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THE FEASIBILITY OF CONCENTRATING/SEPARATING DILUTE
NITROCELLULOSE ACID WASTEWATERS BY REVERSE OSMOSIS

Vincent J. Ciccone

Army Mobility Equipment Research and Development
Center
Fort Belvoir, Virginia

November 1974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) In cooperation with Picatinny Arsenal's Pollution Abatement Program and in response to their Procurement/Work Directive PRON: GG-325205-01-GG-EF, a feasibility study focused on the application of membrane technology for the concentration and/or separation of dilute acid wastewaters was conducted by the Sanitary Sciences Division, USAMERDC. Preliminary laboratory investigations using commercially available cellulose-acetate reverse osmosis (RO) membranes were conducted at Radford Army Ammunition Plant (RAAP) by plant personnel. The objective of this study was to (Continued)		

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concentrate the dilute acids as a unit process toward abating the nitrate pollution problem or as an intermediate step in the recovery of the nitric and sulphuric acids. Results of these preliminary investigations indicated that RO was a potential candidate for larger scale application and, therefore, more detailed work was warranted. Of special interest was the development of an acid-resistant membrane to counter the susceptibility of cellulose-acetate to hydrolysis when continuously exposed in an acidic environment.

Based on the data obtained in the laboratory phase of this study and subject to the data generated in the pilot plant phase, the following conclusions appear valid:

- a. The application of cellulose-acetate and modified sulfonated polyphenylene oxide RO membranes as a unit process in the treatment of dilute acid wastewaters generated at RAAP is technically feasible.
- b. The concentration of nitric and sulphuric acid at acceptable rates for engineering scale-up using RO is feasible and attainable.
- c. The permeation or flux rates attainable in the treatment of RAAP acid wastewaters are acceptable for engineering scale-up.
- d. Hydrolysis of the cellulose-acetate membrane did not significantly impair the performance characteristics of the RO modules.
- e. Acidic corrosion of the metallic components of the RO system can introduce operational problems that will significantly interfere with the rejection and flux rates of the RO membranes.
- f. Continuation of the program into a Phase II RO pilot plant operation located at RAAP for on-site evaluation and performance documentation and/or verification is justified.

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PREFACE

The investigation covered in this report was conducted under the authority of Picatinny Arsenal Pollution Abatement Program Procurement/Work Directive PRON: GG-325205-01-GG-EF. The period covered is from August 1972 to June 1974.

The work was accomplished by LTC Vincent J. Ciccone under the supervision of Richard P. Schmitt, Chief, Sanitary Sciences Division (SSD) and Kennedy K. Harris, Chief, Military Technology Department. Data acquisition was accomplished by James M. McCann and Robert G. Ross of SSD. Data analysis was carried out by Genevieve Meyer, David B. Scott, Jr., and Arthur L. Nickless of the Analysis and Programs Division, USAMERDC.

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THE FEASIBILITY OF CONCENTRATING/SEPARATING DILUTE NITROCELLULOSE ACID WASTEWATERS BY REVERSE OSMOSIS

I. INTRODUCTION

1. **Subject.** This report covers a Picatinny Arsenal-financed study of the feasibility of membrane technology for the concentration and/or separation of dilute acid wastewaters.

2. **Background.** Acid wastewaters are generated in the manufacture of explosives and propellants. The primary pollutants are nitrates in the form of nitric acid and sulfates in the form of sulfuric acid. Nitric acid is generally the nitrating agent used in the production of such commodities as trinitrotoluene (TNT), nitroglycerin (NG), nitrocellulose (NC), and nitroguanidine. Sulfuric acid smooths the nitration reaction and absorbs the water released by esterification. Pollution results from the numerous rinsings following the nitration step and also from spills, leaks, and washdown operations from the manufacturing processes involved in the production of nitric acid and inorganic nitrates.

II. INVESTIGATION

3. **Technical Approach.** The bench scale phase of this project using commercially available cellulose-acetate RO membranes was designed to demonstrate the feasibility of concentrating/separating the spent acid wastewaters. The wastewater used in the experimental setup was a 3000-gallon batch taken from RAAP's Nitrocellulose Boiling Tub Pit. Acid concentrations were as shown in Table I. The experiment using a process evaluation bench scale model with a single spiral-wound module was designed as noted in Figure 1. No pretreatment, such as pH adjustment, was attempted, nor was it deemed necessary to filter the water prior to the RO process. Concurrently with the in-house work being conducted at USAMERDC, a contract was awarded to the Direct Energy Conversion Division, General Electric Company, Lynn, Massachusetts to constitute, cast, and fabricate modified sulfonated polyphenylene oxide (SPPPO) RO membranes which in previous G.E. work had indicated favorable resistance to low pH environments. Time framings on both efforts were such that July 1974 was estimated for on-site pilot plant studies (at RAAP) to confirm findings obtained in the laboratories. The scale of the pilot plant operations was designed to be approximately 1000 gallons per day (gpd) product water.

Table 1. Acid Composition of Wastewater from
Nitrocellulose Area - Boiling Tub Pot
Radford Army Ammunition Plant*

Concentration (ppm)		
Nitrates (NO_3)	Sulfates (SO_4)	pH
3200	5400	1.4

*Collected July 1973

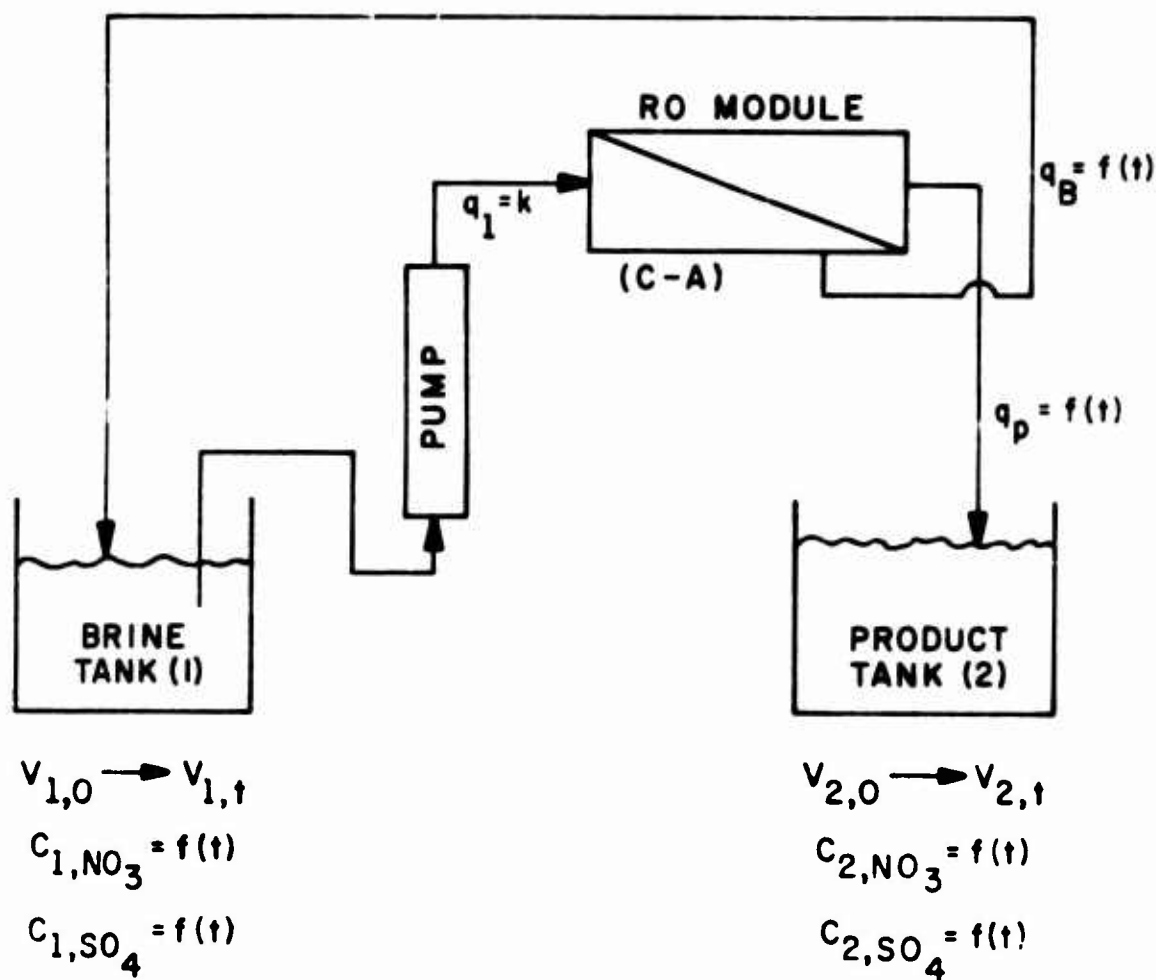


Figure 1. Simplified schematic flow diagram for laboratory setup.

The modeling mathematics of the experiment are detailed in Appendix A. This model was subsequently coded in FORTRAN by the Analysis & Programming Division (USAMERDC) for use on USAMERDC's CDC 6600 digital computer. The program appears as Appendix B. Output is available in the printed mode and as CALCOMP plots and prints.

All sample collection and chemical analyses were accomplished by personnel of the SSD, USAMERDC. Nitrate determinations were made using a nitrate specific ion electrode probe in conjunction with an expanded scale meter. Sulfate concentrations were determined using a Hach DR/2 spectrophotometer and the turbidimetric method found in APHA Standard Methods, 13th edition.

4. Results. The observed data for this phase of the project are shown in Tables 2 through 6. Nitrate concentrations are designated as IMPURITY 1, sulfates as IMPURITY 2. The product flow rate is reported in Table 6, where the change in volume of the product tank is measured as a function of time. The collected data were analyzed and plotted using computer curve fitting techniques and programs. Calcomp plots were produced and are shown as Figures 2 through 4.

