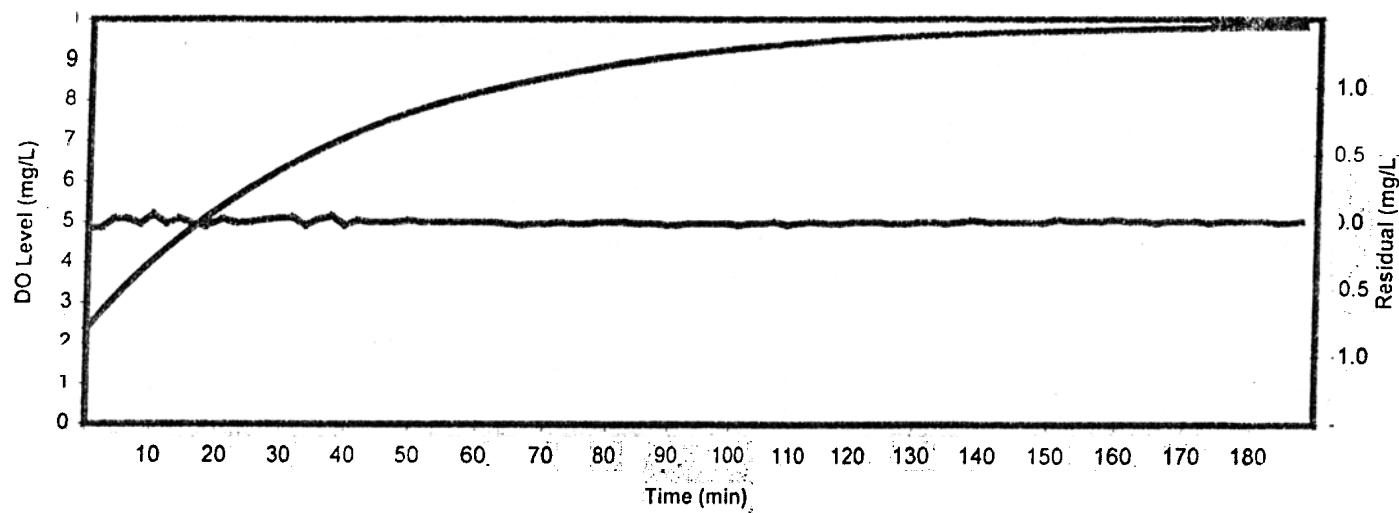
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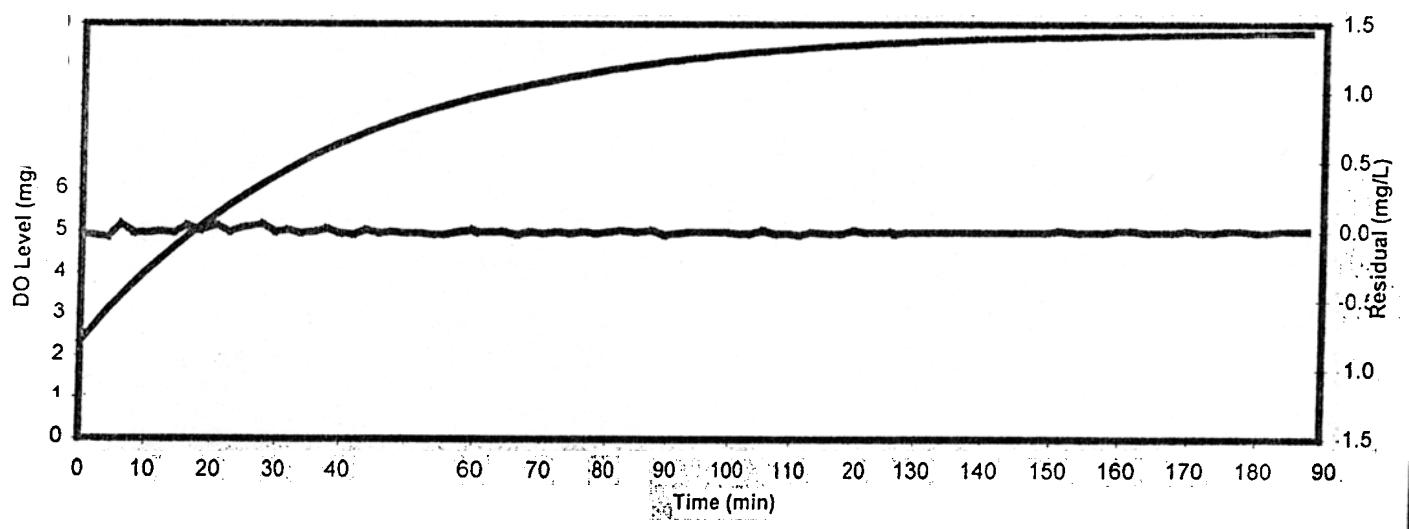
1Hp_Sunburst.xls
Run1 ASCE Output

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132.5	9.61	9.61	0.00	132.5	9.60	9.60	0.00	132.5	9.49	9.49	0.00
134.5	9.62	9.63	-0.01	134.5	9.61	9.61	0.00	134.5	9.50	9.51	-0.01
136.5	9.64	9.64	0.00	136.5	9.62	9.62	0.00	136.5	9.52	9.52	0.00
138.5	9.66	9.65	0.01	138.5	9.64	9.64	0.00	138.5	9.53	9.53	0.00
141.0	9.67	9.67	0.00	141.0	9.65	9.65	0.00	141.0	9.54	9.54	0.00
143.0	9.68	9.68	0.00	143.0	9.66	9.66	0.00	143.0	9.56	9.55	0.01
145.0	9.69	9.69	0.00	145.0	9.67	9.67	0.00	145.0	9.58	9.56	0.02
147.0	9.70	9.70	0.00	147.0	9.68	9.68	0.00	147.0	9.56	9.57	-0.01
