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Title: OXYGEN ABSORPTION INTO WATER USING MULTIPLE PLUNGING JETS

Abstract approved by Redacted for privacy
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A mathematical model which was developed by Hauxwell (3) to predict the absorption rate of a slightly soluble gas entrained by a plunging liquid jet was modified to verify the effect of the use of multiple jets on the mass transfer. To make the analysis less complex, the system was designed as a closed one in which the outlet stream was recycled to the control volume as the feed.

A mass transfer factor, TF, which was defined as the summation of the product of the mass transfer coefficient and interfacial area of all the entrained bubbles, was found to be proportional to the product of jet Reynolds number, N_{Re}, and Weber number, N_{We}. The product of these two dimensionless numbers represented the kinetic energy of the stream entering the control volume. Experiments with multiple nozzles were scheduled such that the amount of input kinetic energy was directly proportional to the number of jet streams. The mass transfer factor, TF, was found to increase directly with the kinetic energy of the entering stream at the high N_{Re} of 16000; however, there was smaller dependency between the mass transfer factor and the kinetic energy at the low N_{Re} of 5000.

The arrangement of multiple nozzles was also found to have an effect on the mass transfer factor, TF. The closer the distance between the impact point of jet streams became, the more vigorous interaction between the bubbles entrained by each jet stream was observed. This interaction, which often produced the combination of two individual bubbles and the hindrance of some bubbles rising up to the pool surface by a neighboring bubble cone, was considered to be responsible for a slight increase in the mass transfer factor.

The jet length was also found to have a relation with TF. Shorter jet lengths resulted in a slight increase of transfer factor.

OXYGEN ABSORPTION INTO WATER USING MULTIPLE PLUNGING JETS

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OXYGEN ABSORPTION INTO WATER

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I. INTRODUCTION

Entrainment of gas by a plunging stream of liquid, an event which is commonly observed around us as in the waterfall or in a water stream from a kitchen faucet, may have a beneficial aspect from the point of efficiency in a vapor-liquid contactor.

The energy supplied by the plunging jet stream causes a great turbulence in the liquid pool; this action can aid blending within the pool and thus eliminate the need of other commonly used mechanical agitating devices. Aeration of wastewater tanks by aqueous jets is particularly favorable from that point.

Another important consequence of plunging jets is that the gas bubbles entrained by the jet stream will create a large interfacial area between the gas and liquid. Since mass transfer rates are directly related to the area of contact, the larger interfacial area should result in a more efficient vapor-liquid contactor.

The mass transfer from the bubbles entrained by a single jet plunging into an aqueous pool has been studied by previous investigators. This project was designed to extend the conclusions of the earlier studies by investigating the effect of the use of multiple jets and their arrangements on the mass transfer rate. It is hoped that the information gained relative to the mass transfer rate may lead to direct application of this study to waste water treatment.

II. THEORETICAL CONSIDERATIONS

Hauxwell reported a general relationship between the absorption rate and the jet stream characteristics using a jet flowing from one nozzle. This investigation extended Hauxwell's study to verify the effect of the use of multiple nozzles on the mass transfer. A physical system similar to Hauxwell's was used in this experiment so that comparison could be made with the data obtained in the earlier investigation.

Consider the absorption pool shown in Figure III-3 as a control volume. The oxygen gas above the pool surface is absorbed into the aqueous pool in three different ways; (1) through the free jet surface, (2) through the pool surface, and (3) through the surface of the entrained gas bubbles. In addition to those three absorption mechanisms, the entering jet stream may contain oxygen. The oxygen absorbed will be accumulated in the pool or be carried out of the control volume through the pool discharge line. A mass balance based on the oxygen in the control volume gives,

$$\frac{d(C_L V)}{dt} = r_s + r_B + \sum_{i=1}^{n} r_{Ji} + \sum_{i=1}^{n} C_J Q_{Ji} - Q_E C_E \qquad (1)$$

where,

C_L = oxygen concentration in the pool (ml/liter)

V = pool volume (liter)

t = time (min.)

Q_{Ji} = volumetric flow rate of ith jet stream (liter/min.)

C_J = oxygen concentration in the jet stream (ml/liter)

r_{Ji} = absorption rate through the ith jet stream surface (ml/min.)

r_S = absorption rate through the pool surface (ml/min.)

r_B = absorption rate through the bubble surface (ml/min.)

Q_E = pool discharge volumetric flow rate (liter/min.)

C_E = oxygen concentration in the pool discharge (ml/liter)

When a constant pool volume, V, is maintained the flow rate of the summation of the input jet streams must be equal to the pool discharge flow rate i.e.,

$$Q_E = \sum_{i=1}^{n} Q_{Ji}$$

If the pool is assumed perfectly mixed, the concentration of the discharge line will be equal to the pool concentration,

$$C_E = C_L$$

When the absorption process is operated on the basis of a closed system, i.e. pool discharge stream is recycled to supply the jet streams, the jet concentration will be equal to the discharge concentration or to the equivalent pool concentration,

$$C_L = C_J$$

and

$$C_E = C_L = C_J$$

The use of sparingly soluble oxygen gas, and a short, small diameter jet streams with a relatively high velocity produces relatively short exposure of the free jet stream. Accordingly, the free jet surface absorption rate, r_J, can be assumed negligible. Another assumption can be made such that the flow is distributed evenly to n number of nozzles,

$$\sum_{i=1}^{n} C_J Q_{Ji} = C_J \sum_{i=1}^{n} Q_{Ji}$$
$$= C_J \cdot n \cdot Q_J$$
$$= C_J \cdot Q_E$$
$$= C_E \cdot Q_E$$

With these assumptions and operation restrictions, equation (1) simplifies to the following equation:

$$V \frac{dC_L}{dt} = r_S + r_B \tag{2}$$

Whitman's two film theory was adopted to describe the absorption rate. For surface absorption

$$r_S = K_{L_S} A_S (C^* - C_L) \tag{3}$$

where,

K_{L_S} = overall mass transfer coefficient for surface absorption.

A_S = area of the pool surface

C^* = oxygen concentration of pool in equilibrium with the vapor phase above the pool

For the rate of absorption through the entrained bubble surface inside some jth bubble,

$$r_{Bj} = k_{Lj}\ A_j\ (\ C_{ij}\ -\ C_{Lj}) \qquad (4)$$

where,

k_{Lj} = liquid film mass transfer coefficient for the jth bubble

C_{ij} = oxygen concentration at gas-liquid interface

C_{Lj} = oxygen concentration at the bulk liquid

A_j = surface area of the jth bubble

The concentration at the gas-liquid interface, C_{ij}, is equal to the equilibrium value, C^*, and the bulk liquid concentration, C_{Lj}, is equal to C_L. By summing overall n entrained bubbles using the overall mass transfer concept, the absorption rate through the bubble surface becomes,

$$r_B = \sum_{j=1}^{n} K_{Lj}\ A_j\ (C^* - C_L) \qquad (5)$$

To calculate r_B in equation (5) the product of the overall mass transfer coefficient and the surface area of each bubble must be known. Unfortunately these are difficult to define. Accordingly, the concept of transfer factor, TF, was used to represent the product of the mass transfer coefficient and the surface area. This concept was successfully adopted by Jackson[4] and Hauxwell[3]. This concept of TF was practical and meaningful to simplify the complex process.

Let

$$TF = \sum_{j=1}^{n} K_{Lj} A_j$$

$$TFS = K_{L_S} A_S$$

then

$$r_B = TF\ (C^* - C_L)$$

$$r_S = TFS\ (C^* - C_L)$$

and equation (2) reduces to

$$V\frac{dC_L}{dt} = TF\ (C^*-C_L) + TFS\ (C^*-C_L)$$

$$= (TF + TFS)\ (C^*-C_L)$$

$$= TTF\ (C^*-C_L) \qquad (6)$$

where,

$$TTF = TF + TFS$$

If equation (6) is divided by $C^*\cdot V$ to get a dimensionless concentration C^+, equation (6) yields,

$$\frac{dC^+}{dt} = \frac{TTF}{V}\ (1-C^+)$$

With the assumption that TTF is not a function of C^+, the solution of the differential equation with the initial condition $C^+ = C_o^+$ at $t=0$ results in

$$\ln \left(\frac{1 - C_o^+}{1 - C^+}\right) = \frac{TTF}{V} t \qquad (7)$$

Equation (7) shows that the data may be plotted as $\ln \left(\frac{1 - C_o^+}{1 - C^+}\right)$ vs time t, and a straight line through the origin should results with a slope of $\frac{TTF}{V}$.

Evaluation of the surface absorption rate, TFS, can be obtained using the same type of graphical analysis. By submerging the jet nozzle just below the pool surface with the same flow conditions which were selected for the entrainment process, the mass transfer can only occur through the surface. Without the bubble input, TTF is reduced to TFS. This procedure results in the following equation,

$$\ln \left(\frac{1 - C_o^+}{1 - C^+}\right) = \frac{TFS}{V} t \qquad (8)$$

When equation (7) and (8) are applied to the properly designed absorption studies, the transfer factor TF as a function of jet stream characteristics can be found.

Hauxwell[(3)] reported that the TF values, resulting from the analysis of his work, had a significant correlation with the product of N_{Re} and N_{We}. The exponent on this dimensionless number product turned out to be nearly unity which would indicate a linear variation of the transfer factor TF with the supply of jet stream kinetic energy. TFS, also was found to correlate well with N_{Re}. In this work, the same analysis will be made to find a correlation of transfer factor with the supply of multiple jet stream kinetic energy.

III. EXPERIMENTAL EQUIPMENT AND PROCEDURE

1. General Equipment Description

The experimental equipment was designed to test the mathematical model which was developed to explain the absorption from entrained gas bubbles.

A 440 mm ID glass cylinder, with the height of 359 mm, was sandwitched between two 12 mm thick plastic plates. Gaskets and silicon rubber sealing were used to provide proper sealings. A pool depth of 300 mm was selected; this depth was chosen so that all of the bubbles entrained from the scheduled experimental jet flow rates would be retained within the pool. This depth was a little bit higher than those selected in the previous investigations, because experimental runs involving higher flow rates were scheduled to meet the desired experimental conditions. The pool volume for this depth was approximately 45.7 liters. Detailed pool volume as a function of depth is tabulated in Table II-4 of Appendix II.

Jet nozzles were placed on the cover plate with tube fittings which were designed so that the nozzles could be easily raised or lowered. The arrangement of the nozzles was determined to test the interaction between the bubbles entrained by the jet streams which were coming out of the neighboring nozzles. The distance between two nozzles and the diagonal distance for four nozzles, was initially 220 mm; this was designated position 0. The distance was then reduced by half, i.e., to 110 mm and this arrangement was designated position A. A third position, designated position B, involved a distance of 55 mm. The last position, designated position C, was set at one eighth of the original distance, or 27.5 mm. The various types of nozzle arrangements are shown on Figure III-1, and Figure III-2. The nozzles were made of copper with a length long enough to insure a fully developed velocity profile. The diameter and L/ID ratio of the nozzle are listed in Table 1.

Table 1. Jet nozzle dimensions

ID (mm)	OD (mm)	L/ID
5.588	6.35	76.23

Three 1/8-inch OD stainless steel tubes were located within the cylinder at 154,51 and 102 mm from the center; these tubes provided pool sampling ports. The sample points, designated A, B, and C respectively were located 57, 146, and 216 mm above the bottom of the cylinder. One more tube, designated D, was located in the absorption pool discharge line, right on the bottom of the pool. A schematic drawing of the enclosed system for this experiment is illustrated in Figure III-3.

A small, shell-tube type heat exchanger was inserted between the discharge line from the pool and the pump to remove any heat which might come from the inefficiency of the pump and to maintain an essentially constant pool temperature. A pump was incorporated with a rotameter for

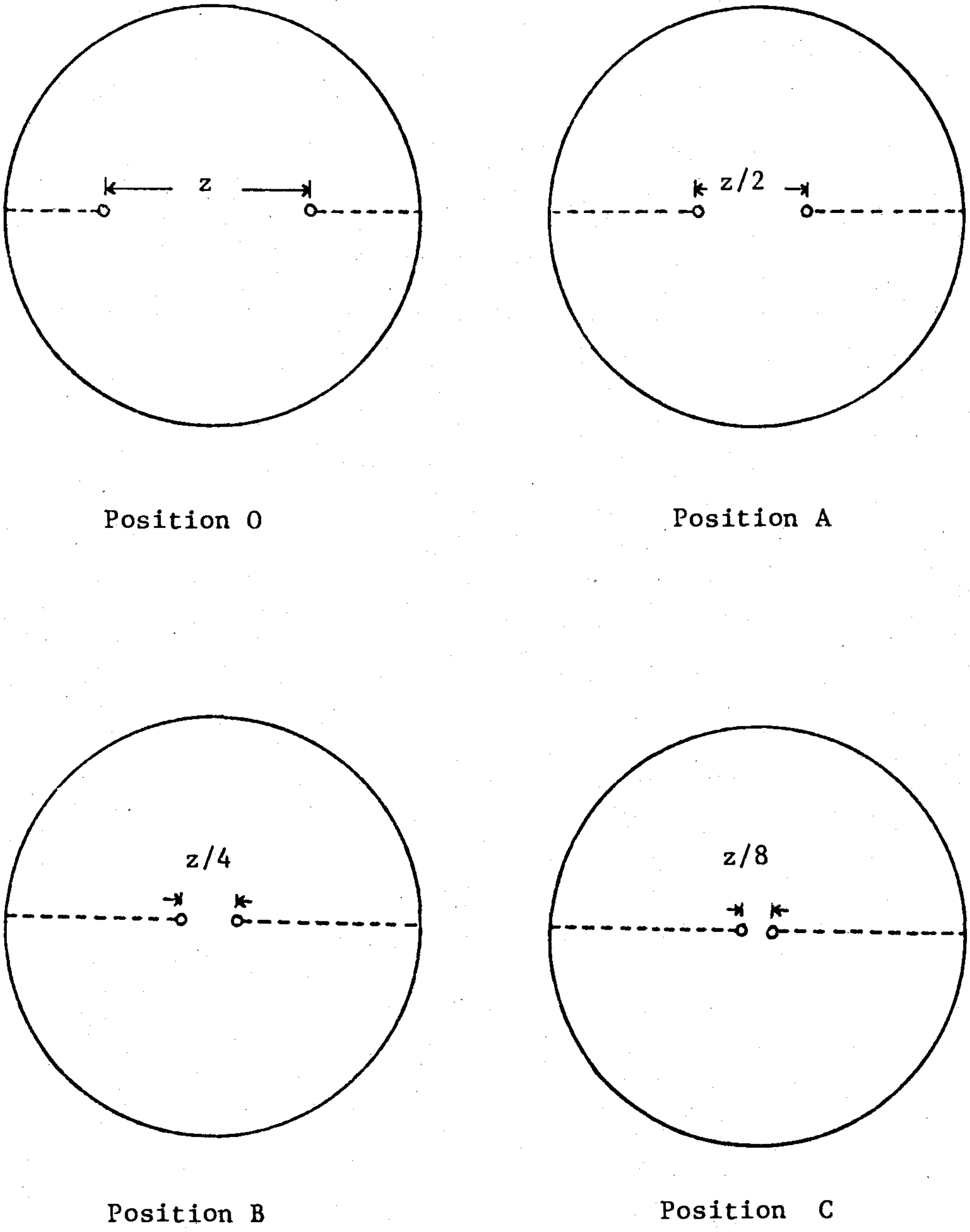

Figure III-1. Various arrangements of two nozzles.

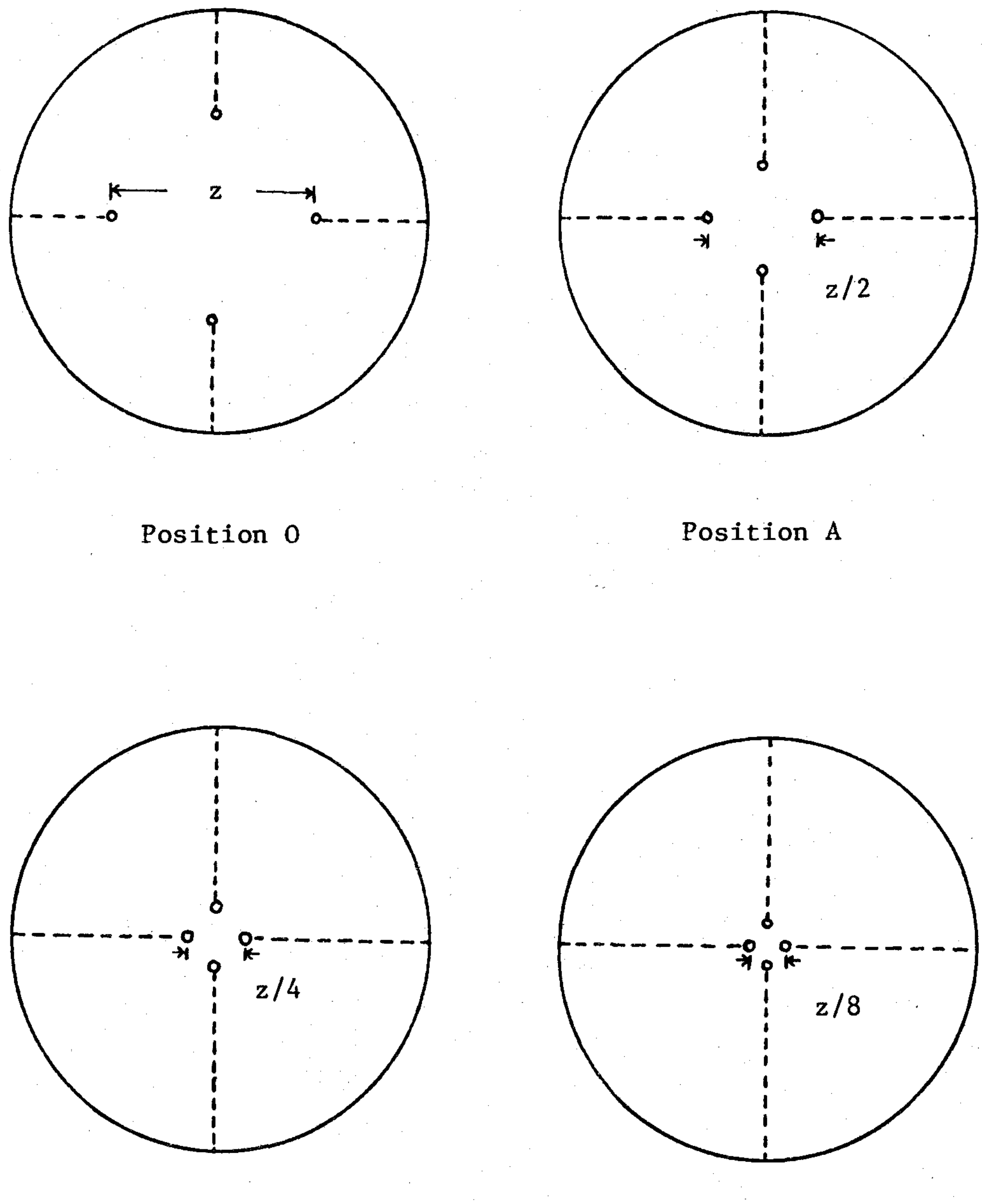

Figure III-2. Various arrangements of four nozzles.