A second-order polynomial curve was used as the data fitting model for the data reported in Tables 2 through 6. The statistical parameters associated with these fits were calculated and are reported in the computer printout attached as Appendix C.

Calculated engineering design parameters, based on second-order curve fits to the observed data, are shown in Table 7.

Calculated flux rates as a function of time are shown in Table 8 and the cartesian coordinate graph of these values in Figure 8.

The observed data as reported by General Electric Company regarding the modified SPRO membrane performance are shown in Table 9.

Figure 5 shows typical acid wastewater as generated at RAAP.

Figure 6 shows a typical section of cellulose acetate RO membrane cut from the actual module used in this study.

Figure 7 shows a typical 2-inch-diameter SPRO RO module mounted on a bench scale experimental setup.

Table 2. Impurity No. 1 (Nitrates), Brine Tank Concentration vs Time*

Time (hr)	Nitrates Conc. (ppm)				
	Run No.				
	1	2	3	4	5
0	2080	2550	2330	2500	2180
2	2080	2500	2310	**	**
4	2030	2460	2360	2420	**
6	2027	**	2190	**	**
8	*	2490	2200	2280	**
10	*	**	2160	**	**
12	**	**	2175	2290	**
14	**	**	2155	**	**
16	**	2320	1990	2190	**
18	**	**	**	1825	**
20	**	2160	1700	**	**
22	**	*	*	1495	**
24	**	*	*	*	**
26	*	*	*	*	1310

*Cellulose-acetate membrane.

**No data collected at this point.

Table 3. Impurity No. 2 (Sulfates), Brine Tank Concentration vs Time*

Time (hr)	Sulfates Conc. (ppm)				
	Run No.				
	1	2	3	4	5
0	3800	5900	5800	6400	6300
2	4100	6300	6500	**	**
4	5600	6200	6600	6900	**
6	5800	**	8500	**	**
8	*	6600	8500	7900	**
10	**	**	9000	**	**
12	**	**	9600	9100	**
14	**	**	8800	**	**
16	**	9800	9000	11,000	**
18	**	**	**	14,000	**
20	**	12,000	10,500	**	**
22	**	*	*	17,000	**
24	**	*	*	*	**
26	*	*	*	*	17,500

*Cellulose-acetate membrane.

**No data collected at this point.

Table 4. Impurity No. 1 (Nitrates), Product Tank Concentration vs Time*

Time (hr)	Nitrates Conc. (ppm)				
	Run No.				
	1	2	3	4	5
0	0	0	0	0	0
2	2180	2700	2590	**	2180
4	2170	2730	2610	2850	**
6	2028	**	2720	**	**
8	*	2800	2670	2850	**
10	**	**	2640	**	**
12	**	**	2650	2720	**
14	**	**	2640	**	**
16	**	2750	2600	2840	**
18	**	**	**	2790	**
20	**	2860	2210	**	**
22	**	*	*	2770	**
24	**	*	*	*	**
26	*	*	*	*	2930

*Cellulose-acetate membrane.

**No data collected at this point.

Table 5. Impurity No. 2 (Sulfates), Product Tank Concentration vs Time*

Time (hr)	Sulfates Conc. (ppm)				
	Run No.				
	1	2	3	4	5
0	0	0	0	0	0
2	300	700	500	**	**
4	200	400	460	680	**
6	200	**	480	**	**
8	*	600	470	620	**
10	**	**	510	**	**
12	**	**	560	820	**
14	**	**	540	**	**
16	**	480	500	850	**
18	**	**	**	800	**
20	**	550	690	**	**
22	**	*	*	950	**
24	**	*	*	*	**
26	*	*	*	*	1750

*Cellulose-acetate membrane.

**No data collected at this point.

Table 6. Volume in Product Tank vs Time

Time (hr)	Volume in Gallons				
	Run No.				
	1	2	3	4	5
0	0	0	0	0	0
2	22.5	23.8	61.0	**	25.0
4	45.0	45.0	88.0	35.0	**
6	57.5	**	104.0	**	**
8	*	70.0	119.0	85.0	**
10	**	**	144.0	**	**
12	**	**	163.0	121.0	**
14	**	**	182.0	**	**
16	**	145.0	198.0	160.0	180.0
18	**	**	**	200.0	211.0
20	**	185.5	240.0	**	237.0
22	*	*	*	235.0	242.0

* Cellulose-acetate membrane.

** No data collected at this point.

Table 7. Calculated Values for Engineering Design Parameters*

(Based on second-order curve fits)

Parameter	Time (hr)		Remarks
	0	20	
Volume 1 (gallons)	345	125*	Brine Tank
Volume 2 (gallons)	0	212	$V_2 = -.13t^2 + 13t + 3.5$ Product Tank
CSO ₄	5640	11096	$CSO_4 = 13t^2 + 11t + 5676$ [Brine] $CNO_3 = -2t^2 + 19t + 2280$ [Tank]
CNO ₃ (ppm)	2330	1860	
CSO ₄	5640	500**	Product Tank
CNO ₃ (ppm)	0	2535**	
pH	1.3**	1.0**	Brine Tank
pH	0	1.6**	Product Tank

* Cellulose-acetate membrane.

** As observed and recorded - average value.

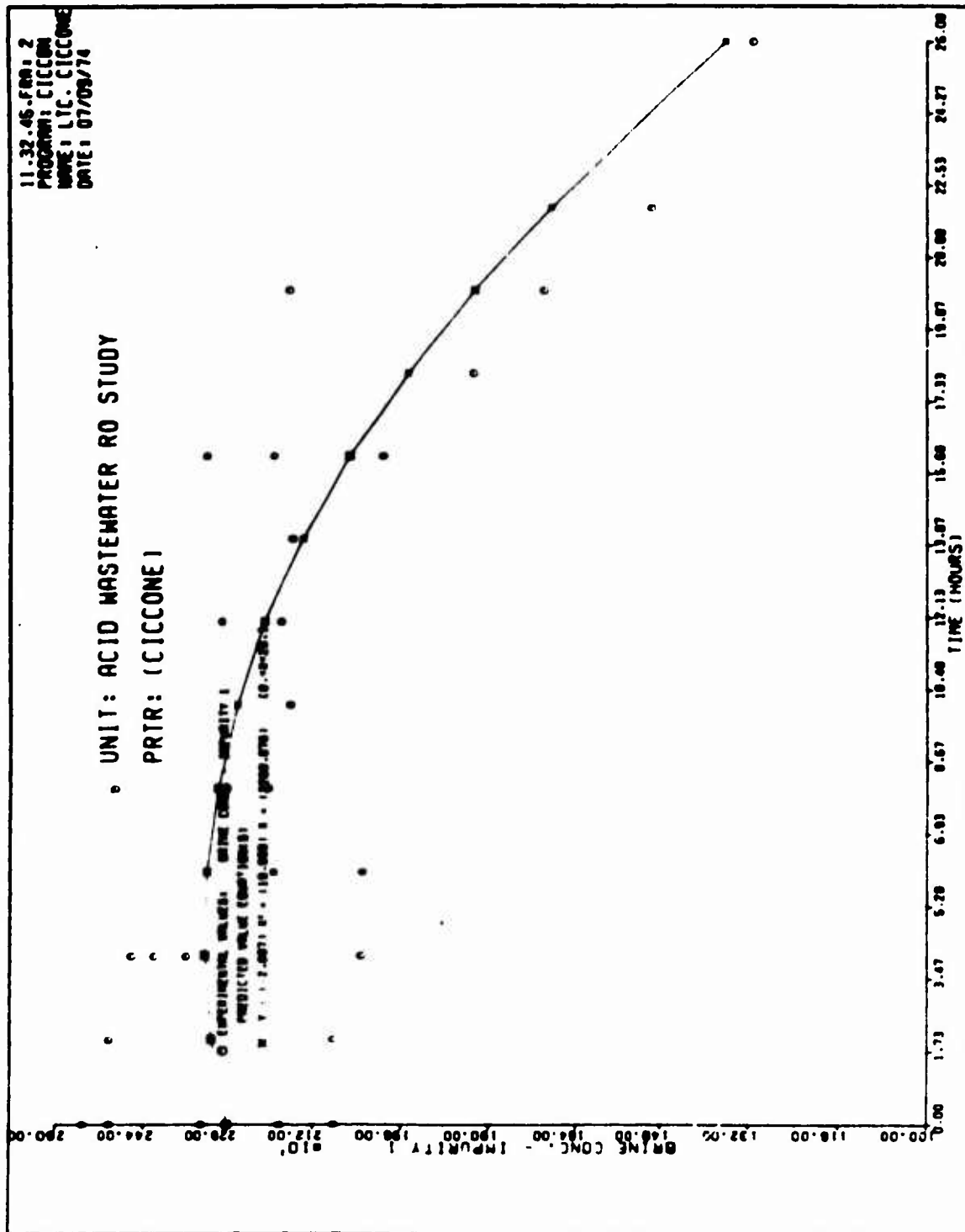
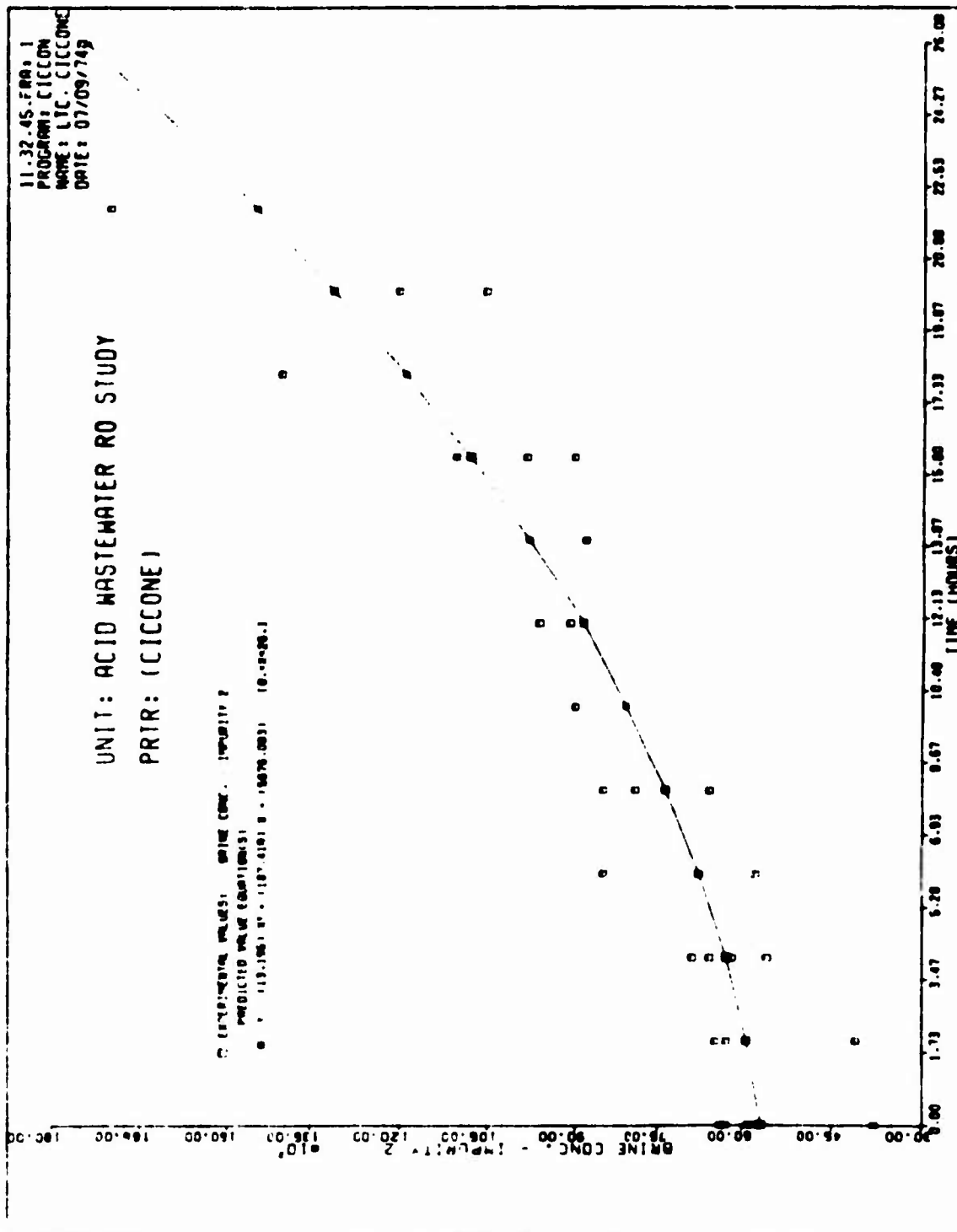