149.0	9.71	9.71	0.00	149.0	9.69	9.69	0.00	149.0	9.58	9.58	0.00
151.0	9.73	9.71	0.02	151.0	9.70	9.69	0.01	151.0	9.61	9.59	0.02
153.5	9.73	9.72	0.01	153.5	9.70	9.70	0.00	153.5	9.61	9.60	0.01
155.5	9.74	9.73	0.01	155.5	9.71	9.71	0.00	155.5	9.60	9.60	0.00
157.5	9.75	9.74	0.01	157.5	9.72	9.72	0.00	157.5	9.63	9.61	0.02
159.5	9.77	9.75	0.02	159.5	9.73	9.72	0.01	159.5	9.62	9.62	0.00
161.5	9.76	9.75	0.01	161.5	9.74	9.73	0.01	161.5	9.63	9.62	0.01
163.5	9.77	9.76	0.01	163.5	9.74	9.74	0.00	163.5	9.64	9.63	0.01
165.5	9.77	9.77	0.00	165.5	9.74	9.74	0.00	165.5	9.64	9.63	0.01
167.5	9.78	9.77	0.01	167.5	9.75	9.75	0.00	167.5	9.64	9.64	0.00
169.5	9.79	9.78	0.01	169.5	9.76	9.75	0.01	169.5	9.66	9.64	0.02