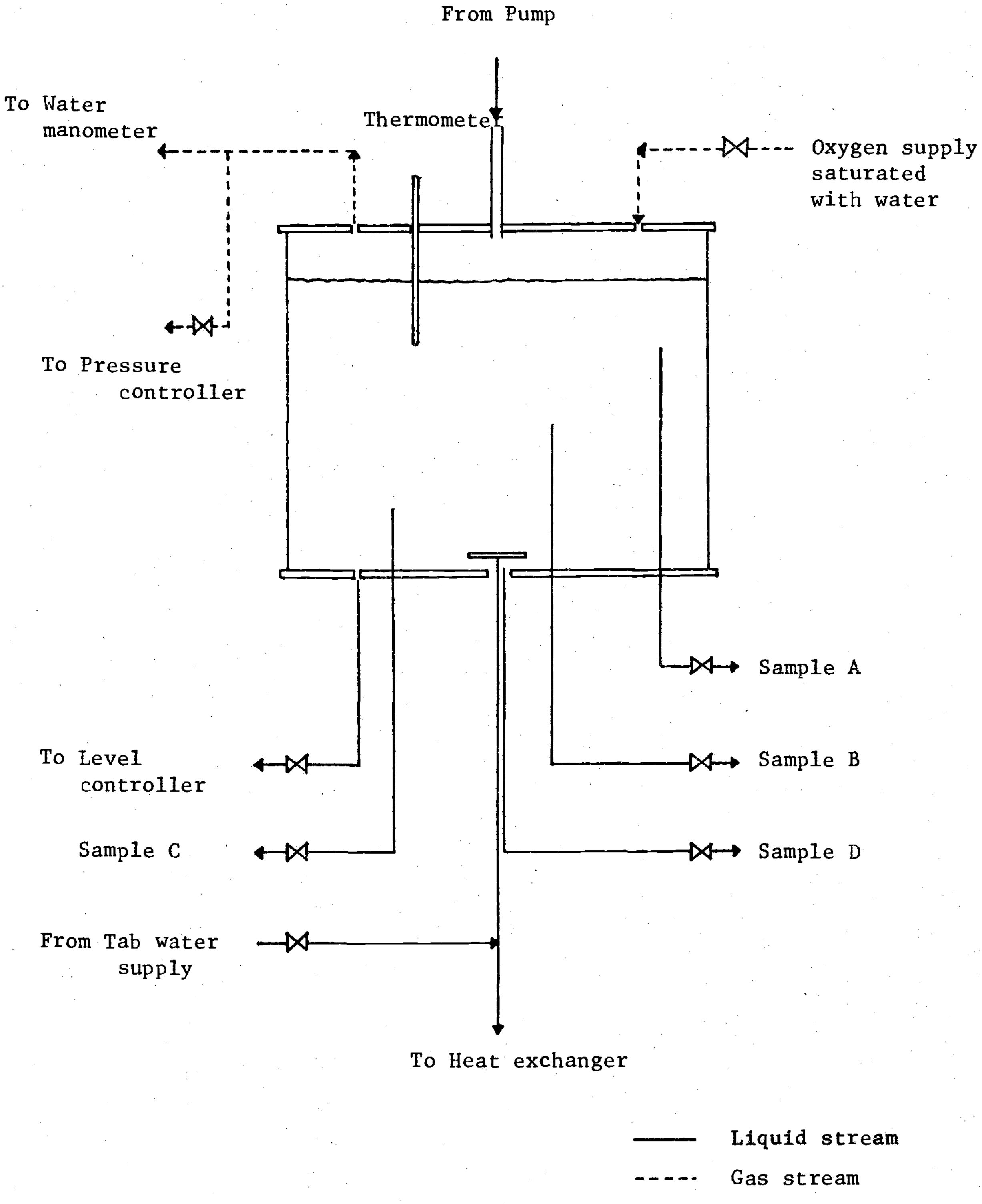

Figure III-3. Schematic drawing of the enclosed system.

adjusting the flow rate of the stream. Pump specification and the rotameter calibration are tabulated in Table II-1, II-5 of Appendix II, respectively. After passing through the rotameter, the flow was distributed to n number of jet branches. Two and four branches were used for running multiple jets. The distributor was made of brass tube fittings.

City water was used in this experiment. It was felt that this would provide an aqueous stream and pool closer to what might actually be encountered in many environmental and industrial processes. Pure oxygen gas was fed continuously through a pressure control valve and then bubbled through a water-filled flask, to assure that the supplied oxygen was saturated with water vapor. From this saturator the oxygen was supplied to the cylinder.

A simply-designed, adjustable bubble device was used to control the pressure of the oxygen gas in the cylinder. The vapor pressure was measured by the water manometer. The schematic diagram of the whole system was illustrated in Figure III-4.

A YSI model 54 ARC oxygen meter, which uses an electrolyte-filled probe, was chosen to analyze the samples taken from the absorption pool. The electrode provided a rapid, accurate analysis of sparingly soluble gases such as oxygen.

Another small cylinder was prepared to saturate the distilled water with air under atmospheric pressure. The samples taken from the absorption pool were diluted with this air-saturated distilled water, whose oxygen concentration was measured prior to being used.

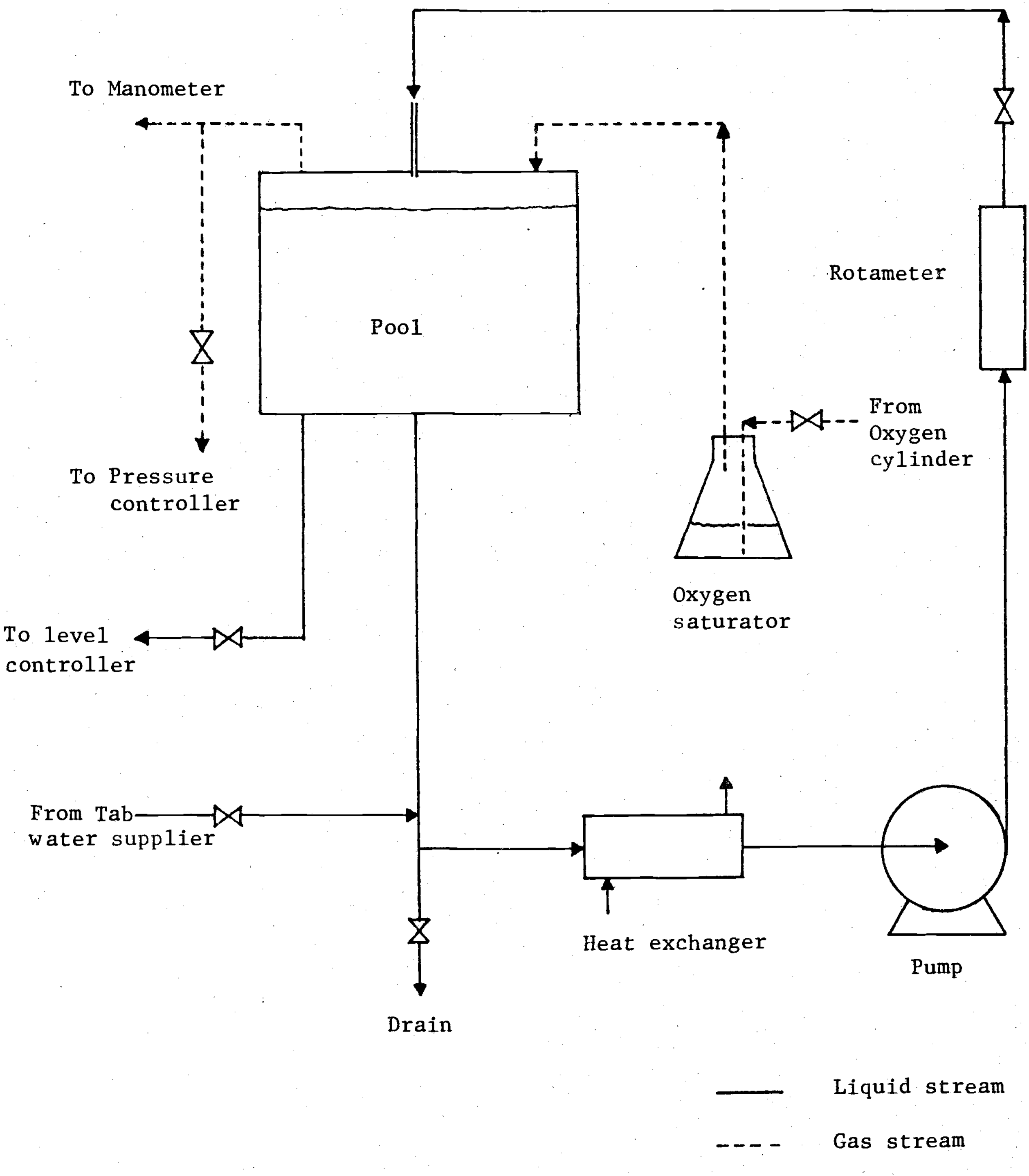

Figure III-4. Schematic diagram of whole system.

2. Procedure

The first step was to measure the oxygen concentration of the air-saturated distilled water which would be used to dilute the samples from the pool or discharge line. It was necessary to have the dilution process to measure the oxygen concentration of sample within the range from 0 to 20 ppm, a range limited by the capacity of the oxygen meter used in this investigation. The distilled water had been saturated with air for over four hours before beginning the experiment. The measurement was repeated two additional times, i.e. during the analysis and after the analysis, to check the consistency of the oxygen concentration.

Following the first step, the cylinder was filled completely with water to sweep all the residual gases out of the cylinder. Then, the proper jet, as well as the flow rate for the desired experimental condition was installed. Jet nozzles were set at 55 mm above the pool surface for the total absorption rate, and were set at 55 mm below the pool surface for the surface absorption rate. The cylinder pool was then drained to the operating level of 300 mm depth, while oxygen gas was fed simultaneously into the cylinder. Excess oxygen gas was supplied throughout the run to keep the oxygen in the cylinder from contamination by atmospheric gases. The pressure of the oxygen gas in the cylinder was maintained at 765 mm Hg, with the excess oxygen gas being bubbled out through the submerged bubble device.

The temperature of the water in the pool was controlled by the heat exchanger to 20 $\pm$ 1^{o}C.

Individual samples were taken simultaneously in 50 ml glass bottles from sampling ports A, B, C, and D. The water in each sampling tube was drained just before taking the samples. The tubes were inserted to the bottom of the sample bottles; these bottles were then filled to the top. These sampled bottles were sealed with solid rubber stoppers to prevent exposure to the atmosphere. Sampling was repeated three additional times at 5 minutes intervals for the total absorption process, and intervals of 30 minutes for the surface absorption process.

The analysis of these samples was taken during the run or right after the run. The 50 ml sample was first transferred to a glass mixing bottle of 290 ml in volume and diluted up to 290 ml with the air-saturated distilled water. A magnetic stirrer was used to mix the solution as perfectly as possible. The oxygen concentration of the mixed solution was measured by inserting the oxygen probe into the mixing bottle; this concentration was recorded in ppm as shown on the scale of the oxygen meter. The probe was polarized and set according to the instructions. The probe was calibrated prior to being used, by following the instruction which was based on the probe temperature and the true local atmospheric pressure. The oxygen probe fitted exactly with the opening of the mixing bottle such that the solution was kept completely separated from the environment. The experimental results were obtained in the form of both time and sample position.

Once the run was over, the water in the cylinder and the lines was completely drained; the cylinder and the lines were then washed out with city water prior to the next run.

IV. ANALYSIS AND DISCUSSION OF RESULTS

The purpose of this study was to find the effect of the number of jets and their arrangements on the gas absorption as a function of time for various jet characteristics. For this investigation the following jet stream conditions, as listed in Table 2, were used.

The experiment was divided into two separate sections. One was for determining only the surface absorption rate and the other was for determining the combination of both surface and entrained bubble absorption rates.

Table 2. Experimental jet conditions

The number of jets	N_{Re}	N_{We}
1	5324	71
1	8908	198
1	13687	466
1	21044	1103
1	24837	1536
1	28819	2068
2	5251	69
2	7640	145
2	12419	384
2	14410	517
2	16401	670
4	5214	68
4	6209	96
4	7205	129
4	8200	167
4	8698	188

The entrained bubble absorption mass transfer rate was determined by subtracting the surface absorption rate from the total absorption rate.

It has been found that mass transfer by entrained bubbles is related to not only the properties of gas and liquid, but also the jet characteristics such as jet length, diameter and velocity. In this investigation, the mass transfer which occurs when using one nozzle was reinvestigated and, as an extended study, the effect of the number of jets and their arrangements on the mass transfer was investigated. Most of the experimental conditions were essentially identical to those used by the previous investigators, except for the jet length and the number of nozzles.

By setting the jet length constant throughout the runs, as well as by fixing the properties of liquid and gas, the emphasis of this investigation involved the effect of the number of jets and their arrangements on the mass transfer rate.

The assumption that the absorption pool was perfectly mixed turned out to be reasonable. The measurement of pool samples at four different positions did not vary significantly. In most cases, the variance among the four samples was less than 2%. An increase in the transfer factor TF was found when the jet length became shorter. This tendency is shown in Figure IV-2 where the results are compared with the previous investigator's[8]. Smith [9] reported that the parameters determing the penetration depth were the velocity, the diameter of the jet at the point of impact, and the amount of entrained gas. It was observed that the entrained bubbles became finer as well as the penetration depth of the plunging liquid increased as the shorter jet length was employed. The fine bubbles, which have less buoyancy momentum than bigger ones, tend to stay longer in the liquid; the fine bubbles also have larger interfacial surface area in total than the larger bubbles for same amount of entrained gas. These are two factors which could explain why higher mass transfer rates occurred when the shorter length of jet was used.

Runs with multiple nozzles were scheduled such that input kinetic energy of jet streams was proportional to the number of jet streams. The kinetic energy of the flowing fluid, as represented by the product of Reynolds number N_{Re}, and the Weber number, N_{We} could be established by fixing the diameter and velocity of jets. The results of the experiments with one nozzle, two nozzles, and four nozzles are shown in Figure IV-1, Figure IV-5, and Figure IV-9, respectively. All of these figures confirmed that the transfer factor TF was strongly related to the product of N_{Re} and N_{We}.

As shown in Figure IV-3, the transfer factor increased as the number of nozzles increased. The mass transfer rate with two nozzles was higher than that with one nozzle within the specified range of $N_{Re} \cdot N_{We}$ parameter and apparently tended to be proportional to the number of applied nozzles at the high value of $N_{Re} \cdot N_{We}$. There was a less noticeable tendency at the low value of $N_{Re} \cdot N_{We}$, where the kinetic energy that was put into the pool was much lower.

As far as the runs with four nozzles were concerned, the results turned out less consistent with the results of two nozzles. The slope of the transfer factor with four nozzles was much steeper than expected when compared with the results using one and two nozzles. Due to the

