**RO-75: A FORTRAN Code for Calculation
and Design Optimization of Reverse
Osmosis Seawater Desalination
Plants**

P. Glueckstern
S. A. Reed
J. V. Wilson

MASTER

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

37
1-11-76
25 exp D71715

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$5.00; Microfiche \$2.25

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Energy Research and Development Administration/United States Nuclear Regulatory Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Contract No. W-7405-eng-26

Engineering Technology Division

RO-75: A FORTRAN CODE FOR CALCULATION AND DESIGN OPTIMIZATION
OF REVERSE OSMOSIS SEAWATER DESALINATION PLANTS

P. Glueckstern S. A. Reed
J. V. Wilson

Date Published: November 1976

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MASTER

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

PagePART I. DESCRIPTION OF DESIGN AND
ECONOMIC COMPUTATION MODEL

ABSTRACT	3
1. INTRODUCTION	3
2. DESIGN OPTIONS	5
2.1 Process Description and Basic Assumptions	5
2.2 Performance Evaluation	5
2.3 Long-Term Membrane Performance and Plant Operating Modes	7
2.4 General Design Procedure	8
3. ECONOMIC EVALUATION	12
3.1 Estimate of Direct Capital Costs	12
3.2 Estimate of Indirect Capital Costs and Total Investment	14
3.3 Estimate of Annual Operating Costs	15
3.4 Summary	16

PART II. PROGRAM DESCRIPTION

1. SUBROUTINE MAINRØ (FMGD, IØPT, IØUT, TCI, CCC)	21
2. SUBROUTINE PLANTR (XØ8, FFFFFF)	27
2.1 Glossary for PLANTR	29
3. SUBROUTINE SIZERØ	31
3.1 Glossary for SIZERØ	33
4. SUBROUTINE CØSTRØ	35
4.1 Glossary for CØSTRØ	35
5. SUBROUTINE RITERØ (IØPT, IØUT, L)	41
6. FUNCTIONS SP AND SP12 AND SUBROUTINE SALP	42
6.1 Subroutine SALP	42
7. SUBROUTINE PRØD (N, PPM, PSI, C, R, PRØD1)	43
8. PROGRAM OPERATION AND INPUT DATA REQUIREMENTS	44
REFERENCES	47
Appendix A. FORTRAN LISTING	49
Appendix B. SAMPLE OUTPUT	81

PART I. DESCRIPTION OF DESIGN AND ECONOMIC COMPUTATION MODEL

RO-75: A FORTRAN CODE FOR CALCULATION AND DESIGN OPTIMIZATION
OF REVERSE OSMOSIS SEAWATER DESALINATION PLANTS

P. Glueckstern*
S. A. Reed
J. V. Wilson

ABSTRACT

The reverse osmosis process has been used extensively for the conversion of brackish waters to potable water. The process is now nearing commercialization as a means for the conversion of seawater. The computer program (RO-75) described herein is a Fortran code for the optimization of the design and economics of seawater reverse osmosis plants. The examples described here are based on currently-available, commercial membrane modules and prevailing prices. However, the code is very flexible and can be used to optimize plants utilizing future technological improvements and different economic parameters.

1. INTRODUCTION

In the past years Oak Ridge National Laboratory (ORNL) has developed a number of process models dealing with nearly all developed or proposed distillation processes for seawater desalination. The reverse osmosis (RO) process, which is now most commonly applied for quality improvement of brackish water, has recently become a potential contender for seawater desalting. In order to make it possible to evaluate and compare the RO process with other processes at various sites and under prevailing economic conditions on an objective basis, this computer program (RO-75) was developed. It is based on data obtained from RO membrane and equipment manufacturers. This program does not, however, optimize or design the membrane properties and the internal structure and flow characteristics of the membrane modules, but assumes membrane module operating characteristics as defined by the membrane manufacturers. This program is therefore to be used to optimize RO systems and evaluate the economics of RO seawater plants based on specific membrane technology,

*Currently Head of Desalting Dept., Mekoroth Water Co., Tel Aviv, Israel.

varying only the operating parameters such as product recovery and operating pressure. It also allows the possible design option of using a two-stage design instead of a one-stage design and of applying different membrane types for each stage.

2. DESIGN OPTIONS

2.1 Process Description and Basic Assumptions

The schematic flow diagram of the RO plants evaluated is shown in Fig. 1. The inlet feedwater is assumed to come via a submarine line type intake system or seawater wells. The incoming seawater is pumped to a pretreatment system which contains, at least, a chlorinator, a filtration system, and an acid feed system, or, if deemed necessary due to the influent quality and/or the applied RO membrane type, additional water treatment features, such as alum coagulation, sedimentation, diatomaceous earth, activated carbon and manganese-zeolite filtration. From the pretreatment system the feedwater is pumped, by centrifugal high-pressure pumps, to a number of trains composed of parallel operating RO modules. The product water is then transferred to a storage tank. If the product salinity of the water in the tank is low enough to be adequate for water supply requirements, the total volume flow is posttreated to neutralize the excess acidity by partially releasing the free CO_2 in a decarbonator and, if required, by addition of neutralizing agent, such as soda ash or caustic (NaOH). The treated product water is then pumped to the product delivery system. However, if the product salinity in the storage tank is too high, some (or all) of it is further processed in one or more second-stage trains of RO modules. In that case, the brine reject from the second stage, which is usually at a lower salinity than the raw seawater, is recycled to the inlet of the first stage. The reject brine from the first-stage trains is routed to an outflow conduit. Optionally, the greater part of the energy contained in the pressurized rejected brine can be recovered with the aid of a water turbine.

2.2 Performance Evaluation

Membrane module performance is usually defined by membrane manufacturers for a set of reference operating conditions, defining the operating pressure and temperature, the inlet feedwater salinity and the product recovery. Some manufacturers provide performance curves expressing

Fig. 1. Schematic diagram of RO plant.

initial membrane module productivity (gallons per day) and salt rejection versus operating parameters.

For the evaluation of membrane modules for which performance curves were available (aromatic polyamid hollow-fibre membranes manufactured by du Pont), fitted performance functions were incorporated in specially written Subroutines (Subroutines PROD and SALP — see Part II).

For membrane modules for which performance functions are not available, initial membrane productivity can be calculated as a function of the net effective pressure (Δp_{net}) and a temperature correction factor. For membranes with a constant membrane water permeability factor (gal/day — ft² — psi or gm/cm² — sec — atm), productivity is proportional to effective pressure Δp_{net} (net driving force). Salt rejection can also be expressed as a function of the net effective pressure. In a limited range this function is nearly linear, the slope being dependent on membrane type. In the RO-75 program an option has been incorporated to evaluate membrane module productivity proportional to Δp_{net} and salt rejection as a linear function of Δp_{net} .

2.3 Long-Term Membrane Performance and Plant Operating Modes

Due to membrane flux degradation with time, the design of RO plants is commonly based on performance characteristics obtained at end of membrane lifetime, or alternatively, on a gradually increasing operating pressure to compensate for flux decline.

The first approach, currently applied in some small brackish water desalting plants, is somewhat too conservative for large plants which will probably be put in operation stagewise, gradually increasing capacity to its final stage. Consequently, membrane modules will also be replaced gradually and membrane modules with different lifetimes (and corresponding productivity rates) will therefore be operated. For this operating mode an averaged flux decline factor was therefore applied.

For systems with membrane modules operating with gradually increasing pressures, consideration of flux decline will obviously affect the design of the high pressure pumping units and the power recovery turbine. Based on considerations similar to those applied for membranes with declining

productivity rates (constant pressure mode), an average pressure was assumed in calculating the energy consumption. The capacities of the high-pressure pumps and the power recovery turbine were however based upon the maximum operating pressure which will have to be applied at the end of the predicted membrane life.

2.4 General Design Procedure

A preliminary design of an RO plant is performed by RO-75 for a given set of input parameters summarized in Table 1. In addition to membrane type the basic design options include a one- or two-stage design and the application of a power recovery turbine.

A detailed description of the design procedure is given in Part II. Basically, the procedure includes the following steps:

1. Performance evaluation of the applied membrane module (productivity and salt rejection) at the assumed operating conditions. These include:
 - site parameters: seawater salinity and temperature
 - membrane module operating parameters: pressure and product recovery
 - membrane module predicted long-term performance: lifetime and log flux decline
2. Calculation of number of first and second stage (if applied) membrane modules to obtain the required product capacity and quality (ppm TDS) and evaluation of all required pumping units and the power recovery turbine (if applied).

Table 1. Summary of design and operation input values

	Total plant		Stage 1		Stage 2	
	XØ or XT array	Built-in value	XØ or XT array	Built-in value	XØ or XT array	Built-in value
Reference membrane characteristics						
Membrane type ^a			XT(160)	1	XT(161)	2
Module outside diam, in.			XT(173)	8	XT(174)	8
Membrane surface area ft ²			XT(175)	5000	XT(176)	6000
Feed concentration, ppm			XT(183)	30,000	XT(184)	1500
Nominal product recovery, %			XT(189)	0.3	XT(190)	0.75
Feed temperature, °F			XT(185)	77	XT(186)	77
Nominal operating pressure, psi			XT(187)	800	XT(188)	400
Initial productivity, gpd/module			XT(164)	5000	XT(165)	14,000
Membrane lifetime, years			XT(169)	2	XT(170)	3
Log flux decline factor			XT(171)	-0.05	XT(172)	-0.05
Nominal salt rejection rate, %			XT(162)	0.985	XT(163)	0.9
Nominal pressure drop, psi			XT(167)	30		
Relative productivity increase per °C	XT(197)	0.025				
General design parameters						
Number of trains			XØ(56)	2	XØ(57)	1
Module shell dimensions						
Outside diameter, in.			XT(177)	9.5	XT(178)	9.5
Outside length, in.			XT(179)	48	XT(180)	48
Number of modules per shell			XT(181)	1	XT(182)	1
Building area requirement, ft ² /Mgd	XT(166)	5000				
Pressure drop between first stage outlet and power recovery turbine, psi	XT(199)	25				

Table 1 (continued)

	Total plant		Stage 1		Stage 2	
	XØ or XT array	Built-in value	XØ or XT array	Built-in value	XØ or XT array	Built-in value
Pumping units parameters						
Efficiencies:						
High pressure pumping units			XØ(53)	0.76	XØ(54)	0.76
Other pumping units	XØ(32)	0.82				
Power recovery turbine	XØ(55)	0.65				
Head of seawater pump, ft	XØ(28)	60				
Head of product pump, ft	XØ(31)	40				
Miscellaneous additional pumping required, hp/Mgd	XØ(58)	20				
Operational design parameters						
Feed salinity, ppm	XØ(36)	35,000				
Product salinity, ppm	XØ(37)	500				
Feed temperature, °F	XØ(40)	77				
Module inlet pressure, psi			XØ(51)	800	XØ(52)	400
Product recovery: ^b						
Upper value			XT(39)	0.30	XT(41)	0.30
Lower value			XT(40)	0.75	XT(42)	0.75
Acid consumption, ppm H ₂ SO ₄	XT(168)	100				
Plant factor	XØ(38)	0.85				
Operating modes						
Number of stages	XØ(50)	2				
Inlet pressure vs time	XØ(59)	1				
Constant: XØ(59) = 1						
Increasing: XØ(59) = 2						

Table 1 (continued)

	Total plant		Stage 1		Stage 2	
	XØ or XT array	Built-in value	XØ or XT array	Built-in value	XØ or XT array	Built-in value
Membrane performance calculation method	XØ(80)					
According to built-in perfor- mance curves	XØ(80)=1					
According to net effective pressure model	XØ(80)=2					
Efficiency of power recovery turbine	XØ(55)=.65					
Parameters used net effective pressure model						
Reference net effective pressure, psi			XT(193)	282	XT(194)	347
Product back pressure, psi			XT(191)	10	XT(192)	10
Averaged concentration polar- ization factor			XT(195)	1.1	XT(196)	1.2

a_1 = Hollow-fibre — polyamid, and 2 = Spiral wound — composite (or other)

b Optimized if desired.

3. ECONOMIC EVALUATION

3.1 Estimate of Direct Capital Costs

The following direct capital components are evaluated in the RO-75 computer program:

- (1) Membrane modules, including housing
- (2) Pumps and motors
- (3) Power recovery turbine
- (4) Valves and piping
- (5) Instrumentation
- (6) Electrical equipment
- (7) Pretreatment system
- (8) Posttreatment system
- (9) Seawater intake and outfall
- (10) Site preparation, including buildings

The cost functions applied for the above cost components were based on the following assumptions:

1. Membrane modules and housing

The cost of first- and second-stage membrane modules, including housing, is calculated by multiplying the initial capacity (at reference operating conditions) by the specific unit membrane costs (\$/gpd) which are input values.

2. Pumps and motors

Seawater and product delivery pumping units are calculated based upon cost functions applied in ORNL's computer programs MSF-21 and VTE-21 escalated to mid-1975 prices.¹ The costs of high-pressure pumping units are calculated according to a cost correlation published in reference 2, escalated to mid-1975 prices.

3. Power recovery turbine

The costs of power recovery turbines are calculated according to a cost function published in OSW Research and Development Report No. 457³ escalated to mid-1975 prices. A 100% additional cost is assumed for mechanical and electrical installations.

4. Valves and piping and module support frame

This item is obviously highly dependent on the detailed design and should therefore be based, at least, on a detailed conceptual design study. At this stage, however, only a rough estimate was applied using the following correlation (see Glossary for C_{STR} in Part II):

$$C_{\text{PIPE}} = C_{\text{PM}} \cdot (M \cdot D^2) + C_{\text{PST}} \cdot \text{TRAIN1} + C_{\text{BTP}} \cdot \text{TRAIN2} + C_{\text{PPG}} \cdot (\text{PMGD/RE} \cdot 1 \cdot 2) \cdot 0.7$$

According to this correlation a partial cost is proportional to the number of membrane modules, a second partial cost is proportional to the number of plant trains and a third partial cost is correlated to an estimated cost of a 1-Mgd plant operating with a 50% product recovery rate.

5. Instrumentation

This item should also be based, as the previous one, on a detailed conceptual design. At this stage, a simplified cost model based on the number of first- and second-stage trains, applying a 0.2 scale factor for variation of cost with train capacity, was applied.

6. Electric equipment

The electrical equipment cost is composed of a base cost plus a cost which varies linearly with pumping power requirements, plus an additional cost for the power recovery turbine when applicable.

7. Pretreatment system

This cost includes the overall cost of pretreatment equipment, excluding acid treatment, correlated to the cost of defined pretreatment system (e.g. such as that recommended in reference 4) using a scale factor of 0.7, and the cost of the acid treatment system correlated to the daily acid consumption.

The cost of cartridge filters is assumed to be included in the pretreatment equipment. The cost function for the acid treatment system is identical to that applied in the modified MSF and VTE computer programs.

8. Posttreatment system

The cost function of the posttreatment assumes a decarbonator and a chemical injection system. The cost of the decarbonator and the chemical injection system uses cost functions applied in the modified MSF and VTE programs.¹

9. Seawater intake and outfall

The seawater intake and outfall are calculated on the basis of a reference cost for a 2-Mgd intake capacity using a scale factor of 0.8.

10. Site preparation including buildings

This cost is calculated on the basis of a reference site preparation cost of a 1-Mgd plant using a 0.35 scale factor and a building cost obtained by multiplying the required building area by an input value defining the assumed unit cost per square feet.

3.2 Estimate of Indirect Capital Costs and Total Investment

The indirect capital costs include:

- (a) Engineering design and supervision
- (b) Escalation during construction
- (c) Interest during construction
- (d) Owner's cost for training and start-up

For the first three cost items the same cost function as those applied in the MSF and VTE computer programs was applied.

Item (a) is calculated as a function of the direct capital cost while items (b) and (c) as functions of the construction time, the annual escalation rate and the interest rate. The resulting indirect capital cost, by applying these functions may, however, be too high for RO plants which require much less field erection work than distillation plants. In order to take this into account, the cost for item (a) and the calculated construction time used in calculating the cost for items (b) and (c) are multiplied by input values, XC(105) and XC(106), expressing the predicted fraction of these factors relative to those of distillation plants.

The owner's cost is calculated as a fraction of the total direct cost, using an input value (XC(107)).

The total investment is calculated by multiplying the total direct cost by a factor obtained by multiplying the individual indirect cost factors and a contingency factor defined by an input value (XC(62)).

3.3 Estimate of Annual Operating Costs

The operating costs include the following components:

- (1) Membrane replacement
- (2) Electrical power
- (3) Operation and maintenance labor
- (4) Supplies and maintenance materials
- (5) Chemicals and other pretreatment materials

1. Membrane replacement

The annual membrane replacement costs are calculated as a function of the unit membrane replacement cost, the total membrane inventory, the membrane life (LMF) and the interest rate (RTEIN). The prorated annual charge (DEPM), as a function of the membrane life and the interest rate, is calculated by:

$$DEPM = RTEIN / ((1 + RTEIN)^{LMF} - 1).$$

2. Electrical power

The total electrical power cost is calculated by multiplying the annual electric power consumption by the unit power cost, which is an input value (XC(54)).

3. Operation and maintenance labor

This cost is calculated by using a reference cost for a 1-Mgd plant and a scale factor of 0.5.

4. Supplies and maintenance materials

These costs are assumed to be proportional to the total direct capital cost. The proportional factor is defined by the input value XC(58).

5. Chemicals and other pretreatment materials

These costs include the cost of acid, chlorine, product pacification chemicals and a calculated total cost for other materials such as carbon and cartridge filters.

The cost of acid is calculated by multiplying the annual acid consumption (acid consumption per unit feedwater is defined by the input value X0(168)) and the unit acid cost — XC(49).

The cost of chlorine is calculated by multiplying the total annual seawater consumption by a unit cost for chlorine treatment XC(50) expressed in \$/lb seawater.

The cost of other pretreatment material is calculated by multiplying the total annual seawater consumption by a unit cost XC(98) expressed in \$/1000 gal seawater (XC(98)).

The cost of posttreatment chemicals is calculated by multiplying the total annual water production by a unit cost XC(103), expressed in cents per 1000 gallons.

3.4 Summary

Table 2 is a summary of costing and economic input data used in the program.

Table 2. Summary of costing and economic input data

	Location in XC array	Built-in value
I. Direct capital costs		
First stage unit membrane module cost, \$/gpd	80	0.75
Second stage unit membrane module cost, \$/gpd	81	0.20
High pressure pumping unit cost = A* (psi * gpm) **0.522		
†Reference A, \$	82	50,500
Reference motor cost for seawater and product delivery pumps, \$/hp	83	25
Valves and piping cost = A* (number of modules) + B* (number of first stage trains) + C* (number of second stage trains) + D* (Mgd sea- water) **0.7		
Reference A, \$/module (incl. frame cost)	84	300
Reference B, \$/train	85	5000
Reference C, \$/train	86	5000
Reference D, \$/Mgd seawater	104	60,000
Instrumentation cost per train = A* (Mgd/0.5) **0.2		
Reference A, \$/per 0.5 Mgd train	87	47,000
Electrical equipment cost = A + B* (total installed kW)		
Reference A, \$	88	25,000
Reference B, \$/kW	89	70
Site preparation cost = A* (Mgd product) **0.35		
Reference A, \$/Mgd	90	150,000
Building cost, \$/ft ²	91	6.5
Seawater intake and outfall cost = A* (Mgd seawater) **0.8		
Reference A, \$/Mgd seawater	92	150,000
Pretreatment system cost: system excluding acid treatment = A* (Mgd seawater/0.75) **0.7		
Reference A, \$	93	176,000
Acid treatment system = B* (tons per day acid consumption/13.15) **0.3		
Reference B, \$	94	80,000

Table 2 (continued)

	Location in XC array	Built-in value
Posttreatment system: decarbonation system = A^* (gpm product/4200) $**0.7$ Reference A, \$	101	46,000
Pacification system = B^* (gpm product/1735) $**0.3$ Reference B, \$	102	20,000
Power recovery turbine — generator system: power recovery TG set cost = A^* (hp/ft head $**0.5$) $**0.398$ Reference A, \$	99	40,000
Turbine governor cost = B^* (hp/1000) $**0.3$ Reference B, \$	100	40,000
II. <u>Indirect capital cost and economic parameters</u>		
Ratio between design and supervision cost plants (percentage of capital cost) to that of distillation plants	105	0.5
Ratio of construction time for RO plants to that of distillation plants (calcu- lated as a function of total direct capital cost)	106	0.5
Annual escalation rate	56	0.08
Annual interest rate	60	0.10
Insurances and taxes	61	0.01
Unusual construction and contingency cost	62	0.15
III. <u>Operating costs</u>		
Operation and maintenance labor = A^* (Mgd product) $**0.5$ Reference A, \$	97	113,000
Supplies and maintenance materials (fraction of total capital cost)	58	0.007
Electrical power cost, \$/kWhr	54	0.02
Unit cost of pre- and posttreatment materials:		
Sulfuric acid (93% H_2SO_4), \$/ton	49	31
Chlorine, \$/lb seawater	50	2.64×10^{-7}
Other pretreatment materials, \$/kgal seawater	98	0.1
Posttreatment chemicals, cents/kgal	103	1.0
Membrane replacement, \$/gpd (nominal initial)		
First stage membranes	95	.55
Second stage membranes	96	.15

[†]The word reference is to signify the "built-in" value.

PART II. PROGRAM DESCRIPTION

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

1. SUBROUTINE MAINRØ (FMGD, IØPT, IØUT, TCI, CCC)

MAINRØ is the introductory subroutine to the RØ plant calculations; it is called by the main program when the process decks are operated in the stand-alone mode and by the economic routines when the process decks are incorporated as a part of the ECØN21 program.

When supplied with the arguments,

FMGD = plant capacity, Mgd.

IØPT = optimization flag

IØPT $\leq$ 0, do not optimize plant.

IØPT > 0, optimize plant.

IØUT = output detail flag

IØUT = 0, condensed summary output sheet is produced.

IØUT > 0, detailed output plus condensed summary is produced.

MAINRØ returns in its argument list

TCI = unit cost of desalted water; cents per kilogallon.

CCC = capital cost of plant (direct + indirect), millions

The sequence of computations in MAINRØ is:

A. Timing the computation

The timing subroutine, ITIME, is a local library routine; hence, if this deck is to be run at another installation, the local timing subroutine should be incorporated or the timing feature should be eliminated from the program. The subroutine

ITIME (J, K)

returns in its argument list

J = integer time of day from the computer clock, in hundredths of seconds.

K = integer time since last call of ITIME, in hundredths of seconds.

The Fortran statements which time the computation (in seconds) are

CALL ITIME (IZX, JZX)

⋮

CALL ITIME (IZXX, JZXX)

TCALC = DFLØAT (IZXX-IZX) * 1.D-2

B. Initialization

The flag $I\emptyset$ is set equal to -2. This suppresses the output from the optimizing subroutine SLIDE. If SLIDE output is desired, MAINM must be recompiled with $I\emptyset > 0$.

Various quantities used in the plant computations are changed from array nomenclature to mnemonic nomenclature. Reference to the Subroutine TITLER will make these computations clear.

C. Variables of optimization and the bounds thereon

Whether the plant is to be optimized or not, initial values must be given to the two variables upon which the plant is optimized. The upper and lower bounds on these variables must also be provided, and one must ensure that the initial values lie on or between the bounds. One must also ensure that the lower bound on a variable is not greater than the upper bound.

The initial values of the variables of optimization are provided by
SUBROUTINE VARSET (FF, $PR\emptyset C$).

The calling arguments are

FF = plant capacity, Mgd.

$PR\emptyset C$ = plant process, in this case "R $\emptyset$ "

The desired initial values are returned as the first two members of the $X\emptyset$ array.

The upper and lower bounds on the variables are members of the XT array.

The variables of optimization are transferred into the X08 array, in which form they are used in subsequent calculations. The upper and lower bounds are transferred into the XH8 and XL8 arrays, respectively, and are used in this form in subsequent calculations.

The Fortran programming involved is

```
DATA  $PR\emptyset C$ /'R $\emptyset$ '/
CALL VARSET (FF,  $PR\emptyset C$ )
D $\emptyset$  110 I = 1, 2
      X08(I) =  $X\emptyset$ (I)
      XH8(I) = XT(*I+37)
      XL8(I) = XT(2*I+38)
110 CONTINUE
```

```

DØ 126I = 1.2
IF(XL8(I) .GT. XH8(I)) XL8(I) = XH8(I)
IF(XØ8(I) .LT. XL8(I)) XØ8(I) = XL8(I)
IF(XØ8(I) .GT. XH8(I)) XØ8(I) = XH8(I)
126 CØNTINUE

```

D. Design of plant and cost of plant and product

If the plant is to be optimized ($IØPT \neq 0$), the optimizing subroutine either LEARCH or SLIDE is called; if a nonoptimized plant is to be designed ($IØPT = 0$), PLANTR is called.

NCALLS, the number of times PLANTR is called is set equal to zero. This number is incremented by one for each call of PLANTR.

The Fortran statements are

```

NCALLS = 0
IND(1) = 0
IF(IØPT .EQ. 0) GØ TØ 115

```

If the plant is not to be optimized, go to E2.

1. Calling for the optimal plant

The optimal plant (that plant which provides product water at the lowest unit cost) is designed by

```

SUBRØUTINE SLIDE (NN, X, BU, BL, FRUP, IO, N1, N2, N3, N4,
NCALLS)

```

The arguments with which SLIDE is called are

NN = integer number of variables upon which the optimization is to be performed. (The largest subscript of the X-array which is to be considered.)

X = array of variables of optimization.

BU = array of upper bounds on the variables.

BL = array of lower bounds on the variables.

FRUP = name of the subroutine which SLIDE is to call with the X-array and from which it receives the unit cost of water. FRUP must be listed in an EXTERNAL statement.

IØ = integer output flag

$IØ \leq 0$, no printed output is provided by SLIDE.

$IØ > 0$, SLIDE provides a detailed step-by-step listing of its optimization procedure. The SLIDE output is provided on tape 6, so that it does not intermingle with the output from RITEM.

N1 = lowest subscript of the integer variables.

N2 = highest subscript of the integer variables.

N3 = difference between the subscripts of the integer variables. All integer variable subscripts must be separated by a constant number.

N4 = lowest subscript of the X-array which is to be considered in computing cross-partial.

SLIDE returns in the X-array those values of the variables which provide the optimum plant and the number of calls of FRUP which were required via NCALLS.

A text is printed by MAINRØ at the top and bottom of the SLIDE output (if output is required) identifying the listing by process and plant size.