Figure 2. Concentration of nitrates in brine tank vs time.



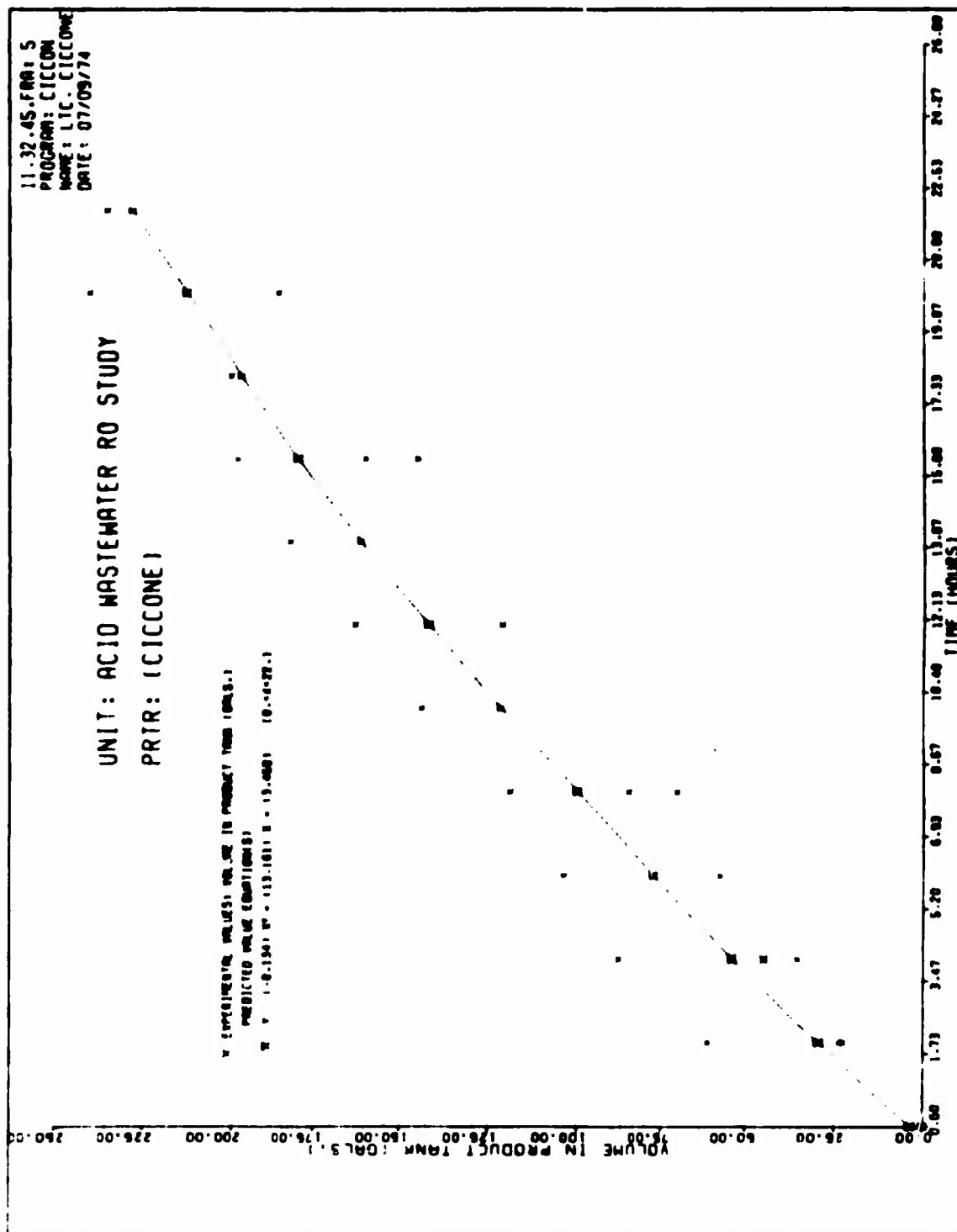


Figure 4. Volume in product tank vs time.

Table 8. Calculated Module Product Ion Rate
(gph & GF²D)
(Based on Second-Order Fitted Curve)

$$V_2 = -0.13t^2 + 13t + 3.5$$

$$\frac{dV_2}{dt} = -0.26t + 13$$

Time (hr)	Production Rate	
	gph	GF ² D*
0	13.00	9.49
2	12.50	9.13
4	11.96	8.73
6	11.44	8.35
8	10.92	7.97
10	10.40	7.59
12	9.88	7.21
14	9.36	6.83
16	8.84	6.45
18	8.32	6.07
20	7.80	5.70

*Module surface area = 33 S.F.

Table 9. Modified Sulfonated Polyphenylene Oxide Membrane Evaluation

Membrane Sample No.	Performance*		
	Test Time (hr)	Flux (GF ² D)	Rejection (%)
1	24	30	87
2	20	11	90
3	17	12	90

Experimental Conditions Were:

Feed: 3000 ppm acid (2000 H₂SO₄, 1000 HNO₃)

Press: 600 psi

Temp: 74°F - 80°F

* As reported by General Electric Co. under Contract DAAK02-73-C-0407 with USAMERDC.



Figure 5. Typical acid wastewater from RAAP.

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Figure 6. Typical section of cellulose acetate RO membrane after exposure to acid wastewater.



Figure 7. Typical 2-inch-diameter SPPO module — in bench scale setup.

III. DISCUSSION

5. **Discussion.** The cellulose acetate membrane experiment described earlier was designed to yield data which could be representative of the module behavior with respect to its ability to reject both acid species and to establish its water production or flux rate. The five runs, as noted in Tables 2 through 6, essentially were discrete repetitions of the same experiment. An objective in producing these data was to structure it into a form which could be acceptable for engineering design of a larger scaled-up system. The second-order curves obtained provide these engineering design data when considering the rate at which the acid species are being affected. Figures 2 and 3 show the nitrate and sulfate concentrations in the brine tank as functions of time. The rates at which these are changing with respect to time are easily obtained by taking the first derivative of the fitted curve; i.e., dC/dt . In this manner, the rates may be computed for any point in time within the bounds of the experiment. Since we are ultimately interested in designing a fullscale plant, practicality dictates that operation stay within a 24-hour period. Hence, the upper bond on the curve is valid (i.e., less than 24 hours) and differentiation of the curve within these time limits yields rates which may be interpreted as truly indicative of the module performance. This technique when applied to the permeate or flux rate (i.e., dV_2/dt , Figure 4) of the module integrates the rate over time, giving a more accurate estimate of this variable as compared to a grab sampling manner of estimation. It is noted in this case that flux rate may be described as an unsteady rather than a steady state condition, and hence time averaging or smoothing is necessary to account for the inherent variations. Given this derived empirical equation, one may then estimate flux at any given point over the time horizon of interest; i.e., within a 24-hour period. Simultaneously, the rate of concentration (or loss) of the particular acid species may also be calculated.