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173.5	9.79	9.79	0.00	173.5	9.76	9.76	0.00	173.5	9.68	9.65	0.03
175.5	9.80	9.79	0.01	175.5	9.78	9.77	0.01	175.5	9.69	9.66	0.03
177.5	9.81	9.80	0.01	177.5	9.78	9.77	0.01	177.5	9.67	9.66	0.01
179.5	9.81	9.80	0.01	179.5	9.78	9.78	0.00	179.5	9.69	9.66	0.03
181.5	9.81	9.80	0.01	181.5	9.78	9.78	0.00	181.5	9.69	9.67	0.02
183.5	9.81	9.81	0.00	183.5	9.79	9.78	0.01	183.5	9.68	9.67	0.01
185.5	9.81	9.81	0.00	185.5	9.80	9.79	0.01	185.5	9.69	9.67	0.02
187.5	9.83	9.82	0.01	187.5	9.80	9.79	0.01	187.5	9.67	9.68	-0.01

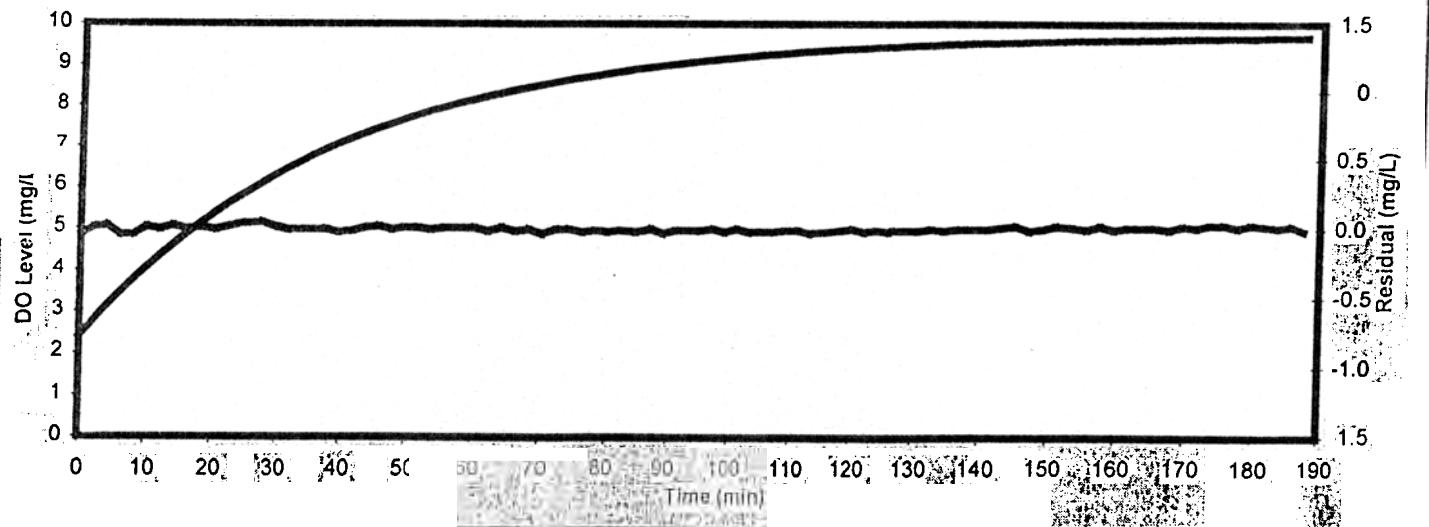
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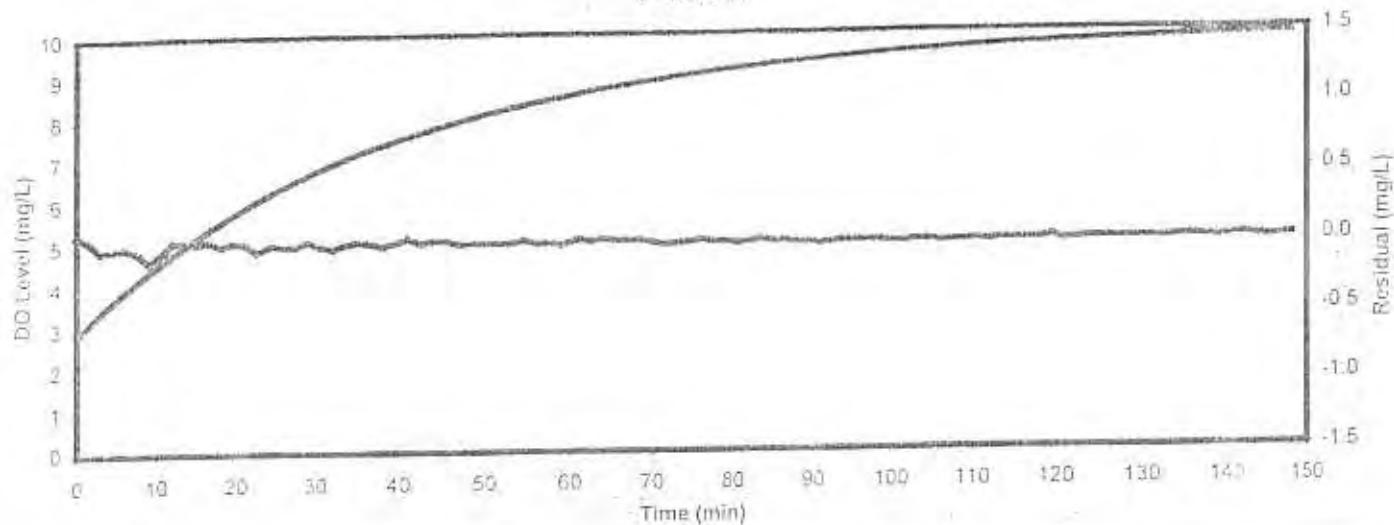
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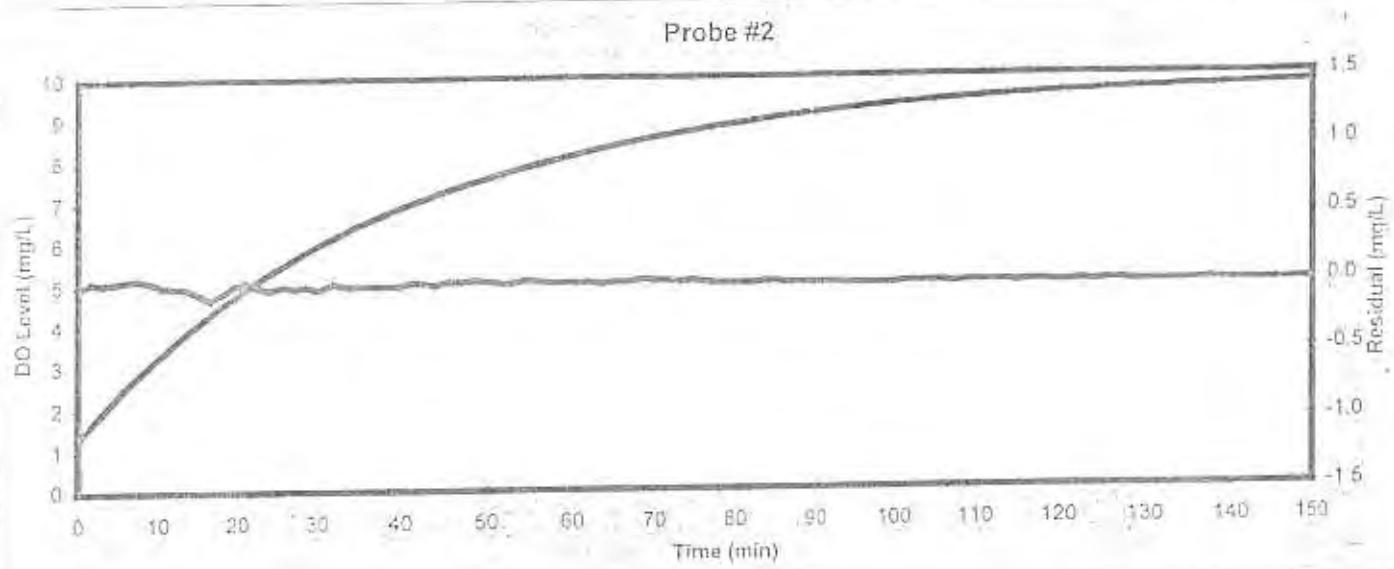