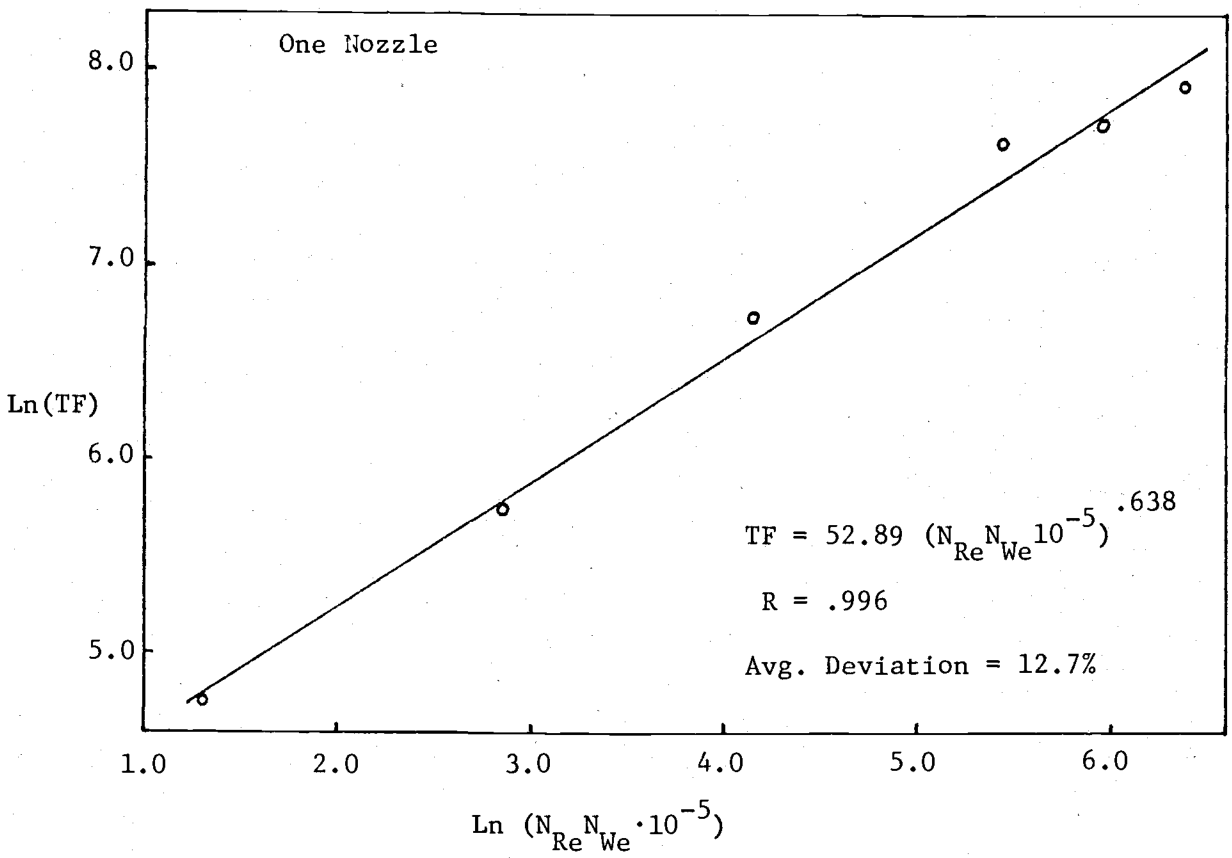

Figure IV-1. TF with one nozzle

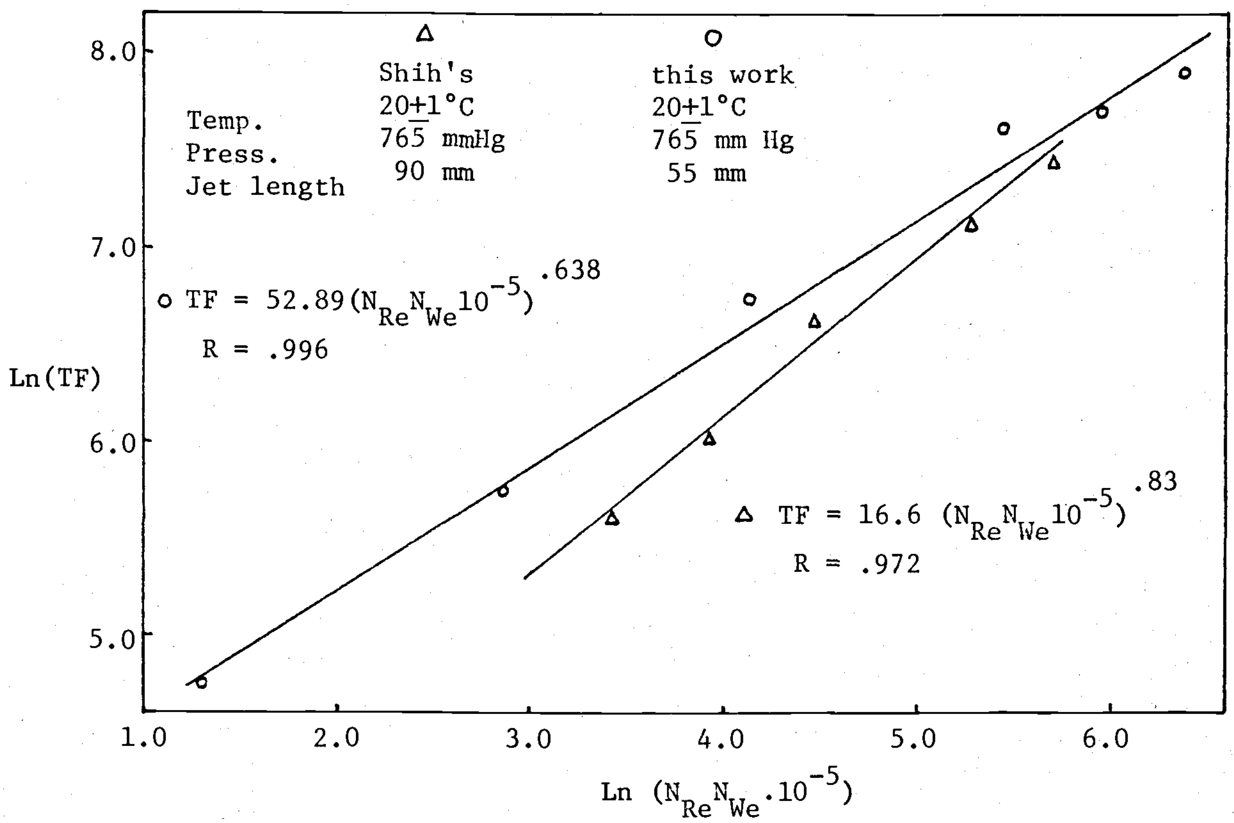

Figure IV-2. Comparison between Shih's correlation and correlation of this work.

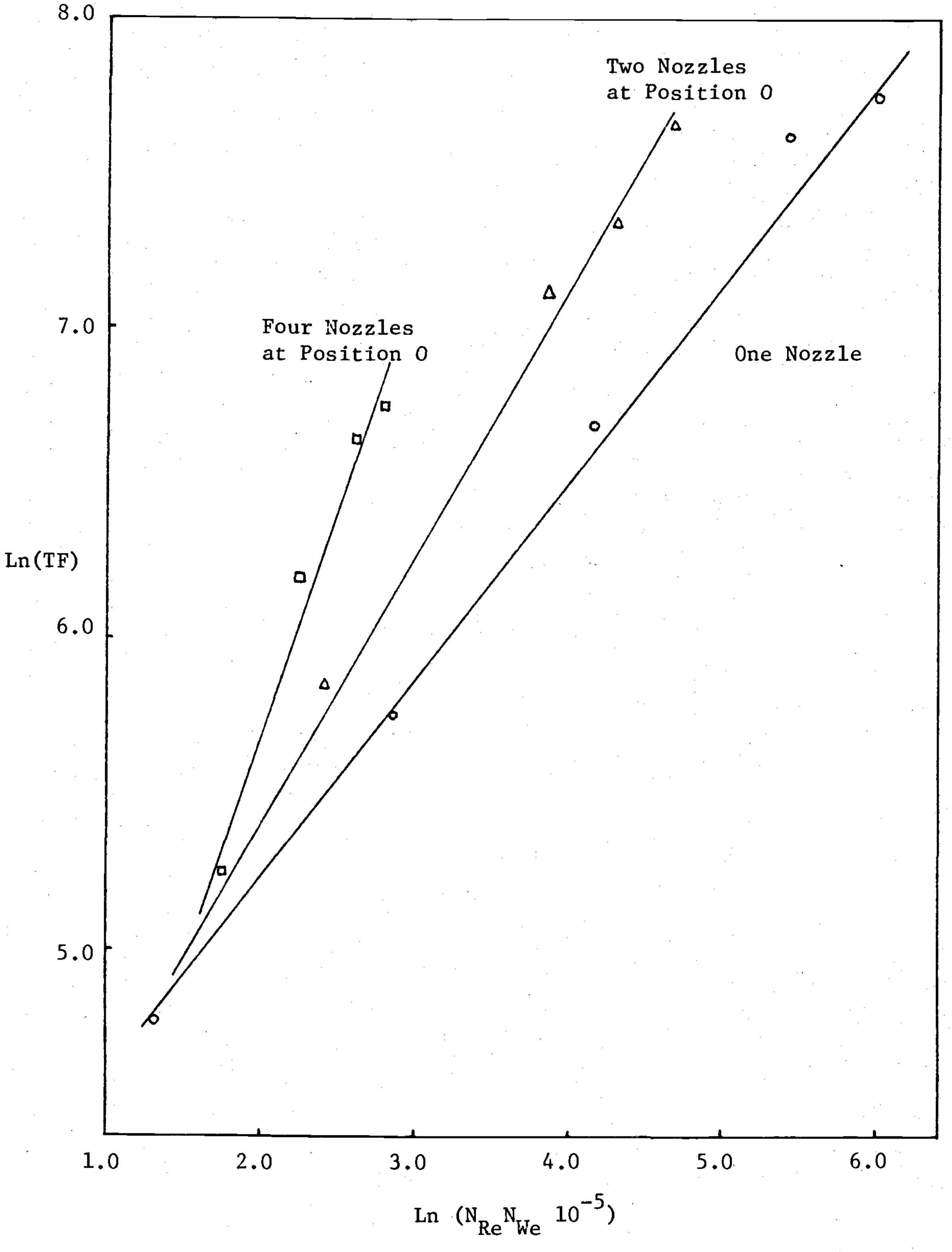

Figure IV-3. Comparison of TF's with different number of nozzles.

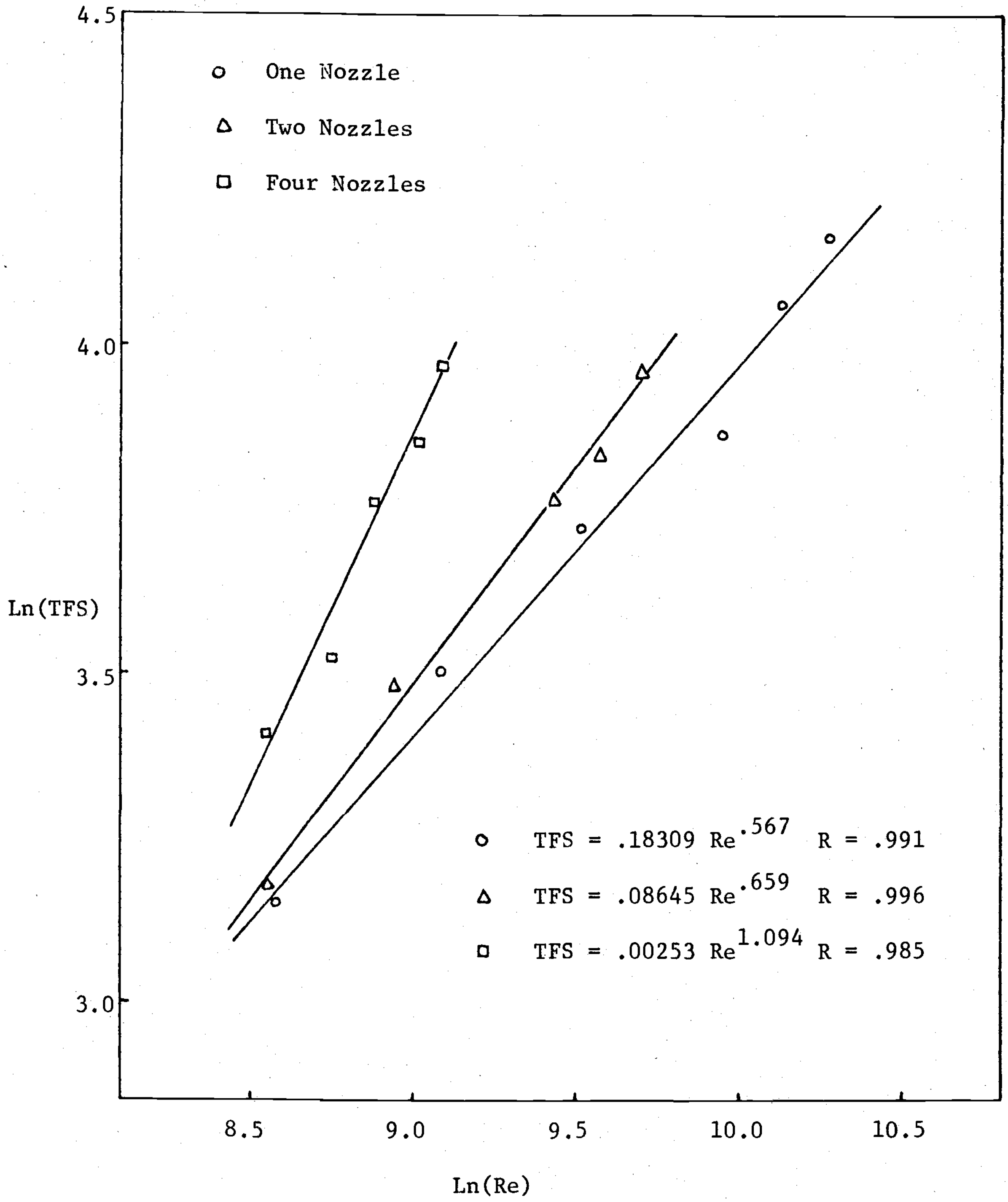

Figure IV-4. Comparison of TFS's with different number of nozzles.

limitation of the quantity of water which could be pumped through the system, the experiments involving the four nozzles were done within a short range of $N_{Re} \cdot N_{We}$; this might be responsible for some inconsistency on the results of four nozzles. Further study with a larger capacity rotameter and a more powerful pump is desirable. However, the data indicated also that higher mass transfer rates occurred as the number of nozzle increased.

It was also found that the surface absorption mass transfer rates increased as the number of nozzles increased. However, Figure IV-4 predicts that the transfer factor for surface absorption,TFS,did not increase as much as the amount of kinetic energy input even at the high Reynolds number, N_{Re} of 16000.

Another investigation was done to verify how the arrangement of the same number of nozzles influenced the mass transfer rates. The results of these experiments, using four different positions with two nozzles, are illustrated from Figure IV-5 to Figure IV-8. At position O, where the distance between the points of impacts is designated Z, there was no noticeable interactions between the bubbles entrained by the streams flowing from the neighboring nozzle appeared. Apparently, no interactions were observed with position A. However, when the jets were at position B, where the distance between two nozzles was Z/4, the bubbles at the boundary of two bubble cones were observed to mix together and to rise simultaneously to the surface of the pool. When the impact point of the nozzles was at position C, where the distance was Z/8, a larger amount of bubbles were found to intermix. Under this condition, the bubbles

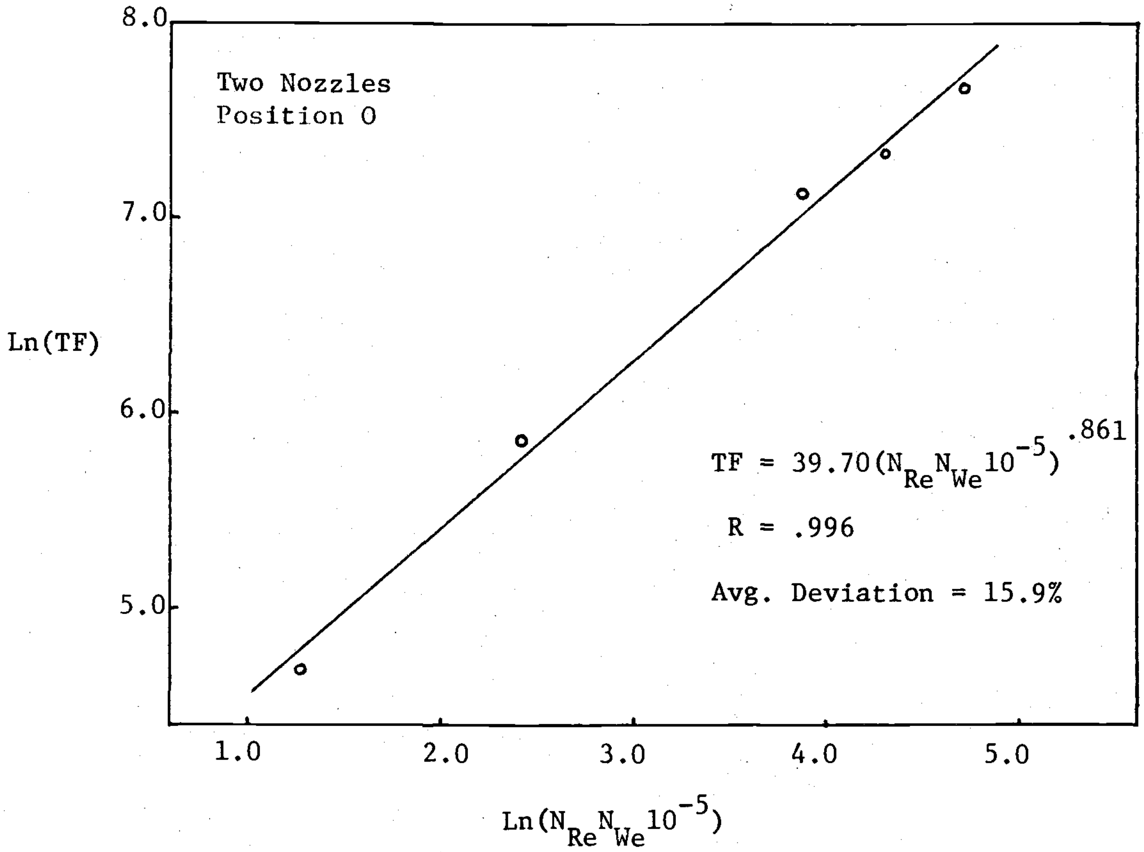

Figure IV-5. TF with two nozzles at position O.