Table 7 shows the calculated values for the parameters of interest, after a 20-hour continuous run, for a single RO spiral-wound module. This performance behavior was encouraging, especially in light of the pH values. Hydrolysis of the membrane is a potential failure mode, and it was expected by this investigator that hydrolysis would occur. A rapid means of detecting gross hydrolysis was used throughout the data collection phase. This involved rinsing the module with tap water and determining the total dissolved solids (TDS) values of the inlet, product, and retentate streams using a dissolved solids meter. In each case, the reported TDS rejection rate was recorded at (on the average) approximately 90 percent. This indicated that gross hydrolysis had not occurred. A possible explanation for this favorable behavior may lie in part in the operational mode followed throughout the experiment. That is, after approximately every 8 hours of continuous operation, a short period of fresh water flushing was accomplished, which in effect tended to modify the membrane pH—a critical condition for hydrolysis to occur. To assume that the membrane pH is consistent with that of the brine or permeate fluids

is not necessarily correct. This assumption needs further verification and its documentation is beyond the scope of this work. The data observed here indicate that there may be an inconsistency in the membrane-fluid pH relationship or that at least a time-reaction element condition exists and it plays a significant role in that relationship.

In reviewing the production or flux rates of the module, evaluating the variable dV_2/dt for selected t values gives an indication of the commonly observed classical "fouling" behavior. The exact mechanism or cause for this phenomenon will not be pursued here, but suffice it to say that the primary cause was believed to be colloidal materials and ferric oxides. The colloidal materials may have been present in the original wastewaters, while the iron oxides may have originated within the experimental system due to the corrosive activity of the acids upon the metallic components of the setup. In any case, the noteworthy item is that Figure 8 is representative of statistically analyzed values which indicate the recoverability of the flux after repeated experiments or exposures. That is, the function may be interpreted as being a predictor for a reversible type degradation of flux overtime (20 hours) when the operational mode includes periodic flushing with a fresh water. Given this empirical "engineering data" and that shown in Table 7, the problem of a properly designed RO system capable of treating acid wastewaters can be approached with an encouraging degree of confidence.

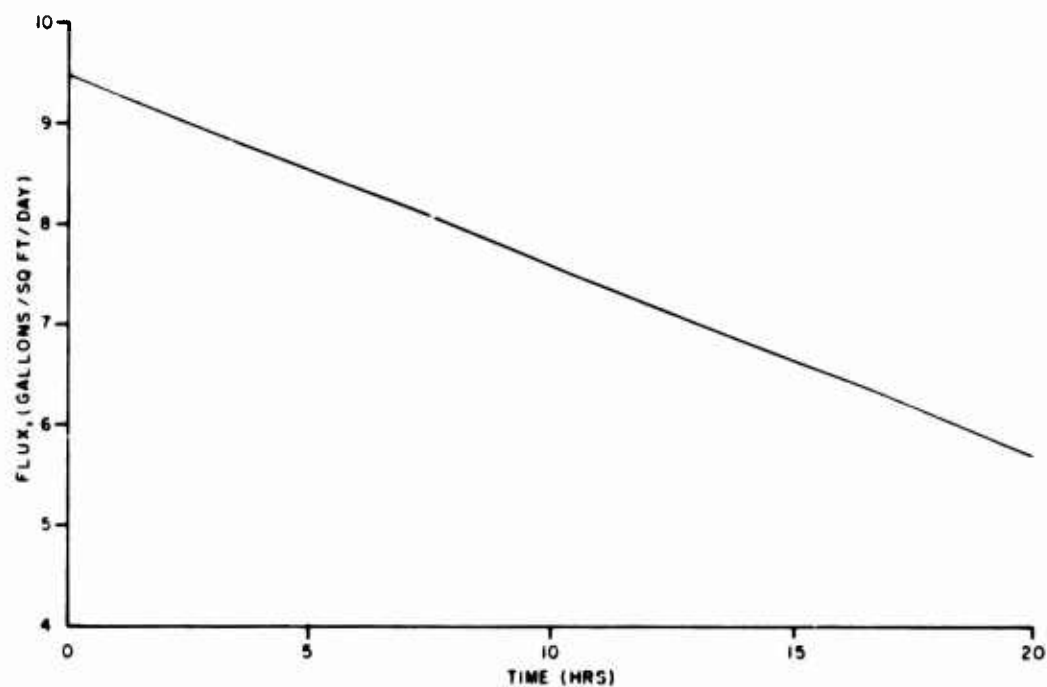


Figure 8. Flux (GF²D) vs Time (hr), Cellulose Acetate RO Membrane.

The data presented on the SPRO membranes (Table 9) showing the flux and rejection rates, although not given the type of analysis as that shown for the cellulose-acetate, appear to be most enlightening. It is noted that significant progress has been made in the G.E. contract. Formulating, casting, and the fabricating of spiral-wound modules has been completed for extensive testing in the scaled-up pilot plant operation noted earlier. During this next phase, rigorous exposure and analysis of the observed data will be accomplished on both these SPRO and other cellulose-acetate spiral-wound RO modules. Therefore, further discussion regarding the SPRO membrane is postponed until completion of the next phase of the project.

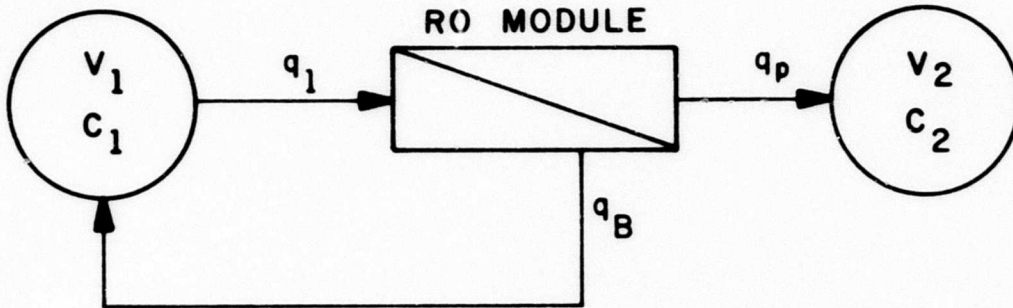
IV. CONCLUSIONS

6. **Conclusions.** Based on the data obtained in the laboratory phase of this study and subject to that data generated in the pilot plant phase, the following conclusions appear valid:

- a. The application of cellulose-acetate and modified sulfonated polyphenylene oxide RO membranes as a unit process in the treatment of dilute acid wastewaters generated at RAAP is technically feasible.
- b. The concentration of nitric and sulphuric acid at acceptable rates for engineering scale-up using RO is feasible and attainable.
- c. The permeation or flux rates attainable in the treatment of RAAP acid wastewaters are acceptable for engineering scale-up.
- d. Hydrolysis of the cellulose-acetate membrane did not significantly impair the performance characteristics of the RO modules.
- e. Acidic corrosion of the metallic components of the RO system can introduce operational problems that will significantly interfere with the rejection and flux rates of the RO membranes.
- f. Continuation of the program into a Phase II RO pilot plant operation located at RAAP for on-site evaluation and performance documentation and/or verification is justified.

APPENDIX A

REJECTION MODEL MATHEMATICS



Definitions:

V_1 = fluid volume in tank 1

V_2 = fluid volume in tank 2

C_1 = concentration in tank 1

C_2 = concentration in tank 2

q_1 = fluid flow rate in - $\frac{dV_1}{dt} = K$

q_p = product flow rate = $\frac{dV_2}{dt}$

q_B = brine flow rate

t = time

$C_{10} = C_1$ at $t=0$

$V_{10} = V_1$ at $t=0$

α = rejection percentage rate

Consider Single Species Only

balance on 1 is:

$$(1) \quad q_1 * C_1 = V_1 C_1 - q_p * C_1 + q_B (1 - \alpha) C_1$$

balance on 2 is:

$$(2) \quad q_p * C_2 = q_1 * C_1 - q_1 * \alpha * C_1$$

$$(2a) \quad \frac{d}{dt} V_2 * C_2 = KC_1 - K \alpha C_1$$

$$\text{from continuity: } q_1 = q_p + q_B \quad (3)$$

$$V_1 + V_2 = V_{10} \quad (4)$$

Overall balance on the system:

$$C_1 V_1 + C_2 V_2 = C_{10} V_{10} \quad (5)$$

$$C_1 = \frac{C_{10} V_{10} - C_2 V_2}{V_{10} - V_2} \quad (6)$$

Now differentiate (2a) and obtain

$$(2b) \quad V_2 \frac{dC_2}{dt} + C_2 \frac{dV_2}{dt} = KC_1 - K \alpha C_1$$

$$(2c) \quad = KC_1 (1 - \alpha)$$

Substitute (6) into (2c)

$$V_2 \frac{dC_2}{dt} + C_2 \frac{dV_2}{dt} = K \left[\frac{C_{10} V_{10} - C_2 V_2}{V_{10} - V_2} \right] [1 - \alpha]$$

Let $\Delta = V_{10} - V_2$

$$\alpha_T = 1 - \left[\frac{C_2 * dV_2}{K[\Delta] dt} \right] - \left[\frac{V_2 * dC_2}{K[\Delta] dt} \right]$$

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C 3 4 - Y DATA CARDS (F1,4)
C DD XTIL,YTIL,TMAG,XKEY,YKEY,RKMAG (6F10.4)
C THIS CARD IS ONLY NECESSARY AFTER A NEW FRAME HAS BEEN REQUESTED
C XTIL,YTIL,TMAG SIZE AND LOCATION OF TITLE HEADING
C XKEY,YKEY,RKMAG SIZE AND LOCATION OF THE GRAPH KEY AND LINE EQUATIONS
C E SEGMENT DATA SETS CONSIST OF CARDS B,C,D, AND POSSIBLY DD
C F COMPLETE DATA SET CONSISTS OF CARDS 2,3,4,5,6,7,8,9, AND ANY E SETS
C COMPLETE RUN SET REQUIRES CARD 1 AT THE TOP

```