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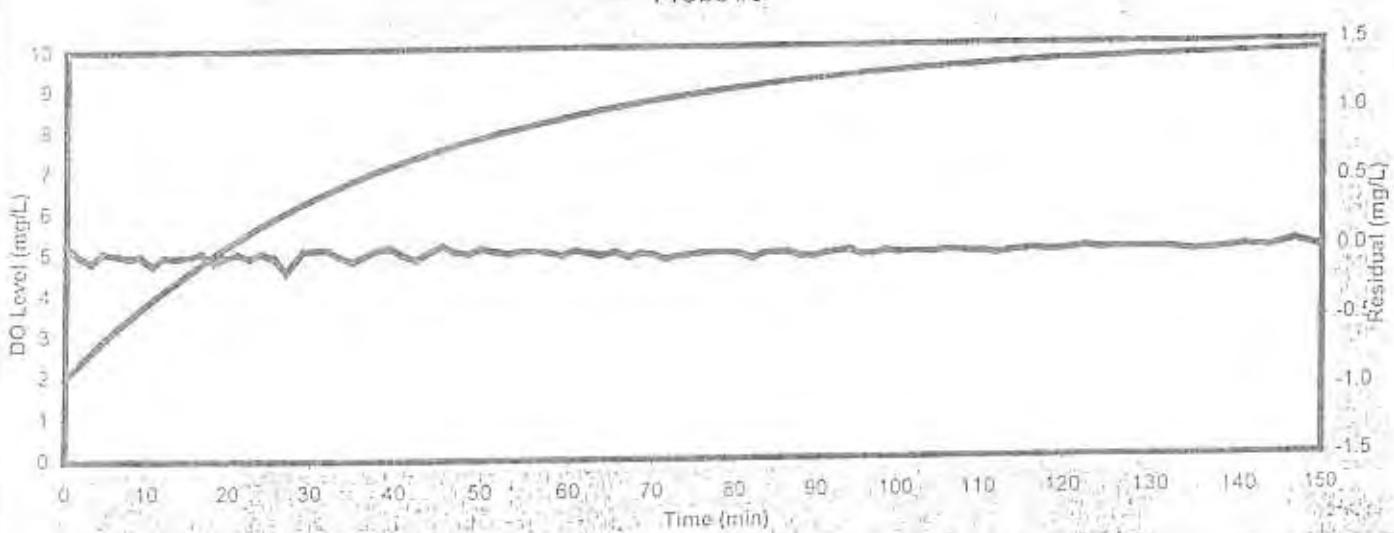
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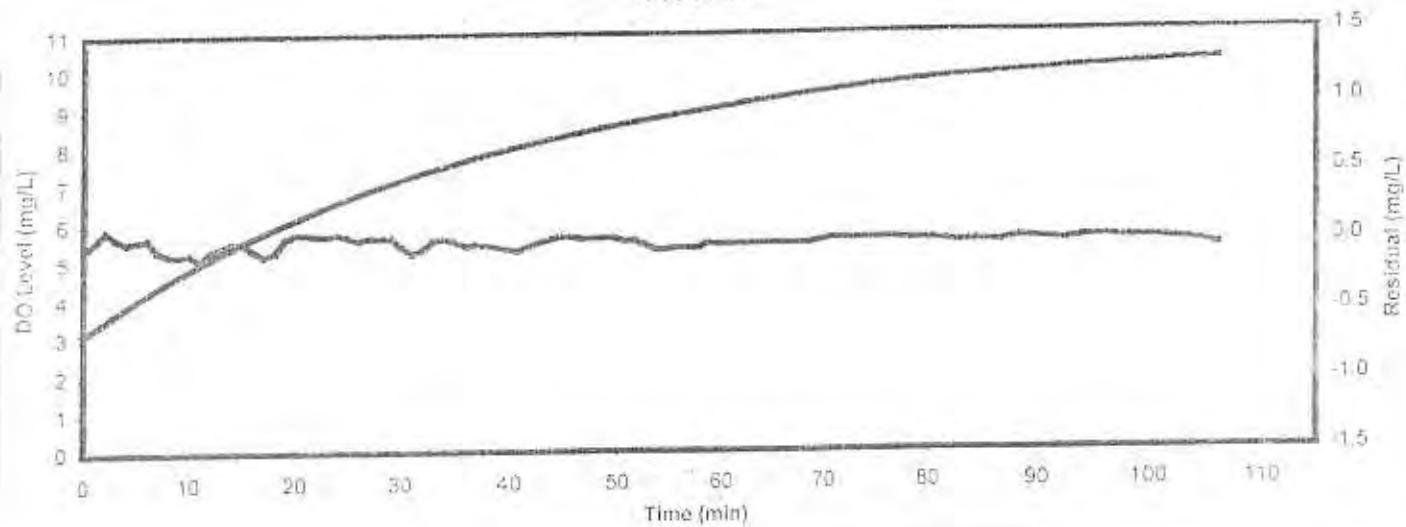
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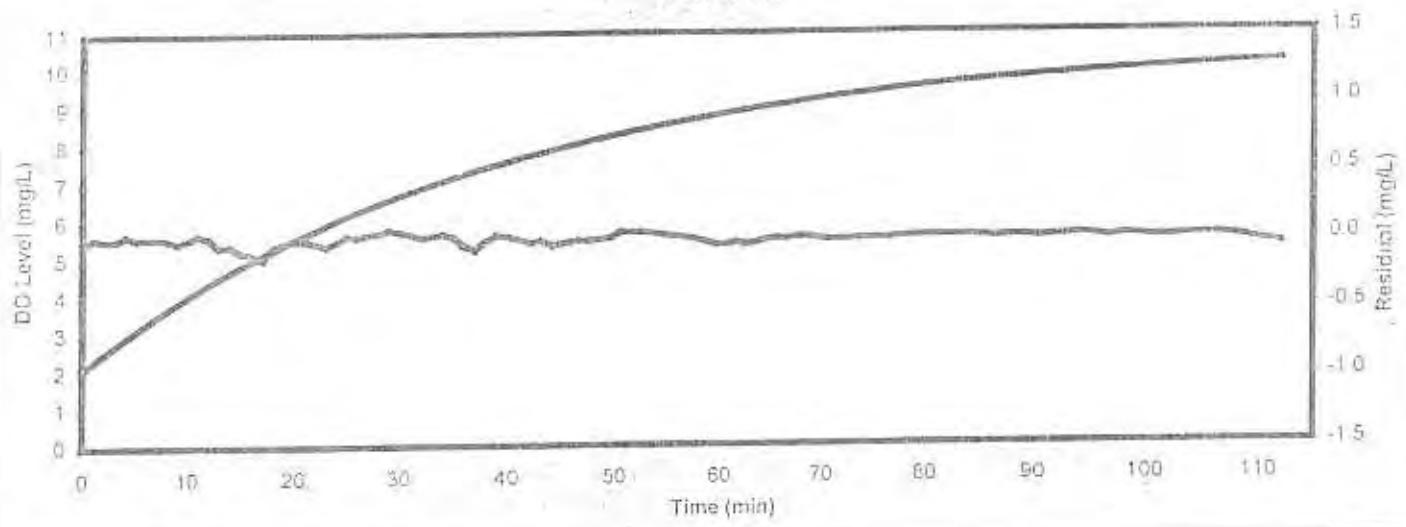
1Hp_Sunburst.xls
Run3 ASCE Output

68.5	9.39	9.40	-0.01	65.5	9.05	9.05	0.00	65.5	9.00	9.01	-0.01
70.5	9.48	9.46	0.02	66.5	9.09	9.09	0.00	66.5	9.04	9.06	-0.02
72.5	9.55	9.53	0.02	67.5	9.14	9.13	0.01	67.5	9.08	9.10	-0.02
74.5	9.61	9.59	0.02	68.5	9.18	9.17	0.01	68.5	9.13	9.14	-0.01
76.5	9.66	9.64	0.02	70.5	9.24	9.25	-0.01	69.5	9.18	9.18	0.00
78.5	9.71	9.70	0.01	72.5	9.31	9.32	-0.01	70.5	9.23	9.22	0.01