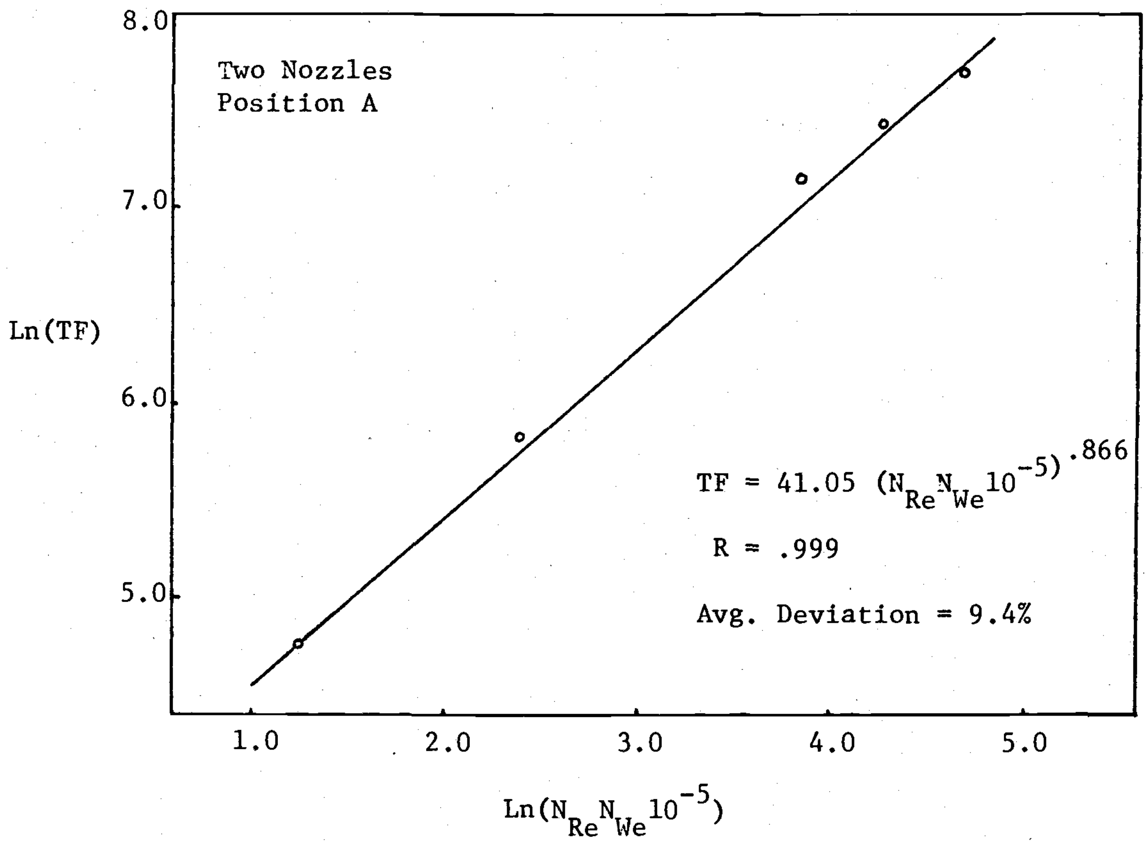

Figure IV-6. TF with two nozzles at position A

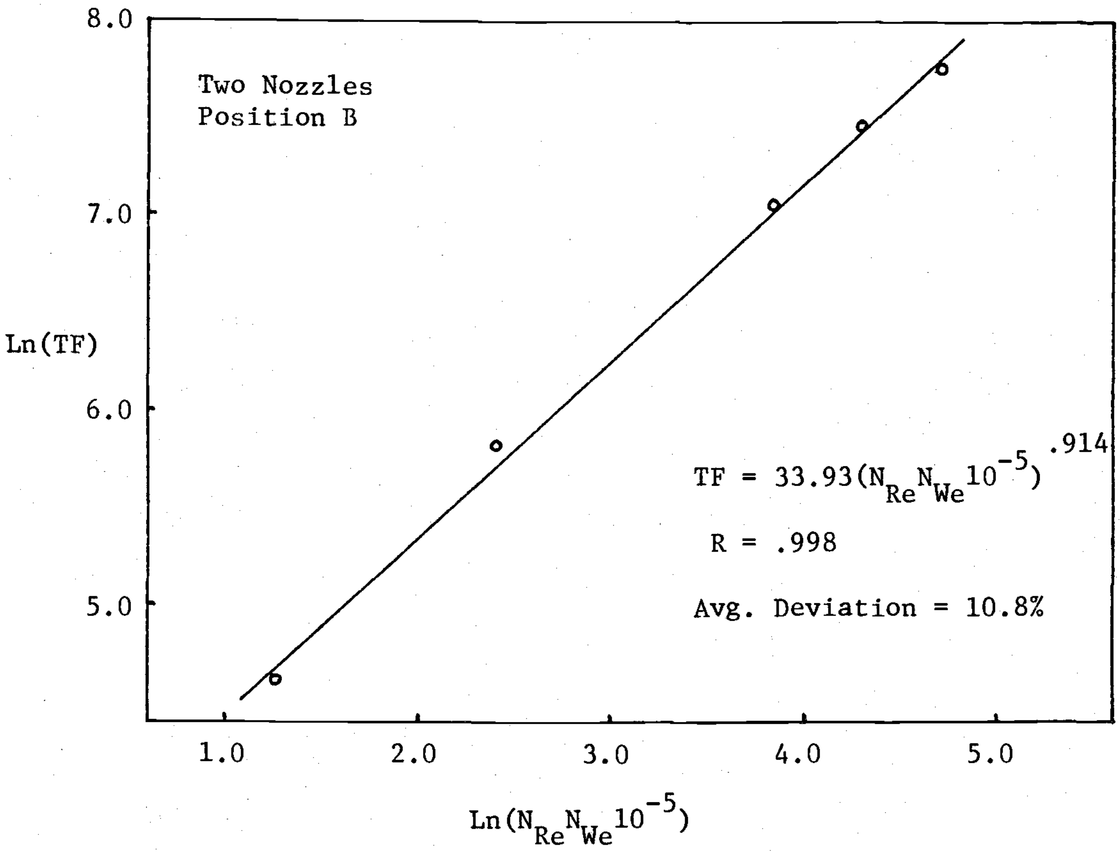

Figure IV-7. TF with two nozzles at Position B

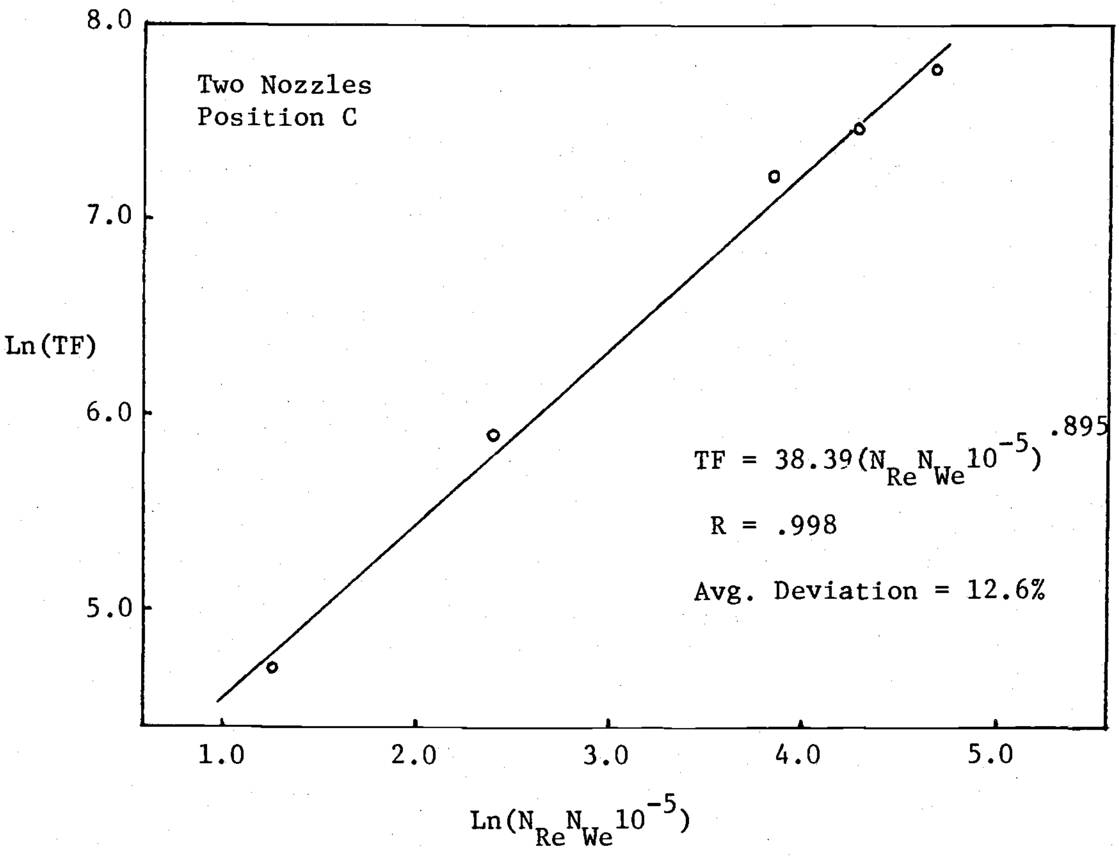

Figure IV-8. TF with two nozzles at position C

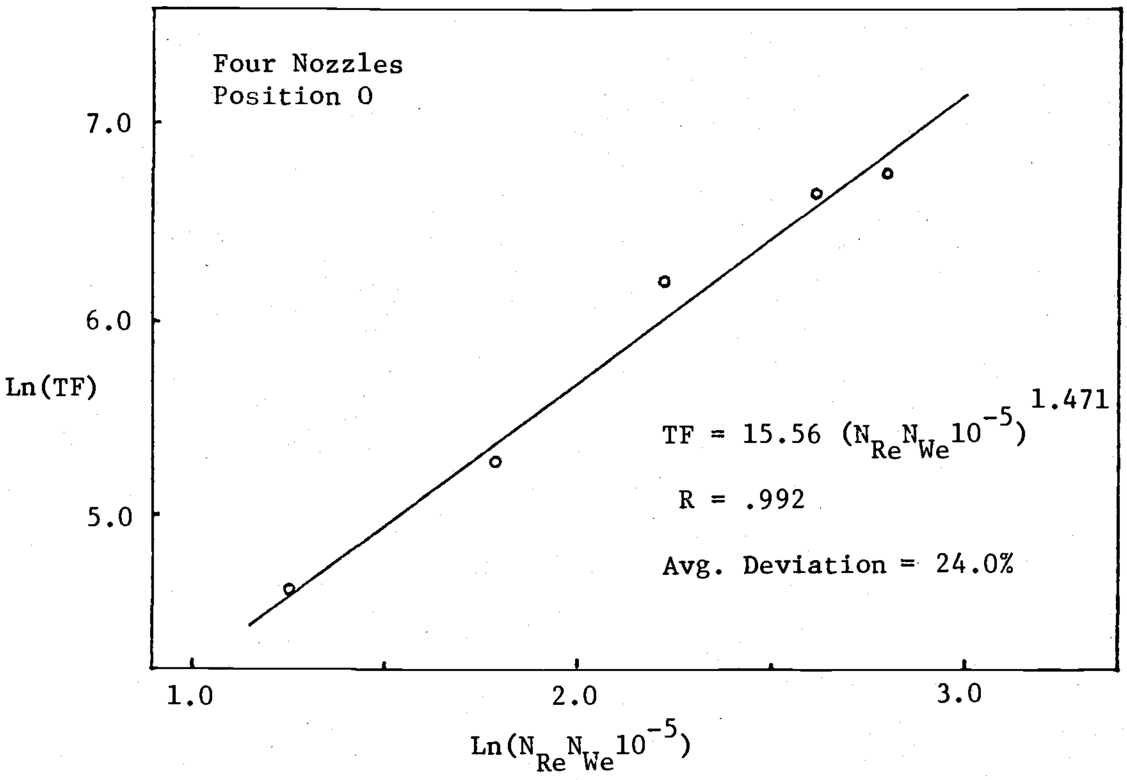

Figure IV-9. TF with four nozzles at position O

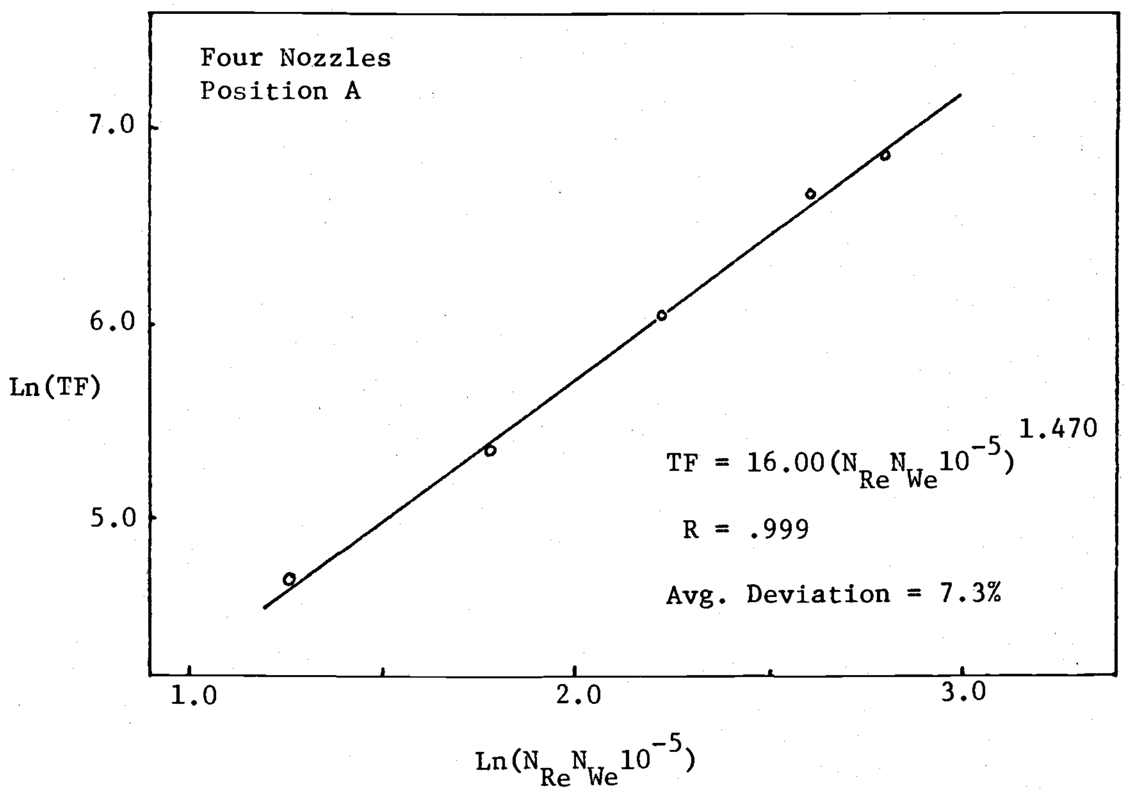

Figure IV-10. TF with four nozzles at position A

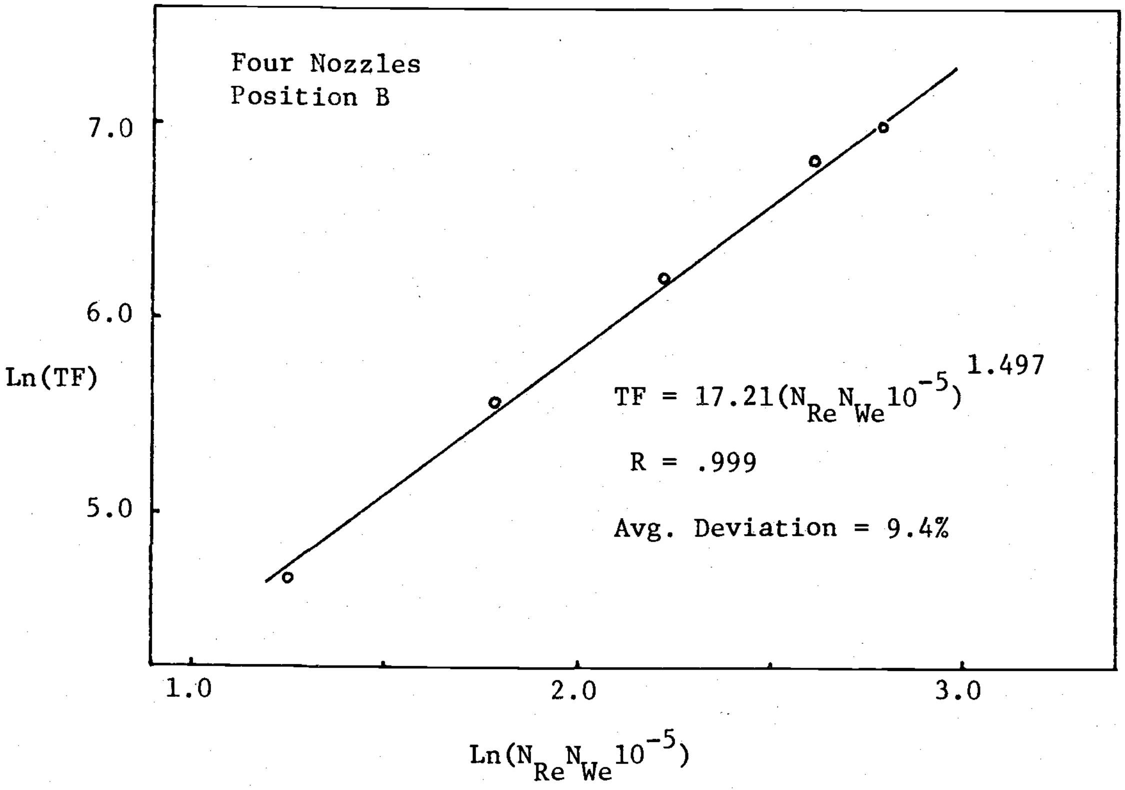

Figure IV-11. TF with four nozzles at position B

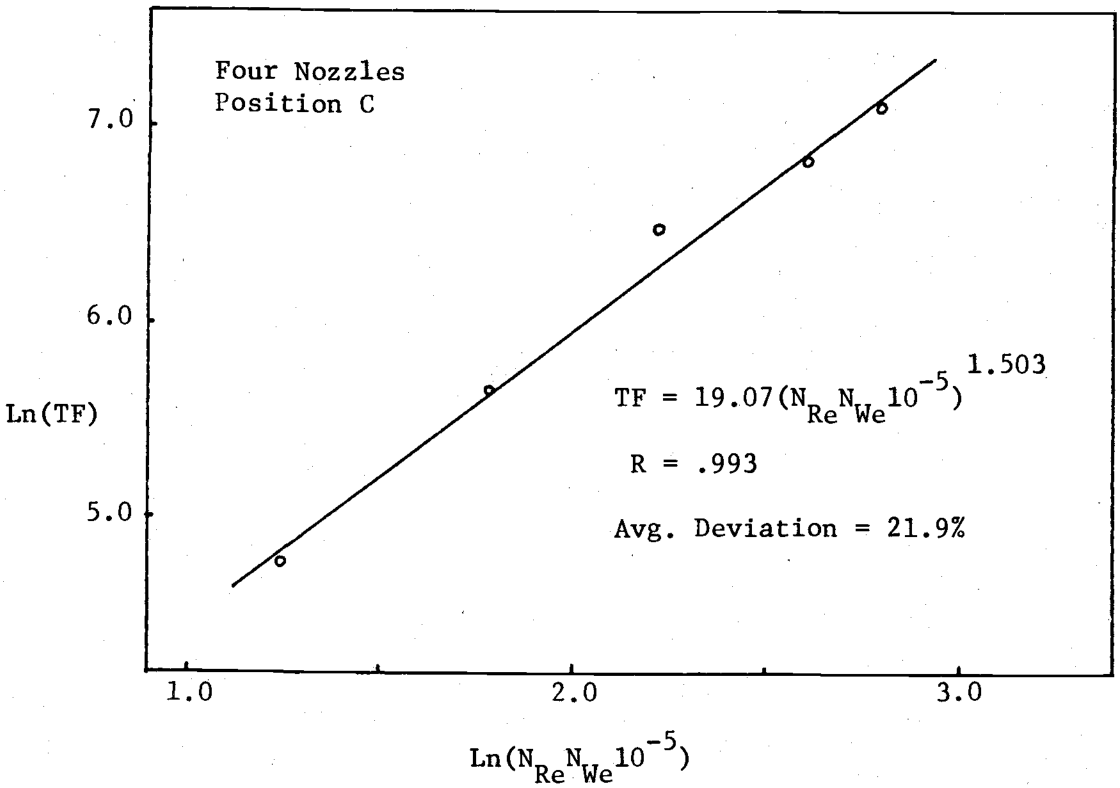

Figure IV-12. TF with four nozzles at position C

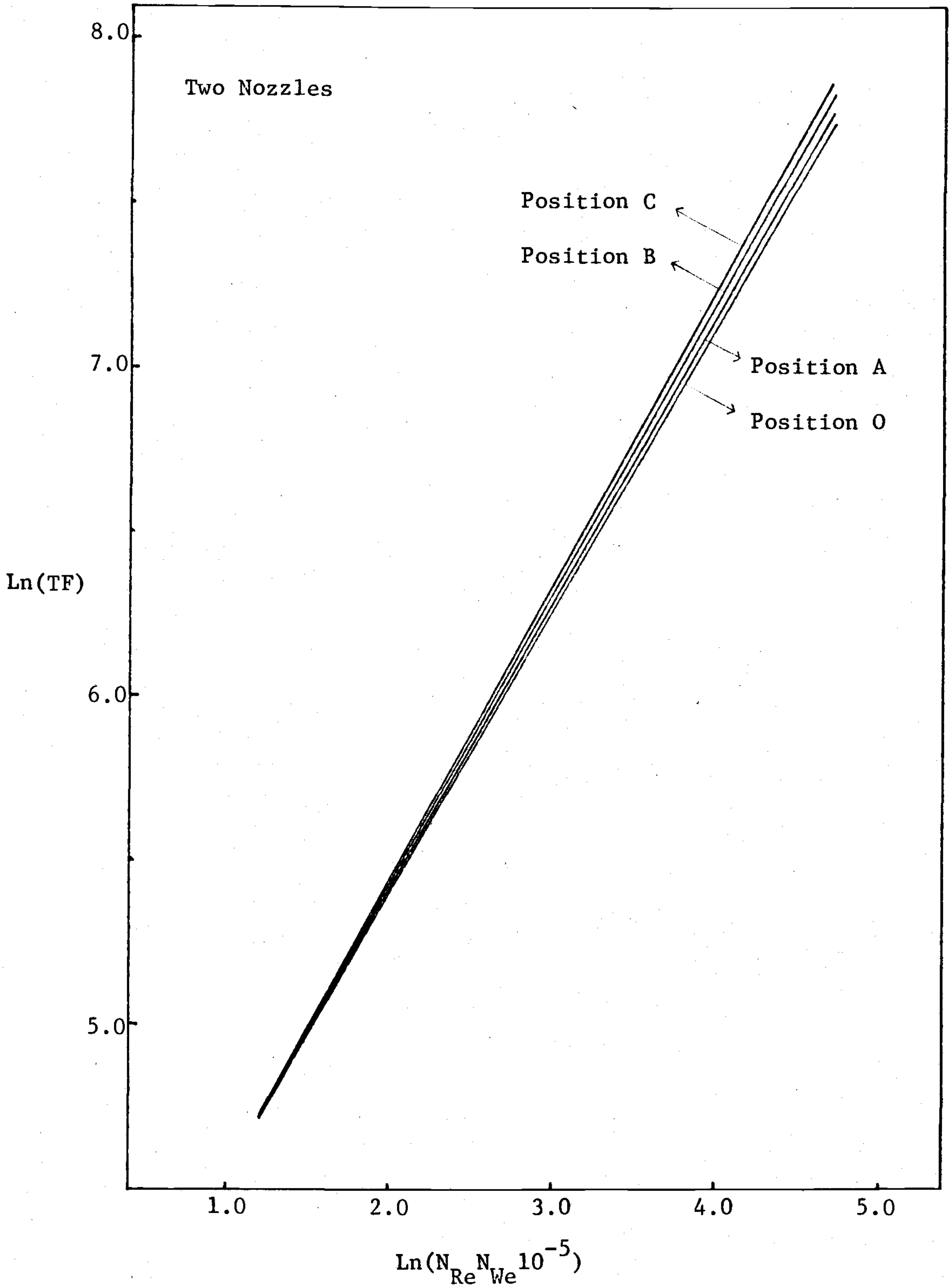

Figure IV-13. Comparison of TF's at different position of two nozzles.

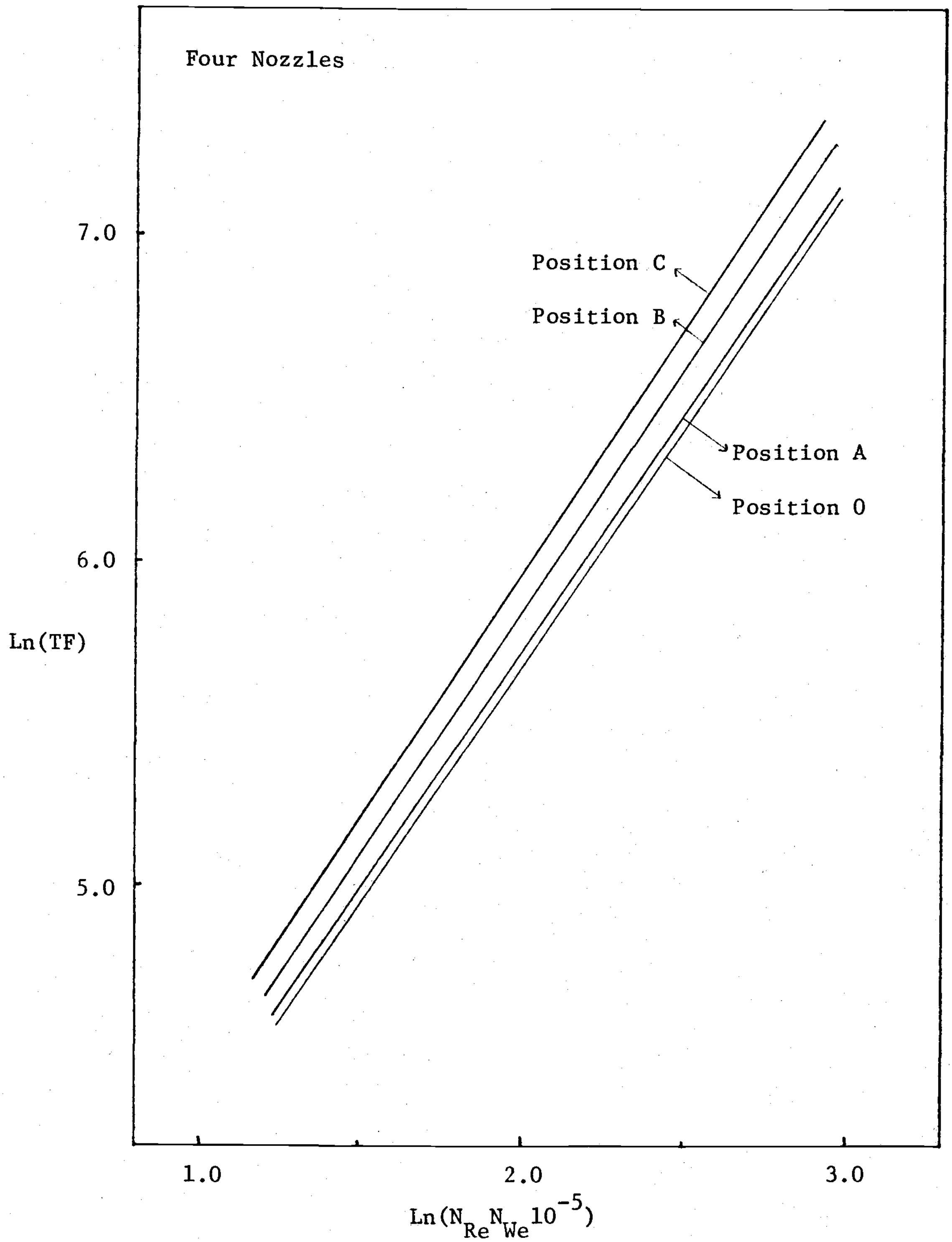

Figure IV-14. Comparison of TF's at different position of four nozzles entrained by one jet stream seemed to prevent the bubbles entrained by another jet stream from rising to the pool surface; accordingly these bubbles were forced to stay longer in the pool than the bubbles formed with the jets located at position B. The same phenomena were observed in the experiments using four nozzles. The results are shown in Figure IV-9 to IV-12. Unfortunately, when the multiple nozzles were used the turbulence was so vigorous, and the bubbles rose so rapidly that it was impossible to see whether the bubbles at the boundaries of each bubble cone combined with each other to make bigger bubbles. The mass transfer rate, which resulted from the possible interaction between the bubbles, turned out to be slightly higher than the runs without any possible interactions. Figure IV-13 and IV-14 showed that the transfer factor TF increased as the distance between the jet streams became closer.

V. CONCLUSION

The conclusions from the study of entrained oxygen absorption by multiple plunging jet streams are:

1. The mass transfer factor TF was found to be proportional to the rate of kinetic energy supplied to the absorption pool by the jet streams which entrained the oxygen bubbles. The product of the jet Reynolds number N_{Re}, and the Weber number, N_{We}, represented the kinetic energy supplied.
2. The transfer factor TF was affected by the length of jet. As shorter jet lengths were employed, bubbles became finer and penetrated more deeply down to the bottom of the pool; this resulted in a slight increase in the mass transfer rate.
3. An increase in the number of jet streams resulted in an increase of the transfer factor TF. The value of TF tended to increase directly with the number of jet streams; in other words, it increased directly as the amount of input kinetic energy increased. This was especially true at the higher range of Reynolds number, but there was a smaller dependency at the lower range of Reynolds number.
4. The surface absorption rate, TFS, was also found to be related to the number of jet streams. Higher TFS values occurred as the number of jet streams increased. However, there was no direct relationship between TFS and the number of jet streams.

5. Higher transfer rates were found to occur when two jets were located closer to each other. When the bubble cones entrained by the jet streams were close enough to contact each other, there was intermixing of the bubbles, which resulted in an increase in the mass transfer factor, TF.

VI. RECOMMENDATIONS FOR FURTHER STUDY

1. The variation of the physical properties of liquid such as viscosity, and surface tension may have an effect on the transfer factor TF. Extended study based on these effects is desirable.

2. The geometry of jet stream turned out to be related to the mass transfer rate. Quantitative evaluation of the effect of jet length on TF should be studied.

3. More detailed study on the interaction between the bubbles, such as combination and hindrance will explain the phenomena precisely when the multiple nozzleswere used.

4. Application of this system to the chemical reactor is of great interest. It may be applied to the gas liquid contactor.

VII. BIBLIOGRAPHY

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APPENDICES

APPENDIX I

Experimental Code

Coding form of each run was

N - Z - xxxxx - yyyy - C

where,

N = The number of nozzles

Z = Distance between the nozzles

(Diagonal distance for four nozzles)

0 = Distance of z

A = Distance of z/2

B = Distance of z/4

C = Distance of z/8

* Z was skipped for one nozzle

xxxxx = N_{Re} of one jet stream

yyyy = N_{We} of one jet stream

C = Run purpose

S = Surface absorption

B = Entrained bubble and surface absorption

APPENDIX II

EQUIPMENT AND MATERIAL SPECIFICATION

Table II-1 Centrifugal pump.

Pump	
Mfgr.	Gorman-Rupp Co.
Model	81 1/2 E1 E3/4

Motor	
Mfgr.	General Electric Co.
Model	5K 43 GG 3266
Size	3/4 HP

Table II-2 Oxygen meter

Mfgr.	Yellow Springs Instrument Co.
Model	54 ARC

Table II-3 Material Specification

Oxygen	99.999% pure

Table II-4 Pool Volume Calibration

Pool depth, h (mm)	Pool volume, V (liter)
66	10
79.5	12
105.5	16
132	20
158	24
184.2	28
210.5	32
237	36
263.3	40
289.5	44
310.9	48

$V = (1.52479)(10^{-1}) \cdot h$
$R = .99987$

By interpolation
at $h = 300mm$,
$V = 45.7437$ liter

Table II-5 Calibration of Rotameter (Fischer & Porter Co. No. B5-27-10/70G)

Meter indication, P (%)	Flow rate, Q (liter/min.)
100	10.392
90	9.23
80	8.162
70	7.124
60	5.982
50	4.962
40	3.893
30	2.889
20	1.894
10	0.829

$Q = (1.056025)(10^{-1}) \cdot P - (2.77714)(10^{-1})$
$R = .99983$