```

MONT=SHIFT(DATE(IJ),6)
ITIME=SHIFT(TIME(IJ),6)
WRITE(4,300)
FORMAT(1H1)

```

```

READ IN THE AXIS TITLES
DO 125 I=1,5

```

```

READ(I,121) (XTITLE(J,I),J=1,4)
FORMAT(4A10)
IF(EOF(I)) 507,127

```

```

CONTINUE
DO 122 I=1,10

```

```

READ(I,121) (YTITLE(J,I),J=1,3)
IF(EOF(I)) 501,122

```

```

CONTINUE
CALL READIN,RETURNS(97,99)

```

```

GO TO (42,101),IFLOT
GO TO (48,101),ISWT

```

```

ISWT = 2
OPEN THE PLOT TAPE IF REQUESTED

```

```

IDARK9 = 6
IDARKT = 6
IDARKP = 2

```

```

CALL CALCOMP(18UF,17,17,17,17)
CALL CALCOMP(17,17,17,17,17)

```

```

CALL BORDER(17,17,17,17,17)
CALL CALCOMP(17,17,17,17,17)

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CALL INFRA(17,17,17,17,17)
CALL CALCOMP(17,17,17,17,17)

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```

CONTINUE
READ(1,22) IXMHCH,IYMHCH,IYSRT,ICUOVE,IORD,4,ITSECNU,ICONT

```

```

1,NXTRP
FORMAT(1E15)
IF(EOF(1)) 61,9191

```

```

CONTINUE
IF(1,22) .AND. IYSRT .NE. 0 NELFNX(IXMHCH)-IYSRT+1

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IF(1,22) .NE. IYMHCH
IF(IXMHCH) IYSRT=1

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IF(IYSRT) IYSRT=1
IF(IXMHCH) IYSRT=1

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IF(IXMHCH) IYSRT=1
IF(IXMHCH) IYSRT=1

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IF(IXMHCH) IYSRT=1
IF(IXMHCH) IYSRT=1

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IF(IXMHCH) IYSRT=1
IF(IXMHCH) IYSRT=1

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IF(IXMHCH) IYSRT=1
IF(IXMHCH) IYSRT=1

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113 IF=AME=FRAME
    IF(NUGRPF.EQ.1) IFRAME=IFRAME+1
    DO 15 I=1,N
        Y(I)=Y*UP(IYSRT+1-1,IYMHCH)
        IF(IYMHCH.EQ.1) YL(I)=ALOG(Y(I))
        X(I,2)=XINP(IYSRT+1-1,IYMHCH)
        CALL BUS(V,N,STATS)
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75 WRITE(4,35) MONT,TIME,IFRAME
   FORMAT(16,'DATE',A10,' TIME',A10,' FRAME NO.',I4)
175 WRITE(4,43) IXMHCH,IYMHCH,IXSRT,IYSRT,ICURVE,IORD,NISEGNUM,ICONT
   NUGRAF,NUAXIS
43  FORMAT(' IXMHCH',I5,' IYMHCH',I5,' IXSRT',I5,' IYSRT',I5,
   1* ICURVE',I5,
   1* IORD',I5,' N',I5,' ISEGNUM',I5,' ICONT',I5,' NUGRAF',I5
   2* NUAXIS',I5)
18  WRITE(2,36) IUNIT
   FORMAT(16,A10)
76  WRITE(2,36) IORD
   WRITE(2,36) IORDP
185  WRITE(4,39) XMIN(IXMHCH),XMAX(IXMHCH),YMIN(IYMHCH),YMAX(IYMHCH),XL
   LEN(IXMHCH),YLEN(IYMHCH),DELTAX(IXMHCH),DELTAY(IYMHCH)
19  FORMAT(' XMIN',F10.4,' XMAX',F10.4,' YMIN',F10.4,' YMAX',F
   11.4,
   1* XLEN',F10.4,' YLEN',F10.4,' DELTAX',F10.4,' DELTAY',
   2* F10.4)
191  WRITE(2,34) (XTITLE(JJ,IXMHCH),JJ=1,4),(YTITLE(KK,IYMHCH),KK=1,3)
   FORMAT(1X,A10,' VS',A10/73,' X VALUE',I15,' Y VALUE',I29,
   1* PREDICT Y VALUE',I45,' RESIDUAL')
33  WRITE(2,5) (X(I,2),Y(I,2),VP(I,2),RES(I,2),I=1,M)
   IF(NXTRP.NE.0) WRITE(2,269)(X(N+I,2),Y(N+I,2),I=1,M,NXTRP)
195  FORMAT(1H,1X,F8.3,23X,F8.1)
   WRITE(2,6) N
269  IF(NXTRP.NE.0) WRITE(2,269) NXTRP,DLXTRP
   FORMAT(' NUMBER OF EXTRAPOLATED POINTS IS',I9,2X,' EVERY',F10.4,
   1* UNITS')
28  GO TO (28,29),ICURVE
   WRITE(2,9) SSR(1)
   WRITE(2,10) SSR(2)
   WRITE(2,11) SSR(3)
   WRITE(2,12) SSR(4)
   WRITE(2,13) 9
   WRITE(2,13) 9
25  FORMAT(1H,2X,' EQUATION IS OF THE FORM Y = A EXP(B X) WHERE A = ',
   1E15.6,3X,' AND B = ',E15.6)
   GO TO 34
29  WRITE(2,12) SSR(4)
   WRITE(2,14)
21  FORMAT(1H,2X,54EQUATION IS OF THE FORM Y = C(I)*X**IORD+...+C(10
   1RD+1))
   DO 201 I=1,IORD
   IORD = IORD-I+1
   IF(IORD.EQ.1) GO TO 215
215  WRITE(2,200)CC(I),IORD
   FORMAT(' WHERE Y =',(I11,3H + ,E15.6,6H *X** ,I2))
   GO TO 231
295  WRITE(2,206)CC(I)
206  FORMAT(11,3H + ,E15.6,3H *X)
201  CONTINUE
   WRITE(2,212)C(IORD+1)
202  FORMAT(11,3H + ,E15.6)
   1 FORMAT(16,' ')
2  FORMAT(1M,16,' SANITARY SCIENCE DIVISION REVERSE OSMOSIS')
3  FORMAT(1M,120,' DATA ANALYSIS')
225  FORMAT(1M,13,' CUM MINS',I15,' TURBID(COAG)',I29,' PREDICT T-COAG',
   1 I45,' RESIDUAL')
5  FORMAT(1M,1X,F8.1,6X,F8.1,9X,F8.1,6X,F8.1)

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234 6 FORMAT(1M0,2X,*,NUMBER OF OBSERVATIONS IS',I4)
9 FORMAT(1M0,2X,*,SS OF RESIDUALS IS',F10.4,E15.6)
10 FORMAT(1M0,2X,*,SSY ABOUT MEAN IS',F10.4,E15.6)
11 FORMAT(1M0,2X,*,ESTIMATE OF ERROR VARIANCE IS',F10.4,E15.6)
12 FORMAT(1M0,2X,*,SQ MULT CORR COEF IS',F10.4,E15.6)
30 WRITE(2,17) STAT
170 FORMAT(17) BASIC STATISTICS ABOUT THE Y INPUT ARE *
17 17 MEAN = *G11.5,
27 SECOND MOMENT = *G11.5,
37 THIRD MOMENT = *G11.5,
47 FOURTH MOMENT = *G11.5,
57 VARIANCE = *G11.5,
67 STANDARD DEVIATION = *G11.5,
77 SKEWNESS = *G11.5,
87 KURTOSIS = *G11.5/

245 PLOTTING SECTION
C
C
C
104 GO TO (104,109),IPL04
109 GO TO(109,72),MUGRAF
111 READ(1,11) XTIL,YTIL,TMAG,XKEY,YKEY,RKMAG
111 FORMAT(5F10.4)
112 WRITE(4,112) XTIL,YTIL,TMAG,XKEY,YKEY,RKMAG
112 FORMAT(17) T6,XTIL = *F10.4,*,YTIL = *F10.4,*,TMAG = *F10.4,*,
176,XKEY = *F10.4,*,YKEY = *F10.4,*,RKMAG = *F10.4,*,
71 CALL CALCP(18,*,*,IDARK,3)
CALL BORDER(18,*,*,IDARK,3)
CALL CALCP(18,*,*,IDARK,3)
CALL IFRAM(18,*,*,IDARK,3)
CALL CALCP(18,*,*,IDARK,3)
CALL AXIS(18,*,*,IDARK,3)
CALL AXIS(18,*,*,IDARK,3)
CALL HEAD(XTIL,YTIL,TMAG)
XFSAX = *
72 GO TO (73,74),MUGRAF
73 CALL AXIS(XFSAX,*,*,YTILE(1,IYMHCH),30,YLEN(IYMHCH),90.,YMIN(IYMHCH),
*,*,DELTA(IYMHCH))
XFSAX = *
74 CALL KEY(XKEY,YKEY,RKMAG,IYMHCH)
RMAGY = YMAX(IYMHCH)
RMINY = YMIN(IYMHCH)
DO 75 I=1,N
XOUM(I) = X(I,2)
IF (XOUM(I) .GT. XMAX(IYMHCH)) XOUM(I) = XMAX(IYMHCH)
IF (XOUM(I) .LT. XMIN(IYMHCH)) XOUM(I) = XMIN(IYMHCH)
IF (Y(I) .GT. RMAGY) Y(I) = RMAGY
IF (Y(I) .LT. RMINY) Y(I) = RMINY
IF (Y(I) .GT. RMAGY) Y(I) = RMAGY
IF (Y(I) .LT. RMINY) Y(I) = RMINY
XOUM(N+1) = XMIN(IYMHCH)
XOUM(N+2) = DELTA(IYMHCH)
Y(N+1) = YMIN(IYMHCH)
Y(N+2) = DELTA(IYMHCH)
CALL CALCP(18,*,*,IDARK,3)
CALL LINE(XOUM,Y,N,1,-1,IYMHCH-1)
IF(NXTP.E2.6) GO TO *2
70 7 1 I=1,MNXTIR

```