80.5	9.76	9.75	0.01	74.5	9.38	9.38	0.00	71.5	9.26	9.26	0.00
82.5	9.79	9.80	-0.01	76.5	9.45	9.45	0.00	73.5	9.33	9.34	-0.01
84.5	9.84	9.84	0.00	78.5	9.52	9.51	0.01	75.5	9.40	9.41	-0.01
86.5	9.88	9.89	-0.01	80.5	9.57	9.56	0.01	77.5	9.46	9.48	-0.02
88.5	9.95	9.93	0.02	82.5	9.63	9.62	0.01	79.5	9.56	9.55	0.01
90.5	9.98	9.97	0.01	84.5	9.68	9.67	0.01	81.5	9.62	9.61	0.01
92.5	10.01	10.01	0.00	86.5	9.72	9.72	0.00	83.5	9.67	9.67	0.00
94.5	10.06	10.04	0.02	88.5	9.77	9.76	0.01	85.5	9.73	9.72	0.01
96.5	10.09	10.07	0.02	90.5	9.81	9.81	0.00	87.5	9.78	9.77	0.01
98.5	10.12	10.11	0.01	92.5	9.86	9.85	0.01	89.5	9.84	9.82	0.02
100.5	10.15	10.14	0.01	94.5	9.91	9.89	0.02	91.5	9.87	9.87	0.00
102.5	10.17	10.17	0.00	96.5	9.93	9.93	0.00	93.5	9.91	9.92	-0.01