The Fortran statements are

```

EXTERNAL PLANTR
IF (IØ .GT. 0) WRITE (6,5) FF
5  FØRMAT (1H1, 'RØ', F8.2, 'MGD')
   CALL SLIDE (2, XØ8, XH8, XL8, PLANTR, IØ, 1,3,1,1, NCALLS)
   IF (IØ .GT. 0) WRITE (6,6) FF
6  FØRMAT (1H0, 'RØ', F8.2, 'MGD')
```

2. Final design computation of the plant

The desired values of the variables of optimization having been provided either by input or by subroutine SLIDE, SUBRØUTINE PLANTR (XØ8, FFFFFFFF) is called to provide the final plant design and the unit cost of product water.

When provided in the argument list with the array

XØ8 = array of variables of optimization,
PLANTR returns in its argument list:

FFFFFFF = unit cost of desalted water, cents per kilogallon.

The number of calls of PLANTR is incremented by 1, and the quantity CCC, which is to be returned by MAINRØ, is computed.

The Fortran statements are

```

115 CONTINUE
IND(13) = 1
CALL PLANTR (XØ8, CH2Ø)
NCALLS = NCALLS + 1
CCC = PØTHER
```

E. Output procedures

The printed output is provided by

SUBROUTINE RITERØ (IØPT, IØUT, L)

The calling arguments are

IØPT = optimization flag

IØPT $\leq$ 0, plant was not optimized

IØPT > 0, plant was optimized

IØUT = output detail flag

IØUT = 0, condensed summary sheet only is to be printed.

IØUT = 1, detailed printout as well as condensed summary sheet is to be provided.

L = integer number of output device on which RITERØ is to write.

The flags IØPT and IØUT have been provided in the calling argument list of MAINRØ. The output device designation is transferred from the INPUT to MAINRØ as LTape2 via a COMMON block. This number is transmitted to RITERØ as KØUT.

2. SUBROUTINE PLANTR (X08, FFFFFFF)

This subroutine is the entry point for all of the actual RO plant calculations. For a once-through calculation it is called by MAINRØ; for calculation of an optimized plant, it is called repetitively by the optimizing routine SLIDE. The array X08 supplies the two variables of optimization, which are the recovery fractions in the two-plant stages. The unit cost of desalted water in cents per kilogallon is returned by PLANTR as the quantity FFFFFFF in the argument list.

PLANTR determines the recovery and reject fractions in the plant stages, the salinity and flow rates of each stream, and the number of modules in each stage. (Figure 2 is a schematic diagram showing the flow arrangements and nomenclature.) After these quantities have been determined, PLANTR calls subroutine SIZERØ, which determines pumping and power requirements, and subroutine CØSTRØ, which computes plant costs and product cost.

The general sequence of operations is shown by the following flow diagram:

It will be noted that there are two iterative calculations which may be performed:

- (a) for a single-stage plant, if the originally specified recovery fraction is too high to produce plant product water of the desired salinity, the recovery fraction is iteratively reduced using Newton's method until the desired salinity is obtained or the low limit specified by the manufacturer is reached. In the latter case, a message is printed and an error return is made;
- (b) for a two-stage plant in which the reject stream of stage 2 is combined with seawater to form the feed to stage 1, the salinity of this feed is calculated iteratively.

The salt passage factors, SALP1 and SALP2, and the productivity factors, PRØD1 and PRØD2, for stages 1 and 2, respectively, are calculated in subroutines SALP and PRØD. The product per module is the product of the nominal productivity per module and the productivity factor

$$WPRØD1 = PRØDN1 * PRØD1$$

$$WPRØD2 = PRØDN2 * PRØD2$$

Fig. 2. Flow chart of subroutine PLANTR.

The salinity of the stage product is obtained by applying the salt passage factors to the nominal recovery factors (1-REJN1) and multiplying by the feed salinity

$$\text{SPR}\phi\text{D1} = \text{PR}\phi\text{D1} * (1-\text{REJN1}) * \text{SFEED1}$$

$$\text{SPR}\phi\text{D2} = \text{PR}\phi\text{D2} * (1-\text{REJN2}) * \text{SPR}\phi\text{D1}$$

The other calculations in the subroutine are based on the application of mass balance relations to the streams in Fig. 2. The blending ratio, defined as the fraction of final product coming from stage 2, is obtained from the mass balance on dissolved salts —

$$\text{final product} = \text{2nd stage product} + \text{1st stage contribution}$$

$$(\text{PMGD})(\text{PR}\phi\text{DS}) = (\text{PMGD})(\text{BLR})(\text{SPR}\phi\text{D2}) + (\text{PMGD})(1-\text{BLR})(\text{SPR}\phi\text{D1})$$

whence

$$\text{BLR} = (\text{SPR}\phi\text{D1} - \text{PR}\phi\text{DS}) / (\text{SPR}\phi\text{D1} - \text{SPR}\phi\text{D2})$$

Similarly, the salinity of feed to stage 1 is determined from the mass balance on dissolved salts.

$$\text{1st stage feed} = \text{seawater feed} + \text{2nd stage reject}$$

$$= \text{seawater feed} + \text{1st stage product} - \text{final product}$$

$$\text{WFEED1} * \text{SFEED1} = \text{WFEED} * \text{SFEED} + \text{PMGD1} * \text{SPR}\phi\text{D1} - \text{PMGD} * \text{PR}\phi\text{DS}$$

whence, since $\text{WFEED1} * \text{REC1} = \text{PMGD1}$

$$\text{SFEED1} = (\text{WFEED} * \text{SFEED} - \text{PMGD} * \text{PR}\phi\text{DS}) / \text{WFEED1} + \text{PMGD1} * \text{REC1}$$

Again, when seawater is blended with first-stage product, the dissolved solids balance is

$$\text{final product} = \text{1st stage product} + \text{added seawater}$$

$$\text{PMGD} * \text{PR}\phi\text{DS} = \text{PMGD1} * \text{SPR}\phi\text{D1} + (\text{PMGD} - \text{PMGD1}) * \text{SFEED}$$

whence the value of PMGD1 is found.

2.1 Glossary for PLANTR

X	temporary value of salt passage factor during iterative solution for first-stage feed rate
BLR	blending ratio: ratio of second-stage product to total product
TC1	cost of product, ¢/kg
X08	array of variable of optimization
MØD1	number of modules in stage 1
MØD2	number of modules in stage 2
PMGD	product flow rate, Mgd

REC1	recovery fraction, stage 1
REC2	recovery fraction, stage 2
REJ1	reject fraction, stage 1
REJ2	reject fraction, stage 2
NMØD1	number of modules in stage 1
NMØD2	number of modules in stage 2
PMGD1	product flow rate from stage 1, Mgd
PRES1	pressure of input to stage 1, psig
PRES2	pressure of input to stage 2, psig
PRØDS	salinity of product, ppm
PRØD1	productivity factor for stage 1
PRØD2	productivity factor for stage 2
REJN1	nominal rejection ratio for stage 1
REJN2	nominal rejection ratio for stage 2
SALP1	salt passage factor for stage 1
SALP2	salt passage factor for stage 2
SFEED	salinity of plant feed, ppm
TEMP1	temperature, °C, of feed to stage 1
WFEED	plant seawater feed rate, Mgd
FFFFFF	cost of product, ¢/kg
MBTYPE	type of brackish water membrane, 2 = duPont B9; 4 = spiral wound
MSTYPE	type of seawater membrane, 1 = duPont B10; 3 = spiral wound
PRØDN1	nominal module production rate of stage 1, Mgd/module
PRØDN2	nominal module production rate of stage 2, Mgd/module
SFEED1	salinity of feed to stage 1, ppm
SPRØD1	salinity of product from stage 1, ppm
SPRØD2	salinity of product from stage 2, ppm
WFEED1	feed rate to stage 1, Mgd
WPRØD1	product flow rate from one module of stage 1, Mgd/module
WPRØD2	product flow rate from one module of stage 2, Mgd/module

3. SUBROUTINE SIZERØ

This subroutine calculates the pumping power required in each stage, the pumping power for the seawater feed pump, product delivery pump, and miscellaneous pumping, and the recovery turbine power.

The calculations of pumping power are all of the form

Power = Constant · flow rate, Mgd · head, psi ÷ Efficiency

where

$$\text{Constant} = 10^6 \frac{\text{gal}}{\text{Mgal}} \cdot P \frac{\text{lb}}{\text{ft}^3} \cdot \frac{2.31 \text{ in.}^3/\text{gal}}{1728 \text{ in.}^3/\text{ft}^3} \cdot \frac{144 \text{ in.}^2/\text{ft}^2}{P \text{ lb}/\text{ft}^3} \cdot \frac{1 \text{ hp sec}}{500 \text{ ft lb}} \cdot$$

$$\frac{1 \text{ day}}{86400 \text{ sec}} = .4051 \frac{\text{hp}}{\text{Mgd} \cdot \text{psi}}$$

The stage pumping power requirements are calculated using either of two options

- (a) PRESØP = 1 the operating pressure is constant during the membrane lifetime and the flux decreases.

It is assumed that

$$\text{flux} = (\text{original flux}) (\text{time})^M$$

$$\text{or } f = f_o t^M.$$

During a lifetime L, the average flux is

$$\bar{f} = \frac{f_o}{L} \int_0^L f_o t^M dt = \frac{f_o}{L} (L^{M+1}/(M+1))$$

$$\bar{f}/f_o = L^M/(M+1).$$

In Fortran the corresponding equations are

$$\text{AFDF1} = (365.*\text{LFM1})*\text{FM1}/(\text{FM1} + 1.)$$

$$\text{AFDF2} = (365.*\text{LFM2})*\text{FM2}/(\text{FM2} + 1.)$$

The average production rates are obtained by multiplying the original rates by these quantities

$$\text{WPRØD1} = (\text{PRØDN1} * \text{PRØD1}) * \text{AFDF1}$$

In this option the number of modules is recomputed using the average production rates.

(b) $PRES\emptyset P = 2$ the operating pressure is increased to keep the flux constant during membrane lifetime.

In this case

$$\text{pressure} = (\text{original pressure}) \div (\text{time})^M$$

$$P = P_o t^{-m}.$$

The maximum pressure, which occurs at the end of the membrane life, is

$$P_m = P_o L^{-m}$$

and the pressure corresponding to the average flux in option (a) is

$$\bar{P} = P_o f_o / \bar{f} \quad \text{or} \quad \bar{P}/P_o = f_o / \bar{f}.$$

The corresponding Fortran equations are

$$PRESIM = PRES1/(365.*LFM1)**FM1$$

$$PRES2M = PRES2/(365.*LFM2)**FM2$$

and

$$PRES1A = PRES1/AFDF1$$

$$PRES2A = PRES2/AFDF2.$$

The recovery turbine and stage pump capacity requirements, TPUMP1 and TPUMP2, are calculated using the quantities, PRES1M and PRES2M. The stage pump total energy requirements are then calculated on the basis of maximum pressures, by using the average-to-peak pressure ratios, and the power generated by the power recovery turbine, that is,

$$PREC\emptyset V * (PRES1A - DELP1) / (PRES1M - DELP1).$$

Finally, the pumping power in horsepower is converted to the electric power in kilowatts, which is T $\emptyset$ TKWA for option (b), or T $\emptyset$ TKW for option (a).

3.1 Glossary for SIZERØ

BLR	blending ratio; ratio of second stage product to total
FM1	logarithmic flux decline rate in stage 1, fraction per year
FM2	logarithmic flux decline rate in stage 2, fraction per year
LFM1	membrane lifetime in stage 1, years
LFM2	membrane lifetime in stage 2, years
MØD1	number of modules in stage 1
MØD2	number of modules in stage 2
PMGD	product flow rate, Mgd
REC1	recovery fraction in stage 1
SØPR	miscellaneous pumping power required, hp/Mgd
AFDF1	weighted flux degradation factor in stage 1
AFDF2	weighted flux degradation factor in stage 2
DELP1	pressure drop across stage 1, psi
NMØD1	number of modules in stage 1
NMØD2	number of modules in stage 2
PPUMP	product pumping power, hp
PRES1	inlet pressure for stage 1, psig
PRES2	inlet pressure for stage 2, psig
PRØDH	product pump head, ft
PRØD1	productivity factor for stage 1
PRØD2	productivity factor for stage 2
PUMP1	first stage pumping power, hp
PUMP2	second stage pumping power, hp
RECJN	nominal recovery factor in stage 1
SPUMP	seawater pumping power, hp
TOTKW	total electric power requirement, kW, when operating pressure is held constant
WFEED	seawater flow rate to plant, Mgd
DELP1N	nominal pressure drop, input stream to recovery stream, in stage 1, psi
EFFICT	efficiency of power recovery turbine
EFFIC1	efficiency of high-pressure pump for stage 1
EFFIC2	efficiency of high-pressure pump for stage 2
EFFIC3	efficiency of high-pressure pump for stage 3

PØTHER	miscellaneous pumping power, hp
PRECØV	recovery turbine power output, hp
PRESØP	operating pressure option: 1 = operating pressure constant during membrane lifetime; 2 = operating pressure increases to offset flux decline
PRES1A	average pressure over lifetime of membrane in stage 1
PRES1M	maximum pressure over lifetime of membrane in stage 1
PRES2A	average pressure over lifetime of membrane in stage 2
PRES2M	maximum pressure over lifetime of membrane in stage 2
PRØDN1	nominal module production rate in stage 1, gpd/module
PRØDN2	nominal module production rate in stage 2, gpd/module
SWHEAD	seawater pump head, ft
TOTKWA	total electric power required, kW, when operating pressure is increased with flux decrease
TPUMP1	first stage pumping power, hp
TPUMP2	second stage pumping power, hp
TRAIN1	number of trains in stage 1
TRAIN2	number of trains in stage 2
WFEED1	feed flow rate to stage 1, Mgd
WPRØD1	product flow rate from stage 1, gpd/module
WPRØD2	product flow rate from stage 2, gpd/module

4. SUBROUTINE CØSTRØ

The computations in CØSTRØ are straightforward and are easily followed from the listing (which is commented) and the glossary.

Unit costs are provided by a call of SUBROUTINE PRICES (PRØC) which, when supplied with an identification of the process by the argument PRØC, returns the unit costs applicable to that process via the XC array.

Financial factors are provided by

SUBROUTINE FNANCE (CD, ASJ, SSMAP, PSAJ, RTEIN, AJBR, WPL, YEAR)

When supplied with the arguments

CD = direct capital cost of plant, millions of dollars..

WPL = plant life, years.

YEAR = calendar year in which plant construction is to begin.

Returns in its argument list

ASJ = higher cost factor, ratio of total investment to direct cost.

SSMAP = amortization factor. Fraction of total investment required annually to retire total investment plus interest over the life of the plant.

PSAJ = annual cost factor. Fraction of plant direct capital cost required to retire total investment plus interest over the life of the plant.

RTEIN = interest rate.

4.1 Glossary for CØSTRØ

FC	array of unit cost multipliers
XC	array of unit costs
XØ	array of environmental parameters
XT	array of technical parameters
ASJ	higher cost factor; ratio of total capital investment to direct capital cost
BLR	blending ratio; fraction of product produced in stage 2
CFG	plant product output, hundreds of thousands of gallons per year
LF2	desalting plant load factor; that is, fraction of time plant operates
ØC1	contribution of operating cost to cost of product water, cents per kilogallon

ØC2	annual plant operating cost, dollars per year
TC1	unit cost of product water, cents per kilogallon
TC2	annual cost of total plant operation, dollars per year
WPL	design life of desalting plants, years
ACID	annual cost of sulfuric acid, dollars per year
CBWM	unit capital cost of brackish water, membranes and housing, dollars per module
CPDP	direct capital cost of product delivery pumps and motors, dollars
CPPG	reference cost of general plant piping for plant with 2 Mgd intake, dollars
CPRT	direct capital cost of pretreatment system, dollars
CSAB	direct capital cost of site and buildings, dollars
CSWM	unit capital cost of seawater membranes and housing, dollars per module
HPRC	unit cost of reference high pressure pump, dollars
LFM1	lifetime of seawater membranes, years
LFM2	lifetime of brackish water membranes, years
MØD1	number of modules in first stage
MØD2	number of modules in second stage
NBWP	number of second-stage high pressure pumps
PMGD	plant capacity, millions of gallons per day
PPMA	parts per million of 100% sulfuric acid added to feed water
PRØC	name of process used in calling subroutine PRICES; in this case 'RØ'
PSAJ	factor by which a direct capital cost is multiplied to obtain an annual cost of amortization
REC1	recovery fraction in stage 1
REC2	recovery fraction in stage 2
STRC	reference annual staff cost for 1-Mgd plants, dollars per year
TØC1	contribution of total operating component costs to product cost, cents per kilogallon
TØC2	annual cost of operating components, dollars per year
UNMC	unit cost of motors, dollars per horsepower
YEAR	calendar year in which plant construction begins
AMSC1	contribution of cost of plant maintenance to product cost, cents per kilogallon

AMSC2	annual cost of plant maintenance, dollars per year
BAREA	floor area of plant buildings, square feet
CADRC	reference cost of 1315 ton/day acid injection system, dollars
CAPI1	total capital investment in plant, direct costs plus indirect costs, dollars
CAPI2	specific plant investment, dollars per gallon per day of output
CAPI3	contribution of total plant capital investment to cost of product, cents per kilogallon
CAPI4	annual cost of amortizing plant capital investment, dollars per year
CBWHP	direct cost of second-stage high pressure pump, dollars per train
CELBC	base cost of electrical equipment, dollars
CELEQ	direct capital cost of electrical equipment, dollars
CIAØR	reference cost of 2-Mgd seawater supply and outfall system, dollars
CINST	direct cost of instrumentation, dollars
CPIPE	direct cost of piping, dollars
CPMØP	unit cost of piping, dollars per module
CPRCT	direct cost of recovery turbine, dollars
CPRTR	reference cost of 0.75-Mgd seawater pretreatment system (not including acid injection system), dollars
CPRT1	contribution of investment in pretreatment system to cost of product, cents per kilogallon
CPRT2	annual cost of amortizing capital cost of pretreatment system, dollars per year
CSAB1	contribution of investment in site and buildings to cost of product, cents per kilogallon
CSAB2	annual cost of amortizing capital cost of site and buildings, dollars per year
CSREF	reference cost for site for 1-Mgd plant, dollars
CSWDP	direct cost of seawater delivery pumps, dollars
CSWHP	direct cost of first stage high-pressure pump, dollars per train
CSWIØ	direct capital cost of seawater intake and outfall, dollars
DELP1	pressure drop, input stream to recovery stream, in stage 1, psi
DEPM1	annual fixed charge rate for stage 1 membrane, fraction per year
DEPM2	annual fixed charge rate for stage 2 membrane, fraction per year
GPMPW	flow rate of product through delivery pumps, gallons per minute

GPMSW	flow rate of seawater through delivery pumps, gallons per minute
PMGD2	product flow rate from stage 2, Mgd
PPUMP	product pump hp
PRES1	inlet pressure to stage 1, psig
PRES2	inlet pressure to stage 2, psig
PRØDH	product pump head, psig
REFGL	reference cost of governor for power recovery turbine, dollars
REFTC	reference cost of power recovery turbine, dollars
REPLC	annual amount which must be set aside over the life of the plant to pay for membrane replacement, dollars per year
REPMC	direct capital cost of replaceable membranes, dollars
RTEIN	interest rate, dollars per year interest per dollar of unamortized debt
SPUMP	seawater delivery pumping power, hp
SSMAP	amortization factor, fraction of investment which must be paid each year to amortize capital and interest during life of plant
TCHEM	annual cost of chemicals, dollars per year
TMØDC	direct capital cost of membranes and housing, dollars
TØTKW	total power requirement, kilowatts
TØTPC	direct capital cost of pumps and drivers, dollars
UCHEM	unit cost of other chemical treatment materials, dollars per thousand gallons feedwater
UEPKW	unit cost of electrical equipment, dollars per kilowatt
WFEED	seawater feed rate to plant, Mgd
BSQFTC	unit cost of buildings, dollars per square foot
BWMØDC	unit cost of brackish water module, dollars per nominal gallon per day
CELEQ1	contribution of investment in electrical equipment to product cost, cents per kilogallon
CELEQ2	annual cost of amortizing capital cost of electrical equipment, dollars per year
CHPØST	unit cost of chemicals for pacification, cents per kilogallon
CINST1	contribution of investment in instrumentation to product cost, cents per kilogallon
CINST2	annual cost of amortizing capital cost of instrumentation, dollars per year
CLØRIN	annual cost of chlorine treatment of feedwater, dollars per year

CPBTØP	unit cost of pipe for second-stage train, dollars per train
CPIPE1	contribution of investment in piping to product cost, cents per kilogallon
CPIPE2	annual cost of amortizing capital cost of piping, dollars per year
CPRCT1	contribution of investment in recovery turbine to product cost, cents per kilogallon
CPRCT2	annual cost of amortizing capital cost of recovery turbine, dollars per year
CPSTØP	unit cost of pipe for first-stage train, dollars per train
CRICPT	reference instrumentation cost for a 0.5-Mgd train, dollars
CSWIØ1	contribution of investment in seawater intake and outfall to cost of product, cents per kilogallon
CSWIØ2	annual cost of amortizing capital cost of seawater intake and outfall
EFFICT	efficiency of power recovery turbine
ØPØSTC	direct capital cost of posttreatment system, dollars
ØPØST1	contribution of investment in posttreatment system to cost of product, cents per kilogallon
ØPØST2	annual cost of amortizing capital cost of posttreatment system
PØCST1	contribution of power cost to cost of product, cents per kilogallon
PØCST2	annual cost of electric power, dollars per year
PRECØV	power recovery turbine power, kilowatts
PRES1M	input pressure to stage 1 at end of life, psig
PRØDN1	nominal productivity of stage 1, gallons per day per module
PRØDN2	nominal productivity of stage 2, gallons per day per module
RCHDSC	reference cost of chemical 1735 gpm pacification system, dollars
RDCRBC	reference cost of 4200 gpm decarbonator, dollars
REPLC1	contribution of cost of membrane replacement to product cost, cents per kilogallon
REPLC2	annual amount which must be set aside over the life of the plant to pay for membrane replacement, dollars per year
RMØD1C	unit replacement cost of seawater membranes, dollars per gallon per day
RMØD2C	unit replacement cost of brackish water membrane, dollars per gallon per day
STAGES	number of stages

SWHEAD	discharge head of seawater delivery pump, ft
SWMØDC	unit cost of seawater module, dollars per nominal gallon per day
TCBWHP	direct cost of second-stage high pressure pumps, dollars
TCHEM1	contribution of chemical treatment operating costs to product cost, cents per kilogallon
TCSWAP	direct capital cost of first-stage high pressure pumps, dollars
TMØDC1	contribution of investment in membranes and housings to cost of product, cents per kilogallon
TMØDC2	annual cost of amortizing capital cost of membranes and housings, dollars per year
TNADCY	daily acid use, tons
TØTCAP	total direct capital cost of plant, dollars
TØTKWA	average total power required, kilowatts (when power is varied to keep flow rate constant)
TØTPC1	contribution of investment in pumps and drivers to cost of product, cents per kilogallon
TØTPC2	annual cost of amortizing capital cost of pumps and drivers, dollars per year
TRAIN1	number of trains in first stage
TRAIN2	number of trains in second stage
UCPUMP	function defining unit cost of pumps, dollars per gallon per minute, as function of head and flow rate
WFEED1	feed rate to stage 1, Mgd
WØCEAN	seawater intake flow rate, lb per hour

5. SUBROUTINE RITERØ (IØPT, IØUT, L)

The written output for the RØ75 program is provided by RITERØ.

The calling arguments are

IØPT = optimization flag

IØPT = 0, the output cover page reports that the plant was not optimized.

IØPT ≠ 0, the output cover page reports that the plant was optimized.

IØUT = output detail flag

IØUT = 0, only the cover page and the condensed summary sheet of output are produced.

IØUT ≠ 0, complete output is provided.

L = output device indicator; device L is written upon by RITEM.

The subroutine is straightforward and can easily be understood by a study of the program listing.

6. FUNCTIONS SP AND SP12 AND SUBROUTINE SALP

These functions generate the salt passage factors from Figs. 6 and 12, respectively, of Reference 5 by a double Lagrangian interpolation in a table of values. Function V and Subroutine ALI are used to perform the interpolation.

6.1 Subroutine SALP

This subroutine calculates the stage salt passage factor, SALP1, when furnished the arguments

N = membrane type number

PPM = feed concentration, ppm

PSI = input pressure, psig

R = stage recovery fraction.

Two in-line functions were used: ØSMX to calculate the increase in dissolved solids content as a function of R, and SALPP to calculate the salt passage as a function of the net effective pressure.

It should be noted that PRØD should be called before SALP for Ajax membranes, since SALP requires the quantities ARFN1 and ARFN2 calculated in PRØD.

7. SUBROUTINE PRØD (N, PPM, PSI, C, R, PRØD1)

This subroutine calculates the membrane productivity, factor PRØD1, given the arguments

N = number designating membrane type
 PPM = salinity of feed, ppm
 PSI = inlet pressure, psig
 C = temperature, °C
 R = recovery fraction.

For hollow fibre-membranes, the factors in Figs. 3, 4, 5, 9, 10, and 13 of Reference 5, which are denoted by PRØD3, PRØD4, PRØD5, PRØD10, and PRØD13, respectively, are calculated from approximating functions which were obtained by least squares fits. Then the factors are multiplied together, giving for seawater membranes, $PRØD1 = PRØD9 * PRØD10 * PRØD13$ and for brackish water membranes, $PRØD1 = PRØD3 * PRØD4 * PRØD5$.

For membranes for which performance curves are not available, a calculation is made on the assumption that the productivity is proportional to the net effective pressure. The osmotic pressure as a function of feed concentration is given by the in-line function ØSM. The increase in average osmotic pressure (and in average dissolved solids content) is given by the in-line function ØSMX. The average osmotic operating pressure on the membrane boundary of stage 1 is

$$AVØP1 = ØSMX(R) * ØSM(PPM * CRF1 * 1.D-6).$$

The pressure drop in the module was assumed to have a scale factor of 1.8 of the recovery fraction

$$DELPI = DELPIN * (RECIN/R)** 1.8/2.0$$

where quantities ending in N are the nominal values. The actual net effective pressure is

$$ARFN1 = PSI - AVØP1 - DELPI - PRBPI.$$

The productivity ratio is then the ratio of actual net effective pressure to nominal net effective pressure, RFN1, with a temperature correction factor

$$PRØD1 = (ARFN1/RFN1)*(1.0 + TEOP)**(T-T_{ref}).$$

Similar relations are used for the second stage membranes.