```

290      XDM(I+N)=X(N+I+23)
        IF(XDM(I+N).GT.XMAX(I+XMMCH)) XDM(I+N)=XMAX(I+XMMCH)
        IF(XDM(I+N).LT.XMIN(I+XMMCH)) XDM(I+N)=XMIN(I+XMMCH)
        IF(VP(I+N).LT.RMIN) VP(I+N)=RMIN
        IF(VP(I+N).GT.RMAX) VP(I+N)=RMAX
        XDM(N+XMMTRP+1)=XMIN(I+XMMCH)
        XDM(N+XMMTRP+2)=DELTA(I+XMMCH)
        VP(N+XMMTRP+1)=YMIN(I+XMMCH)
        VP(N+XMMTRP+2)=DELTA(I+XMMCH)
        CALL LINE(XDM,VP,N+XMMTRP,1,1,13-I+XMMCH-ISECH)
        CALL CALCAP(1,500,9,10,0,3)
        CALL EQD2A(XKEY,RKMA5,KEY,RKMA5,8,XDM(1),XDM(N+XMMTRP),CC)
        YKEY=YKEY+35
        GO TO (60,51,80),ICONT

105      C
110      C
115      C
        THIS IS THE MODEL SECTION UNDER LTD CIGCONES CASE
        READ(1,81) ISMD,IMPUR,DVOLCON,RK,TIME,NOINC,TIME
        FORMAT(2I5,3F10.4,15,F10.4)
        WRITE(4,83) ISMD,IMPUR,DVOLCON,RK,TIME,NOINC,TIME
        FORMAT(2I5,3F10.4,15,F10.4)
        IMPUR=IMPUR+15
        DVOLCON=DVOLCON+15
        TIME=TIME+15
        NOINC=NOINC+15
        LPRE=NOINC+1
        XPRE(1)=TIME
        DELT=(TIME-TIME)/NOINC
        DO 75 I=1,NOINC
        XPRE(I+1)=XPRE(I)+DELT
        CALL CALFON(3)
        IF(IMPUR.EQ.2) GO TO 90
        CALL CALEZM(1)
        CALL DERIV(1)
        IF(IMPUR.EQ.1) GO TO 91
        CONTINUE
        CALL CALEZM(2)
        CALL DERIV(2)
        IF(ISMD.EQ.1) GO TO 92
        CALL DERIV(3)
        GO TO 93
        CONTINUE
        CALL DERIV(4)
        CONTINUE
        JSMT=1
        JJNR=NCURVE(7)
        GO TO (150,151),JJNR
        V1=COEFFS(7,1)*EXP(TIME*COEFFS(7,2))
        GO TO 150
        JJORD=NORD+P(7)+1
        V1=V1
        DO 153 JJ=1,JJORD
        V1=V1+COEFFS(7,JJ)*(TIME**((JJORD-JJ)))
        CONTINUE
        IF(IMPUR.NE.3) GO TO 45
        JSMT=2
        IMEUR=1
        ILM=NOINC+1
        MPOINT=MMCH(IMPUR)
        JJNR=NCURVE(MPOINT)

```

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```

152 GO TO (162,163),JJIMP
153 C1=COEFFS(MPOINT,1)*FXP(VIM*COEFFS(MPOINT,2))
154 GO TO 164
155 JJORD=NORDFP(MPOINT)+1
156 C1=0.
157 NO 165 JJ=1,JJORD
158 C1=C1+COEFFS(MPOINT,JJ)*(TIM*(JJORD-JJ))
159 CONTINUE
160 L=IMPUR+1
161 DO 16 I=1,ILIM
162 CONST=K*(C1+V1C-YPRE(I,IMPUR)*YPRE(I,3))/(V10-YPRE(I,3))
163 Y(I)=(1-(YPRE(I,IMPUR)/CONST*YPRE(I,6))-(YPRE(I,3)/CONST*YPRE(I,1
164 YPUR+3)))*100.
165 CONTINUE
166 WRITE(2,2)
167 WRITE(2,3)
168 IFRAME=FRAME+1.
169 WRITE(2,35) MONT,ITIME,IFRAME
170 WRITE(4,301)
171 WRITE(4,35) MONT,ITIME,IFRAME
172 WRITE(2,36) IUNIT
173 WRITE(2,36) IPRTR
174 IF(RPSI.NE.0.)
175 *WRITE(2,989) RPSI
176 FORMAT(' PRESSURE = ',F10.4,' PSI')
177 WRITE(2,98) (XTITLE(J,1),J=1,4),(VTITLE(J,8+IMPUR),J=1,3)
178 *FORMAT('S,4A10.0 VS ',3A10)
179 WRITE(2,95) (XPRE(J),YPRE(J,IMPUR),YPRE(J,3),YPRE(J,3+IMPUR),
180 YPRE(J,6),Y(J),J=1,ILIM)
181 *FORMAT('TIME',T25.0CP*,T40.0V2*,T54.0CP*,T69.0V2*,T82.
182 *PERC RES',/615X,F10.4))
183 PRINT 166,C10,V10
184 *FORMAT(' C10 = ',G10.4,' V10 = ',G10.4//)
185 XPRE(ILIM+1)=XMIN(IMPUR+0)
186 XPRE(ILIM+2)=DELTA(XIMPUR+0)
187 GO TO(96,95),IPLOT
188 CONTINUE
189 WRITE(4,39) XMIN(1),XMAX(1),YMIN(1),YMAX(1),XLEN(1),YLEN(1),
190 DELTAX(1),DELTAY(1)
191 READ(1,11) XTIL,YTIL,TMAG
192 WRITE(2,112) XTIL,YTIL,TMAG
193 IXMHCH=1
194 CALL CALCHP(0.0,0.0,IOAPK,3)
195 CALL BOPK(0.0,0.0,17.0,11.0)
196 CALL CALCHP(0.0,0.0,IOAPK,3)
197 CALL IOFRAM(14.5,10.0,1.0,14.0)
198 CALL CALCHP(14.5,10.0,IOAPK,3)
199 CALL AXIS(0.0,0.0,XTITLE(1,IXMHCH),-40,XLEN(IXMHCH),0,XMIN(IXMHCH),
200 *DELTAX(IXMHCH))
201 CALL HEND(XTIL,YTIL,TMAG)
202 CALL SCALE(Y,YLEN(1),YLIM,1)
203 WRITE(2,16) Y(ILIM+1),Y(ILIM+2)
204 *FORMAT(' ',F10.4,' YSTART = ',F10.4,' DELTAY = ',F10.4)
205 CALL AXIS(0.0,0.0,YTITLE(1,1),30,YLEN(1),90,Y(ILIM+1),Y(ILIM+2))
206 CALL CALCHP(14.5,10.0,IOAPK,3)
207 CALL LINE(YPRE(1),YLIM,1,1,4)
208 GO TO(61,67),JSWT

```

```

PROGRAM CIRCONE 74/74 OPT=1
47 IMPUR=2
   JSWT=1
   GO TO 45
99 GO TO (103,102),JSWT
   C
   C CLOSE THE PLOT TAPE IF OPENED
   C
102 CALL CALCP(0.,0.,9999,2)
103 STOP
     END

```



```

SUBROUTINE HEAD(X,Y,RMAG)
COMMON/HEAD/UNIT(3),IPRTR(3),RPSI
CALL SYMBOL(X,Y,RMAG,RMAG,6HUNIT),0.,00)
CALL SYMBOL(999.,999.,RMAG,UNIT,0.,00)
CALL SYMBOL(X,Y-(2.*RMAG+.3),RMAG,6HPRTR),0.,05)
CALL SYMBOL(999.,999.,RMAG,IPRTR,0.,00)
IF(RPSI.EQ.0.) GO TO 1
CALL SYMBOL(X,Y-(2.*RMAG+.6),RMAG,SYPSI),0.,05)
CALL NUMBER(999.,999.,RMAG,RPSI,0.,0)
CONTINUE
RETURN
END

```

5

10

74174 OPT 21

CONSECUTIVE CONCORD

```

SURROUTINE EQNDEKA(X,Y,FMAG,8,XLO,XHI,C)
DIMENSION J(2)
COMMON/MHICH/IXMHCH,IXMHCH,IXSRT,IXSRT,ICURVE,IORD,M,ISEGNUM,ICONY
CALL SYMBOL(X,Y,S*RMAG,RMAG,13-IXMHCH-ISEGNUM ,0,-1)
CALL SYMBOL(999.,Y,FMAG,6M Y = 0.,6)
GO TO(1,2) ICURVE
1 CALL NUMBE(999.,999.,FMAG,6(1),0.,3)
CALL SYMBOL(999.,999.,FMAG,5M EXP(0.,5)
CALL NUMBER(999.,999.,FMAG,0(2),0.,3)
CALL SYMBOL(999.,999.,FMAG,3M X1,0.,3)
GO TO 1
2 NN 4 I=1,IORD
NN3 = IORD-I+1
RINDJ = INDO
CALL SYMBOL(999.,999.,FMAG,1M(0.,1)
CALL NUMBER(999.,999.,FMAG,C(I),0.,3)
CALL SYMBOL(999.,999.,FMAG,7M X0,0.,3)
IF(INDO.EQ.1) GO TO 5
CALL NUMBE(999.,Y+(P*AG/2.),FMAG/2.),RINDJ,0.,-1)
CALL SYMBOL(999.,Y,FMAG,3M + ,0.,3)
CONTINUE
CALL SYMBOL(999.,999.,FMAG,1M(0.,1)
CALL NUMBE(999.,999.,FMAG,C(IORD+1),0.,3)
CALL SYMBOL(999.,999.,FMAG,1M(0.,1)
CALL SYMBOL(999.,999.,FMAG,5M 1,0.,5)
CALL NUMBE(999.,999.,FMAG,XLO,0.,8)
CALL SYMBOL(999.,999.,FMAG,3M X-1,0.,3)
CALL NUMBER(999.,999.,FMAG,XHI,0.,4)
CALL SYMBOL(999.,999.,FMAG,1M(0.,1)
RETURN
END