104.5	10.17	10.19	-0.02	98.5	9.97	9.96	0.01	95.5	9.96	9.96	0.00
106.0	10.17	10.21	-0.04	100.5	10.00	10.00	0.00	97.5	10.03	10.00	0.03
				102.5	10.03	10.03	0.00	99.5	10.05	10.04	0.01
				104.5	10.07	10.06	0.01	101.5	10.09	10.08	0.01
				106.5	10.10	10.09	0.01	103.5	10.13	10.11	0.02
				108.5	10.11	10.12	-0.01	105.5	10.16	10.14	0.02
				110.5	10.10	10.14	-0.04	107.5	10.19	10.18	0.01
				112.0	10.10	10.16	-0.06	109.5	10.21	10.21	0.00
								111.5	10.24	10.23	0.01
								113.5	10.26	10.26	0.00
								115.0	10.25	10.28	-0.03

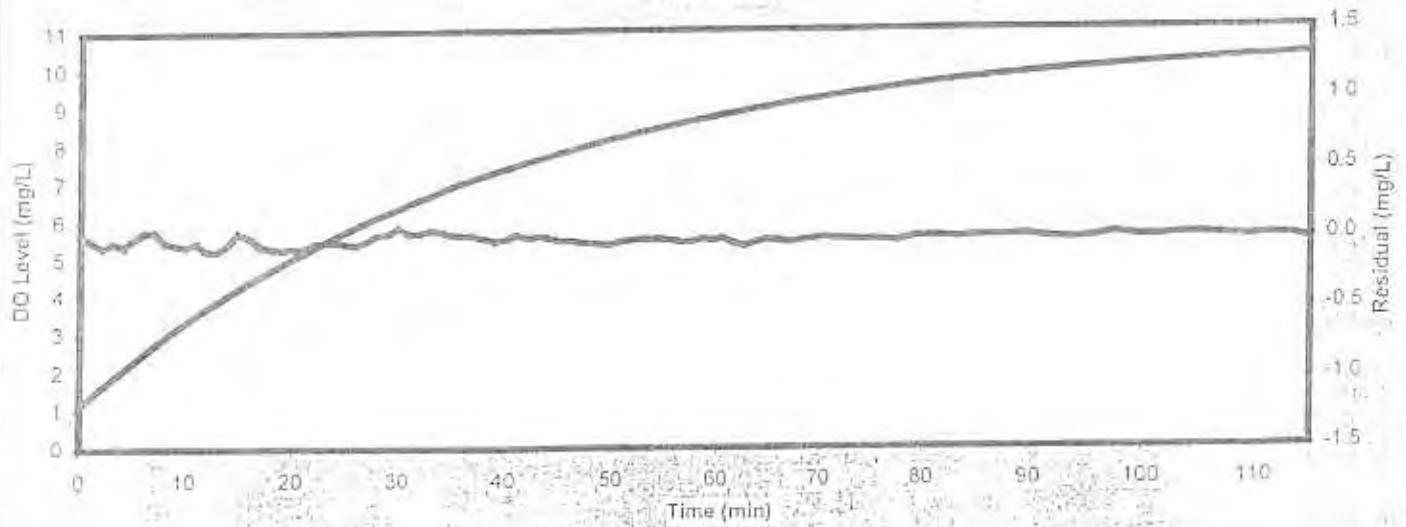
Probe #1



Probe #2



Probe #3



Attachment 2. Summary of Test Conditions

Date	Device	Run	Initial Depth	Initial Temp	Final Depth	Final Temp	Pressure