Table II-6 Physcial Properties of Water at 1 atm (Ref.: Lange[5])

	Temperature (°C)		
	15.0	20.0	25.0
Density (gm/ml)	.999	.998	.997
Viscosity (centipoise)	1.1404	1.005	.8937
Surface tension (dynes/cm)	73.49	72.75	71.97
ρ / μ (Sec/cm^2)	87.60	99.30	111.56
$\rho / \sigma g_c$ (Sec^2/cm^3)	.01359	.01372	.01385

Table II-7 Solubility of oxygen in water exposed to water saturated by air (Ref.: Standard Method for the Examination of Water and Wastewater[7])

Temperature (°C)	Dissolved oxygen (mg/liter)
18	9.5
19	9.4
20	9.2
21	9.0
22	8.8

APPENDIX III

EXPERIMENTAL DATA

TABLE III- 1 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1- 5324- 71-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.62	.20247	8.73	.21679	8.81	.22721	8.98	.24934
B	8.68	.21028	8.75	.21940	8.89	.23763	9.01	.25325
C	8.68	.21028	8.70	.21289	8.87	.23502	8.95	.24544
D	8.69	.21159	8.72	.21549	8.80	.22591	8.91	.24023
AVERAGE		.20866		.21614		.23144		.24706
S.D.		.00361		.00235		.00499		.00482

TEMPERATURE : 19.75'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.53 8.58
AIR SATURATED DISTILLED WATER AVERAGE 8.537

TABLE III- 2 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1- 5324- 71-S

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	30. DATA1	30. DATA2	60. DATA1	60. DATA2	90. DATA1	90. DATA2
A	8.63	.20944	8.74	.22415	8.83	.23620	8.95	.25225
B	8.65	.21211	8.72	.22148	8.85	.23887	9.00	.25895
C	8.70	.21880	8.70	.21880	8.88	.24289	8.97	.25493
D	8.72	.22148	8.75	.22549	8.80	.23218	8.91	.24690
AVERAGE		.21546		.22248		.23754		.25326
S.D.		.00487		.00257		.00390		.00437

TEMPERATURE : 21.00'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.53 8.58
AIR SATURATED DISTILLED WATER AVERAGE 8.537

TABLE III- 3 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1- 8908- 198-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.70	.20969	8.96	.24414	9.12	.26534	9.31	.29051
B	8.75	.21632	9.00	.24944	9.20	.27593	9.40	.30243
C	8.70	.20969	8.85	.22956	9.15	.26931	9.27	.28521
D	8.73	.21367	8.95	.24281	9.15	.26931	9.42	.30508
AVERAGE		.21234		.24149		.26997		.29581
S.D.		.00281		.00732		.00381		.00822

TEMPERATURE : 20.55´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.65 8.60 8.55
AIR SATURATED DISTILLED WATER AVERAGE 8.600

TABLE III- 4 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1- 8908- 198-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.72	.21072	8.90	.23438	8.95	.24096	9.10	.26068
B	8.68	.20546	8.88	.23175	8.95	.24096	9.11	.26199
C	8.75	.21466	8.89	.23307	9.02	.25016	9.04	.25279
D	8.72	.21072	8.80	.22124	9.00	.24753	9.08	.25805
AVERAGE		.21039		.23011		.24490		.25838
S.D.		.00327		.00521		.00405		.00352

TEMPERATURE : 20.20´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.65 8.60 8.55
AIR SATURATED DISTILLED WATER AVERAGE 8.600

TABLE III- 5 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-13687- 466-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.62	.20546	9.40	.30779	9.70	.34715	10.05	.39306
B	8.80	.22908	9.40	.30779	9.82	.36289	10.10	.39962
C	8.70	.21596	9.44	.31304	9.95	.37994	10.22	.41536
D	8.71	.21727	9.42	.31041	9.85	.36682	10.10	.39962
AVERAGE		.21694		.30976		.36420		.40192
S.D.		.00837		.00218		.01170		.00821

TEMPERATURE : 20.10′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.47 8.60 8.50
AIR SATURATED DISTILLED WATER AVERAGE 8.523

TABLE III- 6 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-13687- 466-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.71	.22162	8.80	.23366	8.97	.25641	9.21	.28852
B	8.70	.22028	8.90	.24704	9.00	.26042	9.12	.27648
C	8.80	.23366	8.95	.25373	9.07	.26979	9.10	.27380
D	8.65	.21359	8.88	.24436	9.10	.27380	9.20	.28718
AVERAGE		.22229		.24470		.26511		.28150
S.D.		.00724		.00723		.00699		.00644

TEMPERATURE : 21.00′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.47 8.60 8.50
AIR SATURATED DISTILLED WATER AVERAGE 8.523

TABLE III- 7 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-21044-1103-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.81	.21725	10.08	.38349	10.75	.47120	11.82	.61126
B	8.75	.20940	10.20	.39920	10.88	.48822	11.85	.61519
C	8.76	.21071	10.15	.39266	10.65	.45811	11.80	.60864
D	8.75	.20940	10.00	.37302	10.70	.46465	11.75	.60210
AVERAGE		.21169		.38709		.47054		.60930
S.D.		.00326		.00986		.01120		.00476

TEMPERATURE : 20.00´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.60 8.65 8.67
AIR SATURATED DISTILLED WATER AVERAGE 8.640

TABLE III- 8 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-21044-1103-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.81	.21820	9.15	.26290	9.28	.27999	9.42	.29840
B	8.88	.22740	9.00	.24318	9.30	.28262	9.35	.28919
C	8.85	.22346	9.08	.25370	9.29	.28131	9.37	.29182
D	9.00	.24318	9.05	.24975	9.20	.26947	9.40	.29577
AVERAGE		.22806		.25238		.27835		.29380
S.D.		.00932		.00714		.00521		.00354

TEMPERATURE : 20.20´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.60 8.65 8.67
AIR SATURATED DISTILLED WATER AVERAGE 8.640

TABLE III- 9 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-24837-1536-B

SAMPLE POSITION	TIME (MIN.)							
	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.99	.22749	10.66	.44753	11.26	.52659	12.00	.62409
B	8.95	.22222	10.53	.43040	11.70	.58456	11.75	.59115
C	9.02	.23144	10.52	.42908	11.65	.57797	11.80	.59774
D	8.95	.22222	10.40	.41327	11.50	.55821	11.90	.61091
AVERAGE		.22584		.43007		.56183		.60597
S.D.		.00388		.01213		.02254		.01265

TEMPERATURE : 20.30'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.77 8.76 8.80
AIR SATURATED DISTILLED WATER AVERAGE 8.777