8. PROGRAM OPERATION AND INPUT DATA REQUIREMENTS

The main program reads all input data and prints them out with suitable identification. The basic idea of the program is that built-in or "default" values of all design parameters are used unless they are overridden by input. Thus only those values which are to be changed from the built-in ("default") values must be entered as data. The design parameters are members of the Fortran arrays XC (for costs), XØ (for operational quantities) and XT (for technical quantities). The default values of these parameters are given in Tables 1 and 2. The values are also given in subroutines PRICES, ØTHPAR, and TECPAR, respectively, and their physical significance is given in subroutine TITLER. For example in subroutine PRICES the value of XC(49) is defined as 31. And in subroutine TITLER this is identified as 'cost of acid, \$/ton'; this is also given as the fourth entry in part III of Table 2.

Input data required are:

- (1) a card to specify plant capacity and options.
- (2) as many cards as needed to specify parameter changes
- (3) a blank card to terminate case data.

Format for data cards is shown in Table 3.

If a new value of an XT or XØ parameter is to be specified, the new value is entered in columns 6-15 of the data card. If a new cost parameter is to be specified, the ratio of the new cost to the default cost must be entered. For example, if the cost of acid is to be changed from \$31/ton to \$40/ton, the data card should read

C 39 1.2903

(where $40/31 = 1.2903$).

As an example, the data cards for the first sample case (Appendix B) would be

```

1.0      0  1  4  1
T 39 .28
T 40 .28
T 41 .90
T 42 .90
(blank card)

```

Table 3. Input data formats

Card No.	Columns	Entry
1 (format E10.3, 4I3)	1-10	Plant capacity, Mgd
	13	0 if design is not to be optimized 1 if design is to be optimized
	16	0 if page 1 only of output is desired 1 if pages 1-3 of output are desired
	19	4
	22	1 if acid feed treatment 2 if polyphosphate feed treatment
2 (format A1, I4, E10.3) (One card required for each parameter to be changed. If no parameters are changed, no card is required.)	1	C, $\emptyset$, or T for parameter XC, X $\emptyset$, or XT respectively
	3-5	Index number for parameter to be changed
	6-15	New value of XT or X $\emptyset$ parameter; or new multiplier for XC parameter.
3 (required at end of each case)		(blank)

```

1.0          0  1  4  1
T 175 5000.
T 176 6000.
T 160 1.
T 161 2.
T 181 1.
T 182 1.
T 162 .985
T 163 .9
T 169 3.
T 171 -.03
T 172 -.03
T 164 10000.
T 165 28000.
C  80 .667
C  81 .75
C  95 .618
C  96 .667
T  39 .36
T  40 .36
T 173 12.
T 174 12.
T 183 30000.
Ø  56 1.
Ø  57 1.
T 177 13.5
T 178 13.5
T 179 48.
T 180 48.
(blank card)

```

When a series of cases is run as a single job, any parameter change remains in effect in subsequent cases until specifically changed again. Thus in the example above, the values of T(41) and T(42) are 0.90 in the second case as well as the first, but the values of T(39) and T(40) are 0.28 in the first case and 0.36 in the second.

REFERENCES

1. P. Glueckstern, J. V. Wilson, and S. A. Reed, "Design and Cost Modifications of ORNL's Computer Programs MSF-21 and VTE-21 for the Evaluation and Rapid Optimization of Multistage Flash and Vertical Tube Evaporators," ORNL-TM-5230 (1976).
2. D. G. Thomas, Engineering Development of Hyperfiltration with Dynamic Membranes. Part IV: "Economic Analysis." Desalination 15 (1974), pp. 343-369.
3. K. E. Hickman et al., "Pumping and Energy Recovery Systems for Reverse Osmosis Desalination Plant," OSW Research and Development Progress Report No. 457, August 1969.
4. Ralph Stone and Co., Inc., "The Chula Vista, California, Pilot Plant Testing Program to Evaluate Seawater Pretreatment Methods for Reverse Osmosis," OSW Research and Development Progress Report No. 890, September 1973.
5. V. P. Caracciolo, N. W. Rosenblatt, and V. J. Tosmic, "Dupont's Hollow Fibre Membranes," Reverse Osmosis and Membranes, Theory — Technology — Engineering, Marcel Dekker, Inc., N.Y.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix A
FORTRAN LISTING

```

C      PROGRAM PROC21                                PROC0001
C      THIS PROGRAM RUNS SINGLE DESALTING PLANT CASES WITH CHANGES TO  PROC0002
C      INDIVIDUAL PARAMETERS READ IN ONE PER CARD                      PROC0003
C                                                                    PROC0004
C      OUTPUT CAN BE ROUTED TO DIFFERENT OUTPUT TAPES OR DISKS BY      PROC0005
C      CHANGING LTAPE1 AND LTAPE2.  LTAPE1 CONTAINS THE OVER-APROC0006
C      SUMMARY PAGE, AND LTAPE2 CONTAINS INDIVIDUAL CASE OUTPUT.  PROC0007
C      FOR MOST COMPUTING INSTALLATIONS LTAPE1 = 6 AND LTAPE2 = 6PROC0008
C                                                                    PROC0009
C      IMPLICIT REAL*8(A-H,O-Z)                                PROC0010
C      REAL*8 KBH,KPH,KVE,LBH,      NBH,NPH,NVE,KCON              PROC0011
C      REAL*4 XTXT, XCTXT, XCTXT                                PROC0012
C      DOUBLE PRECISION MM, MSF, MGD, MSFID,MODU                PROC0013
C      DOUBLE PRECISION LPH,      LVE,      IDBH,      IDPH,      LCON,      NCON,  PROC0014
C      1 NTPH, IDCON                                           PROC0015
C      DOUBLE PRECISION LEV,LF2                                PROC0016
C                                                                    PROC0017
C                                                                    PROC0018
C      COMMON/BLOC1/      DIE,      DIH,      DIR,      DOE,      DOH,PROC0019
C      1 DOR,      ELE,      ENE,      RLR,      RNR,      HDEL,PROC0020
C      2 HREC,      APTS,      ENITSR                                PROC0021
C      COMMON/PINHAS/DUMDUM(20),NFEED,IIIII(9)                PROC0022
C      COMMON/BLOC1/      ANE,      HVE,      LPH,      LVE,      ACON,PROC0023
C      1 GPMV,      HPVE,      HSEA,      IDBH,      IDPH,      LCON,PROC0024
C      2 NCON,      NTPH,      ODBH,      ODPH,      ODVE,      POVE,PROC0025
C      3 RPMV,      HFEED,      IDCON,      ODCON,      SUMWT,      VETSA,PROC0026
C      4 APTSCN,      APTSEP,      OVRHGT,      TOTNVE,      VEPMP,      PROC0027
C      COMMON/BLOC2/      A(30),      S,      AE(30),      QE,      TC(30),PROC0028
C      101 TE(30),      TR,      UE(30),      UH(30),      WM,      MT(30),PROC0029
C      2 ABH,      APH,      BPE(30),      CIE(30),      COE(30),      DPE(30),PROC0030
C      3 ELL,      GBH,      GPH,      GPM,      HOO,      KBH,PROC0031
C      4 KPH,      KVE,      LBH,      MGD,      NBH,      NPH,PROC0032
C      5 NVE(30),      QPH,      RBH,      RPH,      RVE,      TOQ,PROC0033
C      6 UBH,      VBH,      VPH,      WPEX(30),      BHLF,      GCON,PROC0034
C      7 HIBH,      HIPH(3),      HOBH,      HOPH(3),      KCON,      LMTD(3),PROC0035
C      8 LVEP,      PHLF,      QMSF(3),      RCON,      SUBF(3),      TCON,PROC0036
C      9 UCON,      VCON,      VLEN,      VTLF,      WOTH(30),      ALFAE(30),PROC0037
C      + CONLF,      HICON,      HOCN,      HOTE1,      PHHGT,      POBLO,PROC0038
C      A POPRO,      POSEA,      SURFF,      VEHGT,      WALVE,      EFFSPC,PROC0039
C      BELBNDL(30),      HCOTCF,      HCOTOD,      HEADBH,      HEADCN,      HEADPH,PROC0040
C      C LMTDBH,      LMTDCN,      PLNTLF,      PODEAS,      POFEED,      SUMMPE,PROC0041
C      D SUMWPH,      TOTAVE,      QESP,VEFEED(30),      WBOOST,      WDCOLD,PROC0042
C      E NE,      NTRN,      IFEED,      IRECYC                                PROC0043
C      COMMON/COMNAM/      AJ,      CB,      CO,      CP,      CR,      PROC0044
C      1 HB,      PI,      PO,      TB,      TO,      TP,      PROC0045
C      2 TS,      WB,      WF,      WO,      WP,      WR,      PROC0046
C      3 AXJ,      HBL,      HPR,      LEV,      LF2,      TCF,      PROC0047
C      4 ENBH,      GPMB,      GPMO,      GPMH,      GPMO,      GPM,      PROC0048
C      5 GPMR,      HDEA,      RPMB,      RPMO,      RPMH,      RPM,      PROC0049
C      6 RPMR,      TSTH,      WHOT,      YEAR,      ACRES,      BHVOL,      PROC0050
C      7 BLDGS,      BNDLS,      HOLES,      HPBLD,      HPDEA,      HPDEL,      PROC0051
C      8 HPPRD,      HPREC,      PLPRD,      PLSEA,      PODEA,      ACNCEW,      PROC0052
C      9 ACNCFL,      ACNCIW,      ACNCPH,      ACNCRF,      ACNCTR,      AEXCAV,      PROC0053
C      + ASTLEW,      ASTLFL,      ASTLIW,      ASTLPH,      ASTLRF,      ASTLTR,      PROC0054
C      A AWEIRS,      BHSURF,      DINTAK,      ENITSE,      ENPIPE,      ENSUPE,      PROC0055
C      B ENSUPR,      PIPELN,      PLSZMG,      REJLEN,      STLEN,      STLTMP,      PROC0056
C      C TNACDY,      TRAINS,      TSAREA,      VOLCNC,      VOLSTL,      MOCEAN,      PROC0057
C      COMMON/BLOC2/      P,      Q,      AH,      AK,      AN,PROC0058

```



```

1      AR,      FF,      GE,      GH,      GR,      HD,PROC0059
2      PB,      PE,      QX(5),    RP,      SE,      SH,PROC0060
3      SR,      TK,      VE,      VH,      VR,      MC,PROC0061
4      AME,      ATN,      BPX(5),    CCF,      HH,      HLH,PROC0062
5      MNH,      MOH,      OMX(5),    PHE,      PO3,      RSE,PROC0063
6      RSH,      RSR,      TC1,      THF,      TKX(5),    TMC,PROC0064
7      TNE,      TPE,      UEX(5),    UME,      UMH,      WPL,PROC0065
8      BKTE,      BKTH,      BKTR,      DTLS(5),    ELEX(5),    HIEX(5),PROC0066
9      HOEX(5),      MODU,      ROE1,      ROE2,      APTSE,      BDEPH,PROC0067
+      CAPI1,      HEADE,      HEADH,      HEADR,      POBLO,      PODEL,PROC0068
A      POPRD,      SUBEX(5),    WCOLD,      WMODC,      WMODH,      BHSHEL,PROC0069
B      CSLTBH,      CSLTBP,      HOTLEN,      HRECOV,      HREJCT,      RECOLN,PROC0070
C      VAPSPC,      WPRTRY,      POREC,      PROC0071
COMMON/BLOCV3/SS(59),TOTOPK      PROC0072
COMMON/BLOCM3/      EA,      ES,      CC1,      CC2,      EA1,PROC0073
1      EA2,      EEC,      HC1,      HC2,      OC1,      OC2,PROC0074
2      PMC,      TC2,      VPC,      BHC1,      BHC2,      CIBC,PROC0075
3      DEA1,      DEA2,      EEC2,      EEC2,      PMC1,      PMC2,PROC0076
4      SITE,      SMAP,      VPC1,      VPC2,      WAIT,      AMSC1,PROC0077
5      AMSC2,      CAPI2,      CAPI3,      CAPI4,      CIBC1,      CIBC2,PROC0078
6      SITE1,      SITE2,      WAIT1,      WAIT2,      CHMPTC,      CHMPT1,PROC0079
7      CHMPT2,      CINSTC,      CINST1,      CINST2,      DEACST,      POCST1,PROC0080
8      POCST2,      RATEIN,      RETU81,      RETU82,      SMAPPH,      SMAPPP,PROC0081
9      CD,      BHC,      ES1,      ES2,      PROC0082
COMMON/BLOCK6/FC(500)      PROC0083
COMMON/BLOC12/XT(300)      PROC0084
COMMON/BLOC13/XO(300)      PROC0085
COMMON/BLOC14/XC(500)      PROC0086
COMMON/SHARE/ IFLIP,ISPOT      PROC0087
COMMON/NAME/ ANAME(10), AMONTH,IIDAY, IYEAR      PROC0088
COMMON/CASEID/ ALINE(5,80), LINKNT      PROC0089
COMMON/PARTXT/ XTTXT(14,230), XOTXT(14,230), XCTXT(14,230)      PROC0090
COMMON/TAPE/ LTAPE2      PROC0091
COMMON/DECKID/ MSFID(10), VTEID(10), EDID(10)      PROC0092
COMMON/VARS/XV(14),IREF      PROC0093
C      DIMENSION OUTP(30,7),JB(13),PROC(4),NOW(2)      PROC0094
      DIMENSION NOT(2)      PROC0095
      DIMENSION SAVXO(14)      PROC0096
      DIMENSION START1(1),START2(1),START3(1)      PROC0097
C      DATA C,O,T/'C','O','T'/      PROC0098
      DATA BLANK/' '/      PROC0099
      DATA BLANK2/' '/      PROC0100
      DATA PROC/'MSF','VTE','ED','RO'/      PROC0101
      EQUIVALENCE (START1(1),DIE),(START2(1),ANE),(START3(1),AJ)      PROC0102
C ***      PROC0103
C      PROC0104
C      LTAPE1 IS LOGICAL NUMBER FOR INPUT TAPE      PROC0105
C      LTAPE2 IS LOGICAL NUMBER FOR OUTPUT TAPE      PROC0106
C      TAPE 6 IS USED IN SEVERAL SUBROUTINES FOR PRINTING OUT ERROR MESS      PROC0107
      LTAPE1=5      PROC0108
      LTAPE2 = 6      PROC0109
C      PROC0110
C      PROC0111
C      IIDAY RETURNS THE DATE IN A8 FORMAT IN THE FORM 10-23-73      PROC0112
      CALL IIDAY(NOW)      PROC0113
C      ICLOCK RETURNS THE TIME IN HUNDREDTHS OF A SECOND      PROC0114
C      PROC0115
      IIDAY=1000      PROC0116
      IYEAR=1972      PROC0117
      AMONTH=BLANK2      PROC0118
      DO 20 J=1,10      PROC0119
      VTEID(J)=BLANK2      PROC0120
      MSFID(J)=BLANK2      PROC0121
20  ANAME(J)=BLANK2      PROC0122
      DO 30 J=1,200      PROC0123
      DO 30 I=1,14      PROC0124
      XTTXT(I,J)=BLANK      PROC0125
      XOTXT(I,J)=BLANK      PROC0126
      PROC0127
      PROC0128

```

	XCTXT(1,J)=BLANK	PROC0129
30	CONTINUE	PROC0130
		PROC0131
		PROC0132
		PROC0133
	THESE LOOPS INITIALIZE THE VARIABLES USED IN 'PRICES'	PROC0134
	JII=3	PROC0135
	PI = 4.000*DATAN(1.000)	PROC0136
	ZIP = PI/16.263	PROC0137
	ENITSR = ZIP	PROC0138
	VEPMPS = ZIP	PROC0139
	WOCEAN = ZIP	PROC0140
	ABH=PI	PROC0141
	LBH=PI	PROC0142
	NBH=PI	PROC0143
	DO 40 IX=1,1000	PROC0144
	START1(IX)=PI	PROC0145
	IF(DABS(START1(IX+1)-ZIP) .LT. 1.0-9) GO TO 50	PROC0146
40	CONTINUE	PROC0147
50	DO 60 IX=1,1000	PROC0148
	START2(IX)=PI	PROC0149
	IF(DABS(START2(IX+1)-ZIP) .LT. 1.0-9) GO TO 70	PROC0150
60	CONTINUE	PROC0151
70	DO 80 IX=1,1000	PROC0152
	START3(IX)=PI	PROC0153
	IF(DABS(START3(IX+1)-ZIP) .LT. 1.0-9) GO TO 90	PROC0154
80	CONTINUE	PROC0155
90	GPMO = 2.*PI	PROC0156
	DO 100 IX=1,20	PROC0157
100	DUMDUM(IX)=PI	PROC0158
	APTSE = PI	PROC0159
	IFLIP = 0	PROC0160
	LTPE2=LTAPE2	PROC0161
		PROC0163
		PROC0164
		PROC0165
		PROC0166
		PROC0167
		PROC0168
		PROC0169
		PROC0170
110	FC(I) = 1.00	PROC0171
	CALL TITLER	PROC0172
	CALL TECPAR	PROC0173
	CALL OTMPAR	PROC0174
120	READ(LTAPE1,8000)SZ,IOPT,IOUT,NTYPE,NFEED	PROC0175
	IF(SZ.LT.0.) GO TO 160	PROC0176
	IF(NTYPE.EQ.0)NTYPE=1	PROC0177
8000	FORMAT(E10.3,4I3)	PROC0178
	WRITE(LTAPE2,8010) SZ,PROC(NTYPE),NOW	PROC0179
8010	FORMAT('1CALCULATION FOR ',F6.1,' MGD',1X,A3,' DESALTING PLANT',	PROC0180
	120X,2A4/////)	PROC0181
	IF(NFEED.EQ.1) WRITE(LTAPE2,8020)	PROC0182
	IF(NFEED.EQ.2) WRITE(LTAPE2,8030)	PROC0183
8020	FORMAT(20X,'ACID FEED TREATMENT')	PROC0184
8030	FORMAT(17X,'THRESHOLD FEED TREATMENT')	PROC0185
	IF(NTYPE.LT.0)CALL EXIT	PROC0186
	IF(NTYPE.GT.4)CALL EXIT	PROC0187
	ARGU=PROC(NTYPE)	PROC0188
	CALL PRICES(ARGU)	PROC0189
	DO 130 I=1,14	PROC0190
130	XO(I)=-1.	PROC0191
140	READ (LTAPE1,8040) PARAM,JC,QUANT	PROC0192
8040	FORMAT(A1,I4,E10.3)	PROC0193
	IF(PARAM.EQ.BLANK) GO TO 150	PROC0194
	IF(PARAM.EQ.C) FC(JC)=QUANT	PROC0195
	IF(PARAM.EQ.O) XO(JC)=QUANT	PROC0196
	IF(PARAM.EQ.T) XT(JC)=QUANT	PROC0197
	IF(PARAM.EQ.O)WRITE(LTPE2,8050)PARAM,JC,QUANT,(XOTXT(K,JC),K=1,14)	PROC0198

```

8050 FORMAT(' THE VALUE OF X',A1,1H(,13,22H) HAS BEEN CHANGED TO E12.4,PROCO199
      1 8H IT IS 14A4) PROCO200
      IF(PARAM.EQ.C)WRITE(LTPE2,8060)PARAM,JC,QUANT,(XCTXT(K,JC),K=1,14)PROCO201
8060 FORMAT(' THE VALUE OF F',A1,1H(,13,22H) HAS BEEN CHANGED TO E12.4,PROCO202
      116H IT MULTIPLIES 14A4) PROCO203
      IF(PARAM.EQ.T)WRITE(LTPE2,8070)PARAM,JC,QUANT,(XTTXX(K,JC),K=1,14)PROCO204
8070 FORMAT(' THE VALUE OF X',A1,1H(,13,22H) HAS BEEN CHANGED TO E12.4,PROCO205
      1 8H IT IS 14A4) PROCO206
      GO TO 140 PROCO207
150 CONTINUE PROCO208
      IF(NTYPE.EQ.1)CALL MAINM(SZ,IOPT,IOUT,CH20,CH21) PROCO209
      IF(NTYPE.EQ.2)CALL MAINV(SZ,IOPT,IOUT,CH20,CH21) PROCO210
      IF(NTYPE.EQ.3)CALL MAINE(SZ,IOPT,IOUT,CH20,CH21) PROCO211
      IF(NTYPE.EQ.4)CALL MAINRO(SZ,IOPT,IOUT,CH20,CH21) PROCO212
      GO TO 120 PROCO213
160 STOP PROCO214
      END PROCO215
      SUBROUTINE MAINE(A,B,C,D,E) MAIN0001
      ENTRY GLOSSM MAIN0002
      ENTRY GLOSSV MAIN0003
      RETURN MAIN0004
      END MAIN0005
      BLOCK DATA MAIN0001
      REAL*8 MSFID, VTEID, EDID MAIN0002
      COMMON/DECKID/ MSFID(10), VTEID(10), EDID(10) MAIN0003
      DATA MSFID/'MSF - EDITION OF APRIL 1969, INCORPORATING BECHTEL CORMAIN0004
1P COSTS OF 3RD QTR 1967 '/' MAIN0005
      DATA VTEID/'VTE - EDITION OF JULY 1969, INCORPORATING BECHTEL CORMAIN0006
1P COSTS OF 3RD QTR 1967 '/' MAIN0007
      DATA EDID/'ED - PROCESS RESEARCH INCORPORATED EDITION OF SPRING MAIN0008
11969 '/' MAIN0009
      END MAIN0010
      SUBROUTINE MAINRO(FMGD,IOPT,IOUT,TC1,CCC) MAIN0001
      IMPLICIT REAL*8(A-H,O-Z) MAIN0002
      REAL*8 LFM1,LFM2 MAIN0003
      COMMON/AJAX/PRBP1,PRBP2,RFN1,RFN2,CRF1,CRF2,TEOP,ARFN1,ARFN2, MAIN0004
1 AVOP1,AVOP2,OSM1,OSM2,NSPOSM MAIN0005
      COMMON/SHARE/IFLIP,ISPOI MAIN0006
      COMMON/TAPE/LTAPE2 MAIN0007
      COMMON/RO/MSTYPE,MSTYPE,STAGES,PRES1,PRES2,PRODS, MAIN0008
1 REJN1,REJN2,PRODN1,PRODN2,PMGD,SPEED,REC1,REC2,EFFIC1,EFFIC2, MAIN0009
2 EFFIC3,EFFIC4,TRAIN1,TRAIN2,BAREA,DELP1N,TEMP1,SWHEAD,PRODM,SOPR MAIN0010
3,WPROD1,SPROD1,WPROD2,SPROD2,BLR,PMGD1,NMOD2,MOD2,NMOD1,MOD1, MAIN0011
4 WFEE1,WFEED,TPUMP1,PUMP1,TPUMP2,PUMP2,SPUMP,PPUMP,POTHR, MAIN0012
5 DELP1,PRECOV,TOTKW,REJ1,REJ2 MAIN0013
6 ,FM1,FM2,PRESOP,PRES1N,PRES2N,TOTKWA MAIN0014
      COMMON/RO1/DMOD1,DMOD2,XLMD1,XLMD2,SMOD1,SMOD2,PRES1N,PRES2N, MAIN0015
* REC1N,REC2N,LFM1,LFM2,TEMPN1,TEMPN2,FNPPM1,FNPPM2,DSHEL1,DSHEL2 MAIN0016
*,NMOD1S,NMOD2S MAIN0017
      COMMON/BLOCK6/FC(500) MAIN0018
      COMMON/BLOC12/XT(300) MAIN0019
      COMMON/BLOC13/XO(300) MAIN0020
      COMMON/BLOC14/XC(300) MAIN0021
      DIMENSION XO8(40),XL8(40),XM8(40) MAIN0022
      DIMENSION IND(14) MAIN0023
      DIMENSION D(2) MAIN0024
      EXTERNAL PLANTR MAIN0025
      DATA PROC/'RO'/ MAIN0026
C
C TECHNOLOGY MAIN0027
C MSTYPE = MEMBRANE TYPE - SEAWATER MAIN0028
C TYPE 1 = POLYAMIDE - HOLLOW FIBER MAIN0029
C TYPE 3 = COMPOSITE - SPIRAL WOUND MAIN0030
C MBTYPE = MEMBRANE TYPE - BRACKISH MAIN0031
C TYPE 2 = POLYAMIDE - HOLLOW FIBER MAIN0032
C TYPE M = COMPOSITE - SPIRAL WOUND MAIN0033
C STAGES = NUMBER OF DESALTING STAGES IN SERIES MAIN0034
C PRES1 = INLET PRESSURE TO STAGE 1 MAIN0035
C PRES2 = INLET PRESSURE TO STAGE 2 MAIN0036
C PRODS = REQUIRED PRODUCT SALINITY, PPM TDS MAIN0037
C MAIN0038