```

```

SUBROUTINE KEY(X,Y,RMAG,IYMHCH)
COMMON/YTITLE/YTITLE(5,10)
CALL SYMBOL(X,Y+.5*RMAG,RMAG,IYMHCH-1,0,,-1)
CALL SYMBOL(999.,Y,RMAG,22H EXPERIMENTAL VALUES,0,22)
CALL SYMBOL(999.,999.,RMAG,YTITLE(1,IYMHCH),0,32)
Y = Y - (3MAG + .14)
CALL SYMBOL(X,Y,RMAG,31H PREDICTED VALUE EQUATION(S),0,31)
Y = Y - (RMAG + .14)
RETURN
END

```

5

1.

```

SUBROUTINE BORDEL (X0,Y0,X1,Y1)
NEW FRAME
CALL CALCMP(C.....,LJ00,2)
OPEN LINES
CALL CALCMP(X1,Y0,99,1)
CALL CALCMP(X1,Y1,99,1)
CALL CALCMP(X0,Y1,99,1)
CALL CALCMP(X0,Y0,99,1)
RETURN
END

```

5

13

SUBROUTINE IOFRAM
7474
OPT=1

FTN 4.1+PSR367
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11.28.57.
PAGE 1

5

SUBROUTINE IOFRAM(X,Y,XMAG)
COMMON/DATE/MONT,ITIME,FRAME
DATA FRAME/-1./
FRAME = FRAME + 1.
CALL SYMBOL(X,Y,XMAG,AMDATE),C,6)
CALL SYMBOL(999,999,XMAG,MONT,8,8)
CALL SYMBOL(X,(Y+.07*XMAG),XMAG,10*NAME),LTC,CICCOM,8,10)
CALL SYMBOL(X,(Y+.14*XMAG),XMAG,XMAG,8*NAME),LTC,CICCOM,8,10)
CALL SYMBOL(X,(Y+.21*XMAG),XMAG,ITIME,8,9)
CALL SYMBOL(999,999,XMAG,SNFRA,8,9)
CALL NUMBER(999,999,XMAG,FRAME,8,-1)
RETURN
END

13

```

SUBROUTINE POLYFIT(XX,Y,N,M,YC,RES,C,SSR)
COMMON/XXX/XXX(500,2)
DIMENSION XX(1,1)
DIMENSION A(1,12),B(2,1),X(200)
EQUIVALENCE(XXX(1,2),X(1))
X,Y ARE INPUT ARRAYS
N IS THE NUMBER OF POINTS
M IS THE ORDER OF THE CURVE TO FIT
YC IS THE CALCULATED Y
RES IS THE RESIDUAL
C IS THE ARRAY OF COEFFICIENTS
SSR IS THE STATISTICS RETURN ARRAY
DIMENSION Y(200),YC(200),RES(200),C(11),SSR(9)
IF (N.LE.1) STOP
IF (N.LE.500) GO TO 2
PRINT 110, N
110 FORMAT(//5X18NUMBER OF POINTS =,I5,2X19EXCEEDS MAX. OF 500/
2 EX18PROGRAM ERROR STOP)
STOP 1
2 IF (M.GT.3) GO TO 3
PRINT 120, M
120 FORMAT(//5X18DEGREE =,I5,9H IN ERROR/5X18PROGRAM ERROR STOP)
STOP 2
3 IF (M.LE.1) GO TO 4
PRINT 130, M
130 FORMAT(//5X18DEGREE =,I5,2X,13HREDUCED TO 10)
M = 10
4 CONTINUE
5 MA = M + 1
MB = M + 2
MC = M + 3
DO 1 I = 1,M2
1 B(I) = X(1)**I
DO 2 J = 1,M2
DO 3 I = 1,M2
2 B(I) = B(I) + X(J)**I
A(I,MA) = N
DO 3 I = 2,MA
3 A(I,MA) = B(I-1)
DO 4 I = 1,MA
K = I - 1
DO 4 J = 2,MA
L = MA - J + 1
K = K + 1
4 A(I,L) = A(K)
SUM = 0.0
DO 5 I = 1,N
5 SUM = SUM + Y(I)
DO 6 I = 1,M
DO 7 I = 1,M
DO 7 J = 2,M
7 B(I) = B(I) - Y(J)*X(J)**I
A(I,MB) = SUM
DO 8 I = 2,MA
8 A(I,MB) = A(I-1)
DO 10 K = 1,M

```

```

60  L = K + 1
    DO 9 J = K, MA
      A(J) = A(I, K)
    DO 11 J = K, MR
      31  A(I, J) = A(I, J) / AR
    DO 10 I = L, MA
      DO 13 J = K, MR
        65  A(I, J) = A(K, J) - A(I, J)
          A(MA, MB) = A(MA, MB) / A(MA, MA)
        DO 11 I = L, MA
          111 C(I) = -A(I, MB)
        DO 12 J = 2, MA
          K = MA - J + 2
          L = K - 1
        DO 12 I = 1, L
          125 C(I) = C(I) - A(I, K) * C(K)
        SUM = 0.0
        SY = 0.0
        SZ = 0.0
        DO 15 I = 1, N
          P = X(I)
          Q = P * C(I)
          IF (M.EQ.1) GO TO 145
        DO 14 J = 2, M
          141 Q = P * (Q + C(J))
          145 YC(I) = Q + C(MA)
          RES(I) = Y(I) - YC(I)
          SUM = SUM + RES(I) ** 2
          SY = SY + Y(I)
          151 SZ = SZ + Y(I) ** 2
          155 SZ = SZ - SY * SY / FLOAT(N)
          SSR(4) = 1.0 - SUM / SZ
        RETURN
      ENR

```

SUBROUTINE DERIV

74/74

OPT=1

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```
5 SUBROUTINE DERIV(INP)
COMMON/DERIVA/YPRE(50,5),XPRE(500),LPRE,OVOLCON
COMMON/EQNS/NCURVE(8),NORDER(8),COEFFS(8,11)
10 IF(INP.EQ.4) GO TO 30
JIND=NCURVE(INP)
GO TO (1,2),JIND
1  DO 3 I=1,LPRE
3  YPRE(I,IMP+3)=COEFFS(INP,2)+YPRE(I,IMP)
2  RETURN
JLIM=NORDER(INP)
80 4 I=1,LPRE
SUM=0.0
DO 5 J=1,JLIM
5  SUM=SUM+COEFFS(INP,J)*(JLIM+1-J)*(XPRE(I)**(JLIM-J))
4  YPRE(I,IMP+3)=SUM
10 RETURN
DO 6 I=1,LPRE
6  YPRE(I,6)=OVOLCON
RETURN
END
```