09/05/00	Concept ₃ 1 HP High Volume	1	3' 11 ⁷ / ₈ "	19.2°C	3' 11 ³ / ₄ "	19.2°C	29.11" Hg
09/10/00	Concept ₃ 1 HP High Volume	2	3' 10 ¹ / ₂ "	19.5°C	3' 10 ¹ / ₂ "	19.6°C	28.91" Hg
09/10/00	Concept ₃ 1 HP High Volume	3	3' 10 ¹ / ₂ "	19.6°C	3' 1 ¹ / ₂ "	19.6°C	28.91" Hg
05/09/00	Concept ₃ 1 HP Sunburst	1	4' 2 ³ / ₄ "	17.6°C	4' 2 ³ / ₄ "	17.2°C	29.10" Hg
05/09/00	Concept ₃ 1 HP Sunburst	2	4' 2 ¹³ / ₁₆ "	17.3°C	4' 2 ¹³ / ₁₆ "	16.9°C	29.18" Hg
05/09/00	Concept ₃ 1 HP Sunburst	3	4' 2 ¹³ / ₁₆ "	16.5°C	4' 2 ¹³ / ₁₆ "	16.1°C	29.17" Hg

Attachment 3. Individual Flowrate Test Results

<i>Concept₃ 1 Hp High Volume</i>		<i>Concept₃ 1 Hp Sunburst</i>	
Run	Flowrate (GPM)	Run	Flowrate (GPM)
	917	1	529
2	919	2	529
3	920	3	529
4	921	4	530
5	922	5	530
6	923	6	530