```

C	REJN1 = NOMINAL MEMBRANE SALT REJECTION - 1ST STAGE	MAIN0039
C	REJN2 = NOMINAL MEMBRANE SALT REJECTION - 2ND STAGE	MAIN0040
C	PRODN1 = NOMINAL MODULE PRODUCTION RATE - 1ST STAGE - GPD	MAIN0041
C	PRODN2 = NOMINAL MODULE PRODUCTION RATE - 2ND STAGE - GPD	MAIN0042
C	PMGD = REQUIRED PLANT CAPACITY, MGD	MAIN0043
C	SPEED = SEAWATER SALINITY, PPM TDS	MAIN0044
C	REC1 = PRODUCT RECOVERY IN 1ST STAGE	MAIN0045
C	REC2 = PRODUCT RECOVERY IN 2ND STAGE	MAIN0046
C	EFFIC1 = EFFICIENCY OF HIGH PRESSURE PUMP FOR STAGE 1	MAIN0047
C	EFFIC2 = EFFICIENCY OF HIGH PRESSURE PUMP FOR STAGE 2	MAIN0048
C	EFFIC3 = EFFICIENCY OF OTHER PUMPS	MAIN0049
C	EFFCT = EFFICIENCY OF POWER RECOVERY TURBINE	MAIN0050
C	TRAIN1= NO. OF 1ST STAGE TRAINS	MAIN0051
C	TRAIN2= NO. OF 2ND STAGE TRAINS	MAIN0052
C	BAREA = SPECIFIC BUILDING AREA REQUIREMENT, SQ.FT./MGD	MAIN0053
C	DELPIN = NOMINAL PRESSURE DROP IN 1ST STAGE, PSI	MAIN0054
C	TEMP1 = FEED TEMPERATURE IN 1ST STAGE	MAIN0055
C	SWHEAD = HEAD OF SEAWATER PUMP, PSI	MAIN0056
C	SOPR = OTHER PUMPING REQUIREMENTS, HP/MGD	MAIN0057
	CALL ITIME(IZX,JZX)	MAIN0058
	IO = -2	MAIN0059
	IFLIP = 1	MAIN0060
	PMGD=FMGD	MAIN0061
	FF = PMGD	MAIN0062
	SWHEAD=XO(28)	MAIN0063
	PRODN=XO(31)	MAIN0064
	EFFIC3=XO(32)	MAIN0065
	SPEED=XO(36)	MAIN0066
	PRODS=XO(37)	MAIN0067
	TEMP1=5.*(XO(40)-32.)/9.	MAIN0068
	STAGES=XO(50)	MAIN0069
	M=STAGES	MAIN0070
	PRES1=XO(51)	MAIN0071
	PRES2=XO(52)	MAIN0072
	EFFIC1=XO(53)	MAIN0073
	EFFIC2=XO(54)	MAIN0074
	TRAIN1=XO(56)	MAIN0075
	TRAIN2=XO(57)	MAIN0076
	SOPR=XO(58)	MAIN0077
	PRESOP=XO(59)	MAIN0078
	MSTYPE=XT(160)	MAIN0079
	MBTYPE=XT(161)	MAIN0080
	REJN1=XT(162)	MAIN0081
	REJN2=XT(163)	MAIN0082
	PRODN1=XT(164)	MAIN0083
	PRODN2=XT(165)	MAIN0084
	BAREA=XT(166)	MAIN0085
	DELPIN=XT(167)	MAIN0086
	LFM1=XT(169)	MAIN0087
	LFM2=XT(170)	MAIN0088
	FM1=XT(171)	MAIN0089
	FM2=XT(172)	MAIN0090
	DMOD1=XT(173)	MAIN0091
	DMOD2=XT(174)	MAIN0092
	SMOD1=XT(175)	MAIN0093
	SMOD2=XT(176)	MAIN0094
	DSHEL1=XT(177)	MAIN0095
	DSHEL2=XT(178)	MAIN0096
	XLMOD1=XT(179)	MAIN0097
	XLMOD2=XT(180)	MAIN0098
	NMOD1S=XT(181)	MAIN0099
	NMOD2S=XT(182)	MAIN0100
	FNPPM1=XT(183)	MAIN0101
	FNPPM2=XT(184)	MAIN0102
	TEMPN1=XT(185)	MAIN0103
	TEMPN2=XT(186)	MAIN0104
	PRES1N=XT(187)	MAIN0105
	PRES2N=XT(188)	MAIN0106
	REC1N=XT(189)	MAIN0107
	REC2N=XT(190)	MAIN0108

```

PRBP1=XT(191)
PRBP2=XT(192)
RFN1=XT(193)
RFN2=XT(194)
CRF1=XT(195)
CRF2=XT(196)
TEOP=XT(197)
NSPOSW=XT(198)
CALL VARSET(FF,PROC)
XO(3)=1.00
DO 10 I=1,3
  X08(I)= XO(I)
  XM8(I)= XT(2*I+37)
  XL8(I)= XT(2*I+38)
10 CONTINUE
  IF(IOPT.EQ.0) GO TO 80
  IYCT=1
  Y=X08(1)
20 IF(MSTYPE.EQ.3)CALL PRODIM(MSTYPE,SPEED,PRES1,TEMP1,REC1,PROD1)
  CALL SALP(MSTYPE,SPEED,PRES1,Y,SALP1)
  SPROD1=(1.00-REJN1)*SALP1*SPEED
  IF(DABS(SPROD1-PRODS).LT.1.00) GO TO 30
  CALL SALP(MSTYPE,SPEED,PRES1,Y-.0100,X)
  Y=Y -.0100*(SPROD1-PRODS)/(SPROD1-X)
  IYCT=IYCT+1
  IF(IYCT.LT.30) GO TO 20
  Y=XL8(1)
30 IF(M-1) 40,40,50
40 X08(1)=Y
  IF(X08(1).LT.XL8(1)) X08(1)=XL8(1)
  IF(X08(1).GT.XM8(1)) X08(1)=XM8(1)
  GO TO 100
50 IF(Y.LT.XM8(1)) GO TO 70
60 M=1
  GO TO 40
70 XL8(1)=DMAX1(Y,XL8(1))
80 DO 90 I=1,3
  IF(XL8(I).GT. XM8(I)) XL8(I)=XM8(I)
  IF(X08(I).LT. XL8(I)) X08(I)=XL8(I)
  IF(X08(I).GT. XM8(I)) X08(I)=XM8(I)
90 CONTINUE
C
  NCALLS = 0
  IND(1) = 0
  IF(IOPT.EQ. 0) GO TO 100
  IF(10.GT. 0) WRITE(6,8000) FF
8000 FORMAT(1H1,'RO ',F8.2,' MGD')
C
  CALL SLIDE(3,X08,XM8,XL8,PLANTR,10,3,3,1,1,NCALLS)
  IF(10.GT. 0) WRITE(6,8010) FF
8010 FORMAT(1H0,'RO ',F8.2,' MGD')
100 CONTINUE
  IND(13) = 1
  CALL PLANTR(X08,CH20)
  IF(REC1.LT.XL8(1)) GO TO 120
  NCALLS= NCALLS +1
  KOUT = LTape2
  CALL RITERO(1OPT,IOUT,KOUT)
  WRITE(KOUT,8020) NCALLS,IND(1)
8020 FORMAT(1H ,21HNUMBER OF PLANT CALLS ,15,110)
  CALL ITIME(IZXX,JZXX)
  TCALC = DFLOAT(IZXX-IZX)*1.0-2
  WRITE(KOUT,8030) TCALC
8030 FORMAT(1H0,18HTIME FOR THIS CASE,F8.2,2X7HSECONDS)
  TC1=CH20
  CCC=POTHER
110 CONTINUE
  RETURN

```

MAIN0109
 MAIN0110
 MAIN0111
 MAIN0112
 MAIN0113
 MAIN0114
 MAIN0115
 MAIN0116
 MAIN0117
 MAIN0118
 MAIN0119
 MAIN0120
 MAIN0121
 MAIN0122
 MAIN0123
 MAIN0124
 MAIN0125
 MAIN0126
 MAIN0127
 MAIN0128
 MAIN0129
 MAIN0130
 MAIN0131
 MAIN0132
 MAIN0133
 MAIN0134
 MAIN0135
 MAIN0136
 MAIN0137
 MAIN0138
 MAIN0139
 MAIN0140
 MAIN0141
 MAIN0142
 MAIN0143
 MAIN0144
 MAIN0145
 MAIN0146
 MAIN0147
 MAIN0148
 MAIN0149
 MAIN0150
 MAIN0151
 MAIN0152
 MAIN0153
 MAIN0154
 MAIN0155
 MAIN0156
 MAIN0157
 MAIN0158
 MAIN0159
 MAIN0160
 MAIN0161
 MAIN0162
 MAIN0163
 MAIN0164
 MAIN0165
 MAIN0166
 MAIN0167
 MAIN0168
 MAIN0169
 MAIN0170
 MAIN0171
 MAIN0172
 MAIN0173
 MAIN0174
 MAIN0175
 MAIN0176

MAIN0177
 MAIN0178
 MAIN0179
 MAIN0180
 PLAN0001
 PLAN0002
 PLAN0003
 PLAN0004
 PLAN0005
 PLAN0006
 PLAN0007
 PLAN0008
 PLAN0009
 PLAN0010
 PLAN0011
 PLAN0012
 PLAN0013
 PLAN0014
 PLAN0015
 PLAN0016
 PLAN0017
 PLAN0018
 PLAN0019
 PLAN0020
 PLAN0021
 PLAN0022
 PLAN0023
 PLAN0024
 PLAN0025
 PLAN0026
 PLAN0027
 PLAN0028
 PLAN0029
 PLAN0030
 PLAN0031
 PLAN0032
 PLAN0033
 PLAN0034
 PLAN0035
 PLAN0036
 PLAN0037
 PLAN0038
 PLAN0039
 PLAN0040
 PLAN0041
 PLAN0042
 PLAN0043
 PLAN0044
 PLAN0045
 PLAN0046
 PLAN0047
 PLAN0048
 PLAN0049
 PLAN0050
 PLAN0051
 PLAN0052
 PLAN0053
 PLAN0054
 PLAN0055
 PLAN0056
 PLAN0057
 PLAN0058
 PLAN0059
 PLAN0060
 PLAN0061
 PLAN0062
 PLAN0063
 PLAN0064
 PLAN0065
 PLAN0066

```

CALL PROD(MBTYPE,SPROD1,PRES2,TEMP1,REC2,PROD2)
WPROD2=PRODN2*PROD2
CALL SALP(MBTYPE,SPROD1,PRES2,REC2,SALP2)
REJ2=1.-(1.-REJN2)*SALP2
SPROD2=SPROD1*(1.-REJN2)*SALP2
C   REQUIRED BLENDING RATIO
    BLR=(SPROD1-PRODS1)/(SPROD1-SPROD2)
    IF(BLR.LT.0.00) BLR=0.00
    PMGD1=PMGD*(1./REC2-1.)*BLR+1.)
C   NUMBER OF SECOND STAGE MODULES
    NMOD2=PMGD *BLR*1.06/WPROD2+.9900
    MOD2=NMOD2
C   NUMBER OF FIRST STAGE MODULES
50  NMOD1=1.06*PMGD1/WPROD1+.9900
    MOD1=NMOD1
C   FIRST STAGE FEED RATE, MGD
    WFEED1=PMGD1/REC1
C   SEAWATER FEED RATE
    WFEED=WFEED1+PMGD-PMGD1
    IF(BLR.LE.0.00) GO TO 60
    SFEEED1=(WFEED*SAVE-PMGD*PRODS)/WFEED1+REC1*SPROD1
    IF(DABS(SFEEED1-SFEED).LT.1.00) GO TO 60
    SFEED=SFEED1*0.500+0.500*SFEED
    GO TO 10
60  SFEED=SAVE
    IF(BLR.LT.0.00) GO TO 20
    CALL SIZERO
    CALL COSTRO(TC1)
    FFFFFF=TC1
    IFLIP=IFLIP+1
    RETURN
END
SUBROUTINE SIZERO
IMPLICIT REAL*8(A-H,O-Z)
REAL*8 LFM1,LFM2
COMMON/RO2/PROD1,PROD2,AFDF1,AFDF2
COMMON/RO/MSTYPE,MBTYPE,STAGES,PRES1,PRES2,PRODS,
1  REJN1,REJN2,PRODN1,PRODN2,PMGD,SFEED,REC1,REC2,EFFIC1,EFFIC2,
2  EFFIC3,EFFICT,TRAIN1,TRAIN2,BAREA,DELP1N,TEMP1,SMHEAD,PRODM,SOPR
3  WPROD1,SPROD1,WPROD2,SPROD2,BLR,PMGD1,NMOD2,MOD2,NMOD1,MOD1,
4  WFEED1,WFEED,TPUMP1,PUMP1,TPUMP2,PUMP2,SPUMP,PPUMP,POTHER,
5  DELP1,PRECQV,TOTKW,REJ1,REJ2
6  FM1,FM2,PRESOP,PRES1M,PRES2M,TOTKWA
COMMON/BLOC12/XT(300)
COMMON/RO1/DMOD1,DMOD2,SHEL1L,SHEL2L,SMOD1,SMOD2,PRES1N,PRES2N,
*  REC1N,REC2N,LFM1,LFM2,TEMPN1,TEMPN2,FNPPM1,FNPPM2,DSHEL1,DSHEL2
*  NMOD1S,NMOD2S
AFDF1=(365.*LFM1)**FM1/(1.+FM1)
AFDF2=(365.*LFM2)**FM2/(1.+FM2)
IF(PRESOP.GT.1.00) GO TO 20
C   PRESOP=1 OPERATING PRESSURE IS CONSTANT DURING MEMBRANE LIFETIME
C   PRESOP=2 OPERATING PRESSURE IS INCREASED WITH FLUX DECLINE
10  WPROD1=PRODN1*PROD1*AFDF1
    PRES1A=PRES1
    PRES1M=PRES1
    WPROD2=PRODN2*PROD2*AFDF2
    PRES2A=PRES2
    PRES2M=PRES2
    MOD1=MOD1/AFDF1
    NMOD1=NMOD1/AFDF1
    NMOD2=NMOD2/AFDF2
    MOD2=MOD2/AFDF2
    GO TO 30
20  PRES1A=PRES1/AFDF1
    PRES1M=PRES1/(365.*LFM1)**FM1
    PRES2A=PRES2/AFDF2
    PRES2M=PRES2/(365.*LFM2)**FM2
30  CONTINUE
C   FIRST AND SECOND STAGE PUMPING POWER, HP
    TPUMP1=.405*WFEED1*PRES1M/EFFIC1

```

PLAN0067
 PLAN0068
 PLAN0069
 PLAN0070
 PLAN0071
 PLAN0072
 PLAN0073
 PLAN0074
 PLAN0075
 PLAN0076
 PLAN0077
 PLAN0078
 PLAN0079
 PLAN0080
 PLAN0081
 PLAN0082
 PLAN0083
 PLAN0084
 PLAN0085
 PLAN0086
 PLAN0087
 PLAN0088
 PLAN0089
 PLAN0090
 PLAN0091
 PLAN0092
 PLAN0093
 PLAN0094
 PLAN0095
 PLAN0096
 PLAN0097
 PLAN0098
 SIZE0001
 SIZE0002
 SIZE0003
 SIZE0004
 SIZE0005
 SIZE0006
 SIZE0007
 SIZE0008
 SIZE0009
 SIZE0010
 SIZE0011
 SIZE0012
 SIZE0013
 SIZE0014
 SIZE0015
 SIZE0016
 SIZE0017
 SIZE0018
 SIZE0019
 SIZE0020
 SIZE0021
 SIZE0022
 SIZE0023
 SIZE0024
 SIZE0025
 SIZE0026
 SIZE0027
 SIZE0028
 SIZE0029
 SIZE0030
 SIZE0031
 SIZE0032
 SIZE0033
 SIZE0034
 SIZE0035
 SIZE0036
 SIZE0037
 SIZE0038

```

PUMP1=TPUMP1/TRAIN1
TPUMP2=.405*PMGD*BLR*PRES2M/EFFIC2
PUMP2=TPUMP2/TRAIN2
C SEAWATER FEED PUMP, HP
40 SPUMP=.405*WFEED*SWHEAD/EFFIC3
PPUMP=.405*PMGD*PRODH/EFFIC3
POTHER=PMGD*SOPR
DELP1=DELPIN*(REC1/REC1N)**(-0.7D0)+XT(199)
IF( NMOD1S.GT.1) DELP1=DELPIN*(REC1N/REC1)**1.8D0+XT(199)
C TURBINE RECOVERY POWER, HP
PRECOV=.383*WFEED*(1.-REC1)*(PRES1M-DELP1)*EFFICT
C TOTAL POWER REQUIREMENT, KW
TOTKW=.746*(TPUMP1*PRES1A/PRES1M+TPUMP2*PRES2A/PRES2M
1 + SPUMP+PPUMP+POTHER-PRECOV*(PRES1A-DELP1)/(PRES1M-DELP1))
50 TOTKW=.746*(TPUMP1+TPUMP2+SPUMP+PPUMP+POTHER)
RETURN
END
SUBROUTINE COSTRO(TC1)
IMPLICIT REAL*8(A-H,O-Z)
REAL*8 LFM1,LFM2,LF2,LEV
COMMON/RO3/PSAJ,CFG
COMMON/BLOC3/ TMODE, ES, TCHEM1, TCHEM, TMODE1,COST0005
1 TMODE2, CELEQ, HCL, HC2, OC1, OC2,COST0006
2 TOTPC, TC2, CPIPE, TOC1, TOC2, CIBC,COST0007
3 CAPI1, ATC1, CELEQ1, CELEQ2, TOTPC1, TOTPC2,COST0008
4 CSAB, SSMAP, CPIPE1, CPIPE2, CSMIO, AMSC1,COST0009
5 AMSC2, CAPI2, CAPI3, CAPI4, CIBC1, CIBC2,COST0010
6 CSAB1, CSAB2, CSMIO1, CSMIO2, CPRT, CPRT1,COST0011
7 CPRT2, CINST, CINST1, CINST2, DEACST, POCST1,COST0012
8 POCST2, RTEIN, REPLC1, REPLC, OPOSTC, CPRCT,COST0013
9 CD, ASJ, ES1, ES2, COST0014
COMMON/COMNAM/ AJ, CB, CO, CP, CR, COST0015
1 HB, PI, PO, TB, TP, COST0016
2 TS, WB, WF, MO, MP, MR, COST0017
3 AXJ, HBL, HPR, LEV, LF2, TCF, COST0018
4 ENBH, GPMB, GPMO, GPMH, GPMO, GPMH, COST0019
5 GPMR, HDEA, RPMB, RPMO, RPMH, RPMH, COST0020
6 RPMR, TSTH, WHOT, YEAR, ACRES, BHVOL, COST0021
7 BLDGS, BNDLS, HOLES, HPBLD, HPDEA, HPDEL, COST0022
8 HPPRD, HPREC, PLPRD, PLSEA, PODEA, ACNCEW, COST0023
9 ACNCFL, ACNCIW, ACNCPH, ACNCRF, ACNCTR, AEXCAV, COST0024
+ ASTLEW, ASTLFL, ASTLIW, ASTLPH, ASTLRF, ASTLTR, COST0025
A AWEIRS, BHSURF, DINTAK, ENITSE, ENPIPE, ENSUPE, COST0026
B ENSUPR, PIPELN, PLSZMG, REJLEN, STLEN, STLTMP, COST0027
C TNACDY, TRAINS, TSAREA, VOLCNC, VOLSTL, WOCEAN, COST0028
COMMON/BLOC12/XT(300)
COMMON/BLOC13/XO(300)
COMMON/BLOC14/XC(300)
COMMON/BLOCK6/FC(500)
COMMON/RO/MSTYPE,MBTYPE,STAGES,PRES1,PRES2,PRODS,
1 REJN1,REJN2,PRODN1,PRODN2,PMGD,SFEED,REC1,REC2,EFFIC1,EFFIC2,
2 EFFIC3,EFFICT,TRAIN1,TRAIN2,BAREA,DELPIN,TEMP1,SWHEAD,PRODH,SOPR
3,WPROD1,SPROD1,WPROD2,SPROD2,BLR,PMGD1,NMOD2,MOD2,NMOD1,MOD1,
4 WFEED1,WFEED,TPUMP1,PUMP1,TPUMP2,PUMP2,SPUMP,PPUMP,POTHER,
5 DELP1,PRECOV,TOTKW,REJ1,REJ2
6 ,FM1,FM2,PRESOP,PRES1M,PRES2M,TOTKWA
COMMON/RO1/DMOD1,DMOD2,XLMOD1,XLMOD2,SMOD1,SMOD2,PRES1N,PRES2N,
* REC1N,REC2N,LFM1,LFM2,TEMPN1,TEMPN2,FNPPM1,FNPPM2,DSHEL1,DSHEL2
*,NMOD1S,NMOD2S
DATA PROC/'RO'/
C SWMODC = SEAWATER MODULE COST, $/GPD (NOMINAL)
C BWMODC = BRACKISH WATER MODULE COST, $/GPD (NOMINAL)
C PRTRTC = COST OF REFERENCE PRETREATMENT SYSTEM, $
C HPRC = COST OF REFERENCE HIGH PRESSURE PUMP, $
C UNMC = UNIT MOTOR COST, $/HP
C CPMOP = UNIT PIPE COST $/MODULE
C CPSTOP = UNIT PIPE COST FOR FIRST STAGE TRAIN, $/TRAIN
C CPBTOP = UNIT PIPE COST FOR 2ND STAGE TRAIN, $/TRAIN
C CELBC = ELECTRICAL EQUIPMENT BASE COST, $
C UEPKW = UNIT COST OF ELECTRICAL EQUIPMENT, $/KW

```



```

C CSREF = REFERENCE SITE COST FOR 1 MGD PLANT, $ COST0054
C BSQFTC = BUILDING COST, $/SQ. FT. COST0055
C RMOD1C = UNIT REPLACEMENT COST OF SEAWATER MEMBRANE, $/GPD COST0056
C RMOD2C = UNIT REPLACEMENT COST OF BRACKISH MEMBRANE, $/GPD COST0057
C RTEIN = INTEREST RATE COST0058
C WPL = PLANT LIFETIME, YRS COST0059
C LF2= PLANT OPERATING FACTOR COST0060
C LFM1 = LIFETIME OF SEAWATER MEMBRANES, YEARS COST0061
C LFM2 = LIFETIME OF BRACKISH MEMBRANES, YEARS COST0062
C REFTC = REFERENCE COST OF POWER RECOVERY TURBINE, $ COST0063
C REFGC = REFERENCE COST OF GOVERNOR FOR POWER RECOVERY TURBINE, $ COST0064
C XC(49) = COST OF ACID, $/TON COST0065
C XC(50) = COST OF CHLORINE TREATMENT, $OLB. SEAWATER COST0066
C XC(54) = UNIT POWER COST, $/KWHR COST0067
C XC(58) = MAINTENANCE COST, FRACTION OF CAPITAL COST0068
C XC(61) = INSURANCE AND TAXES COST0069
C XC(62) = UNUSUAL CONSTRUCTION COST, + CONTINGENCY COST0070
C STRC = REFERENCE ANNUAL STAFF COST, FOR 1 MGD PLANT COST0071
C CIAOR=REFERENCE COST OF 2 MGD SEAWATER SUPPLY AND OUTFALL SYSTEM, COST0072
C CPRTR = REFERENCE COST OF .75 MGD SEAWATER PRETREATMENT SYSTEM (NOT ICOST0073
C ACID INJECTION SYSTEM) COST0074
C CADRC = REFERENCE COST OF ACID INJECTION SYSTEM (1315 TON/DAY),-$ COST0075
C TNACDY = DAILY ACID CONSUMPTION, TONS. COST0076
C RDCRBC= REFERENCE DECARBONATOR COST, $ COST0077
C RCHDSC= REFERENCE CHEMICAL PACIFICATION SYSTEM COSR, $ COST0078
C CHPOST=UNIT COST OF CHEMICALS FOR PACIFICATION, CENTS/KILOGALLON COST0079
C CPPG=COST OF GENERAL PLANT PIPING FOR PLANT WITH 2 MGD SEAWATER INTACOST0080
C PPMA = PPM OF ACID ADDITION (100 PERCENT H2SO4) COST0081
C COST0082
C UNIT COST OF PUMPS, $/GPM COST0083
C UCPUMP(G,H)=44.7*(1.-.8696*DEXP(-.01018D0*H))/G**0.15 COST0084
C COST0085
C CALL PRICES(PROC) COST0086
C DO 10 I=1,300 COST0087
10 XC(I)=XC(I)*FC(I) COST0088
C RTEIN=XC(60) COST0089
C SWMODC=XC(80) COST0090
C BWMODC=XC(81) COST0091
C HPRC=XC(82) COST0092
C UNMC=XC(83) COST0093
C CPHOP=XC(84) COST0094
C CPSTOP=XC(85) COST0095
C CPBTOP=XC(86) COST0096
C CRICPT=XC(87) COST0097
C CELBC=XC(88) COST0098
C UEPKW=XC(89) COST0099
C CSREF=XC(90) COST0100
C BSQFTC=XC(91) COST0101
C CIAOR=XC(92) COST0102
C PPMA=XT(168) COST0103
C CPRTR=XC(93) COST0104
C CADRC=XC(94) COST0105
C RMOD1C=XC(95) COST0106
C RMOD2C=XC(96) COST0107
C STRC=XC(97) COST0108
C UCHEM=XC(98) COST0109
C REFTC=XC(99) COST0110
C REFGC=XC(100) COST0111
C RDCRBC=XC(101) COST0112
C RCHDSC=XC(102) COST0113
C CHPOST=XC(103) COST0114
C CPPG=XC(104) COST0115
C WPL=XO(33) COST0116
C YEAR=XO(79) COST0117
C LF2=XO(38) COST0118
C SBPS1=3.00 COST0119
C IF(TRAIN1.LT.11.00) SBPS1=2.00 COST0120
C IF(TRAIN1.LT.6.000) SBPS1=1.00 COST0121
C SBPS2=3.00 COST0122
C IF(TRAIN2.LT.11.00) SBPS2=2.00 COST0123