TABLE III-10 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-24837-1536-S

SAMPLE POSITION	TIME (MIN.)							
	0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	9.05	.23437	9.34	.27241	9.48	.29078	9.80	.33276
B	9.05	.23437	9.30	.26717	9.53	.29734	9.73	.32358
C	9.07	.23699	9.27	.26323	9.45	.28685	9.60	.30652
D	9.10	.24093	9.20	.25405	9.51	.29472	9.66	.31439
AVERAGE		.23667		.26422		.29242		.31931
S.D.		.00268		.00671		.00398		.00983

TEMPERATURE : 20.10'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.77 8.76 8.80
AIR SATURATED DISTILLED WATER AVERAGE 8.777

TABLE III-11 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-28819-2068-B

SAMPLE POSITION	TIME (MIN.)							
	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.65	.23753	10.60	.49559	11.55	.62131	12.10	.69410
B	8.70	.24414	10.70	.50882	11.60	.62793	11.80	.65440
C	8.60	.23091	10.80	.52206	11.40	.60146	11.90	.66763
D	8.70	.24414	10.80	.52206	11.41	.60278	11.80	.65440
AVERAGE		.23918		.51213		.61337		.66763
S.D.		.00549		.01097		.01150		.01621

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.20 8.30 8.35
AIR SATURATED DISTILLED WATER AVERAGE 8.283

TABLE III-12 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 1-28819-2068-S

SAMPLE POSITION	TIME (MIN.)							
	0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.70	.24414	8.90	.27061	9.10	.29708	9.45	.34340
B	8.80	.25738	9.10	.29708	9.20	.31031	9.35	.33016
C	8.80	.25738	8.90	.27061	9.17	.30634	9.45	.34340
D	8.65	.23753	9.00	.28385	9.25	.31693	9.37	.33281
AVERAGE		.24911		.28054		.30767		.33744
S.D.		.00860		.01097		.00719		.00603

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.20 8.30 8.35
AIR SATURATED DISTILLED WATER AVERAGE 8.283

TABLE III-13 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0- 5251- 69-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.75	.21389	8.85	.22712	8.90	.23374	8.95	.24036
B	8.78	.21786	8.80	.22050	8.91	.23506	9.00	.24697
C	8.70	.20727	8.83	.22448	8.90	.23374	8.98	.24433
D	8.65	.20065	8.78	.21786	8.85	.22712	8.95	.24036
AVERAGE		.20992		.22249		.23242		.24300
S.D.		.00655		.00356		.00310		.00281

TEMPERATURE : 20.50'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.64 8.62 8.60
AIR SATURATED DISTILLED WATER AVERAGE 8.620

TABLE III-14 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0- 5251- 69-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.85	.22712	8.92	.23639	9.01	.24830	9.10	.26021
B	8.81	.22183	8.90	.23374	9.00	.24697	9.09	.25888
C	8.82	.22315	8.96	.24168	9.08	.25756	9.12	.26285
D	8.90	.23374	8.95	.24036	9.03	.25094	9.13	.26418
AVERAGE		.22646		.23804		.25094		.26153
S.D.		.00463		.00316		.00408		.00209

TEMPERATURE : 20.50'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.64 8.62 8.60
AIR SATURATED DISTILLED WATER AVERAGE 8.620

TABLE III-15 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0- 7640- 145-B

SAMPLE POSITION	TIME (MIN.)							
	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.96	.21072	9.20	.24227	9.40	.26857	9.70	.30801
B	9.00	.21598	9.30	.25542	9.43	.27251	9.66	.30275
C	8.92	.20546	9.17	.23833	9.49	.28040	9.67	.30406
D	9.00	.21598	9.27	.25148	9.50	.28171	9.70	.30801
AVERAGE		.21203		.24687		.27580		.30571
S.D.		.00436		.00686		.00546		.00235

TEMPERATURE : 20.20′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.87 8.90 8.90
AIR SATURATED DISTILLED WATER AVERAGE 8.890

TABLE III-16 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0- 7640- 145-S

SAMPLE POSITION	TIME (MIN.)							
	0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.91	.20594	9.10	.23114	9.23	.24839	9.32	.26032
B	8.98	.21523	9.15	.23778	9.21	.24573	9.29	.25634
C	9.00	.21788	9.08	.22849	9.25	.25104	9.32	.26032
D	8.99	.21655	9.20	.24441	9.24	.24971	9.33	.26165
AVERAGE		.21390		.23545		.24872		.25966
S.D.		.00469		.00618		.00196		.00199

TEMPERATURE : 20.60′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.87 8.90 8.90
AIR SATURATED DISTILLED WATER AVERAGE 8.890

TABLE III-17 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0-12419- 384-B

SAMPLE POSITION	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	9.05	.21566	9.85	.32084	10.50	.40630	11.10	.48518
B	9.02	.21172	9.80	.31426	10.45	.39972	11.10	.48518
C	8.95	.20251	9.75	.30769	10.39	.39183	11.03	.47598
D	9.03	.21303	9.88	.32478	10.55	.41287	11.05	.47861
AVERAGE		.21073		.31689		.40268		.48124
S.D.		.00495		.00651		.00780		.00405

TIME (MIN.)

TEMPERATURE : 20.20'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.95 8.97 8.94
AIR SATURATED DISTILLED WATER AVERAGE 8.953

TABLE III-18 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0-12419- 384-S

SAMPLE POSITION	0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	9.10	.22127	9.45	.26708	9.52	.27625	9.72	.30243
B	9.18	.23174	9.43	.26447	9.48	.27101	9.60	.28672
C	9.20	.23436	9.35	.25399	9.48	.27101	9.58	.28410
D	9.25	.24090	9.35	.25399	9.54	.27886	9.65	.29326
AVERAGE		.23207		.25988		.27428		.29163
S.D.		.00707		.00596		.00340		.00707

TIME (MIN.)

TEMPERATURE : 20.00'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.95 8.97 8.94
AIR SATURATED DISTILLED WATER AVERAGE 8.953

TABLE III-19 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0-14410- 517-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	DATA2	5. DATA1	DATA2	10. DATA1	DATA2	15. DATA1	DATA2
A	9.55	.25706	10.52	.38404	11.29	.48483	11.89	.56337
B	9.49	.24921	10.52	.38404	11.25	.47959	11.72	.54112
C	9.52	.25314	10.50	.38142	11.39	.49792	11.78	.54897
D	9.50	.25052	10.39	.36702	11.12	.46258	11.72	.54112
AVERAGE		.25248		.37913		.48123		.54864
S.D.		.00300		.00707		.01267		.00909

TEMPERATURE : 20.00′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 9.20 9.15 9.15
AIR SATURATED DISTILLED WATER AVERAGE 9.167

TABLE III-20 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0-14410- 517-S

SAMPLE POSITION	TIME (MIN.) 0. DATA1	DATA2	30. DATA1	DATA2	60. DATA1	DATA2	90. DATA1	DATA2
A	9.39	.23561	9.65	.26957	9.85	.29569	10.09	.32704
B	9.45	.24344	9.62	.26565	9.75	.28263	10.05	.32181
C	9.59	.26173	9.60	.26304	9.85	.29569	9.95	.30875
D	9.55	.25650	9.65	.26957	9.78	.28655	10.00	.31528
AVERAGE		.24932		.26695		.29014		.31822
S.D.		.01035		.00277		.00572		.00687

TEMPERATURE : 19.90′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 9.20 9.15 9.15
AIR SATURATED DISTILLED WATER AVERAGE 9.167

TABLE III-21 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0-16401- 670-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	9.22	.22627	10.62	.40993	11.55	.53194	12.35	.63689
B	9.28	.23414	10.75	.42699	11.42	.51488	12.08	.60147
C	9.22	.22627	10.58	.40469	11.28	.49652	12.29	.62902
D	9.23	.22759	10.59	.40600	11.15	.47946	12.22	.61983
AVERAGE		.22857		.41190		.50570		.62180
S.D.		.00326		.00892		.01966		.01320

TEMPERATURE : 20.10′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 9.00 9.10 9.07
AIR SATURATED DISTILLED WATER AVERAGE 9.057

TABLE III-22 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-0-16401- 670-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	9.29	.23753	9.45	.25870	9.65	.28517	9.84	.31031
B	9.20	.22562	9.47	.26135	9.65	.28517	9.85	.31164
C	9.25	.23223	9.40	.25208	9.64	.28385	9.85	.31164
D	9.30	.23885	9.45	.25870	9.60	.27855	9.80	.30502
AVERAGE		.23356		.25771		.28318		.30965
S.D.		.00521		.00342		.00273		.00273

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 9.00 9.10 9.07
AIR SATURATED DISTILLED WATER AVERAGE 9.057

TABLE III-23 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-A- 5251- 69-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.70	.20172	8.78	.21228	8.89	.22681	8.96	.23605
B	8.68	.19908	8.80	.21492	8.86	.22284	8.95	.23473
C	8.65	.19511	8.81	.21624	8.90	.22813	8.97	.23737
D	8.71	.20304	8.80	.21492	8.85	.22152	8.95	.23473
AVERAGE		.19974		.21459		.22483		.23572
S.D.		.00303		.00144		.00272		.00109

TEMPERATURE : 20.40′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.68 8.62 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.667

TABLE III-24 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-A- 7640- 145-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.83	.21817	9.00	.24054	9.30	.28003	9.48	.30372
B	8.75	.20764	9.02	.24317	9.25	.27344	9.45	.29977
C	8.80	.21422	8.95	.23396	9.20	.26686	9.50	.30635
D	8.80	.21422	9.00	.24054	9.30	.28003	9.51	.30766
AVERAGE		.21356		.23955		.27509		.30437
S.D.		.00378		.00340		.00546		.00302

TEMPERATURE : 20.25′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.68 8.62 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.667

TABLE III-25 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-A-12419- 384-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.60	.21359	9.20	.29335	10.05	.40633	10.85	.51267
B	8.51	.20163	9.30	.30664	10.05	.40633	10.75	.49938
C	8.54	.20562	9.40	.31993	10.00	.39969	10.60	.47944
D	8.70	.22689	9.25	.30000	9.90	.38640	10.80	.50603
AVERAGE		.21193		.30498		.39969		.49938
S.D.		.00965		.00983		.00814		.01243

TEMPERATURE : 20.70'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.45 8.50 8.40
AIR SATURATED DISTILLED WATER AVERAGE 8.450

TABLE III-26 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-A-14410- 517-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.70	.21394	9.60	.33150	10.60	.46211	11.00	.51436
B	8.70	.21394	9.70	.34456	10.80	.48824	11.40	.56661
C	8.80	.22700	9.90	.37068	10.57	.45820	11.40	.56661
D	8.68	.21133	9.80	.35762	10.70	.47518	11.41	.56791
AVERAGE		.21655		.35109		.47093		.55387
S.D.		.00613		.01460		.01181		.02282

TEMPERATURE : 19.90'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.60 8.50
AIR SATURATED DISTILLED WATER AVERAGE 8.533

TABLE III-27 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-A-16401- 670-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	DATA2	5. DATA1	DATA2	10. DATA1	DATA2	15. DATA1	DATA2
A	8.85	.23404	10.10	.39767	11.20	.54166	12.00	.64638
B	8.73	.21833	10.00	.38458	11.00	.51548	11.85	.62674
C	8.79	.22619	10.15	.40421	11.20	.54166	11.80	.62020
D	8.80	.22750	9.95	.37803	11.10	.52857	12.00	.64638
AVERAGE		.22652		.39112		.53184		.63493
S.D.		.00558		.01035		.01085		.01169

TEMPERATURE : 20.00´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.60 8.50
AIR SATURATED DISTILLED WATER AVERAGE 8.533

TABLE III-28 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-B- 5251- 69-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	DATA2	5. DATA1	DATA2	10. DATA1	DATA2	15. DATA1	DATA2
A	8.55	.19417	8.62	.20337	8.71	.21521	8.80	.22704
B	8.57	.19680	8.61	.20206	8.75	.22047	8.85	.23361
C	8.59	.19943	8.65	.20732	8.75	.22047	8.85	.23361
D	8.56	.19549	8.62	.20337	8.69	.21258	8.81	.22835
AVERAGE		.19647		.20403		.21718		.23066
S.D.		.00194		.00197		.00342		.00299

TEMPERATURE : 20.20´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.60 8.54
AIR SATURATED DISTILLED WATER AVERAGE 8.547

TABLE III-29 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-B- 7640- 145-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.75	.21999	8.85	.23310	9.15	.27246	9.45	.31182
B	8.68	.21080	8.90	.23966	9.18	.27640	9.35	.29870
C	8.70	.21343	8.89	.23835	9.25	.28558	9.47	.31444
D	8.80	.22654	8.92	.24229	9.19	.27771	9.45	.31182
AVERAGE		.21769		.23835		.27804		.30919
S.D.		.00611		.00334		.00476		.00615

TEMPERATURE : 20.10′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.60 8.54
AIR SATURATED DISTILLED WATER AVERAGE 8.547

TABLE III-30 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-B-12419- 384-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.63	.21376	9.15	.28212	10.00	.39387	10.75	.49248
B	8.57	.20587	9.35	.30842	10.15	.41359	10.65	.47933
C	8.61	.21113	9.55	.33471	9.95	.38730	10.68	.48328
D	8.69	.22164	9.45	.32156	10.15	.41359	10.80	.49905
AVERAGE		.21310		.31170		.40209		.48853
S.D.		.00569		.01945		.01174		.00772

TEMPERATURE : 20.20′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.52 8.40 8.47
AIR SATURATED DISTILLED WATER AVERAGE 8.463

TABLE III-31 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-B-14410- 517-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.62	.21384	9.60	.34354	10.35	.44279	11.40	.58175
B	8.60	.21120	9.70	.35677	10.35	.44279	11.20	.55528
C	8.53	.20193	9.65	.35015	10.60	.47587	11.10	.54204
D	8.45	.19134	9.62	.34618	10.55	.46926	11.15	.54866
AVERAGE		.20458		.34916		.45768		.55693
S.D.		.00883		.00498		.01507		.01507

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.52 8.40 8.47
AIR SATURATED DISTILLED WATER AVERAGE 8.463

TABLE III-32 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-B-16401- 670-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.92	.23127	10.00	.37420	11.20	.53301	12.25	.67197
B	8.80	.21539	10.00	.37420	11.15	.52639	11.95	.63226
C	8.80	.21539	10.40	.42714	11.35	.55286	11.90	.62565
D	8.90	.22863	10.40	.42714	11.20	.53301	11.95	.63226
AVERAGE		.22267		.40067		.53632		.64053
S.D.		.00734		.02647		.00993		.01835

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.60 8.70 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.667

TABLE III-33 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-C- 5251- 69-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.70	.20211	8.80	.21513	8.89	.22685	8.95	.23466
B	8.71	.20342	8.81	.21644	8.90	.22815	9.00	.24117
C	8.73	.20602	8.78	.21253	8.86	.22295	8.97	.23727
D	8.70	.20211	8.78	.21253	8.90	.22815	8.99	.23987
AVERAGE		.20342		.21416		.22653		.23824
S.D.		.00159		.00169		.00213		.00250

TEMPERATURE : 19.75´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.66 8.65 8.60
AIR SATURATED DISTILLED WATER AVERAGE 8.637

TABLE III-34 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-C- 7640- 145-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.82	.22133	9.14	.26367	9.38	.29544	9.53	.31529
B	8.80	.21868	9.15	.26500	9.35	.29147	9.55	.31793
C	8.87	.22794	9.12	.26103	9.30	.28485	9.45	.30470
D	8.80	.21868	9.17	.26765	9.32	.28750	9.49	.30999
AVERAGE		.22166		.26434		.28981		.31198
S.D.		.00379		.00239		.00401		.00508

TEMPERATURE : 20.50´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.66 8.65 8.60
AIR SATURATED DISTILLED WATER AVERAGE 8.637

TABLE III-35 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-C-12419- 384-B

SAMPLE POSITION	TIME (MIN.)							
	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.50	.22461	9.10	.30402	10.25	.45621	10.55	.49591
B	8.51	.22594	9.27	.32651	10.10	.43636	10.50	.48929
C	8.48	.22197	9.41	.34504	10.10	.43636	10.55	.49591
D	8.54	.22991	9.33	.33445	10.05	.42974	10.75	.52238
AVERAGE		.22560		.32751		.43966		.50087
S.D.		.00287		.01507		.00993		.01271

TEMPERATURE : 20.50'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.20 8.21 8.25
AIR SATURATED DISTILLED WATER AVERAGE 8.220

TABLE III-36 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-C-14410- 517-B

SAMPLE POSITION	TIME (MIN.)							
	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.82	.23180	10.05	.39476	10.70	.48088	11.40	.57361
B	8.79	.22783	9.95	.38151	10.80	.49412	11.35	.56699
C	8.65	.20928	9.75	.35501	10.70	.48088	11.40	.57361
D	8.85	.23578	10.00	.38814	10.65	.47425	11.20	.54712
AVERAGE		.22617		.37986		.48253		.56533
S.D.		.01015		.01509		.00722		.01086

TEMPERATURE : 20.55'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.55 8.58
AIR SATURATED DISTILLED WATER AVERAGE 8.543

TABLE III-37 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 2-C-16401- 670-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.60	.20310	10.25	.42219	11.10	.53505	12.05	.66118
B	8.60	.20310	10.30	.42882	11.20	.54832	12.00	.65455
C	8.75	.22302	10.20	.41555	11.05	.52841	11.90	.64127
D	8.80	.22966	10.00	.38899	11.05	.52841	11.92	.64392
AVERAGE		.21472		.41389		.53505		.65023
S.D.		.01185		.01512		.00813		.00804

TEMPERATURE : 20.65'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.55 8.58
AIR SATURATED DISTILLED WATER AVERAGE 8.543

TABLE III-38 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-O- 5214- 68-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.85	.20814	8.90	.21476	8.97	.22402	9.10	.24122
B	8.80	.20152	8.87	.21078	8.95	.22137	9.05	.23461
C	8.78	.19887	8.83	.20549	8.98	.22534	9.07	.23725
D	8.78	.19887	8.85	.20814	8.95	.22137	9.05	.23461
AVERAGE		.20185		.20979		.22303		.23692
S.D.		.00379		.00342		.00172		.00271

TEMPERATURE : 20.50'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.77 8.80 8.81
AIR SATURATED DISTILLED WATER AVERAGE 8.793

TABLE III-39 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 5214- 68-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.68	.19762	8.78	.21082	8.90	.22667	9.00	.23987
B	8.60	.18705	8.75	.20686	8.88	.22403	9.05	.24648
C	8.70	.20026	8.85	.22007	8.91	.22799	9.02	.24252
D	8.70	.20026	8.80	.21346	8.95	.23327	9.01	.24119
AVERAGE		.19630		.21280		.22799		.24252
S.D.		.00544		.00481		.00337		.00247