```

SUBROUTINE CALCON(INP)
COMMON/CONS/NCURVE(8),NORDER(8),COEPPS(8,11)
COMMON/DEI/VA/YPRE(500,6),XPRE(500),LPRE,OVOLCOM
JIND=NCURVE(INP)
GO TO (1,2),JIND
DO 3 I=1,LPRE
  YPRE(I,INP)=COEPPS(INP,I)*EXP(XPRE(I)*COEPPS(INP,2))
RETURN
JLIM=NORDER(INP)+1
DO 4 I=1,LPRE
  SUM=0.0
DO 5 J=1,JLIM
  SUM=SUM+COEPPS(INP,J)*(XPRE(I)**(JLIM-J))
  YPRE(I,INP)=SUM
RETURN
END

```

APPENDIX C

COMPUTER ANALYSIS - OBSERVED DATA

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATA ANALYSIS

DATE 07/05/74 TIME 11.32.45. FRAME NO. 1

ACID WAST-WATER RO STUDY

(CICZONE)

X VALUE	TIME (HOURS)	Y VALUE	PREDICT Y VALUE	VS RESIDUAL	VS BRINE CONC. - IMPURITY 2
0.1	3500.0	5676.1	5676.1	-1076.1	223.9
0.1	3500.0	5676.1	5676.1	223.9	123.9
0.1	3500.0	5676.1	5676.1	5676.1	723.9
0.1	3500.0	5676.1	5676.1	5676.1	623.9
2.0	4100.0	5943.7	5943.7	-1043.7	356.3
2.0	5300.0	5943.7	5943.7	356.3	556.3
2.0	5300.0	5943.7	5943.7	5943.7	-716.9
2.0	5300.0	5943.7	5943.7	5943.7	-116.9
4.0	6300.0	6316.9	6316.9	243.1	583.1
4.0	6300.0	6316.9	6316.9	6316.9	-995.6
4.0	6300.0	6316.9	6316.9	6316.9	1704.6
6.0	7300.0	7379.9	7379.9	-779.9	1127.1
6.0	7300.0	7379.9	7379.9	7379.9	527.1
8.0	8300.0	9300.2	9300.2	9300.2	734.0
8.0	8300.0	9300.2	9300.2	9300.2	234.0
10.0	9300.0	966.2	966.2	-966.2	-966.2
12.0	9300.0	13772.0	13772.0	-972.0	-972.0
12.0	9300.0	13772.0	13772.0	13772.0	-1772.0
14.0	11000.0	1172.0	1172.0	227.2	2115.1
14.0	11000.0	1172.0	1172.0	1172.0	-1102.6
16.0	12000.0	13102.6	13102.6	-2652.6	2974.1
16.0	12000.0	13102.6	13102.6	13102.6	111.0
18.0	13500.0	14425.9	14425.9	14425.9	17389.0
20.0	17000.0	17389.0	17389.0	17389.0	17389.0
22.0	17500.0	17389.0	17389.0	17389.0	17389.0
24.0	17500.0	17389.0	17389.0	17389.0	17389.0

NUMBER OF OBSERVATIONS IS 29

SO MULT CORR COEF IS

.969798E+00

EQUATION IS OF THE FORM $Y = C(1) * X^{C(2)} + C(3) * X^{C(4)} + \dots + C(I) * X^{C(I)}$

WHERE $Y =$ $\begin{matrix} + & .131954E+02 & * X^{0.2} \\ + & .172410E+03 & * X \\ + & .567608E+04 \end{matrix}$

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 8446.3
 SECOND MOMENT = .1845E+08
 THIRD MOMENT = .4674E+11
 FOURTH MOMENT = .4964E+15
 VARIANCE = .1123E+08
 STANDARD DEVIATION = 3351.4
 SKEWNESS = 1.2453
 KURTOSIS = 1.2211

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATA ANALYSIS
 DATE 17/3/74 TIME 11.32.45. FRAME NO. 2
 ACID WASTEWATER RO STUDY
 (CICCONO)

X VALUE	TIME (HOURS)	PREDICT Y VALUE	VS RESIDUAL	BRINE CONC. - IMPURITY 1
3.1	2093.0	2200.9	-200.9	269.1
3.1	2550.0	2290.9	269.1	49.1
3.1	2330.0	2290.9	49.1	219.1
3.1	2510.0	2280.9	219.1	-100.9
1.1	2190.0	2200.9	-100.9	-230.3
2.1	2090.0	2310.3	-230.3	189.7
2.1	2500.0	2310.3	189.7	-3
2.1	2310.0	2323.0	-3	-293.0
4.1	2130.0	2323.0	-293.0	137.0
4.1	2450.0	2323.0	137.0	37.0
4.1	2350.0	2323.0	37.0	97.0
4.1	2420.0	2319.1	97.0	-292.1
5.1	2127.0	2319.1	-292.1	-129.1
6.1	2190.0	2298.4	-129.1	191.6
8.1	2490.0	2298.4	191.6	-98.4
1.1	2230.0	2298.4	-98.4	-18.4
8.1	2280.0	2261.0	-18.4	-101.0
10.1	2160.0	2207.0	-101.0	-32.0
12.1	2175.0	2207.0	-32.0	83.0
12.1	2230.0	2136.2	83.0	10.0
14.1	2155.0	2148.7	10.0	274.3
16.1	2329.0	2148.7	274.3	-58.7
16.1	1930.0	2148.7	-58.7	141.3
16.1	2190.0	2048.7	141.3	-119.6
18.1	1025.0	1944.6	-119.6	336.3
2.1	2150.0	1923.7	336.3	-123.7
2.1	1700.0	1923.7	-123.7	-191.1
22.1	1495.0	1686.1	-191.1	-50.9
26.1	1310.0	1360.9	-50.9	

NUMBER OF OBSERVATIONS IS 29

SQ MULT CORR COEF IS

.651898E+30

EQUATION IS OF THE FORM $Y = C(1) * X^{**} IOR0 + \dots + C(IOR0+1)$

WHERE $Y = +$
 $- .233735E+31 * X^{**} 2$
 $+ .1838785E+02 * X$
 $+ .223088E+34$

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 2164.
 SECOND MOMENT = 11534.
 THIRD MOMENT = -.26944E+80
 FOURTH MOMENT = .29940E+11
 VARIANCE = 84518.
 STANDARD DEVIATION = 290.72
 SKEWNESS = -1.2416
 KURTOSIS = 1.496

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATE 07/09/74 DATA ANALYSIS
 RADIO WASTE-WATER RD STUDY FRAME NO. 3
 (ICICOME)

X VALUE	TIME (HOURS)	PREDICT Y VALUE	VS RESIDUAL	PRODUCT CONC. - IMPURITY 1
2.7	2100.0	2409.9	-809.5	
2.0	2770.0	2400.5	-210.5	
2.3	2590.0	2409.5	109.5	
4.4	2170.0	2591.9	-301.9	
4.0	2730.0	2551.9	170.1	
4.0	2610.0	2551.9	50.1	
4.0	2059.0	2591.9	290.1	
6.0	2120.0	2681.6	-575.6	
6.0	2720.0	2681.6	116.4	
9.0	2000.0	2600.0	199.2	
8.0	2570.0	2644.0	25.2	
9.0	2950.0	2644.0	209.2	
10.0	2040.0	2675.4	-35.4	
12.0	2650.0	2695.4	-45.4	
12.0	2720.0	2695.4	24.6	
14.0	2640.0	2704.0	-64.0	
16.0	2750.0	2703.7	46.3	
16.0	2570.0	2703.7	-103.7	
16.0	2040.0	2703.7	136.3	
18.0	2790.0	2692.0	98.0	
20.0	2960.0	2669.7	109.3	
20.0	2210.0	2669.7	-459.7	
22.0	2770.0	2636.0	133.2	

NUMBER OF OBSERVATIONS IS 23

SQ MULT CORR COEF IS

.980106E-01

EQUATION IS OF THE FORM $Y = C(1) * X^{**} IORD + \dots + C(IORD+1)$

WHERE $Y = +$
 $+ .132196E+01 * X^{**} 2$
 $+ .391919E+02 * X$
 $+ .241665E+04$

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 2624.7
 SECOND MOMENT = 55250.
 THIRD MOMENT = -.17457E+28
 FOURTH MOMENT = .13925E+11
 VARIANCE = 57762.
 STANDARD DEVIATION = 240.34
 SKEWNESS = -1.3442
 KURTOSIS = .57809

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATE 07/09/74 TIME 11.32.45. FRAME NO. 6
ACID WASTEWATER RO STUDY
(UNCOMED)

X VALUE	TIME (HOURS)	Y VALUE	PREDICT Y VALUE	VS. PRODUCT CONC. - IMPURITY 2.2
2.0	300.0	461.0	460.9	-160.9
2.0	700.0	460.9	460.9	271.1
2.0	571.0	460.9	460.9	31.1
4.0	200.0	483.3	483.3	-283.3
4.0	420.0	483.3	483.3	-83.3
4.0	460.0	483.3	483.3	-23.3
4.0	680.0	483.3	483.3	190.7
6.0	433.0	501.6	501.6	-21.6
6.0	680.0	523.9	523.9	76.1
8.0	470.0	523.9	523.9	53.9
8.0	620.0	523.9	523.9	96.1
10.0	510.0	550.1	550.1	-40.1
12.0	960.0	580.2	580.2	-28.2
12.0	820.0	580.2	580.2	239.8
14.0	540.0	616.3	616.3	-74.3
16.0	440.0	682.4	682.4	-172.4
16.0	570.0	652.4	652.4	-152.4
16.0	950.0	652.4	652.4	197.6
18.0	800.0	694.2	694.2	189.7
2.0	520.0	740.2	740.2	-198.2
20.0	520.0	740.2	740.2	-50.2
22.0	950.0	798.1	798.1	159.9

NUMBER OF OBSERVATIONS IS 22

SQ MULT CORP COEF IS

.519387E+00

EQUATION IS OF THE FORM $Y = C(1) * X^{**} IORD + \dots + C(IORD+1)$

WHERE $Y = + .492494E+00 * X^{**} 2$
 $+ .240671E+01 * X$
 $+ .453438E+03$

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 575.45
 SECOND MOMENT = 30734.
 THIRD MOMENT = .96274E+06
 FOURTH MOMENT = .26384E+10
 VARIANCE = 32197.
 STANDARD DEVIATION = 179.44
 SKEWNESS = .16012
 KURTOSIS = -.15393

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATE 7/19/74 DATA ANALYSIS
 ACID WASTE WATER RO STUDY TIME 11.32.45. FRAME NO. 5
 (CICCONI)

X VALUE	TIME (HOURS)	PREDICT Y VALUE	VS VOLUME IN PRODUCT TANK (GALS.)
0.0	0.0	3.5	-3.5
0.0	0.0	3.5	-3.5
0.0	0.0	3.5	-3.5
0.0	0.0	3.5	-3.5
2.0	22.5	29.2	-6.7
2.0	23.0	29.2	-5.4
2.0	61.0	29.2	31.8
4.0	45.0	53.9	-8.9
4.0	45.0	53.9	-8.9
4.0	48.0	53.9	34.1
4.0	35.0	53.9	-18.9
6.0	57.5	77.6	-20.1
6.0	174.0	77.6	26.4
8.0	100.1	100.1	-30.1
8.0	119.0	100.1	18.9
8.0	35.0	100.1	-15.1
10.0	144.0	121.6	22.4
12.0	163.0	142.0	21.0
12.0	121.0	142.0	-21.0
14.0	142.0	161.4	20.6
16.0	145.0	179.6	-34.6
16.0	198.0	179.6	18.4
16.0	160.0	179.6	-19.6
18.0	200.0	196.0	3.2
20.0	135.5	212.9	-27.4
20.0	240.0	212.9	27.1
22.0	235.0	227.9	7.1

NUMBER OF OBSERVATIONS IS 27

SO MULT COEF IS

.029820E+30

EQUATION IS OF THE FORM $Y = C(1) \cdot X^{C(2)} + C(3) \cdot X^{C(4)} + \dots + C(I) \cdot X^{C(I+1)}$

WHERE $Y =$ $-.134436E+00 \cdot X^{2.2}$

$+.131615E+02 \cdot X$

$+.345023E+01$

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 101.03

SECOND MOMENT = 5572.7

THIRD MOMENT = .10397E+06

FOURTH MOMENT = .57157E+08

VARIANCE = 5787.1

STANDARD DEVIATION = 76.073

SKEWNESS = .24992

KURTOSIS = -1.1599