```

C	IF (TRAIN2.LT.6.000) SBPS2=1.00	COST0124
C	COST OF MEMBRANES AND HOUSING	COST0125
20	CSWM=SWMODC*PRODN1	COST0126
	CBWM=BWMDOC*PRODN2	COST0127
	IF (STAGES.LT.2.) MOD2=0	COST0128
	TMODC=MOD1*CSWM+MOD2*CBWM	COST0129
C	PUMP AND DRIVER COSTS	COST0130
C	FIRST STAGE HIGH PRESSURE PUMP	COST0131
	CSWHP = HPRC*(694.4*WFEED1/TRAIN1*PRES1/.506)**0.522	COST0132
	TCSWHP=(TRAIN1+SBPS1)*CSWHP	COST0133
C	SECOND STAGE HIGH PRESSURE PUMP	COST0134
	CBWHP=HPRC*(694.4*PMGD1*BLR*PRES2/REC2/TRAIN2/.506)**0.522	COST0135
	TCBWHP=0.00	COST0136
	IF (MOD2.GT.0) TCBWHP=(TRAIN2+SBPS2)*CBWHP	COST0137
	GPMSW = 694.4*WFEED/2.	COST0138
C	SEAWATER DELIVERY PUMP AND MOTOR COST, \$	COST0139
30	CSWDP=3.*UCPUMP(GPMSW,SWHEAD)*GPMSW+UNMC*SPUMP*1.5	COST0140
	GPMPW=694.4*PMGD/2.	COST0141
C	PRODUCT DELIVERY PUMP AND MOTOR COST, \$	COST0142
	CPDP=3.*UCPUMP(GPMPW,PRODH)*GPMPW+UNMC*PPUMP*1.5	COST0143
C	TOTAL PUMP AND DRIVER COST	COST0144
	TOTPC=TCSWHP+TCBWHP+CSWDP+CPDP	COST0145
	CPRCT=0.	COST0146
	IF (EFFICT.EQ.0.) GO TO 40	COST0147
	CPRCT=REFTC*(PRECOV/(2.3*(PRES1M-DELP1))**0.5)**0.398+	COST0148
	1 REFGC*(PRECOV/1000.0)**0.3	COST0149
C	PIPING COST	COST0150
40	CPIPE=CPMOP*(MOD1+MOD2)+CPSTOP*TRAIN1+CPBTOP*TRAIN2	COST0151
	1 +CPPG*(PMGD/(REC1*2.0))**0.7	COST0152
C	INSTRUMENTATION COST	COST0153
	CINST=CRICPT* (PMGD/TRAIN1/.5)**.2*TRAIN1+(PMGD*BLR/TRAIN2/.5)**.2	COST0154
	1 *TRAIN2	COST0155
C	ELECTRICAL EQUIPMENT COST	COST0156
	CELEQ=CELCB+UEPKW*(TOTKW+.746*PRECOV)	COST0157
C	SITE AND BUILDING COST	COST0158
	CSAB=CSREF*PMGD**0.35+BAREA*PMGD*BSQFTC	COST0159
C	SEAWATER INTAKE AND OUTFALL	COST0160
50	CSWIO=CIADR*(PMGD/REC1/2.0)**0.8	COST0161
C	PRETREATMENT COST	COST0162
	TNACDY=.4180-2*PPMA*PMGD/REC1	COST0163
	CPRT=CPRT*(PMGD/REC1/.75)**0.7+CADRC*(TNACDY/13.15)**0.3	COST0164
C	POST-TREATMENT SYSTEM COST	COST0165
	OPOSTC=ROCRBC*(694.4*PMGD/4.203)**0.7+RCHDSC*(694.4*PMGD/1735.0)**0.3	COST0166
	1.3	COST0167
C	TOTAL CAPITAL COST	COST0168
	TOTCAP=TMODC+TOTPC+CPRCT+CPIPE+CINST+CELEQ+CSAB+CSWIO+CPRT	COST0169
	1+OPOSTC	COST0170
C	REPLACABLE MEMBRANE COST	COST0171
	REPMC=RMODC*MOD1*PRODN1+RMOD2C*MOD2*PRODN2	COST0172
C	DEPRECIABLE CAPITAL COST	COST0173
	DEPCAP=TOTCAP-REPMC	COST0174
C	DIRECT CAPITAL COST, MILLIONS OF \$	COST0175
60	CD=1.0-6*TOTCAP	COST0176
	CALL FNANCE(CD,ASJ,SSMAP,PSAJ,RTEIN,AJBR,WPL,YEAR)	COST0177
C	DIRECT AND INDIRECT CAPITAL, \$	COST0178
	CAP11=CD*1.06*ASJ	COST0179
C	SPECIFIC INVESTMENT, \$/GPC	COST0180
	CAP12=CAP11/(PMGD*1.06)	COST0181
C	CALCULATE COST OF COMPONENTS, \$/YEAR	COST0182
	TMODC2=(TMODC-REPMC)*PSAJ+REPMC*RTEIN*ASJ	COST0183
70	TOTPC2=TOTPC*PSAJ	COST0184
	CPIPE2=CPIPE*PSAJ	COST0185
	CINST2=CINST*PSAJ	COST0186
	CELEQ2=CELEQ*PSAJ	COST0187
	CPRCT2=CPRCT*PSAJ	COST0188
	CSAB2=CSAB*PSAJ	COST0189
	CSWIO2=CSWIO*PSAJ	COST0190
		COST0191

```

CPRT2=CPRT*PSAJ
OPOST2=OPOSTC*PSAJ
C  CALCULATE COST OF COMPONENTS,CENTS/KILOGALLON
80 CFG=.365*LF2*PMGD*1.D4
TMODC1=TMODC2/CFG
TOTPC1=TOTPC2/CFG
CPIPE1=CPIPE2/CFG
CINST1=CINST2/CFG
CELEQ1=CELEQ2/CFG
CPRCT1=CPRCT2/CFG
CSAB1=CSAB2/CFG
CSWIO1=CSWIO2/CFG
CPRT1=CPRT2/CFG
OPOST1=OPOST2/CFG
C  COST OF CAPITAL ITEMS, CENTS/KILOGALLON
90 CAPI3=TMODC1+TOTPC1+CPIPE1+CINST1+CELEQ1+CSAB1+CSWIO1+CPRT1
1+CPRCT1+OPOST1
C  COST OF CAPITAL ITEMS, $/YR
CAPI4=CAPI3*CFG
C  OPERATING COST, $/YR
ACID=365.*LF2*TNACDY*XC(49)
WOCEAN=PMGD/REC1*3.505
CLORIN=8760.*WOCEAN*LF2*XC(50)
C  OTHER PRETREATMENT MATERIALS
100 OTCHEM= UCHEM*PMGD/REC1*LF2*.365D6
TCHEM=ACID+CLORIN+OTCHEM+CHPOST*CFG
C  MEMBRANE REPLACEMENT COST
DEPM1=RTEIN/((1.+RTEIN)**LFM1-1.)
DEPM2=RTEIN/((1.+RTEIN)**LFM2-1.)
REPLC=RMOD1C*MOD1*PRODN1*DEPM1+RMOD2C*MOD2*PRODN2*DEPM2
C  POWER COST
POCST2=8760.*LF2*TOTKWA*XC(54)
C  STAFF COST
110 OC2=STRC*(PMGD)**0.5
C  MAINTENANCE COST
AMSC2=XC(58)*CAPI1
C  OPERATING COSTS, CENTS/KILOGALLON
TCHEM1=TCHEM/CFG
REPLC1=REPLC/CFG
POCST1=POCST2/CFG
OC1=OC2/CFG
AMSC1=AMSC2/CFG
C  COST OF PRODUCT WATER, CENTS/KILOGALLON
120 TC1=CAPI3+TCHEM1+REPLC1+POCST1+OC1+AMSC1
ATC1=TC1
C  COST OF PRODUCT WATER
TC2=TC1*CFG
TOC1=TCHEM1+POCST1+OC1+AMSC1
TOC2=TCHEM+POCST2+OC2+AMSC2
RETURN
END
SUBROUTINE RITERO(IOPT,IOUT,L)
IMPLICIT REAL*8(A-H,O-Z)
REAL*8 LFM1,LFM2,LF2,LEV
COMMON/DEBUG/SFEED1
COMMON/RO2/PROD1,PRUD2,AFDF1,AFDF2
COMMON/RO3/PSAJ,CFG
COMMON/RO/MSTYPE,MATYPE,STAGES,PRES1,PRES2,PRODS,
1 REJN1,REJN2,PRODN1,PRODN2,PMGD,SFEED,REC1,REC2,EFFIC1,EFFIC2,
2 EFFIC3,EFFIC1,TRAIN1,TRAIN2,BAREA,DELP1N,TEMP1,SWHEAD,PRODH,SOPR
3,WPROD1,SPROD1,WPROD2,SPROD2,BLR,PMGD1,NMOD2,MOD2,NMOD1,MOD1,
4 WFEED1,WFEED,TPUMP1,PUMP1,TPUMP2,PUMP2,SPUMP,PPUMP,POTHER,
5 DELP1,PRECOV,TOTKW,REJ1,REJ2
6 ,FM1,FM2,PRESOP,PRES1M,PRES2M,TOTKWA
COMMON/AJAX/PRBP1,PRBP2,RFN1,RFN2,CRF1,CRF2,TEOP,ARFN1,ARFN2,
1 AVOP1,AVOP2,OSM1,OSM2,NSPOSW
COMMON/RO1/DMOD1,DMOD2,SHEL1L,SHEL2L,SMOD1,SMOD2,PRES1N,PRES2N,
* REC1N,REC2N,LFM1,LFM2,TEMPN1,TEMPN2,FNPPM1,FNPPM2,DSHEL1,DSHEL2
*,NMOD1S,NMOD2S
COMMON/BLOCN3/ EA, ES, CC1, CC2, EA1,RITE0019

```

```

1      EA2,      EEC,      HC1,      HC2,      OC1,      OC2,RITE0020
2      PMC,      TC2,      VPC,      BHC1,      BHC2,      CIBC,RITE0021
3      DEA1,      DEA2,      EEC1,      EEC2,      PNC1,      PMC2,RITE0022
4      SITE,      SMAP,      VPC1,      VPC2,      WAIT,      AMSC1,RITE0023
5      AMSC2,      CAPI2,      CAPI3,      CAPI4,      CIBC1,      CIBC2,RITE0024
6      SITE1,      SITE2,      WAIT1,      WAIT2,      CHMPTC,      CHMPT1,RITE0025
7      CHMPT2,      CINSTC,      CINST1,      CINST2,      DEACST,      POCST1,RITE0026
8      POCST2,      RATEIN,      RETUB1,      RETUB2,      SMAPPH,      SMAPPP,RITE0027
9      CD,      BHC,      ES1,      ES2,      RITE0028
COMMON/COMMON/      AJ,      CB,      CO,      CP,      CR,      RITE0029
1      HB,      PI,      PO,      TB,      TO,      TP,      RITE0030
2      TS,      WB,      WF,      WO,      WP,      WR,      RITE0031
3      AXJ,      HBL,      HPR,      LEV,      LF2,      TCF,      RITE0032
4      ENBH,      GPMB,      GPMO,      GPMH,      GPMO,      GPMP,      RITE0033
5      GPMR,      HDEA,      RPMB,      RPMO,      RPMH,      RPMP,      RITE0034
6      RPMR,      TSTH,      WHOT,      YEAR,      ACRES,      BHVOL,      RITE0035
7      BLDGS,      BNDLS,      HOLES,      HPBLD,      HPDEA,      HPDEL,      RITE0036
8      HPPRD,      HPREC,      PLPKD,      PLSEA,      PODEA,      ACNCEW,      RITE0037
9      ACNCFL,      ACNCIN,      ACNCPH,      ACNCRF,      ACNCTR,      AEXCAV,      RITE0038
+      ASTLEW,      ASTLFL,      ASTLIN,      ASTLPH,      ASTLRF,      ASTLTR,      RITE0039
A      AWEIRS,      BHSURF,      DINTAK,      ENITSE,      ENPIPE,      ENSUPE,      RITE0040
B      ENSUPR,      PIPELN,      PLSZMG,      REJLEN,      STLLEN,      STLTMP,      RITE0041
C      TNACDY,      TRAINS,      TSAREA,      VOLCNC,      VOLSTL,      WOCEAN,      RITE0042
COMMON/BLOC12/XT(300)      RITE0043
COMMON/ BLOC13/XO(300)      RITE0044
COMMON/BLOC14/XC(300)      RITE0045
COMMON/NAME/ ANAME(10), AMONTH, IDAY, IYEAR      RITE0046
C      DIMENSION ROTYPE(6),POWREV(2)      RITE0047
C      DATA POWREV/'YES      NO      '/      RITE0048
DATA ROTYPE/'POLYAMID - HOLLOW FIBER COMPOSITE - SPIRAL WOUND' /      RITE0049
L=6      RITE0050
NPAGE = 1      RITE0051
WRITE(L,8060) NPAGE      RITE0052
8000 FORMAT(1H ,10A8)      RITE0053
WRITE(L,8010) AMONTH      RITE0054
8010 FORMAT(1H ,A8,I3,',',',15)      RITE0055
FF=PMGD      RITE0056
EFF=XQ(32)      RITE0057
AJ=BHC      RITE0058
CAPI1=DEA1      RITE0059
CCC = CAPI1 *1.0-6      RITE0060
POTHER=CCC      RITE0061
TC1=DEA2      RITE0062
TOC1=BHC1      RITE0063
CPRCT=SMAPPP      RITE0064
COMM=1.06*CD      RITE0065
CPRCT2=CPRCT*PSAJ      RITE0066
CPRCT1=CPRCT2/CFG      RITE0067
OPCSTC=SMAPPH      RITE0068
OPOST2=OPOSTC*PSAJ      RITE0069
OPOST1=OPOST2/CFG      RITE0070
TOC2=BHC2      RITE0071
UFC=100.00*XC(54)      RITE0072
WPL=XQ(33)      RITE0073
WRITE(L,8020) (ANAME(KK),KK=1,10),FF,TC1,CCC      RITE0074
8020 FORMAT(//////////1H ,10A8////1H ,'      PLARITE0075
INT CAPACITY - MGD',F29.3/1H0,'UNIT COST OF DESALTED WATER - CENTS      RITE0076
2PER KILOGALLON',F19.3/1H0,'CAPITAL COST OF PLANT(DIRECT+INDIRECT)-      RITE0077
3 MILLIONS OF DOLLARS',F10.3)      RITE0078
8030 FORMAT(1H0,/1H0,'THE PLANT HAS NOT BEEN OPTIMIZED')      RITE0079
8040 FORMAT(1H0,/1H0,'THE PLANT HAS BEEN OPTIMIZED')      RITE0080
N=1      RITE0081
IF(EFFICT.EQ.0.00) N=2      RITE0082
WRITE(L,8050)POWREV(N)      RITE0083
8050 FORMAT (' POWER RECOVERY -',A4)      RITE0084
IF(IOPT .EQ. 0) WRITE(L,8030)      RITE0085
IF(IOPT .NE. 0) WRITE(L,8040)      RITE0086
C      RITE0087
RITE0088
RITE0089

```

C	IF(10UT.EQ. 0) GO TO 20	RITE0090
	NPAGE = 2	RITE0091
	WRITE(L,8060) NPAGE	RITE0092
	WRITE(L,8010) AMONTH	RITE0093
8060	FORMAT('1REVERSE OSMOSIS SEAWATER DESALTING PLANT - ROUTINE R075	RITE0094
	1PAGE',12)	RITE0095
	WRITE(L,8070)	RITE0096
8070	FORMAT(1H0,31X,17HCOST SUMMARY PAGE)	RITE0097
	WRITE(L,8080)	RITE0098
8080	FORMAT(1H0,18HCAPITAL COMPONENTS ,8X,9HCOST-\$/YR,7X,11HCOST-C/K	RITE0099
	1GAL,5X,12HCOST-\$DIRECT)	RITE0100
	WRITE(L,8090)	RITE0101
8090	FORMAT(1H ,18H----- 8X,9H-----,7X,11H-----	RITE0102
	1---,5X,12H-----)	RITE0103
	WRITE(L,8100) EA2,EA1,EA	RITE0104
8100	FORMAT(1H0,20HMODULES AND HOUSING F15.2,F16.4,F19.2)	RITE0105
	WRITE(L,8110) PMC2,PMC1,PMC	RITE0106
8110	FORMAT(1H ,20HPUMPS AND MOTORS ,F15.2,F16.4,F19.2)	RITE0107
	WRITE(L,8120) VPC2,VPC1,VPC	RITE0108
8120	FORMAT(1H ,20HVALVES AND PIPING ,F15.2,F16.4,F19.2)	RITE0109
	WRITE(L,8130) CINST2,CINST1,CINSTC	RITE0110
8130	FORMAT(1H ,20HINSTRUMENTS ,F15.2,F16.4,F19.2)	RITE0111
	WRITE(L,8140) EEC2,EEC1,EEC	RITE0112
8140	FORMAT(1H ,20HELECTRICAL ,F15.2,F16.4,F19.2)	RITE0113
	WRITE(L,8150) CHMPT2,CHMPT1,CHMPTC	RITE0114
8150	FORMAT(1H ,20HPRETREATMENT SYSTEM F15.2,,F16.4,F19.2)	RITE0115
	WRITE(L,8160) OPOST2,OPOST1,OPOSTC	RITE0116
8160	FORMAT(21H POSTTREATMENT SYSTEM,F15.2,F16.4,F19.2)	RITE0117
	WRITE(L,8170) WAIT2,WAIT1,WAIT	RITE0118
8170	FORMAT(1H ,20HSEA-WATER INTAKE ,F15.2,F16.4,F19.2)	RITE0119
	WRITE(L,8180) SITE2,SITE1,SITE	RITE0120
8180	FORMAT(1H ,20HSITE, BLDGS, CRANES ,F15.2,F16.4,F19.2)	RITE0121
	WRITE(L,8190) CPRCT2,CPRCT1,CPRCT	RITE0122
8190	FORMAT(21H POWER RECOV. TURBINE,F15.2,F16.4,F19.2)	RITE0123
	WRITE(L,8200) CAPI4,CAPI3,CDMM	RITE0124
8200	FORMAT(1H0,20H TOTAL CAPITAL ,F15.2,F16.4,F19.2)	RITE0125
	WRITE(L,8210)	RITE0126
8210	FORMAT(1H0,20HTOTAL INVESTMENT,)	RITE0127
	WRITE(L,8220) CAPI1	RITE0128
8220	FORMAT(1H ,20H \$DIR+IND ,31X,F19.2)	RITE0129
	WRITE(L,8230)	RITE0130
8230	FORMAT(1H ,20HSPECIFIC INVESTMENT,)	RITE0131
	WRITE(L,8240) CAPI2	RITE0132
8240	FORMAT(1H ,20H \$/GPD ,31X,F16.5)	RITE0133
	WRITE(L,8250) RETUB2, RETUB1	RITE0134
8250	FORMAT(1H0,20HMEMBRANE REPLACEMENT,F15.2,F16.4)	RITE0135
	WRITE(L,8260)	RITE0136
8260	FORMAT(1H0,20HOPERATING COMPONENTS)	RITE0137
	WRITE(L,8270)	RITE0138
8270	FORMAT(1H ,20H-----)	RITE0139
	WRITE(L,8280) POCST2,POCST1	RITE0140
8280	FORMAT(1H ,20HPOWER ,F15.2,F16.4)	RITE0141
	WRITE(L,8290) CC2,CC1	RITE0142
8290	FORMAT(1H ,20HCHEMICALS ,F15.2,F16.4)	RITE0143
	WRITE(L,8300) OC2, OC1	RITE0144
8300	FORMAT(1H ,20HOPERATING ,F15.2,F16.4)	RITE0145
	WRITE(L,8310) AMSC2, AMSC1	RITE0146
8310	FORMAT(1H ,20HMAINT. + SUPPLIES ,F15.2,F16.4)	RITE0147
	WRITE(L,8320) TOC2, TOC1	RITE0148
8320	FORMAT(1H0,20H TOTAL OPERATING ,F15.2,F16.4)	RITE0149
	WRITE(L,8330) TC2, TC1	RITE0150
8330	FORMAT(1H0,20HTOTAL(CAP+RETUB+QP) ,F15.2,F16.4)	RITE0151
	WRITE(L,8340)	RITE0152
8340	FORMAT(1H0,20HCOST FACTORS)	RITE0153
	WRITE(L,8350) UFC	RITE0154
8350	FORMAT(1H0,20HCOST OF POWER,C/KWHR , F15.6)	RITE0155
	WRITE(L,8360) SNAP	RITE0156
8360	FORMAT(1H ,20HANNUAL CHARGE RATE , F15.6)	RITE0157
	WRITE(L,8370) RATEIN	RITE0158
		RITE0159

8370	FORMAT(1H ,20HINTEREST RATE	, F15.6)	RITE0160
	WRITE(L,8380) AJ		RITE0161
8380	FORMAT(1H ,20HHIGHER COST FACTOR	, F15.6)	RITE0162
	WRITE(L,8390) LF2		RITE0163
8390	FORMAT(1H ,20HPLANT LOAD FACTOR	, F15.6)	RITE0164
	WRITE(L,8400) WPL		RITE0165
8400	FORMAT(1H ,20HPLANT LIFE,YEARS	, F15.6)	RITE0166
	WRITE(L,8410)EFFIC1,EFFIC2,EFFIC3,EFFIC4		RITE0167
8410	FORMAT(1H0,9X,'PUMP AND MOTOR EFFICIENCY'/		RITE0168
	1 13X,'HIGH PRESSURE PUMP - 1ST STAGE',T53,F12.3/		RITE0169
	2 13X,'HIGH PRESSURE PUMP - 2ND STAGE',T53,F12.3/		RITE0170
	3 13X,'OTHER PUMPS',T53,F12.3/		RITE0171
	4 13X,'POWER RECOVERY TURBINE',T53,F12.3)		RITE0172
	WRITE(L,8420)LFM1,LFM2		RITE0173
8420	FORMAT(1H ,9X,'MEMBRANE LIFETIME, YEARS'/		RITE0174
	1 13X,'FIRST STAGE',T53,F12.2/		RITE0175
	2 13X,'SECOND STAGE',T53,F12.2)		RITE0176
	WRITE(L,8430)FM1,FM2		RITE0177
8430	FORMAT(1H ,9X,'LOG FLUX DECLINE RATE'/		RITE0178
	113X,'FIRST STAGE M FACTOR',T53,F12.4/		RITE0179
	113X,'SECOND STAGE M FACTOR',T53,F12.4)		RITE0180
	WRITE(L,8440)XC(95),XC(96)		RITE0181
8440	FORMAT(1H ,9X,'MEMBRANE REPLACEMENT COST, \$/GPD'/		RITE0182
	1 13X,'FIRST STAGE',T53,F12.2/		RITE0183
	1 13X,'SECOND STAGE',T53,F12.2)		RITE0184
C			RITE0185
	NPAGE = 3		RITE0186
	REC=PMGD/WFEED		RITE0187
	TOTAR=PMGD*BAREA		RITE0188
	IF(STAGES.LE.1.00)TRAIN2=0.00		RITE0189
	IF(MOD2.EQ.0)TRAIN2=0.00		RITE0190
	TRAINT=TRAIN1+TRAIN2		RITE0191
	MODT=MOD1+MOD2		RITE0192
	GPMH1=694.4*WFEED1		RITE0193
	FTHDH1=2.3*PRES1M		RITE0194
	PHTKW1=.746*TPUMP1		RITE0195
	GPMH2=694.4*PMGD*BLR/REC2		RITE0196
	FTHDH2=2.3*PRES2M		RITE0197
	PHTKW2=.746*TPUMP2		RITE0198
	GPMSW=694.4*WFEED		RITE0199
	FTHDSW=2.3*SWHEAD		RITE0200
	PSKW=.746*SPUMP		RITE0201
	GPMP=694.4*PMGD		RITE0202
	FTHDP=2.3*PRODH		RITE0203
	PPKW=.746*PPUMP		RITE0204
	WRITE(L,8060) NPAGE		RITE0205
	WRITE(L,8010) AMONTH		RITE0206
	WRITE(L,8450) (ANAME(KK),KK=1,10)		RITE0207
8450	FORMAT(1H0,10A8)		RITE0208
	WRITE(L,8460)		RITE0209
8460	FORMAT(1H ,27H I SUMMARY OF PLANT DATA)		RITE0210
	WRITE(L,8470)		RITE0211
8470	FORMAT(1H0,14H GENERAL)		RITE0212
	WRITE(L,8480) PMGD		RITE0213
8480	FORMAT(1H ,35H PLANT CAPACITY, MGD	,F16.2)	RITE0214
	WRITE(L,8490) SFEED		RITE0215
8490	FORMAT(1H ,36H SEA WATER CONCENTRATION,PPM,F15.2)		RITE0216
	WRITE(L,8500) PRODS		RITE0217
8500	FORMAT(1H ,35H PRODUCT CONCENTRATION, PPM ,F16.2)		RITE0218
	WRITE(L,8510) REC		RITE0219
8510	FORMAT(1H ,35H PRODUCT RECOVERY	,F16.2)	RITE0220
	WRITE(L,8520) STAGES		RITE0221
8520	FORMAT(1H ,35H NO OF STAGES	,F16.2)	RITE0222
	WRITE(L,8530) YEAR		RITE0223
8530	FORMAT(1H ,35H YEAR CONSTRUCTION STARTED	,F16.2)	RITE0224
	WRITE(L,8540) XO(40)		RITE0225
8540	FORMAT(1H ,35H OCEAN TEMPERATURE, F	,F16.2)	RITE0226
	WRITE(L,8550)		RITE0227
8550	FORMAT(1H0,34H II DESCRIPTION OF PHYSICAL PLANT ,10X,	*TOTAL	RITE0228
	* STAGE 1 STAGE 2')		RITE0229

```

      WRITE(L,8560) TOTAR
8560 FORMAT(1H,35H          TOTAL PLANT AREA,SQ FT      ,T38,F12.0)  RITE0230
      WRITE(L,8570) TRAI NT,TRAIN1,TRAIN2                RITE0231
8570 FORMAT(1H,35H          NO OF TRAINS                ,T38,3F12.0)  RITE0232
      WRITE(L,8580) MODT,MOD1,MOD2                        RITE0233
8580 FORMAT(1H,35H          NO OF MODULES               ,T38,3I12)  RITE0234
      ZIPPQ=0.00                                           RITE0235
      ZIP=0.00                                             RITE0236
      WRITE(L,8590)                                        RITE0237
8590 FORMAT(1H0,'III MEMBRANE PARAMETERS')              RITE0238
      KKK=3*((MSTYPE+1)/2)                                RITE0239
      KK=KKK-2                                             RITE0240
      WRITE(L,8600)(ROTYPE(J),J=KK,KKK)                 RITE0241
8600 FORMAT(10X,'MEMBRANE TYPE',T53,3A8)                RITE0242
      WRITE(L,8610) DMOD1,DMOD2                          RITE0243
8610 FORMAT(10X,'MODULE OUTSIDE DIAM., IN.              ',T53,2F12.2) RITE0244
      WRITE(L,8620)DSHEL1,OSHEL2,SHEL1L,SHEL2L           RITE0245
8620 FORMAT(10X,'SHELL DIMENSIONS'/                     RITE0246
      1 13X,'OUTSIDE DIAM., IN.',T53,2F12.2/            RITE0247
      2 13X,'LENGTH, IN.' T53,2F12.2)                  RITE0248
      IF(MSTYPE.GT.2)WRITE(L,8630)CRF1,CRF2              RITE0249
8630 FORMAT(1H+,80X,'CONCENTRATION POLARIZATION FACTOR ', RITE0250
      1 F5.2,F6.2)                                         RITE0251
      WRITE(L,8640)NMOD1S,NMOD2S                         RITE0252
8640 FORMAT(10X,'NO. OF MODULES IN SHELL',T53,2I12)     RITE0253
      IF(MSTYPE.GT.2) WRITE(6,8650) RFN1,RFN2            RITE0254
8650 FORMAT(1H+,80X,'REFERENCE NET EFFECTIVE PRESSURE, PSI ', RITE0255
      1F5.1,F6.1)                                         RITE0256
      WRITE(L,8660) SMOD1,SMOD2                          RITE0257
8660 FORMAT(10X,'MEMBRANE SURFACE, SQ.FT.              ',T53,2F12.2) RITE0258
      IF(MSTYPE.GT.2) WRITE(L,8670)PRBP1,PRBP2           RITE0259
8670 FORMAT(1H+,80X,'PRODUCT BACK PRESSURE ON MEMBRANE, PSI ', RITE0260
      1 F5.1,F6.1)                                         RITE0261
      WRITE(L,8680) PRES1N,PRES2N                        RITE0262
8680 FORMAT(10X,'NOMINAL OPERATING PRESSURE, PSI',T53,2F12.1) RITE0263
      WRITE(L,8690) REC1N,REC2N                          RITE0264
8690 FORMAT(10X,'NOMINAL PRODUCT RECOVERY',T53,2F12.4)  RITE0265
      WRITE(L,8700) REJN1,REJN2                          RITE0266
8700 FORMAT(10X,'NOMINAL REJECTION RATE                ',T53,2F12.4) RITE0267
      WRITE(L,8710)PRODN1,PRODN2,FNPPM1,FNPPM2,TEMPN1,TEMPN2 RITE0268
8710 FORMAT(10X,'INITIAL PRODUCTIVITY, GPD/MODULE',T53,2F12.2/ RITE0269
      1 10X,'REFERENCE FEED CONCENTRATION, PPM' ,T53,2F12.2/    RITE0270
      2 10X,'REFERENCE FEED TEMPERATURE, F' ,T53,2F12.2)       RITE0271
      WRITE(L,8720) LFM1,LFM2                            RITE0272
8720 FORMAT(1H,9X,20HMEMBRANE LIFE,YEARS,T53,2F12.2)   RITE0273
      WRITE(L,8730)                                       RITE0274
8730 FORMAT('UIV ACTUAL OPERATING PARAMETERS')          RITE0275
      IF(PRESP. LE.1.00)                                  RITE0276
      1WRITE(L,8740)PRES1,PRES2                          RITE0277
8740 FORMAT(10X,'MODULE INLET PRESSURE, PSI',T53,2F12.2) RITE0278
      IF(PRESP.GT.1.00) WRITE(L,8750)PRES1,PRES2,PRES1M,PRES2M,PRES1A,PRES2A RITE0279
8750 FORMAT(10X,'MODULE INLET PRESSURE, PSI'/            RITE0280
      1 13X,'INITIAL',T53,2F12.2/                        RITE0281
      2 13X,'END OF LIFETIME',T53,2F12.2/               RITE0282
      3 13X,'WEIGHTED AVERAGE',T53,2F12.2)             RITE0283
      WRITE(L,8760) REC1,REC2                             RITE0284
8760 FORMAT(10X,'PRODUCT RECOVERY',T53,2F12.4)          RITE0285
      IF(BLR.GT.0.00) GO TO 10                           RITE0286
      REJ2=1.00                                           RITE0287
      SPROD2=0.00                                         RITE0288
      WPROD2=0.00                                         RITE0289
10 CONTINUE                                              RITE0290
      PRT1=1.00-REJ1                                     RITE0291
      PRT2=1.00-REJ2                                     RITE0292
      WRITE(L,8770)PRT1,PRT2                             RITE0293
8770 FORMAT(10X,'SALT PASSAGE',T53,2F12.4)              RITE0294
      IF(STAGES.GT.1.00) WRITE(L,8780) SFEED1           RITE0295