TEMPERATURE : 20.40′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.71 8.70 8.63
AIR SATURATED DISTILLED WATER AVERAGE 8.680

TABLE III-40 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 6209- 96-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.60	.20418	8.70	.21738	8.88	.24115	9.05	.26360
B	8.55	.19757	8.80	.23059	8.90	.24379	9.10	.27020
C	8.65	.21078	8.72	.22002	8.84	.23587	9.08	.26756
D	8.60	.20418	8.70	.21738	8.90	.24379	8.95	.25039
AVERAGE		.20418		.22134		.24115		.26294
S.D.		.00467		.00544		.00323		.00761

TEMPERATURE : 20.40′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.56 8.50 8.51
AIR SATURATED DISTILLED WATER AVERAGE 8.523

TABLE III-41 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 6209- 96-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.23	.19838	8.31	.20885	8.48	.23111	8.60	.24682
B	8.25	.20100	8.30	.20755	8.40	.22064	8.58	.24420
C	8.15	.18791	8.40	.22064	8.47	.22980	8.60	.24682
D	8.20	.19446	8.35	.21409	8.45	.22718	8.70	.25991
AVERAGE		.19544		.21278		.22718		.24943
S.D.		.00493		.00515		.00403		.00614

TEMPERATURE : 20.00′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.10 8.15 8.09
AIR SATURATED DISTILLED WATER AVERAGE 8.113

TABLE III-42 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 7205- 129-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.90	.22981	9.10	.25616	9.55	.31545	9.76	.34312
B	8.85	.22322	9.20	.26934	9.40	.29569	9.75	.34180
C	8.78	.21400	9.30	.28251	9.50	.30886	9.82	.35103
D	8.87	.22586	9.23	.27329	9.63	.32599	9.80	.34839
AVERAGE		.22322		.27032		.31150		.34609
S.D.		.00582		.00947		.01098		.00377

TEMPERATURE : 20.30′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.60 8.62 8.72
AIR SATURATED DISTILLED WATER AVERAGE 8.647

TABLE III-43 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 7205- 129-S

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	30. DATA1	30. DATA2	60. DATA1	60. DATA2	90. DATA1	90. DATA2
A	8.79	.22586	8.90	.24035	9.00	.25352	9.25	.28647
B	8.70	.21400	8.97	.24957	9.10	.26670	9.22	.28251
C	8.72	.21663	8.82	.22981	9.03	.25748	9.20	.27988
D	8.68	.21136	8.90	.24035	9.01	.25484	9.18	.27724
AVERAGE		.21696		.24002		.25814		.28152
S.D.		.00546		.00700		.00515		.00341

TEMPERATURE : 20.30'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF AIR SATURATED DISTILLED WATER : 8.50 8.60 8.55 AVERAGE 8.550

TABLE III-44 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 8200- 167-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.80	.21663	9.25	.27592	9.70	.33522	10.40	.42745
B	8.86	.22454	9.22	.27197	9.80	.34839	10.35	.42086
C	8.75	.21004	9.20	.26934	9.75	.34180	10.20	.40110
D	8.87	.22586	9.29	.28119	9.69	.33390	10.10	.38792
AVERAGE		.21927		.27461		.33983		.40933
S.D.		.00639		.00447		.00578		.01571

TEMPERATURE : 20.30'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF AIR SATURATED DISTILLED WATER : 8.60 8.62 8.72 AVERAGE 8.647

TABLE III-45 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 8200- 167-S

SAMPLE POSITION	TIME (MIN.)							
	0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.42	.20014	8.60	.22371	8.75	.24334	8.95	.26952
B	8.50	.21062	8.66	.23156	8.75	.24334	9.00	.27607
C	8.40	.19753	8.60	.22371	8.83	.25381	9.05	.28261
D	8.40	.19753	8.59	.22240	8.81	.25119	8.90	.26298
AVERAGE		.20145		.22534		.24792		.27279
S.D.		.00540		.00363		.00467		.00732

TEMPERATURE : 20.00′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.36 8.30 8.32
AIR SATURATED DISTILLED WATER AVERAGE 8.327

TABLE III-46 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-0- 8698- 188-B

SAMPLE POSITION	TIME (MIN.)							
	0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.59	.21681	9.05	.27768	9.65	.35709	10.21	.43120
B	8.70	.23137	9.12	.28695	9.75	.37032	10.20	.42988
C	8.70	.23137	9.10	.28430	9.60	.35047	10.10	.41664
D	8.71	.23269	9.20	.29754	9.70	.36371	10.35	.44973
AVERAGE		.22806		.28662		.36040		.43186
S.D.		.00652		.00715		.00740		.01178

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.33 8.42 8.45
AIR SATURATED DISTILLED WATER AVERAGE 8.400

TABLE III-47 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-O- 8698- 188-S

SAMPLE POSITION	TIME (MIN.) 0.		30.		60.		90.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.45	.21004	8.60	.22976	8.96	.27709	9.03	.28629
B	8.43	.20741	8.71	.24422	8.90	.26920	9.05	.28892
C	8.50	.21661	8.80	.25605	8.89	.26789	9.10	.29550
D	8.50	.21661	8.72	.24554	8.80	.25605	9.00	.28235
AVERAGE		.21267		.24389		.26756		.28827
S.D.		.00405		.00936		.00752		.00479

TEMPERATURE : 20.20'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.21 8.30 8.33
AIR SATURATED DISTILLED WATER AVERAGE 8.280

TABLE III-48 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-A- 5214- 68-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.78	.21279	8.85	.22214	8.93	.23282	9.00	.24217
B	8.75	.20879	8.81	.21680	8.91	.23015	9.05	.24884
C	8.76	.21012	8.79	.21413	8.90	.22881	9.00	.24217
D	8.74	.20745	8.82	.21813	8.95	.23549	9.03	.24617
AVERAGE		.20979		.21780		.23182		.24484
S.D.		.00197		.00289		.00256		.00283

TEMPERATURE : 20.90'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.70 8.70 8.65
AIR SATURATED DISTILLED WATER AVERAGE 8.683

TABLE III-49 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-A- 6209- 96-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.78	.20977	8.82	.21503	9.10	.25189	9.30	.27821
B	8.80	.21240	8.90	.22556	9.12	.25452	9.20	.26505
C	8.70	.19924	8.90	.22556	9.10	.25189	9.23	.26900
D	8.79	.21109	8.89	.22425	9.13	.25583	9.20	.26505
AVERAGE		.20812		.22260		.25353		.26933
S.D.		.00521		.00440		.00171		.00538

TEMPERATURE : 20.25′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.65 8.70 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.683

TABLE III-50 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-A- 7205- 129-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.77	.22762	9.00	.25813	9.36	.30587	9.40	.31118
B	8.65	.21171	9.10	.27139	9.32	.30057	9.55	.33107
C	8.72	.22099	9.15	.27802	9.30	.29792	9.40	.31118
D	8.68	.21569	9.13	.27537	9.30	.29792	9.50	.32444
AVERAGE		.21900		.27073		.30057		.31947
S.D.		.00597		.00765		.00325		.00861

TEMPERATURE : 20.60′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.45 8.57 8.55
AIR SATURATED DISTILLED WATER AVERAGE 8.523

TABLE III-51 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-A- 8200- 167-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.65	.21101	9.30	.29694	9.70	.34981	9.85	.36964
B	8.70	.21762	9.33	.30090	9.90	.37625	10.10	.40269
C	8.80	.23084	9.28	.29429	9.85	.36964	10.00	.38947
D	8.70	.21762	9.30	.29694	9.82	.36568	10.20	.41591
AVERAGE		.21927		.29727		.36535		.39443
S.D.		.00720		.00236		.00973		.01709

TEMPERATURE : 20.45′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.45 8.57 8.55
AIR SATURATED DISTILLED WATER AVERAGE 8.523

TABLE III-52 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-A- 8698- 188-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.68	.21412	9.20	.28293	9.90	.37557	10.15	.40866
B	8.65	.21015	9.30	.29617	9.90	.37557	10.38	.43909
C	8.60	.20353	9.35	.30278	9.80	.36234	10.30	.42851
D	8.75	.22338	9.45	.31602	9.97	.38483	10.40	.44174
AVERAGE		.21279		.29948		.37458		.42950
S.D.		.00719		.01193		.00802		.01301

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.48 8.60 8.52
AIR SATURATED DISTILLED WATER AVERAGE 8.533

TABLE III-53 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-B- 5214- 68-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.65	.19262	8.80	.21247	8.90	.22571	8.95	.23232
B	8.70	.19924	8.72	.20189	8.85	.21909	8.90	.22571
C	8.72	.20189	8.75	.20586	8.80	.21247	8.98	.23629
D	8.70	.19924	8.79	.21115	8.95	.23232	9.05	.24556
AVERAGE		.19825		.20784		.22240		.23497
S.D.		.00342		.00424		.00740		.00719

TEMPERATURE : 20.50′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.73 8.65 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.693

TABLE III-54 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-B- 6209- 96-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.50	.21353	8.70	.24003	8.90	.26652	9.10	.29302
B	8.50	.21353	8.72	.24268	8.80	.25327	9.05	.28640
C	8.55	.22015	8.65	.23340	8.85	.25990	9.00	.27977
D	8.48	.21088	8.75	.24665	8.92	.26917	9.12	.29567
AVERAGE		.21452		.24069		.26222		.28871
S.D.		.00343		.00482		.00617		.00617

TEMPERATURE : 20.55′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.32 8.35 8.30
AIR SATURATED DISTILLED WATER AVERAGE 8.323

TABLE III-55 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-B- 7205- 129-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.65	.20619	8.95	.24542	9.30	.29119	9.60	.33041
B	8.70	.21273	9.00	.25196	9.40	.30426	9.61	.33172
C	8.69	.21142	9.05	.25850	9.35	.29772	9.70	.34349
D	8.70	.21273	9.05	.25850	9.30	.29119	9.73	.34741
AVERAGE		.21077		.25359		.29609		.33826
S.D.		.00270		.00542		.00542		.00734

TEMPERATURE : 19.95´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.49 8.59 8.56
AIR SATURATED DISTILLED WATER AVERAGE 8.547

TABLE III-56 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-B- 8200- 167-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.45	.21129	9.15	.30403	9.40	.33715	9.93	.40737
B	8.53	.22189	9.10	.29741	9.60	.36365	10.00	.41664
C	8.45	.21129	9.00	.28416	9.55	.35702	10.20	.44314
D	8.48	.21527	9.20	.31065	9.60	.36365	10.10	.42989
AVERAGE		.21493		.29906		.35537		.42426
S.D.		.00433		.00980		.01086		.01352

TEMPERATURE : 20.55´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.25 8.30 8.30
AIR SATURATED DISTILLED WATER AVERAGE 8.283

TABLE III-57 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-B- 8698- 188-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.60	.23091	9.42	.33943	9.89	.40163	10.20	.44265
B	8.60	.23091	9.30	.32355	9.95	.40957	10.40	.46912
C	8.55	.22429	9.25	.31693	9.91	.40427	10.40	.46912
D	8.66	.23885	9.45	.34340	9.90	.40295	10.42	.47177
AVERAGE		.23124		.33083		.40461		.46317
S.D.		.00516		.01093		.00301		.01189

TEMPERATURE : 20.50´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.25 8.30 8.30
AIR SATURATED DISTILLED WATER AVERAGE 8.283

TABLE III-58 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-C- 5214- 68-B

SAMPLE POSITION	TIME (MIN.) 0. DATA1	0. DATA2	5. DATA1	5. DATA2	10. DATA1	10. DATA2	15. DATA1	15. DATA2
A	8.87	.22681	8.97	.23996	9.08	.25442	9.17	.26625
B	8.90	.23076	8.96	.23865	9.05	.25048	9.15	.26363
C	8.82	.22024	8.96	.23865	9.03	.24785	9.12	.25968
D	8.88	.22813	8.98	.24127	9.06	.25179	9.15	.26363
AVERAGE		.22648		.23963		.25114		.26330
S.D.		.00388		.00109		.00237		.00235

TEMPERATURE : 20.20´C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.70 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.633

TABLE III-59 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-C- 6209- 96-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.35	.20060	8.50	.22047	8.70	.24697	8.90	.27347
B	8.30	.19398	8.48	.21782	8.68	.24432	9.05	.29334
C	8.40	.20722	8.62	.23637	8.73	.25094	9.00	.28672
D	8.32	.19663	8.51	.22180	8.65	.24035	8.95	.28009
AVERAGE		.19961		.22412		.24565		.28340
S.D.		.00499		.00722		.00386		.00741

TEMPERATURE : 20.55′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.23 8.30 8.25
AIR SATURATED DISTILLED WATER AVERAGE 8.260

TABLE III-60 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-C- 7205- 129-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.87	.22681	9.20	.27020	9.60	.32279	9.93	.36617
B	8.90	.23076	9.22	.27283	9.55	.31621	9.90	.36223
C	8.80	.21761	9.25	.27677	9.63	.32673	10.10	.38852
D	8.85	.22418	9.25	.27677	9.65	.32936	9.90	.36223
AVERAGE		.22484		.27414		.32377		.36979
S.D.		.00479		.00279		.00495		.01094

TEMPERATURE : 20.20′C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF : 8.50 8.70 8.70
AIR SATURATED DISTILLED WATER AVERAGE 8.633

TABLE III-61 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-C- 8200- 167-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.82	.21695	9.40	.29370	9.90	.35987	10.20	.39957
B	8.80	.21430	9.59	.31885	9.92	.36252	10.40	.42604
C	8.76	.20901	9.50	.30694	9.89	.35855	10.42	.42869
D	8.90	.22753	9.55	.31355	10.00	.37311	10.55	.44589
AVERAGE		.21695		.30826		.36351		.42505
S.D.		.00675		.00940		.00572		.01657

TEMPERATURE : 20.50'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF AIR SATURATED DISTILLED WATER : 8.73 8.70 8.60
AVERAGE 8.677

TABLE III-62 MEASUREMENTS OF OXYGEN CONTENT OF DILUTED SAMPLES(DATA1,PPM) AND DIMENSIONLESS POOL CONCENTRATION(DATA2) FOR RUN 4-C- 8698- 188-B

SAMPLE POSITION	TIME (MIN.) 0.		5.		10.		15.	
	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2	DATA1	DATA2
A	8.79	.21020	9.70	.32906	10.20	.39437	10.82	.47536
B	8.80	.21151	9.60	.31600	10.25	.40090	10.80	.47274
C	8.85	.21804	9.55	.30947	10.25	.40090	10.80	.47274
D	8.85	.21804	9.78	.33951	10.38	.41788	10.90	.48581
AVERAGE		.21445		.32351		.40352		.47666
S.D.		.00362		.01162		.00871		.00539

TEMPERATURE : 19.90'C
PRESSURE : 765 MM HG
OXYGEN CONCENTRATION OF AIR SATURATED DISTILLED WATER : 8.73 8.70 8.60
AVERAGE 8.677

Table III-63. Values of TFS for one nozzle

Run Number	TFS (ml/min.)	95% Confidence Limits	Correlation Coefficient
1-5324-71-S	23.3	± 1.2%	.951
1-8908-198-S	33.0	± 7.9%	.971
1-13687-466-S	41.4	±10.3%	.952
1-21044-1103-S	47.3	± 9.0%	.963
1-24837-1536-S	58.0	± 7.1%	.978
1-28819-2068-S	64.2	± 7.7%	.973

Table III-64. Values of TFS for two nozzles

Run Number	TFS (ml/min.)	95% Confidence Limits	Correlation Coefficient
2-0-5251-69-S	23.8	± 9.0%	.964
2-0-7640-145-S	32.5	± 9.3%	.961
2-0-12419-384-S	42.7	±10.0%	.954
2-0-14410-517-S	46.2	±10.4%	.960
2-0-16401-670-S	52.2	± 4.5%	.991

Table III-65. Values of TFS for four nozzles

Run Number	TFS (ml/min.)	95% Confidence Limits	Correlation Coefficient
4-0-5214-68-S	30.4	± 7.9%	.972
4-0-6209-96-S	33.9	± 9.4%	.963
4-0-7205-129-S	43.2	± 7.6%	.974
4-0-8200-167-S	47.0	± 7.0%	.979
4-0-8698-188-S	53.2	± 8.2%	.967

Table III-66. Values of TTF for one nozzle

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
1-5324-71-B	142.0	± 12.1%	.952
1-8908-198-B	343.7	± 6.4%	.981
1-13687-466-B	883.4	± 7.1%	.979
1-21044-1103-B	2061.4	± 4.6%	.990
1-24837-1536-B	2270.9	± 7.9%	.973
1-28819-2068-B	2801.8	± 9.0%	.966

Table III-67. Values of TTF for two nozzle at position O

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
2-0-5251-69-B	132.1	± 11.3%	.944
2-0-7640-145-B	388.0	± 4.8%	.989
2-0-12419-384-B	1281.5	± 2.1%	.998
2-0-14410-517-B	1588.6	± 3.7%	.994
2-0-16401-670-B	2158.8	± 4.4%	.991

Table III-68. Values of TTF for two nozzle at position A

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
2-A-5251-69-B	144.1	± 6.1%	.983
2-A-7640-145-B	369.1	± 4.7%	.991
2-A-12419-384-B	1328.1	± 4.7%	.992
2-A-14410-517-B	1743.1	± 4.7%	.990
2-A-16401-670-B	2292.0	± 2.6%	.997

Table III-69. Values of TTF for two nozzles at Position B

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
2-B-5251-69-B	125.6	± 9.1%	.972
2-B-7640-145-B	366.4	± 7.4%	.982
2-B-12419-384-B	1291.8	± 4.2%	.992
2-B-14410-517-B	1780.5	± 3.6%	.994
2-B-16401-670-B	2360.8	± 4.1%	.992

Table III-70. Values of TTF for two nozzles at position C

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
2-C-5251-69-B	135.0	± 5.3%	.988
2-C-7640-145-B	398.5	± 6.4%	.983
2-C-12419-384-B	1377.1	± 4.6%	.990
2-C-14410-517-B	1802.3	± 3.7%	.994
2-C-16401-670-B	2462.6	± 2.7%	.997

Table III-71. Values of TTF for four nozzles at position O

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
4-0-5214-68-B	129.8	± 9.5%	.968
4-0-6209-96-B	226.9	± 8.9%	.968
4-0-7205-129-B	536.4	± 5.9%	.984
4-0-8200-167-B	816.6	± 6.1%	.986
4-0-8698-188-B	898.9	± 5.5%	.989

Table III-72. Values of TTF for four nozzles at position A.