```

```

0780 FORMAT(10X,'FIRST STAGE FEED CONCENTRATION,PPM',T54,F11.0)      RITE0298
      IF(PRESOP.GT.1.00) WRITE(L,8790)WPROD1,WPROD2                  RITE0299
0790 FORMAT(10X,'MODULE PRODUCTIVITY, GPD',T53,2F12.2)              RITE0300
      PRT1=WPROD1/AFDF1                                              RITE0301
      PRT2=WPROD2/AFDF2                                              RITE0302
      PRT3=WPROD1*(1.00+FM1)                                         RITE0303
      PRT4=WPROD2*(1.00+FM2)                                         RITE0304
      IF(PRESOP.LE.1.00) WRITE(L,8800)PRT1,PRT2,PRT3,PRT4,WPROD1,WPROD2 RITE0305
0800 FORMAT(10X,'MODULE PRODUCTIVITY, GPD'/                          RITE0306
      1 13X,'INITIAL',T53,2F12.2/                                     RITE0307
      2 13X,'END OF LIFETIME',T53,2F12.2/                           RITE0308
      3 13X,'WEIGHTED AVERAGE',T53,F12.2,F12.2)                   RITE0309
      PRT1=PMGD*BLR                                                  RITE0310
      WRITE(L,8810)PMGD1,PRT1                                         RITE0311
0810 FORMAT(10X,'TOTAL STAGE PRODUCTION, MGD',T53,2F12.4)          RITE0312
      IF(MSTYPE.GT.2)WRITE(L,8820)OSM1,OSM2                         RITE0313
0820 FORMAT(1H+,80X,'AVERAGE OSMOTIC PRESSURE, PSI',               RITE0314
      IF6.1,F6.1)                                                    RITE0315
      WRITE(L,8830)SPROD1,SPRGD2                                     RITE0316
0830 FORMAT(10X,'STAGE PRODUCT QUALITY, PPM',T53,2F12.2)          RITE0317
      IF(MSTYPE.GT.2) WRITE(L,8840)AVOP1,AVOP2                     RITE0318
0840 FORMAT(1H+,80X,'AVG OSMOTIC PRESSURE AT MEMBRANE SURFACE',    RITE0319
      IF5.1,F6.1)                                                    RITE0320
      WRITE(L,8850)REJ1,REJ2                                         RITE0321
0850 FORMAT(10X,'MODULE REJECTION RATE',T53,2F12.4)               RITE0322
      IF(MSTYPE.GT.2)WRITE(L,8860)ARFN1,ARFN2                     RITE0323
0860 FORMAT(1H+,80X,'ACTUAL AVG NET EFFECTIVE PRESSURE, PSI',      RITE0324
      IF5.1,F6.1)                                                    RITE0325
      WRITE(L,8870) BLR                                              RITE0326
0870 FORMAT(10X,'BLENDING RATIO, 2ND STAGE/TOTAL',T65,F12.4)     RITE0327
      WRITE(L,8880)                                                  RITE0328
0880 FORMAT(1H0,23H V PUMPING PARAMETERS )                        RITE0329
      WRITE(L,8890)                                                  RITE0330
0890 FORMAT(1H0, 38X,8HFLOW-GPM,8X,7HHEAD-FT, 8X,8HPOWER-KW)     RITE0331
      WRITE(L,8900) GPMH1,FTHDH1,PHTKW1                             RITE0332
0900 FORMAT(1H ,32H 1ST STAGE HIGH PRESSURE ,3F15.1)             RITE0333
      WRITE(L,8910) GPMH2,FTHDH2,PHTKW2                             RITE0334
0910 FORMAT(1H ,32H 2ND STAGE HIGH PRESSURE ,3F15.1)             RITE0335
      WRITE(L,8920) GPMSW,FTHDSW,PSKW                               RITE0336
0920 FORMAT(1H ,32H SEA-WATER DELIVERY ,3F15.1)                  RITE0337
      WRITE(L,8930) GPMP,FTHDP,PPKW                                 RITE0338
0930 FORMAT(1H ,32H PRODUCT ,3F15.1)                              RITE0339
      WRITE(L,8940) TOTKW                                           RITE0340
0940 FORMAT(1H0,32H TOTAL ,30X,F15.1)                             RITE0341
C                                                                    RITE0342
      PRT1=WFEED1*(1.00-REC1)*694.4                                RITE0343
      PRT2=(PRES1M-DELP1)*2.3                                       RITE0344
      PRT3=.746*PRECOV                                              RITE0345
      WRITE(L,8950)PRT1,PRT2,PRT3                                   RITE0346
0950 FORMAT(1H ,9X,'POWER RECOVERY TURBINE',T34,3F15.1)          RITE0347
      20 CONTINUE                                                  RITE0348
      RETURN                                                       RITE0349
      END                                                         RITE0350
      SUBROUTINE FNANCE(CD,ASJ,SSMAP,PSAJ,RTEIN,AJBR,WPL,YEAR)      FNAN0001
      IMPLICIT REAL*8(A-H,O-Z)                                     FNAN0002
      DIMENSION XC(500)                                           FNAN0003
      COMMON/BLOC14/ XC                                           FNAN0004
C                                                                    FNAN0005
C      OVERHEAD FOR DESIGN AND JOB SUPERVISION                   FNAN0006
C      AJSD = 'OAK RIDGE'                                         FNAN0007
C      ABSD = 'BURNS AND ROE'                                     FNAN0008
C      AJSD = 1.05+.17582*DEXP(-2.089D-2*CD) *XC(105)           FNAN0009
      ABSD = .4977*(AJSD-1.)*1.                                     FNAN0010
      AJSDCT = AJSD                                                FNAN0011
C      CONSTRUCTION TIME IN MONTHS                               FNAN0012
      TIME = 54.1*(1.-(.006*CD+1.1))*(-2.632))*XC(106)          FNAN0013
C      INTEREST RATE                                              FNAN0014
      RTEIN = XC(60)                                              FNAN0015
C      INTEREST DURING CONSTRUCTION                             FNAN0016
      AJIC = 1.+0.0399*TIME*RTEIN                                  FNAN0017

```


C	ESCALATION DURING CONSTRUCTION	FNAN0018
	AJESC=1.+0.0434*TIME*XC(56)	FNAN0019
C	UNUSUAL CONSTRUCTION EXPENSE AND CONTINGENCY	FNAN0020
	AJFOR = 1.00+XC(62)	FNAN0021
C	OWNERS COST (TRAINING AND STARTUP)	FNAN0022
	AJOWN = 1.019	FNAN0023
C	HIGHER COST FACTOR	FNAN0024
C	ASJ = 'OAK RIDGE'	FNAN0025
C	AJBR = 'BURNS AND ROE'	FNAN0026
C	ASJ = AJSDCT*AJIC*AJESC*AJFOR*AJOWN	FNAN0027
	AJBR = ABSD*AJIC*AJESC	FNAN0028
C		FNAN0029
C	ANNUAL CHARGE FACTOR ON TOTAL CAPITAL	FNAN0030
C	SSMAP = XC(61)+RTEIN/(1.-1./(1.+RTEIN))*MPL	FNAN0031
C		FNAN0032
C	ANNUAL CHARGE FACTOR ON DIRECT CAPITAL	FNAN0033
	PSAJ = SSMAP *ASJ	FNAN0034
C		FNAN0035
	RETURN	FNAN0036
	END	FNAN0037
	SUBROUTINE OTHPAR	FNAN0038
	IMPLICIT REAL*8(A-H,O-Z)	OTHP0001
	COMMON/BLOC13/XO(300)	OTHP0002
	XO(28)=60.	OTHP0003
	XO(31)=40.	OTHP0004
	XO(32)=-.82	OTHP0005
	XO(33)=30.00	OTHP0006
	XO(36)=35000.00	OTHP0007
	XO(37)=500.	OTHP0008
	XO(38)=-.8500	OTHP0009
	XO(40)=77.	OTHP0010
	XO(50)=2.	OTHP0011
	XO(51)=800.00	OTHP0012
	XO(52)=400.	OTHP0013
	XO(53)=-.7600	OTHP0014
	XO(54)=-.7600	OTHP0015
	XO(55)=-.65	OTHP0016
	XO(56)=2.	OTHP0017
	XO(57)=1.	OTHP0018
	XO(58)=20.	OTHP0019
	XO(59)=1.00	OTHP0020
	XO(79)=1976.00	OTHP0021
	RETURN	OTHP0022
	END	OTHP0023
	SUBROUTINE MAINM(A,B,C,D,E)	OTHP0024
	RETURN	MAIN0001
	END	MAIN0002
	SUBROUTINE C(TEXT, J)	MAIN0003
	COMMON/PARTXT/ XTTXT(14,230), XOTXT(14,230), XCTXT(14,230)	CAIN0001
	COMMON/SHARE/ IFLIP,ISPOT	CAIN0002
	DIMENSION TEXT(14)	CAIN0003
	IF(IFLIP .GT. 0) RETURN	CAIN0004
	DO 10 I=1,14	CAIN0005
10	XCTXT(I,J) = TEXT(I)	CAIN0006
	RETURN	CAIN0007
	END	CAIN0008
	SUBROUTINE O(TEXT, J)	CAIN0009
	COMMON/PARTXT/ XTTXT(14,230), XOTXT(14,230), XCTXT(14,230)	QAIN0001
	COMMON/SHARE/ IFLIP,ISPOT	QAIN0002
	DIMENSION TEXT(14)	QAIN0003
	IF(IFLIP .GT. 0) RETURN	QAIN0004
	DO 10 I=1,14	QAIN0005
10	XOTXT(I,J) = TEXT(I)	QAIN0006
	RETURN	QAIN0007
	END	QAIN0008
	SUBROUTINE T(TEXT, J)	QAIN0009
	COMMON/PARTXT/ XTTXT(14,230), XOTXT(14,230), XCTXT(14,230)	TAIN0001
	COMMON/SHARE/ IFLIP,ISPOT	TAIN0002
	DIMENSION TEXT(14)	TAIN0003
		TAIN0004

```

      IF(IFLIP.GT. 0) RETURN
      DO 10 I=1,14
10  XTTXT(I,J) = TEXT(I)
      RETURN
      END
      SUBROUTINE PRICES(PROC)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/BLOC14/XC(300)
      XC(49)=31.
      XC(50)=2.64D-7
      XC(54)=.02
      XC(56)=.08
      XC(58)=.007
      XC(60)=.100
      XC(61)=.01
      XC(62)=.15
      XC(80)=.7500
      XC(81)=0.2000
      XC(82)=50500.00
      XC(83)=25.00
      XC(84)=300.00
      XC(85)=5000.00
      XC(86)=5000.00
      XC(87)=47000.00
      XC(88)=25000.00
      XC(89)=70.00
      XC(90)=150000.00
      XC(91)=6.500
      XC(92)=150000.00
      XC(93)=176000.00
      XC(94)=80000.00
      XC(95)=.5500
      XC(96)=.1500
      XC(97)=113000.00
      XC(98)=.1000
      XC(99)=40000.00
      XC(105)=0.500
      XC(106)=0.500
      XC(100)=40000.00
      XC(101)=46000.00
      XC(102)=20000.00
      XC(103)=1.00
      XC(104)=60.03
      RETURN
      END
      SUBROUTINE TECPAR
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/BLOC12/XT(300)
      XT(39)=.300
      XT(40)=.7500
      XT(41)=0.300
      XT(42)=0.7500
      XT(43)=1.00
      XT(44)=0.00
      XT(160)=1.00
      XT(161)=2.0 0
      XT(162)=.98500
      XT(163)=.900
      XT(164)=5000.00
      XT(165)=14000.00
      XT(166)=5000.00
      XT(167)= 30.00
      XT(168)=100.00
      XT(169)=2.00
      XT(170)=3.00
      XT(171)=-.0500
      XT(172)=-.0500
      XT(173)=2.00
      XT(173)=8.00
      XT(174)=8.00

```

```

      TAIN0005
      TAIN0006
      TAIN0007
      TAIN0008
      TAIN0009
      PRIC0001
      PRIC0002
      PRIC0003
      PRIC0004
      PRIC0005
      PRIC0006
      PRIC0007
      PRIC0008
      PRIC0009
      PRIC0010
      PRIC0011
      PRIC0012
      PRIC0013
      PRIC0014
      PRIC0015
      PRIC0016
      PRIC0017
      PRIC0018
      PRIC0019
      PRIC0020
      PRIC0021
      PRIC0022
      PRIC0023
      PRIC0024
      PRIC0025
      PRIC0026
      PRIC0027
      PRIC0028
      PRIC0029
      PRIC0030
      PRIC0031
      PRIC0032
      PRIC0033
      PRIC0034
      PRIC0035
      PRIC0036
      PRIC0037
      PRIC0038
      PRIC0039
      PRIC0040
      TECP0001
      TECP0002
      TECP0003
      TECP0004
      TECP0005
      TECP0006
      TECP0007
      TECP0008
      TECP0009
      TECP0010
      TECP0011
      TECP0012
      TECP0013
      TECP0014
      TECP0015
      TECP0016
      TECP0017
      TECP0018
      TECP0019
      TECP0020
      TECP0021
      TECP0022
      TECP0023
      TECP0024
      TECP0025

```

XT(175)=5000.DO	TECP0026
XT(176)=6000.DO	TECP0027
XT(177)=9.500	TECP0028
XT(178)=9.500	TECP0029
XT(179)=48.00	TECP0030
XT(180)=48.00	TECP0031
XT(181)=1.00	TECP0032
XT(182)=1.00	TECP0033
XT(183)=30000.DO	TECP0034
XT(184)=1500.DO	TECP0035
XT(185)=77.00	TECP0036
XT(186)=77.00	TECP0037
XT(187)=800.00	TECP0038
XT(188)=400.00	TECP0039
XT(189)=0.300	TECP0040
XT(190)=0.7500	TECP0041
XT(191)=10.00	TECP0042
XT(192)=10.00	TECP0043
XT(193)=282.00	TECP0044
XT(194)=347.00	TECP0045
XT(195)=1.100	TECP0046
XT(196)=1.200	TECP0047
XT(197)=.02500	TECP0048
XT(198)=1.00	TECP0049
XT(199)=25.00	TECP0050
RETURN	TECP0051
END	TECP0052
SUBROUTINE TITLER	TITL0001
IMPLICIT REAL*8(A-H,O-Z)	TITL0002
	TITL0003
	TITL0004
	TITL0005
CALLC('COST OF ACID, \$/TON	(RO)', 49)TITL0006
CALLC('COST OF CHEMICAL TREATMENT,\$/LB SEAWATER	(RO)', 50)TITL0007
CALLC('UNIT POWER COST, \$/KWH	(RO)', 54)TITL0008
CALLC('ESCALATION RATE DURING CONSTRUCTION	(RO)', 56)TITL0009
CALLC('MAINTENANCE COST, FRACTION OF CAPITAL/YR	(RO)', 58)TITL0010
CALLC('INTEREST RATE	(RO)', 60)TITL0011
CALLC('INSURANCE AND TAXES COST	(RO)', 61)TITL0012
CALLC('UNUSUAL CONSTRUCTION AND CONTINGENCY COST	(RO)', 62)TITL0013
CALLC('SEAWATER MODULE COST, \$/MGD	(RO)', 80)TITL0014
CALLC('BRACKISH WATER MODULE COST, \$/MGD	(RO)', 81)TITL0015
CALLC('COST OF REFERENCE HIGH PRESSURE PUMP,\$	(RO)', 82)TITL0016
CALLC('INIT MOTOR COST, \$/HP	(RO)', 83)TITL0017
CALLC('UNIT PIPE COST, \$/MODULE	(RO)', 84)TITL0018
CALLC('UNIT PIPE COST FOR 1ST STAGE TRAIN, \$/TRAIN	(RO)', 85)TITL0019
CALLC('UNIT PIPE COST FOR 2ND STAGE TRAIN, \$/TRAIN	(RO)', 86)TITL0020
CALLC('UNIT COST OF INSTRUMENTATION FOR 0.5 MGD TRAIN \$	(RO)', 87)TITL0021
CALLC('ELECTRIC EQUIPMENT BASE COST, \$	(RO)', 88)TITL0022
CALLC('UNIT COST OF ELECTRICAL EQUIPMENT, \$/KW	(RO)', 89)TITL0023
CALLC('REFERENCE SITE COST FOR 1 MGD PLANT, \$	(RO)', 90)TITL0024
CALLC('BUILDING COST, \$/SQ FT	(RO)', 91)TITL0025
CALLC('REFERENCE COST FOR 2 MGD SEAWATER INTAKE, ETC	(RO)', 92)TITL0026
CALLC('REFERENCE COST FOR .75 MGD PRETREATMENT SYSTEM	(RO)', 93)TITL0027
CALLC('REFERENCE COST FOR ACID INJECTION SYSTEM 1315 T/D	(RO)', 94)TITL0028
CALLC('UNIT REPLACEMENT COST OF 1ST STAGE MEMBRANES\$/GPD	(RO)', 95)TITL0029
CALLC('UNIT REPLACEMENT COST OF 2ND STAGE MEMBRANES\$/GPD	(RO)', 96)TITL0030
CALLC('REFERENCE ANNUAL STAFF COST FOR 1 MGD PLANT	(RO)', 97)TITL0031
CALLC('UCHEM=UNIT COST OF PRETREATMENT CHEMICALS	(RO)', 98)TITL0032
CALLC('REFERENCE COST FOR POWER RECOVERY TURBINE,\$	(RO)', 99)TITL0033
CALLC('REFERENCE COST FOR POWER RECOV. TURBINE GOVERNOR	(RO)', 100)TITL0034
CALLC('REFERENCE DECARBONATOR COST,\$	(RO)', 101)TITL0035
CALLC('REFERENCE CHEMICAL PACIFICATION SYSTEM COST, \$	(RO)', 102)TITL0036
CALLC('COST OF CHEMICALS FOR PACIFICATION, CENTS/KGAL	(RO)', 103)TITL0037
CALLC('COST OF GENERAL PLANT PIPING, 2 MGD SEAWATER INLET	(RO)', 104)TITL0038
CALLC('RATIO DESIGN AND SUPERV. COSR RO/DIST. PLANTS	(RO)', 105)TITL0039
CALLC('RATIO CONSTRUCTION TIME RO/DIST. PLANTS	(RO)', 106)TITL0040
	TITL0041
CALLO('SEAWATER PUMP HEAD, FT	(RO)', 28)TITL0042
CALLO('PRODUCT HEAD, FT	(RO)', 31)TITL0043

C
C
C

C

```

CALLO(*OTHER PUMP EFFICIENCY
CALLO(*PLANT LIFETIME, YR
CALLO(*FEED SALINITY, PPM
CALLO(*PRODUCT SALINITY, PPM
CALLO(*LOAD FACTOR
CALLO(*FEED TEMPERATURE, F
CALLO(*NUMBER OF STAGES
CALLO(*INLET PRESSURE FOR STAGE 1, PSI
CALLO(*INLET PRESSURE FOR STAGE 2, PSI
CALLO(*EFFICIENCY OF HIGH PRESSURE PUMP FOR STAGE 1
CALLO(*EFFICIENCY OF HIGH PRESSURE PUMP FOR STAGE 2
CALLO(*RECOVERY TURBINE EFFICIENCY
CALLO(*NUMBER OF 1ST STAGE TRAINS
CALLO(*NUMBER OF 2ND STAGE TRAINS
CALLO(*MISC. PUMPING REQUIRED, HP/MGD
CALLO(*PRESSURE OPTION 1=CONSTANT, 2=INCREASING
CALLO(*YEAR CONSTRUCTION STARTS
C
CALLT(*UPPER LIMIT FOR PRODUCT RECOVERY IN STAGE 1
CALLT(*LOWER LIMIT FOR PRODUCT RECOVERY IN STAGE 1
CALLT(*UPPER LIMIT FOR PRODUCT RECOVERY IN STAGE 2
CALLT(*LOWER LIMIT FOR PRODUCT RECOVERY IN STAGE 2
CALLT(*UPPER LIMIT FOR X08(3) RECOVERY TURBINE OPTION
CALLT(*LOWER LIMIT FOR X08(3) RECOVERY TURBINE OPTION
CALLT(*MEMBRANE TYPE - SEAWATER
CALLT(*MEMBRANE TYPE - BRACKISH WATER
CALLT(*NOMINAL MEMBRANE SALT REJECTION - STAGE 1
CALLT(*NOMINAL MEMBRANE SALT REJECTION - STAGE 2
CALLT(*NOMINAL MODULE PRODUCTION RATE - STAGE 1, GPD
CALLT(*NOMINAL MODULE PRODUCTION RATE - STAGE 2, GPD
CALLT(*SPECIFIC BUILDING AREA REQUIREMENT, SQ.FT/MGD
CALLT(*NOMINAL PRESSURE DROP IN STAGE 1, PSI
CALLT(*PPM OF ACID ADDITION (PURE H2SO4)
CALLT(* MEMBRANE LIFETIME, STAGE 1, YRS
CALLT(* MEMBRANE LIFETIME, STAGE 2, YRS
CALLT(*LOG FLUX DECLINE RATE,
CALLT(*LOG FLUX DECLINE RATE,
CALLT(*MODULE DIAMETER, INCHES
CALLT(*MODULE DIAMETER, INCHES
CALLT(*MEMBRANE SURFACE, SQ. IN.
CALLT(*MEMBRANE SURFACE, SQ. IN.
CALLT(*SHELL DIAMETER, INCHES
CALLT(*SHELL DIAMETER, INCHES
CALLT(*SHELL LENGTH, INCHES
CALLT(*SHELL LENGTH, INCHES
CALLT(*NUMBER OF MODULES IN SHELL
CALLT(*NUMBER OF MODULES IN SHELL
CALLT(*REFERENCE FEED CONCENTRATION,PPM
CALLT(*REFERENCE FEED CONCENTRATION,PPM
CALLT(*REFERENCE FEED TEMPERATURE,F
CALLT(*REFERENCE FEED TEMPERATURE, F M
CALLT(*REFERENCE FEED PRESSURE, PSI
CALLT(*REFERENCE FEED PRESSURE, PSI
CALLT(*REFERENCE RECOVERY RATE
CALLT(*REFERENCE RECOVERY RATE
CALLT(*REFERENCE PRODUCT BACK PRESSURE, PSI
CALLT(*REFERENCE PRODUCT BACK PRESSURE, PSI
CALLT(*REFERENCE NET PRESSURE PSI
CALLT(*REFERENCE NET PRESSURE PSI
CALLT(*REFERENCE CONCENTRATION POLARIZN FACTOR
CALLT(*REFERENCE CONCENTRATION POLARIZN FACTOR
CALLT(*INCREASE IN PRODUCTION PER DEGREE C
CALLT(*SALT PASSAGE DEPENDS ON NET EFF. PRESSURE 1=NO
CALLT(*PRESS. DROP - 1ST STAGE OUTLET TO REC. TURB.
RETURN
END
FUNCTION SP(R,C)
IMPLICIT REAL*8(A-H,O-Z)

```

(R)*, 32)TITL0044
(R)*, 33)TITL0045
(R)*, 36)TITL0046
(R)*, 37)TITL0047
(R)*, 38)TITL0048
(R)*, 40)TITL0049
(R)*, 50)TITL0050
(R)*, 51)TITL0051
(R)*, 52)TITL0052
(R)*, 53)TITL0053
(R)*, 54)TITL0054
(R)*, 55)TITL0055
(R)*, 56)TITL0056
(R)*, 57)TITL0057
(R)*, 58)TITL0058
(R)*, 59)TITL0059
(R)*, 79)TITL0060
TITL0061
(R)*, 39)TITL0062
(R)*, 40)TITL0063
(R)*, 41)TITL0064
(R)*, 42)TITL0065
(R)*, 43)TITL0066
(R)*, 44)TITL0067
(R)*,160)TITL0068
(R)*,161)TITL0069
(R)*,162)TITL0070
(R)*,163)TITL0071
(R)*,164)TITL0072
(R)*,165)TITL0073
(R)*,166)TITL0074
(R)*,167)TITL0075
(R)*,168)TITL0076
(R)*,169)TITL0077
(R)*,170)TITL0078
STAGE 1,(R)*,171)TITL0079
STAGE 2,(R)*,172)TITL0080
STAGE 1,(R)*,173)TITL0081
STAGE 2,(R)*,174)TITL0082
STAGE 1,(R)*,175)TITL0083
STAGE 2,(R)*,176)TITL0084
STAGE 1,(R)*,177)TITL0085
STAGE 2,(R)*,178)TITL0086
STAGE 1,(R)*,179)TITL0087
STAGE 2,(R)*,180)TITL0088
STAGE 1,(R)*,181)TITL0089
STAGE 2,(R)*,182)TITL0090
STAGE 1,(R)*,183)TITL0091
STAGE 2,(R)*,184)TITL0092
STAGE 1,(R)*,185)TITL0093
STAGE 2,(R)*,186)TITL0094
STAGE 1,(R)*,187)TITL0095
STAGE 2,(R)*,188)TITL0096
STAGE 1,(R)*,189)TITL0097
STAGE 2,(R)*,190)TITL0098
STAGE 1,(R)*,191)TITL0099
STAGE 2,(R)*,192)TITL0100
STAGE 1,(R)*,193)TITL0101
STAGE 2,(R)*,194)TITL0102
STAGE 1,(R)*,195)TITL0103
STAGE 2,(R)*,196)TITL0104
(R)*,197)TITL0105
(R)*,198)TITL0106
(R)*,199)TITL0107
TITL0108
TITL0109
SPIN0001
SPIN0002

```

DIMENSION SPF(4,8),CONC(8),REC(4),F(3,3)
DATA REC / .2500, .5000, .7500, .9000/
DATA CONC/ .2500, .5000, 1.00, 2.00, 2.500, 5.00, 10.00, 20.00/
DATA SPF/ .2000, .3000, .8200, 2.0800, .2100, .3200, .9000, 2.100,
*      .2500, .3800, .9500, 2.1800, .3000, .5000, 1.000, 2.400,
*      .3000, .5200, 1.100, 2.500, .4500, .8100, 1.5500, 3.8200,
*      .8100, 1.3500, 2.7500, 5.00, 1.500, 2.1500, 4.8500, 7.300/
IC=1
IR=1
IF( R.GT.0.5) IR=2
DO 10 J=1,6
  IF(C.GT.CONC(J)) IC=J
10 CONTINUE
DO 20 I=1,3
DO 20 J=1,3
20 F(I,J)=SPF(IR+I-1,IC+J-1)
SP=V(F,REC(IR),CONC(IC),R,C)
RETURN
END
FUNCTION V(F,X,Y,XX,YI)
IMPLICIT REAL*8(A-H,O-Z)
C GIVEN TABLE F(I,J)=F(X(I),Y(J)) RETURNS F(XX,YI)
DIMENSION F(3,3),X(3),Y(3),G(3)
DO 10 I=1,3
CALL ALI(XX,X,F(I,I),G(I))
10 CONTINUE
CALL ALI(YI,Y,G,Q)
V=Q
RETURN
END
SUBROUTINE ALI(PT,X,F,ANS)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION X(3),F(3)
SUM=0.
PROD=1.
DO 30 J=1,3
  PROD=PROD*(PT-X(J))
  DENOM=1.
DO 20 K=1,3
  IF(K.NE.J) GO TO 10
  D=PT
  IF(D.NE.X(K)) GO TO 20
  ANS=F(K)
  GO TO 40
10 D=X(J)
20 DENOM=DENOM*(D-X(K))
30 SUM=SUM+F(J)/DENOM
  ANS=SUM*PROD
40 RETURN
END
SUBROUTINE MAINV
RETURN
END
SUBROUTINE SALP(N,PPM,PSI,R,SALP1)
IMPLICIT REAL*8(A-H,O-Z)
COMMON/AJAX/PRBP1,PRBP2,RFN1,RFN2,CRF1,CRF2,TEOP,ARFN1,ARFN2,
1 AVOP1,AVOP2,OSM1,OSM2,NSPOSM
C OSMX(R) FROM AJAX GLOSSARY OF R.O. TERMS (AIC-1-1275)
C OSMX(R)=DLOG(1.00/(1.00-R))/R
C SALPP FROM GRAPH FURNISHED BY GLEUCKSTERN
C SALPP(P)=.4700+1.5300*DEXP(-0.005500*(P-175.00))
C GO TO (10,20,30,40),N
C DUPONT TYPE B-10
10 SALP12=SP12(R,0.00100*PPM)
  PNET=800.00-(130.00+(PPM-10000.00)*0.015300)*(OSMX(R)/OSMX(0.300))
  SALP1=SALP12*SALPP(PNET+PSI-800.00)/SALPP(PNET)
  RETURN
20 CONTINUE

```

```

SPIN0003
SPIN0004
SPIN0005
SPIN0006
SPIN0007
SPIN0008
SPIN0009
SPIN0010
SPIN0011
SPIN0012
SPIN0013
SPIN0014
SPIN0015
SPIN0016
SPIN0017
SPIN0018
SPIN0019
SPIN0020
SPIN0021
VPIN0001
VPIN0002
VPIN0003
VPIN0004
VPIN0005
VPIN0006
VPIN0007
VPIN0008
VPIN0009
VPIN0010
VPIN0011
ALIN0001
ALIN0002
ALIN0003
ALIN0004
ALIN0005
ALIN0006
ALIN0007
ALIN0008
ALIN0009
ALIN0010
ALIN0011
ALIN0012
ALIN0013
ALIN0014
ALIN0015
ALIN0016
ALIN0017
ALIN0018
ALIN0019
ALIN0020
MAIN0001
MAIN0002
MAIN0003
SALP0001
SALP0002
SALP0003
SALP0004
SALP0005
SALP0006
SALP0007
SALP0008
SALP0009
SALP0010
SALP0011
SALP0012
SALP0013
SALP0014
SALP0015
SALP0016
SALP0017

```

```

C   DUPONT TYPE B-9
      SALP3=16.899/(.046769*PSI-1.)
      SALP6=.00100*PPM
      SALP6=SP(R,SALP6)
      SALP1=SALP3*SALP6
      RETURN
30  SALP1=OSMX(R)
      IF(NSPOSW.GT.1) SALP1=SALP1*SALPP(ARFN1)/SALPP(RFN1)
      RETURN
40  SALP1=OSMX(R)
      IF(NSPOSW.GT.1) SALP1=SALP1*SALPP(ARFN2)/SALPP(RFN2)
      RETURN
      END
      SUBROUTINE PROD(N,PPM,PSI,C,R,PROD1)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/RO/MSTYPE,MSTYPE,STAGES,PRES1,PRES2,PRODS,
1  REJN1,REJN2,PRODN1,PRODN2,PMGD,SFEED,REC1,REC2,EFFIC1,EFFIC2,
2  EFFIC3,EFFIC4,TRAIN1,TRAIN2,BAREA,DELP1N,TEMP1,SWHEAD,PRODH,SOPR
3  WPROD1,SPROD1,WPROD2,SPROD2,BLR,PMGD1,NMOD2,MOD2,NMOD1,MOD1,
4  WFEED1,WFEED,TPUMP1,PUMP1,TPUMP2,PUMP2,SPUMP,PPUMP,POTHER,
5  DELP1,PRECOV,TOTKW,REJ1,REJ2
6  ,FM1,FM2,PRESOP,PRES1M,PRES2M,TOTKWA
      COMMON/AJAX/PRBP1,PRBP2,RFN1,RFN2,CRF1,CRF2,TEOP,ARFN1,ARFN2,
1  AVOP1,AVOP2,OSM1,OSM2,NSPOSW
      COMMON/RO1/DMOD1,DMOD2,XLMOD1,XLMOD2,SMOD1,SMOD2,PRES1N,PRES2N,
*  REC1N,REC2N,LFM1,LFM2,TEMPN1,TEMPN2,FNPPM1,FNPPM2,DSHELL1,DSHELL2
*  ,NMOD1S,NMOD2S
C
C   OSMX(R) FROM AJAX GLOSSARY OF R.O. TERMS (AIC-1-1275)
      OSMX(R)=DLOG(1.00/(1.00-R))/R
C   OSM(C) FROM OSW DATA BOOK
      OSM(C)=4.44483D0+C*(9610.99D0+26290.4D0*C)
C
      GO TO (10,20,30,40),N
C   DUPONT TYPE B-10
10  PROD9=(PSI-435.00)/365.00
      PROD10=1.1215+0.285*R-2.25*R*R
      PROD10=(2.1+0.5*R)+(PPM/30000.)*(PROD10-2.1-0.5*R)
      PROD13=1.028**((C-25.))
      PROD1=PROD9*PROD10*PROD13
      RETURN
20  CONTINUE
C   DUPONT TYPE B-9
      PROD3=(PSI-30.)/370.
      Z=.001*PPM
      A=1.13564+R*.0475912-R*R*.107188
      B=.01*(-.826456-7.47946*R-2.90277*R*R)
      G=.001*(-3.38392+8.06127*R-1.53813*R*R)
      PROD4=A+Z*(B+Z*G)
      PROD5=(1.0317+.000087*C)**((C-25.))
      PROD1=PROD3*PROD4*PROD5
      RETURN
C
C   NET EFFECTIVE MODEL
C
C   GLOSSARY
C   ARFN = ACTUAL NET EFFECTIVE PRESSURE
C   CRF = CONCENTRATION POLARIZATION FACTOR
C   NSPOSW=SALT PASSAGE OPTION SWITCH
C   IS SALT PASSAGE FUNCTION OF NET EFFECTIVE PRESSURE ? 1=NO, 2=YES
C   PRBP=PRODUCT BACK PRESSURE, PSI
C   RFN= REFERENCE NET EFFECTIVE PRESSURE, PSI
C   TEOP = INCREASE IN PRODUCTION PER DEGREE C
C
30  OSM1=OSM(PPM*CRF1*1.0-6)
      AVOP1=OSM1*OSMX(R)
      DELP1=(DELP1N*(R/REC1N)**(-0.7D0))/2.00
      IF(NMOD1S.GT.1) DELP1=(DELP1N*(REC1N/R)**1.8D0)/2.00
      ARFN1=PSI-AVOP1-DELP1-PRBP1
      T66=5.*(TEMPN1-32.00)/9.

```

```

      PROD1=(ARFN1/RFN1)*(1.00+TEOP)**(C-T66)
      RETURN
40  OSM2=OSM(PPM*CRF2*1.0-6)
      AVOP2=OSM2*OSMX(R)
      DELP2N=DELP1N
      DELP2=(DELP2N*(R/REC1N)**(-0.7D0))/2.00
      IF (NMOD25.GT.1) DELP2=(DELP2N*(REC1N/R)**1.8D0)/2.00
      ARFN2=PSI-AVOP2-DELP2-PRBP2
      T66=5.*(TEMPN2-32.00)/9.
      PROD1=(ARFN2/RFN2)*(1.00+TEOP)**(C-T66)
      RETURN
      END
      FUNCTION SP12(R,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION SPF(4,8),CONC(8),REC(4),F(3,3)
      DATA REC/.200,.300,.400,.500/
      DATA CONC/5.00,10.00,15.00,20.00,25.00,30.00,35.00,40.00/
      DATA SPF/.4600,.5000,.5500,.6500,.5000,.5500,.6200,.7200,
1         .5500,.6000,.7000,.8500,.6000,.6800,.8300,1.0200,
2         .7000,.8100,1.000,1.2900,.8500,1.0100,1.2700,1.7500,
3         1.0500,1.3000,1.7700,3.400,1.300,1.700,2.600,3.4500/
      IC=1
      IR=1
      IF(R.GE.0.300) IR=2
      DO 10 J=1,6
        IF(C.GT.CONC(J)) IC=J
10  CONTINUE
      DO 20 I=1,3
      DO 20 J=1,3
20  F(I,J)=SPF(IR+I-1,IC+J-1)
      SP12=V(F,REC(IR),CONC(IC),R,C)
      RETURN
      END
      SUBROUTINE ITIME(I,J)
      J=1
      I=ICLOCK(0)
C      ICLOCK(0) RETURNS THE TIME IN HUNDREDTHS OF A SECOND
      IF(J.LT.100000) J=I-J
      RETURN
      END
      DOUBLE PRECISION FUNCTION DMATEQ(A,B,III,JJJ,ID)
C  PROGRAM AUTHORS R. E. FUNDERLIC AND R. G. EDWARDS,
C  COMPUTING TECHNOLOGY CENTER, UNION CARBIDE CORP., NUCLEAR DIV.,
C  OAK RIDGE, TENN.
C
C  CTC ORD PROGRAM NO. 9067.1
      DIMENSION A(ID,1),B(ID,1)
      DOUBLE PRECISION A,B,R,S,D
      KK=III
      NV=IABS(JJJ)
      D=1.
      IF(JJJ.LT.0)D=0.
      KKM=KK-1
      DO90I=1,KKM
      S=0.0
      DO10J=1,KK
      R=DABS(A(J,I))
      IF(R.LT.S) GO TO 10
      S=R
      L=J
10  CONTINUE
      IF(L.EQ.1) GO TO 50
      DO 20 J=1,KK
      S=A(I,J)
      A(I,J)=A(L,J)
20  A(L,J)=S
      IF(NV.LE.0) GO TO 40
      DO 30 J=1,NV
      S=B(I,J)
      B(I,J)=B(L,J)

```

```

PROD0058
PROD0059
PROD0060
PROD0061
PROD0062
PROD0063
PROD0064
PROD0065
PROD0066
PROD0067
PROD0068
PROD0069
SP120001
SP120002
SP120003
SP120004
SP120005
SP120006
SP120007
SP120008
SP120009
SP120010
SP120011
SP120012
SP120013
SP120014
SP120015
SP120016
SP120017
SP120018
SP120019
SP120020
SP120021
ITIM0001
ITIM0002
ITIM0003
ITIM0004
ITIM0005
ITIM0006
ITIM0007
ITIM0001
ITIM0002
ITIM0003
ITIM0004
ITIM0005
ITIM0006
ITIM0007
ITIM0001
ITIM0002
ITIM0003
ITIM0004
ITIM0005
ITIM0006
ITIM0007
ITIM0008
ITIM0009
ITIM0010
ITIM0011
ITIM0012
ITIM0013
ITIM0014
ITIM0015
ITIM0016
ITIM0017
ITIM0018
ITIM0019
ITIM0020
ITIM0021
ITIM0022
ITIM0023
ITIM0024
ITIM0025
ITIM0026
ITIM0027
ITIM0028
ITIM0029
ITIM0030

```

```

30 B(I,J)=S
40 D=-D
50 IF(A(I,I).EQ. 0.) GO TO 90
   IPO=I+1
   DO80J=IPO, KK
   IF(A(J,I).EQ. 0.) GO TO 80
   S=A(J,I)/A(I,I)
   A(J,I)=0.0
   DO 60 K=IPO, KK
60  A(J,K)=A(J,K)-A(I,K)*S
   IF(NV.LE. 0) GO TO 80
   DO 70 K=1, NV
70  B(J,K)=B(J,K)-B(I,K)*S
80  CONTINUE
90  CONTINUE
   DO100I=1, KK
100 D=D*A(I,I)
   IF(NV.LE.0) GO TO 130
   KMO = KK-1
   DO120K=1, NV
   B(KK,K)=B(KK,K)/A(KK,KK)
   DO120I=1, KMO
   N=KK-I
   DO110J=N, KMO
110 B(N,K)=B(N,K)-A(N,J+1)*B(J+1,K)
120 B(N,K)=B(N,K)/A(N,N)
130 DMATEQ=C
   RETURN
   END
   SUBROUTINE SLIDE(NN,X,BU,BL,FRUP,IO,N1,N2,N3,N4,NCALLS)
   IMPLICIT REAL*8(A-H,O-Z)
   DIMENSION X(40),BU(40),BL(40),G(40),G2(40),Y(40),DX(40),DG(40),
1  IG(40),R(40),GXX(14,14),LBND(40)
   DIMENSION G0(14), GXX0(14,14)
   COMMON/INDEX/ IND(40)

C
   N=NN
   DC = 2.D-6
   NBOTT = 0
   IFLAG = 0
   NBUMP = 0
   IK = 1
   IXK = IK
   NCALLS = 0
   TXCO = 1000.
   IZK = 1
   RMF = .1000
   DO 10 I1 = 1, N
   IND(I1) = 0
   IG(I1) = 0
   R(I1) = BU(I1)-BL(I1)
10  DG(I1) = .002*R(I1)
   DO 20 I=N1,N2,N3
   IVAR=X(I)+.5
   X(I)=IVAR
   X(I) = DMIN1(X(I),BU(I))
   X(I) = DMAX1(X(I),BL(I))
   DX(I) = 0.000
20  R(I) = 0.000
   IND(I3) = 1
   CALL FRUP( X ,FFF)
   TCSTRT = FFF
   TXCO = FFF
   NCALLS = NCALLS +1
   IND(I3) = 0
   IF( IO .GT. 0) WRITE(6,8010) NCALLS ,TXCO
   IF( IO .GT. 0) WRITE(6,8000) (X(J),J=1,N)
8000 FORMAT(1H0,4HEXES/(4D25.16))
8010 FORMAT(1H0,/1H0,6HNCALLS,14,6X,3HTC1,D25.16)
C

```

```

ITIM0031
ITIM0032
ITIM0033
ITIM0034
ITIM0035
ITIM0036
ITIM0037
ITIM0038
ITIM0039
ITIM0040
ITIM0041
ITIM0042
ITIM0043
ITIM0044
ITIM0045
ITIM0046
ITIM0047
ITIM0048
ITIM0049
ITIM0050
ITIM0051
ITIM0052
ITIM0053
ITIM0054
ITIM0055
ITIM0056
ITIM0057
ITIM0058
ITIM0059
SLID0001
SLID0002
SLID0003
SLID0004
SLID0005
SLID0006
SLID0007
SLID0008
SLID0009
SLID0010
SLID0011
SLID0012
SLID0013
SLID0014
SLID0015
SLID0016
SLID0017
SLID0018
SLID0019
SLID0020
SLID0021
SLID0022
SLID0023
SLID0024
SLID0025
SLID0026
SLID0027
SLID0028
SLID0029
SLID0030
SLID0031
SLID0032
SLID0033
SLID0034
SLID0035
SLID0036
SLID0037
SLID0038
SLID0039
SLID0040
SLID0041

```



```

30 SGSQR = 0.000
ISMIG = 0
IF(NCALLS .GT. 300) GO TO 400
C
  IF(IFLAG .NE. 0) GO TO 80
  DO 40 J=1,14
    G(J) = 0.00
    GXX(J,J) = 1.00
    GZ(J) = 1.00
    DO 40 K=1,14
      IF(J .NE. K) GXX(J,K) = 0.00
40 CONTINUE
  DO 70 I=N1,N2,N3
    Y(I) = X(I)
    NGO = 0
50 CONTINUE
  IF((BU(I)-X(I)) .LT. .5) GO TO 60
  X(I) = X(I) + 1.
  NGO = NGO + 1
  IND( I) = 1
  CALL FRUP(X,FFF)
  NCALLS = NCALLS+1
  IND(13) = 0
  IF(FFF .GT. TXC0) GO TO 60
  Y(I) = X(I)
  TXC0 = FFF
  NBOTT = 0
  GO TO 50
60 CONTINUE
  IND( I) = 0
  IF((NGO .GT. 1) .OR. ((Y(I)-BL(I)) .LT. .5)) GO TO 70
  X(I) = Y(I) - 1.
  IND( I) = 1
  CALL FRUP(X,FFF)
  NCALLS = NCALLS + 1
  IND(I) = 0
  IND(13) = 0
  IF(FFF .GE. TXC0) GO TO 70
  Y(I) = X(I)
  TXC0 = FFF
  NBOTT = 0
  GO TO 60
70 X(I) = Y(I)
  IND(13)=1
  CALL FRUP(X,TXC0)
  NCALLS = NCALLS+1
  IND(13)=0
  IF( IO .GT. 0) WRITE(6,8010) NCALLS ,TXC0
  IF( IO .GT. 0) WRITE(6,8000) (X(J),J=1,N)
80 CONTINUE
C
  DO 130 I2 =1,N
    ISMIG = ISMIG + IG(I2)
    LBND(I2) = 0
90 CONTINUE
  Y(I2) = X(I2)
  IF((IG(I2) .NE. 0) .OR. (DABS(R(I2)) .LT. 2.E-8)) GO TO 120
  IND(I2) = 1
  X(I2) = Y(I2) + DG(I2)
  CALL FRUP( X ,FFF)
  TXCF = FFF
  NCALLS = NCALLS + 1
  IF((DABS(Y(I2)-BU(I2)) .LT. 1.E-7) .AND. (TXCF .LT. TXC0))GOTO110
  IF((DABS(Y(I2)-BL(I2)) .LT. 1.E-7) .AND. (TXCF .GT. TXC0))GOTO110
  X(I2) = Y(I2)-DG(I2)
  CALL FRUP( X, FFF)
  TXCB = FFF
  NCALLS = NCALLS + 1

```

```

SLID0042
SLID0043
SLID0044
SLID0045
SLID0046
SLID0047
SLID0048
SLID0049
SLID0050
SLID0051
SLID0052
SLID0053
SLID0054
SLID0055
SLID0056
SLID0057
SLID0058
SLID0059
SLID0060
SLID0061
SLID0062
SLID0063
SLID0064
SLID0065
SLID0066
SLID0067
SLID0068
SLID0069
SLID0070
SLID0071
SLID0072
SLID0073
SLID0074
SLID0075
SLID0076
SLID0077
SLID0078
SLID0079
SLID0080
SLID0081
SLID0082
SLID0083
SLID0084
SLID0085
SLID0086
SLID0087
SLID0088
SLID0089
SLID0090
SLID0091
SLID0092
SLID0093
SLID0094
SLID0095
SLID0096
SLID0097
SLID0098
SLID0099
SLID0100
SLID0101
SLID0102
SLID0103
SLID0104
SLID0105
SLID0106
SLID0107
SLID0108
SLID0109

```

```

IND(13) = 0
G(I2) = .5*(TXCF-TXCB)/DG(I2)
IF((G(I2) .LT. 0.00) .AND. (DABS(BU(I2)-Y(I2)) .LT. 1.0-7))GOTO1105
IF((G(I2) .GT. 0.00) .AND. (DABS(BL(I2)-Y(I2)) .LT. 1.0-7))GOTO1105
G2(I2) = (TXCF+TXCB-2.*TXCO)/DG(I2)**2
IF(DABS(G2(I2)*DG(I2)**2) .GE. .5*DC) GO TO 100
IF(DABS(DG(I2)-.010*R(I2)) .LT. 1.0-6) GO TO 100
DG(I2) = DMIN1(.010*R(I2),2.*DG(I2))
X(I2) = Y(I2)
GO TO 90
100 CONTINUE
IF((DABS(TXCF-TXCB) .LT. 2.E-8) .AND. (G2(I2) .GT. 0.0))G(I2)=0.00
IF(DABS(TXCF-TXCB) .LT. 2.E-10) G(I2) = 0.000
IF(0.500*G(I2)**2.LT.DABS(1.0-9*G2(I2))) G(I2)=0.00
GO TO 120
110 G(I2) = 0.000
G2(I2) = 1.000
LBND(I2) = 1
120 X(I2) = Y(I2)
IG(I2) = 1
IND(I2) = 0
130 SGSQR = SGSQR + G(I2)**2
C
IF(IG .GT. 0) WRITE(6,8020) (G(J),J=1,N)
8020 FORMAT(1H0, 9HGRADIENTS/(7E17.8))
IF(IG .GT. 0) WRITE(6,8030) (G2(K),K=1,N)
8030 FORMAT(1H0,15HSECOND PARTIALS/(7E17.8))
IF(SGSQR .LT. 1.E-14) GO TO 370
DO 140 J=1,N
GXX(J,J) = G2(J)
140 CONTINUE
IF(ISMIG .NE. 0) GO TO 210
IVAR = 1
IJ=N-1
NJ = N4
IF(NBOTT .EQ. 0) GO TO 210
150 CONTINUE
IND(13) = 1
IF((DABS(R(NJ)) .GT. 2.0-8) .AND. (LBND(NJ) .EQ. 0))GO TO 170
DO 160 I=1,N
IF(I .EQ. NJ) GO TO 160
GXX(NJ,I) = 0.000
GXX(I,NJ) = 0.000
160 CONTINUE
GO TO 200
170 CONTINUE
K=1
180 CONTINUE
IF((DABS(R(NJ+K)) .LT. 2.0-8) .OR. (LBND(NJ+K) .GT. 0)) GO TO 190
IND(NJ+K)=1
X(NJ) = Y(NJ) + DG(NJ)
X(NJ+K) = Y(NJ+K)+DG(NJ+K)
CALL FRUP(X,TXCF)
NCALLS = NCALLS+1
X(NJ) = Y(NJ)-DG(NJ)
X(NJ+K) = Y(NJ+K)-DG(NJ+K)
CALL FRUP(X,TXCB)
NCALLS = NCALLS+1
GXX(NJ,NJ+K) = (TXCF+TXCB-2.*TXCO-GXX(NJ,NJ)*DG(NJ)**2
- GXX(NJ+K,NJ+K)*DG(NJ+K)**2)/(2.*DG(NJ)*DG(NJ+K))
GXX(NJ+K,NJ) = GXX(NJ,NJ+K)
X(NJ+K) = Y(NJ+K)
IND(NJ+K) = 0
IND(13)=0
190 CONTINUE
K = K+1
IF((NJ+K) .LE. N) GO TO 180
200 CONTINUE
X(NJ) = Y(NJ)
NJ = NJ+1