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
4-A-5214-68-B	132.6	± 8.4%	.975
4-A-6209-96-B	247.0	± 8.3%	.973
4-A-7205-129-B	459.1	± 9.0%	.964
4-A-8200-167-B	838.5	± 7.7%	.973
4-A-8698-188-B	1008.8	± 4.7%	.990

Table III-73. Values of TTF for four nozzles at position B.

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
4-B-5214-68-B	139.9	± 14.8%	.919
4-B-6209-96-B	298.7	± 6.6%	.980
4-B-7205-129-B	531.6	± 4.1%	.993
4-B-8200-167-B	940.4	± 5.1%	.988
4-B-8698-188-B	1129.2	± 4.2%	.992

Table III-74. Values of TTF for four nozzles at position C.

Run number	TTF (ml/min.)	95% Confidence Limits	Correlation Coefficient
4-C-5214-68-B	149.1	± 6.3%	.982
4-C-6209-96-B	314.7	± 8.7%	.971
4-C-7205-129-B	705.7	± 4.4%	.991
4-C-8200-167-B	958.4	± 5.6%	.986
4-C-8698-188-B	1254.1	± 3.1%	.996

Table III-75. Calculated values of TF for one nozzle

Run number	TF (ml/min.)	Deviation of TF values
1-5324-71	118.7	± 20.0 (16.9%)
1-8908-198	310.7	± 24.7 (7.9%)
1-13687-466	842.0	± 67.0 (8.0%)
1-21044-1103	2014.1	± 99.4 (4.9%)
1-24837-1536	2212.9	±183.2 (8.3%)
1-28819-2068	2737.6	±257.6 (9.4%)

Table III-76. Calculated values of TF for two nozzles at position O

Run number	TF (ml/min.)	Deviation of TF values
2-0-5251-69	108.3	± 17.1 (15.7%)
2-0-7640-145	355.5	± 21.6 (6.1%)
2-0-12419-384	1238.8	± 30.6 (2.5%)
2-0-14410-517	1542.4	± 63.4 (4.1%)
2-0-16401-670	2106.6	± 97.5 (4.6%)

Table III-77. Calculated values of TF for two nozzles at position A

Run number	TF (ml/min.)	Deviation of TF values
2-A-5251-69	120.3	± 10.9 (9.1%)
2-A-7640-145	336.6	± 20.4 (6.1%)
2-A-12419-384	1285.4	± 67.2 (5.2%)
2-A-14410-517	1696.9	± 87.1 (5.1%)
2-A-16401-670	2239.8	± 62.9 (2.8%)

Table III-78. Calculated values of TF for two nozzles at position B

Run number	TF (ml/min.)	Deviation of TF values
2-B-5251-69	101.8	± 13.5 (13.3%)
2-B-7640-145	333.9	± 30.2 (9.1%)
2-B-12419-384	1249.1	± 58.3 (4.7%)
2-B-14410-517	1734.3	± 68.3 (3.9%)
2-B-16401-670	2308.6	±100.1 (4.3%)

Table III-79. Calculated values of TF for two nozzles at position C

Run number	TF (ml/min.)	Deviation of TF values
2-C-5251-69	111.2	± 9.4 (8.4%)
2-C-7640-145	366.0	± 28.5 (7.8%)
2-C-12419-384	1334.4	± 67.9 (5.1%)
2-C-14410-517	1756.1	± 71.2 (4.1%)
2-C-16401-670	2410.4	± 69.4 (2.9%)

Table III-80. Calculated values of TF for four nozzles at position O

Run number	TF (ml/min.)	Deviation of TF values
4-0-5214-68	99.4	± 14.7 (14.8%)
4-0-6209-96	193.0	± 23.4 (12.1%)
4-0-7205-129	493.2	± 34.9 (7.1%)
4-0-8200-167	769.6	± 53.0 (6.9%)
4-0-8698-188	845.7	± 53.4 (6.3%)

Table III-81. Calculated values of TF for four nozzles at position A

Run number	TF (ml/min.)	Deviation of TF values
4-A-5214-68	102.2	± 13.5 (13.2%)
4-A-6209-96	213.1	± 23.7 (11.1%)
4-A-7205-129	415.9	± 44.7 (10.8%)
4-A-8200-167	791.5	± 67.8 (8.6%)
4-A-8698-188	955.6	± 52.1 (5.5%)

Table III-82. Calculated values of TF for four nozzles at position B

Run number	TF (ml/min.)	Deviation of TF values
4-B-5214-68	109.5	± 23.1 (21.1%)
4-B-6209-96	264.8	± 22.9 (8.6%)
4-B-7205-129	488.4	± 24.9 (5.1%)
4-B-8200-167	893.4	± 50.8 (5.7%)
4-B-8698-188	1076.0	± 51.5 (4.8%)

Table III-83. Calculated values of TF for four nozzles at position C

Run number	TF (ml/min.)	Deviation of TF values
4-C-5214-68	118.7	± 11.7 (9.9%)
4-C-6209-96	280.8	± 30.6 (10.9%)
4-C-7205-129	662.5	± 30.9 (4.7%)
4-C-8200-167	911.4	± 56.5 (6.2%)
4-C-8698-188	1200.9	± 43.0 (3.6%)

APPENDIX IV

SAMPLE CALCULATION

Run 1-8908-198-B and 1-8908-198-S in Table III-3 and III-4 of Appendix III were used to illustrate the way of calculating values of TTF and TFS respectively.

16 samples in each table, which were taken at four different sample positions and at four different times with same time interval were analyzed with the average value of air saturated distilled water for each run.

If the oxygen concentration of a sample has a function of time and position, i.e. C (time, position), then the demonstrating oxygen concentration in Table III-3 is

$$C\ (15,\ B) = 9.40$$

Since this oxygen concentration is measured in the diluted state, the actual concentration must be calculated using a simple mass balance equation.

$$\text{Actual Concentration} = \left[\left(\begin{matrix}\text{Diluted sample}\\ \text{Concentration}\end{matrix}\right) \times \left(\begin{matrix}\text{Diluted sample}\\ \text{volume}\end{matrix}\right) - \left(\begin{matrix}\text{Air saturated water}\\ \text{concentration}\end{matrix}\right) \times \left(\begin{matrix}\text{Air saturated}\\ \text{water volume}\end{matrix}\right)\right] / (\text{Pool sample volume})$$

where,

Diluted sample volume = 290 ml

Air saturated water volume = 240 ml

Pool sample volume = 50 ml

then

$$C_{Actual}(15,B) = \frac{9.4 \times 290 - 8.6 \times 240}{50} = 13.24 \text{ (ppm)}$$

The solubility of oxygen exposed to air saturated water at 760 mmHg, 20.55°C was found to be 9.09 by interpolation from Table II-7 of Appendix II. The actual solubility corresponding to the experimental condition is

$$\begin{array}{l}\text{Actual} \\ \text{Solubility}\end{array} = 9.09 \text{ (ppm)} \times \frac{765 \text{ mmHg}}{760 \text{ mmHg}} \times \frac{99.999\% \text{ pure } O_2}{20.9\% \; O_2 \text{ in Air}}$$

$$= 43.77852 \text{ (ppm)}$$

Then the dimensionless pool concentration C^+ is obtained by dividing actual concentration by actual solubility

$$C^+(15, B) = \frac{13.24}{43.77852} = 0.30243$$

C_o^+, the average value of C^+ at time = 0, is one quater of the summation of all C^+ at time = 0, which were computed in the previous way. In this case,

$$C_o^+ = 0.21234$$

then

$$\ln\left(\frac{1-C_o^+}{1-C^+}\right) = \ln\left(\frac{1 - 0.21234}{1 - 0.30243}\right) = 0.12146$$

The value, $\ln\left(\frac{1 - C_o^+}{1 - C^+}\right)$ of the other samples are a function of time. To obtain the slope of this function, the data were analyzed by a linear regression method. In this work, subroutine RLONE in IMSL (International Mathematical and Statistical Library), which is based on the theory in the book, Applied Regression Analysis[2], was used. The slope, $\frac{TTF}{V}$ turned out to be

$$\frac{TTF}{V} = .00751408$$

and

$$TTF = (.00751408) \cdot V = (.00751408) \cdot (45743.7)$$
$$= 343.7218 \text{ (ml/min.)}$$

Upper confidence limit of $\frac{TTF}{V} = .00799714$

Lower confidence limit of $\frac{TTF}{V} = .00703102$

Then,

$$TTF = 343.7218 \pm 22.0970 \text{ (ml/min.)}$$

or $$= 343.7218 \pm 6.43\% \text{ (ml/min.)}$$

TFS was calculated in the same way

$$\text{TFS} = 32.9852 \pm 2.5993 \quad (\text{ml/min.})$$

or

$$= 32.9852 \pm 7.88\% \quad (\text{ml/min.})$$

Therefore, the calculated TF was

$$\text{TF} = \text{TTF} - \text{TFS}$$

and

$$\text{Upper C.L. of TF} = \text{Upper C.L.}_{\text{TTF}} - \text{Lower C.L.}_{\text{TFS}}$$

$$\text{Lower C.L. of TF} = \text{Lower C.L.}_{\text{TTF}} - \text{Upper C.L.}_{\text{TFS}}$$

Then

$$\text{TF} = 343.7218 - 32.9852$$

$$= 310.7366 \quad (\text{ml/min.})$$

$$\text{Upper C.L. of TF} = 22.0970 - (-2.5993)$$

$$= 24.6963$$

$$\text{Lower C.L. of TF} = -22.0970 - 2.5993$$

$$= -24.6963$$

Therefore,

$$\text{TF} = 310.7366 \pm 24.6963 \quad (\text{ml/min.})$$

or

$$= 310.7366 \pm 7.95\% \quad (\text{ml/min.})$$

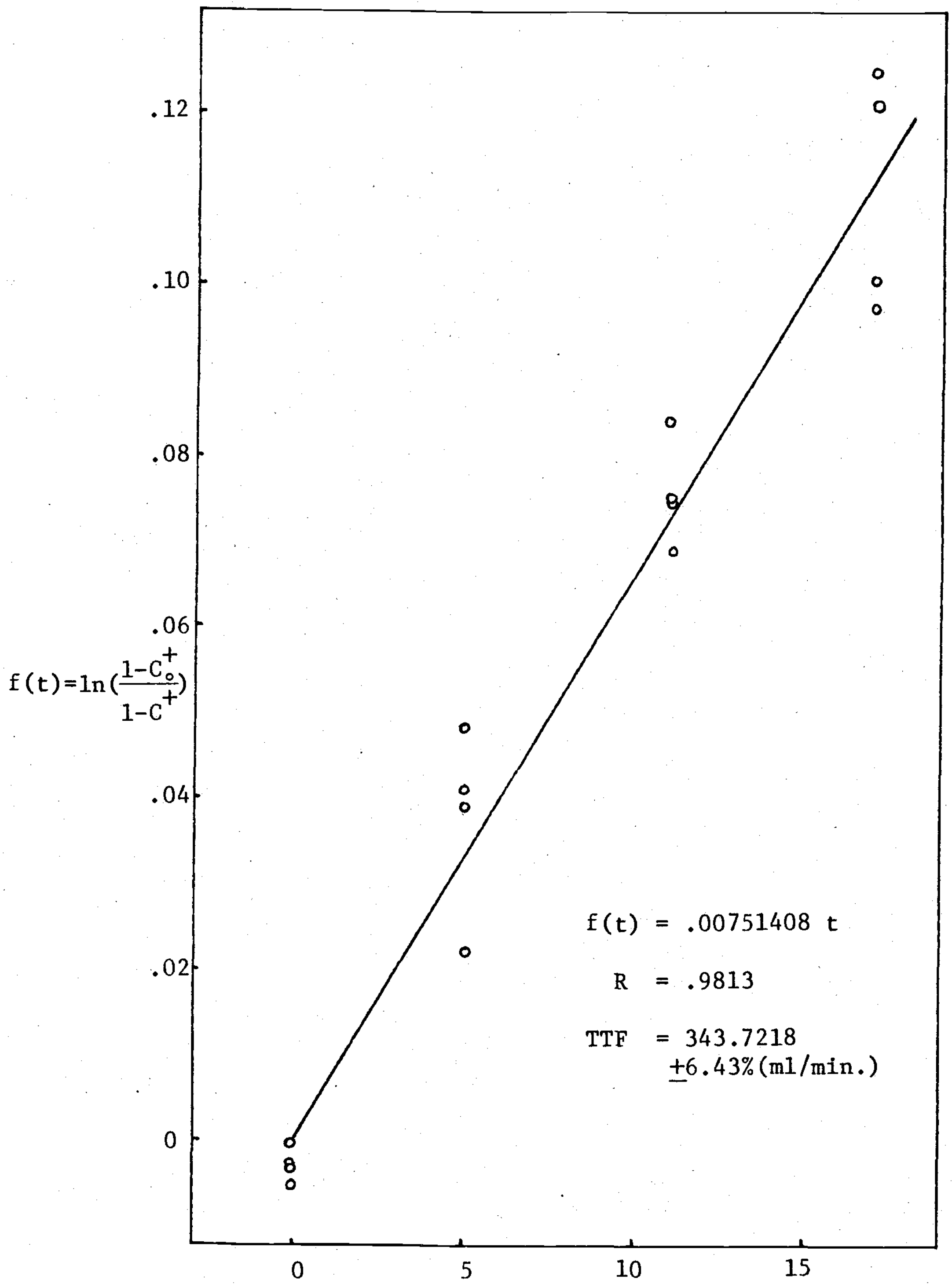

Fig.VIII-1. Determination of TTF

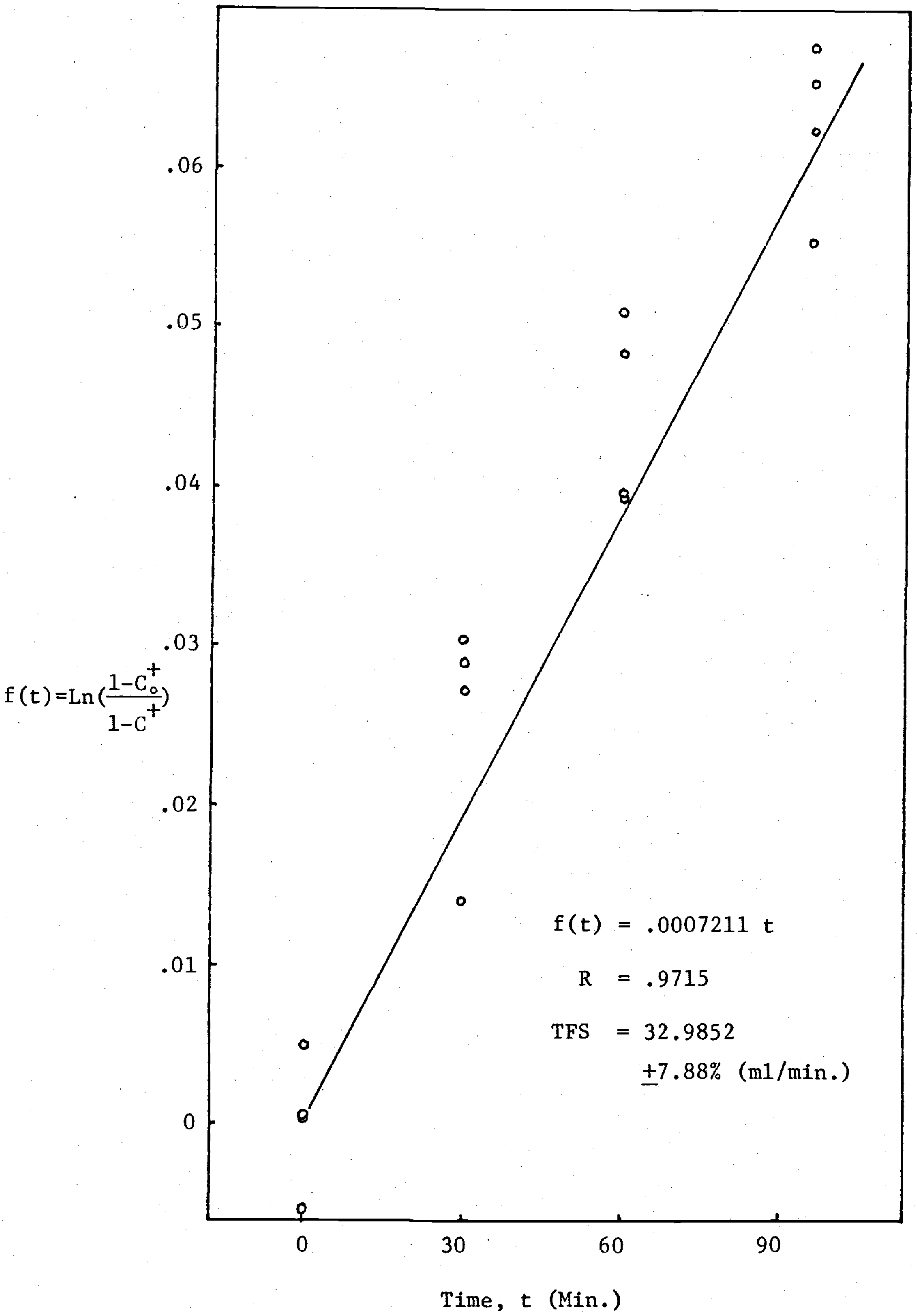

Fig. VIII-2. Determination of TFS

APPENDIX V

NONMENCLATURE

Symbol	Sifnificance
A	Interfacial area
C	Concentration of oxygen in water
C.L.	95% Confidence Limits
D	Diameter of jet
g_c	Newton's law conversion factor
h	Pool depth
K	Overall mass transfer coefficient
k	Mass transfer coefficient
L	Length of nozzle
N_{Re}	Reynolds number of jet ($D_J V_J \rho/\mu$)
N_{We}	Weber number of jet ($D_J V_J^2 \rho/\sigma g_c$)
n	The number of jets
Q	Volumetric flow rate
R	Linear correlation coefficient
r	Rate of oxygen absorption
S.D.	Standard deviation
t	Time
TF	Transfer factor
TFS	Surface transfer factor
TTF	Total transfer factor

Symbol	Significance
V	Pool volume
v	Velocity of jet stream

Greek

μ	Viscosity
ρ	Density
σ	Surface tension

Subscript

B	Bubble
E	Exit Stream
J	Jet
L	Liquid
O	Initial condition
S	Surface

Superscript

*	Equilibrium value
+	Dimensionless value