```

```

      IF(NJ .LE. 1J) GO TO 150
      IVAR = 0
      IF(10.GT. 0 ) WRITE(6,8040) ((GXX(I,J),J=5,12),I=5,12)
8040  FORMAT(1H0,3HGXX/(8D14.5))
      210  CONTINUE
      DO 220 J=1,14
      GO(J) = -G(J)
      DO 220 K=1,14
      GXX0(J,K) = GXX(J,K)
      220  CONTINUE
      CALL DMATEQ(GXX0,GO,14,1,14)
      DC1 = 0.00
      DC2 = 0.00
      DO 230 I=1,N
      DC1 = DC1+G(I)*GO(I)
      DO 230 J=1,N
      DC2 = DC2+.5*GXX(I,J)*GO(I)*GO(J)
      230  CONTINUE
      DELTC = DC1+DC2
      IF(10 .GT. 0) WRITE(6,8050) DELTC
8050  FORMAT(1H , 'DELTC',D17.8)
      IVAR = ISMIG+IVAR
C
      DZZ = 1.010
      DO 240 I=1,N
      DX(I) = GO(I)
      IF(DELTC .GT. 0.000) DX(I)=-.15*RMF*G(I)/DABS(G2(I))
      IF(DABS(DX(I)) .LT. 1.0-10) GO TO 240
      DYY = (BU(I)-Y(I))/DX(I)
      IF(DX(I) .LT. 0.0) DYY = (BL(I)-Y(I))/DX(I)
      DYZ = DMIN1(1.000,DYY)
      IF(DZZ .GT. DYZ) DZZ=DYZ
      240  CONTINUE
      DZZ=DMAX1(DZZ, .100)
      PRORA = DABS(DELTC)/(DABS(TCSTRT-TXC0)+1.0-10)
      IF(DABS(DELTC) .LE. 1.0-5) PRORA = 1.0-5
      IF((IVAR .EQ. 0) .AND. (DELTC .LE. 0.00) .AND. (PRORA .LE. 1.0-2)
      1 .AND. (DABS(DZZ-1.00) .LT. 1.0-8)) GO TO 1000
      STEPF = DMIN1(DZZ,RMF)
C
      DO 260 I3=1,N
      IND(I3) = 0
      IF(DABS(R(I3)) .LT. 2.E-8) GO TO 250
      DX(I3) = DX(I3)*STEPF
      IF((Y(I3)+DX(I3)) .GT. BU(I3)) DX(I3) = BU(I3)-Y(I3)
      IF((Y(I3)+DX(I3)) .LT. BL(I3)) DX(I3) = BL(I3)-Y(I3)
      X(I3) = Y(I3)+DX(I3)
      DG(I3) = DMIN1(.010* R(I3), DSQRT( DC /DABS(G2(I3))))
      IF(DABS(DX(I3)).GT.1.0-15) IND(I3) = 1
      250  CONTINUE
      IF( X(I3) .GT. BU(I3)) X(I3)= BU(I3)
      IF( X(I3) .LT. BL(I3)) X(I3)= BL(I3)
      260  CONTINUE
      IF(ISMIG .EQ. 0) IND(I3)=1
      IND(IK)=1
      IND(I2K)=1
      IF( ISMIG .EQ. 0) NSTP = 0
C
      CALL FRUP( X ,FFF)
      TXC1 = FFF
      NCALLS = NCALLS +1
      IF(10 .GT. 0) WRITE(6,8010) NCALLS ,TXC1
      IF(10 .GT. 0) WRITE(6,8000) (X(J1), J1=1,N)
      IF(TXC1 .GT. TXC0) GO TO 350
C
      NSTP = NSTP + 1
      IFLAG = 1
      IF(10 .GT. 0) WRITE(6,8060) NSTP
8060  FORMAT(1H0,15MSUCCESSFUL STEP,15 )
      IF(NSTP .GT. 15) GO TO 330

```

SLID0180
 SLID0181
 SLID0182
 SLID0183
 SLID0184
 SLID0185
 SLID0186
 SLID0187
 SLID0188
 SLID0189
 SLID0190
 SLID0191
 SLID0192
 SLID0193
 SLID0194
 SLID0195
 SLID0196
 SLID0197
 SLID0198
 SLID0199
 SLID0200
 SLID0201
 SLID0202
 SLID0203
 SLID0204
 SLID0205
 SLID0206
 SLID0207
 SLID0208
 SLID0209
 SLID0210
 SLID0211
 SLID0212
 SLID0213
 SLID0214
 SLID0215
 SLID0217
 SLID0218
 SLID0219
 SLID0220
 SLID0221
 SLID0222
 SLID0223
 SLID0224
 SLID0225
 SLID0226
 SLID0227
 SLID0228
 SLID0229
 SLID0230
 SLID0231
 SLID0232
 SLID0233
 SLID0234
 SLID0235
 SLID0236
 SLID0237
 SLID0238
 SLID0239
 SLID0240
 SLID0241
 SLID0242
 SLID0243
 SLID0244
 SLID0245
 SLID0246
 SLID0247
 SLID0248
 SLID0249

```

RMF = RMF+.100
IF(GXX(11,12) .EQ. 0.00) GO TO 270
DCP = DC1*STEPF+DC2*STEPF**2
IF(DCP .GE. 0.00) GO TO 270
DC3 = (TXC1-TXC0-DCP)/STEPF**3
IF(DC3 .LT. 0.00) RMF = 1.00
IF(DC3 .LT. 0.00) GO TO 270
DISCRM = .01*DC2**2-.4*DC1*DC3
IF(((DC1*DC3) .GT. 0.00) .OR. (DISCRM .LT. 0.00)) GO TO 270
RMZ = .5*(DSQRT(DISCRC)-.1*DC2)/DC3
RMF = DMAX1(RMZ,RMF)
270 CONTINUE
RMF = DMIN1(1.00,RMF)
IZK = 1
DO 290 J=1,N
DGXX = 0.000
DO 280 K=1,N
IF(DABS(GO(K)) .LT. 1.0-10) GO TO 280
DGXX = DGXX+GXX(J,K)*DABS(DX(K))*GO(K)/DABS(GO(K))
280 CONTINUE
G(J) = G(J)+DGXX
IF(NSTP .GT. 10) GO TO 290
IF((DABS(G(J)) .LE. 2.0-8) .AND. (DABS(DGXX) .GT. 2.0-8)) IG(J)=0
IF(DABS(G(J)) .LT. 2.0-8) G(J) = 0.000
IF(IG(J) .EQ. 0) IZK=J
290 CONTINUE
FNDR = 0.0
DO 320 I4 =1,N
IND(I4) = 0
IF(DABS(G(I4)) .LT. 2.E-8) GO TO 320
IF(DABS(R(I4)) .LT. 2.E-8) GO TO 320
IF(DABS(X(I4)-BU(I4)) .LT. 1.0-7) G(I4) = 0.000
IF(DABS(X(I4)-BL(I4)) .LT. 1.0-7) G(I4) = 0.000
IF(DABS(G(I4)) .GT. 2.0-8) GO TO 310
G2(I4) = 1.00
GXX(I4,I4) = 1.000
DO 300 K=1,N
IF(K .NE. I4) GXX(I4,K) = 0.000
300 GXX(K,I4) = GXX(I4,K)
310 CONTINUE
IF(I4 .EQ. IXK) GO TO 320
IF(.G(I4)**2/DABS(G2(I4)) .GT. FNDR ) IK = I4
IF( G(I4)**2/DABS(G2(I4)) .GT. FNDR ) FNDR = G(I4)**2/DABS(G2(I4))
320 CONTINUE
IG(IK) = 0
IXK = IK
TXC0 = TXC1
NBUMP = 0
GO TO 30
C
330 DO 340 I=1,N
340 Y(I) = X(I)
TXC0 = TXC1
350 IF(10 .GT. 0) WRITE(6,8070)
8070 FORMAT(1H0,17HUNSUCCEESSFUL STEP)
NBUMP = NBUMP+1
IFLAG = NBUMP-1
NBOTT = NBOTT+1
DC = DC/DFLOAT(NBUMP)
IF(DC .LT. 2.0-8) DC=2.0-8
RMF = .1000
DO 360 I5 =1,N
IND(I5) = 0
IG(I5) = 0
IF(DC .GT. 2.10-8) DG(I5)=DG(I5)/DSQRT(DFLOAT(NBUMP))
X(I5) = Y(I5)
360 CONTINUE
IF(10 .GT. 0)WRITE(6,8080) (X(K),K=1,N)
8080 FORMAT(1H0,17HNEW STARTING EXES/(7E17.8))
IND(13) = 1

```

```

SL100250
SL100251
SL100252
SL100253
SL100254
SL100255
SL100256
SL100257
SL100258
SL100259
SL100260
SL100261
SL100262
SL100263
SL100264
SL100265
SL100266
SL100267
SL100268
SL100269
SL100270
SL100271
SL100272
SL100273
SL100274
SL100275
SL100276
SL100277
SL100278
SL100279
SL100280
SL100281
SL100282
SL100283
SL100284
SL100285
SL100286
SL100287
SL100288
SL100289
SL100290
SL100291
SL100292
SL100293
SL100294
SL100295
SL100296
SL100297
SL100298
SL100299
SL100300
SL100301
SL100302
SL100303
SL100304
SL100305
SL100306
SL100307
SL100308
SL100309
SL100310
SL100311
SL100312
SL100313
SL100314
SL100315
SL100316
SL100317
SL100318
SL100319

```

```

      IF(NBUMP .EQ. 4) GO TO 450
      GO TO 30
C
370 IF((DABS(TXCO -TXCOO) .LT. 5.D-8) .AND. (ISMIG .EQ. 0))GO TO 390
      IF(10 .GT. 0) WRITE(6,8090)
8090 FORMAT(1H0,27HGRADIENTS CONDITIONALLY NIL)
      IFLAG = 0
      NBUMP = 0
      NBOTT = NBOTT+1
      RMF = .1000
      TXCOO = TXCO
      DO 380 I=1,N
      IG(I6) = 0
      IND(I6)=0
380 DG(I6) = DMIN1(2.*DG(I6),.02*R(I6))
      IND(13) = 1
      GO TO 30
C
390 IF(10 .GT. 0) WRITE(6,8010) NCALLS ,TXCO
      IF(10 .GT. 0) WRITE(6,8000) (X(I),I=1,N)
      IF(10 .GT. 0) WRITE(6,8100) NCALLS
8100 FORMAT(1H0,6HNCALLS,14,6X13HGRADIENTS NIL)
      IF(10 .GT. 0) WRITE(6,8020) (G(J), J=1,N)
      IF(10 .GT. 0) WRITE(6,8030) (G2(J), J=1,N)
      IND(1) = 1
      RETURN
400 IF(10 .GT. 0) WRITE(6,8110)NCALLS
8110 FORMAT(1H0,6HNCALLS,14,6X, '500 PLANT CALLS EXCEEDED')
      IND(1) = 2
      RETURN
410 IF(10 .GT. 0) WRITE(6,8120) NCALLS,DELTC
8120 FORMAT(1H0,6HNCALLS,14,6X, 'TRIVIAL FURTHER PROJECTED COST REDUCTI
      ION=',D17.8)
      IND(1) = 3
      DO 420 I=1,N
      Y(I) = X(I)
      IF(R(I) .LT. 1.D-8) GO TO 420
      X(I) = X(I)+DX(I)
420 CONTINUE
      IND(13) = 1
      CALL FRUP(X,TXC1)
      NCALLS = NCALLS+1
      IF(TXC1 .GT. TXCO) GO TO 430
      DELTC = TXC1-TXCO
      IF(10 .GT. 0) WRITE(6,8130) DELTC
8130 FORMAT(1H0,'SUCCESSFUL LAST STEP-      DELTC=',D17.8)
      IF(10 .GT. 0) WRITE(6,8010) NCALLS,TXC1
      IF(10 .GT. 0) WRITE(6,8000)(X(J),J=1,N)
      RETURN
430 IF(10 .GT. 0) WRITE(6,8140)
8140 FORMAT(1H ,'UNSUCCESSFUL LAST STEP')
      DO 440 I=1,N
440 X(I) = Y(I)
      RETURN
450 IF(10 .GT. 0) WRITE(6,8150) NCALLS
8150 FORMAT(1H0,6HNCALLS,14,6X, 'BUMPED FOUR CONSECUTIVE TIMES')
      IND(1) = 4
      RETURN
      END
      SUBROUTINE VARSET(FF,PROC)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/BLOC13/XO
      DIMENSION XO(300)
      DIMENSION XV(14)
C
      RO
110 XV(1)=-.4000
      XV(2)=-.7500
      XV(3)=1.00
120 DO 130 I=1,14
      XO(I) = XV(I)

```

SLID0320
 SLID0321
 SLID0322
 SLID0323
 SLID0324
 SLID0325
 SLID0326
 SLID0327
 SLID0328
 SLID0329
 SLID0330
 SLID0331
 SLID0332
 SLID0333
 SLID0334
 SLID0335
 SLID0336
 SLID0337
 SLID0338
 SLID0339
 SLID0340
 SLID0341
 SLID0342
 SLID0343
 SLID0344
 SLID0345
 SLID0346
 SLID0347
 SLID0348
 SLID0349
 SLID0350
 SLID0351
 SLID0352
 SLID0353
 SLID0354
 SLID0355
 SLID0356
 SLID0357
 SLID0358
 SLID0359
 SLID0360
 SLID0361
 SLID0362
 SLID0363
 SLID0364
 SLID0365
 SLID0366
 SLID0367
 SLID0368
 SLID0369
 SLID0370
 SLID0371
 SLID0372
 SLID0373
 SLID0374
 SLID0375
 SLID0376
 SLID0377
 SLID0378
 VAR0001
 VAR0002
 VAR0004
 VAR0005
 VAR0006
 VAR0160
 VAR0161
 VAR0162
 VAR0163
 VAR0164
 VAR0165

C 130 CONTINUE
RETURN
END

VARSO166
VARSO167
VARSO168
VARSO169

Appendix B
SAMPLE OUTPUT

CALCULATION FOR 1.0 MGD RO DESALTING PLANT

07-07-76

ACID FEED TREATMENT

THE VALUE OF XT(39) HAS BEEN CHANGED TO	0.28000 00	IT IS UPPER LIMIT FOR PRODUCT RECOVERY IN STAGE 1	(RO)
THE VALUE OF XT(40) HAS BEEN CHANGED TO	0.28000 00	IT IS LOWER LIMIT FOR PRODUCT RECOVERY IN STAGE 1	(RO)
THE VALUE OF XT(41) HAS BEEN CHANGED TO	0.90000 00	IT IS UPPER LIMIT FOR PRODUCT RECOVERY IN STAGE 2	(RO)
THE VALUE OF XT(42) HAS BEEN CHANGED TO	0.90000 00	IT IS LOWER LIMIT FOR PRODUCT RECOVERY IN STAGE 2	(RO)

REVERSE OSMOSIS SEAWATER DESALTING PLANT - ROUTINE R075 PAGE 1

PLANT CAPACITY - MGD	1.000
UNIT COST OF DESALTED WATER - CENTS PER KILOGALLON	438.235
CAPITAL COST OF PLANT(DIRECT+INDIRECT)- MILLIONS OF DOLLARS	4.471
POWER RECOVERY -YES	

THE PLANT HAS NOT BEEN OPTIMIZED

REVERSE OSMOSIS SEAWATER DESALTING PLANT - ROUTINE R075 PAGE 2

COST SUMMARY PAGE

CAPITAL COMPONENTS	COST-\$/YR	COST-C/KGAL	COST-\$DIRECT
-----	-----	-----	-----
MODULES AND HOUSING	188740.53	60.8350	1296250.00
PUMPS AND MOTORS	49208.95	15.8611	303589.25
VALVES AND PIPING	34142.22	11.0047	210636.71
INSTRUMENTS	15236.66	4.9111	94000.88

ELECTRICAL	23168.42	7.4677	142935.02
PRETREATMENT SYSTEM	91809.45	29.5921	566408.37
POSTTREATMENT SYSTEM	4578.37	1.4757	28245.77
SEA-WATER INTAKE	38663.27	12.4620	238528.80
SITE, BLDGS, CRANES	29581.53	9.5347	182500.00
POWER RECOV. TURBINE	22511.02	7.2558	138879.27

TOTAL CAPITAL	497640.42	160.3998	3201974.08
---------------	-----------	----------	------------

TOTAL INVESTMENT,			
\$CIR+IND			4471167.82
SPECIFIC INVESTMENT,			
\$/GPD			4.47117

MEMBRANE REPLACEMENT	444075.31	143.1347
----------------------	-----------	----------

OPERATING COMPONENTS

POWER	142888.93	46.0561
CHEMICALS	130721.18	42.1341
OPERATING	113000.00	36.4222
MAINT. + SUPPLIES	31298.17	10.0881

TOTAL OPERATING	417908.28	134.7005
-----------------	-----------	----------

TOTAL (CAP+RETUB+CP)	1359624.01	438.2350
----------------------	------------	----------

COST FACTORS

COST OF POWER, C/KWHR	2.000000
ANNUAL CHARGE RATE	0.116079
INTEREST RATE	0.100000
HIGHER COST FACTOR	1.396379
PLANT LOAD FACTOR	0.850000
PLANT LIFE, YEARS	30.000000

PUMP AND MOTOR EFFICIENCY

HIGH PRESSURE PUMP - 1ST STAGE	0.760
HIGH PRESSURE PUMP - 2ND STAGE	0.760
OTHER PUMPS	0.820
POWER RECOVERY TURBINE	0.650

MEMBRANE LIFETIME, YEARS

FIRST STAGE	2.00
SECOND STAGE	3.00

LOG FLUX DECLINE RATE

FIRST STAGE M FACTOR	-0.0500
SECOND STAGE M FACTOR	-0.0500

MEMBRANE REPLACEMENT COST, \$/GPD

FIRST STAGE	0.55
SECOND STAGE	0.15

I SUMMARY OF PLANT DATA

GENERAL

PLANT CAPACITY, MGD	1.00
SEA WATER CONCENTRATION,PPM	35000.00
PRCCUCT CONCENTRATION, PPM	500.00
PRODUCT RECOVERY	0.27
NO OF STAGES	2.00
YEAR CONSTRUCTION STARTED	1976.00
OCEAN TEMPERATURE, F	77.00

II DESCRIPTION OF PHYSICAL PLANT

	STAGE 1	STAGE 2	TOTAL
TOTAL PLANT AREA,SQ FT			5000.
NO CF TRAINS	2.	1.	3.
NO OF MODULES	327	25	352

III MEMBRANE PARAMETERS

	POLYAMID - HOLLOW FIBER	
MEMBRANE TYPE		
MODULE OUTSIDE DIAM., IN.	8.00	8.00
SHELL DIMENSIONS		
OUTSIDE DIAM., IN.	9.50	9.50
LENGTH, IN.	48.00	48.00
NO. OF MODULES IN SHELL	1	1
MEMBRANE SURFACE, SQ.FT.	5000.00	6000.00
NOMINAL OPERATING PRESSURE, PSI	800.0	400.0
NOMINAL PRODUCT RECOVERY	0.3000	0.7500
NOMINAL REJECTION RATE	0.9850	0.9000
INITIAL PRCCUCTIVITY, GPD/MODULE	5000.00	14000.00
REFERENCE FEED CONCENTRATION, PPM	30000.00	1500.00
REFERENCE FEED TEMPERATURE, F	77.00	77.00
MEMBRANE LIFE,YEARS,	2.00	3.00

IV ACTUAL OPERATING PARAMETERS

MODULE INLET PRESSURE, PSI	800.00	400.00	
PRCCUCT RECOVERY	0.2800	0.9000	
SALT PASSAGE	0.0183	0.2023	
MODULE PRODUCTIVITY, GPD			
INITIAL	4160.41	14416.95	
END OF LIFETIME	2992.06	10160.21	
WEIGHTED AVERAGE	3149.53	10694.96	
TOTAL STAGE PRODUCTION, MGD	1.0296	0.2665	
STAGE PRODUCT QUALITY, PPM	635.02	128.45	
MODULE REJECTION RATE	0.9817	0.7977	
BLENDING RATIO, 2ND STAGE/TOTAL			0.2665
			FIRST STAGE FEED CONCENTRATION,PPM 34760.

V PUMPING PARAMETERS

	FLOW-GPM	HEAD-FT	POWER-KW
1ST STAGE HIGH PRESSURE	2553.4	1840.0	1169.5
2ND STAGE HIGH PRESSURE	205.6	920.0	42.4
SEA-WATER DELIVERY	2532.9	138.0	80.6
PRODUCT	694.4	92.0	14.7
TOTAL			1322.1
POWER RECOVERY TURBINE	1838.5	1710.1	362.6
NUMBER OF PLANT CALLS 1	0		
TIME FOR THIS CASE 0.06 SECONDS			

CALCULATION FOR 1.0 MGD RO DESALTING PLANT

07-07-76

ACID FEED TREATMENT

THE VALUE OF XT(175) HAS BEEN CHANGED TO	0.50000 04	IT IS MEMBRANE SURFACE, SQ. IN.	STAGE 1, (RO)
THE VALUE OF XT(176) HAS BEEN CHANGED TO	0.60000 04	IT IS MEMBRANE SURFACE, SQ. IN.	STAGE 2, (RO)
THE VALUE OF XT(160) HAS BEEN CHANGED TO	0.10000 01	IT IS MEMBRANE TYPE - SEAWATER	(RO)
THE VALUE OF XT(161) HAS BEEN CHANGED TO	0.20000 01	IT IS MEMBRANE TYPE - BRACKISH WATER	(RO)
THE VALUE OF XT(181) HAS BEEN CHANGED TO	0.10000 01	IT IS NUMBER OF MODULES IN SHELL	STAGE 1, (RO)
THE VALUE OF XT(182) HAS BEEN CHANGED TO	0.10000 01	IT IS NUMBER OF MODULES IN SHELL	STAGE 2, (RO)
THE VALUE OF XT(162) HAS BEEN CHANGED TO	0.98500 00	IT IS NOMINAL MEMBRANE SALT REJECTION - STAGE 1	(RO)
THE VALUE OF XT(163) HAS BEEN CHANGED TO	0.90000 00	IT IS NOMINAL MEMBRANE SALT REJECTION - STAGE 2	(RO)
THE VALUE OF XT(169) HAS BEEN CHANGED TO	0.30000 01	IT IS MEMBRANE LIFETIME, STAGE 1, YRS	(RO)
THE VALUE OF XT(171) HAS BEEN CHANGED TO	-0.30000-01	IT IS LOG FLUX DECLINE RATE,	STAGE 1, (RO)
THE VALUE OF XT(172) HAS BEEN CHANGED TO	-0.30000-01	IT IS LOG FLUX DECLINE RATE,	STAGE 2, (RO)
THE VALUE OF XT(164) HAS BEEN CHANGED TO	0.10000 05	IT IS NOMINAL MODULE PRODUCTION RATE - STAGE 1, GPD	(RO)
THE VALUE OF XT(165) HAS BEEN CHANGED TO	0.28000 05	IT IS NOMINAL MODULE PRODUCTION RATE - STAGE 2, GPD	(RO)
THE VALUE OF FC(80) HAS BEEN CHANGED TO	0.66700 00	IT MULTIPLIES SEAWATER MODULE COST, \$/MGD	(RO)
THE VALUE OF FC(81) HAS BEEN CHANGED TO	0.75000 00	IT MULTIPLIES BRACKISH WATER MODULE COST, \$/MDD	(RO)
THE VALUE OF FC(95) HAS BEEN CHANGED TO	0.61800 00	IT MULTIPLIES UNIT REPLACEMENT COST OF 1ST STAGE MEMBRANES\$/GPD	(RO)
THE VALUE OF FC(96) HAS BEEN CHANGED TO	0.66700 00	IT MULTIPLIES UNIT REPLACEMENT COST OF 2ND STAGE MEMBRANES\$/GPD	(RO)
THE VALUE OF XT(39) HAS BEEN CHANGED TO	0.36000 00	IT IS UPPER LIMIT FOR PRODUCT RECOVERY IN STAGE 1	(RO)
THE VALUE OF XT(40) HAS BEEN CHANGED TO	0.36000 00	IT IS LOWER LIMIT FOR PRODUCT RECOVERY IN STAGE 1	(RO)
THE VALUE OF XT(173) HAS BEEN CHANGED TO	0.12000 02	IT IS MODULE DIAMETER, INCHES	STAGE 1, (RO)
THE VALUE OF XT(174) HAS BEEN CHANGED TO	0.12000 02	IT IS MODULE DIAMETER, INCHES	STAGE 2, (RO)
THE VALUE OF XT(183) HAS BEEN CHANGED TO	0.30000 05	IT IS REFERENCE FEED CONCENTRATION, PPM	STAGE 1, (RO)
THE VALUE OF XO(56) HAS BEEN CHANGED TO	0.10000 01	IT IS NUMBER OF 1ST STAGE TRAINS	(RO)
THE VALUE OF XO(57) HAS BEEN CHANGED TO	0.10000 01	IT IS NUMBER OF 2ND STAGE TRAINS	(RO)
THE VALUE OF XT(177) HAS BEEN CHANGED TO	0.13500 02	IT IS SHELL DIAMETER, INCHES	STAGE 1, (RO)
THE VALUE OF XT(178) HAS BEEN CHANGED TO	0.13500 02	IT IS SHELL DIAMETER, INCHES	STAGE 2, (RO)
THE VALUE OF XT(179) HAS BEEN CHANGED TO	0.48000 02	IT IS SHELL LENGTH, INCHES	STAGE 1, (RO)
THE VALUE OF XT(180) HAS BEEN CHANGED TO	0.48000 02	IT IS SHELL LENGTH, INCHES	STAGE 2, (RO)

REVERSE OSMOSIS SEAWATER DESALTING PLANT - ROUTINE R075 PAGE 1

PLANT CAPACITY - MGD 1.000

UNIT COST OF DESALTED WATER - CENTS PER KILOGALLON 305.142

CAPITAL COST OF PLANT(DIRECT+INDIRECT)- MILLIONS OF DOLLARS 3.517

POWER RECOVERY -YES

THE PLANT HAS NOT BEEN OPTIMIZED

REVERSE OSMOSIS SEAWATER DESALTING PLANT - ROUTINE R075 PAGE 2

COST SUMMARY PAGE

CAPITAL COMPONENTS -----	COST-\$/YR -----	COST-C/KGAL -----	COST-\$DIRECT -----
MODULES AND HOUSING	136175.97	43.8923	927630.00
PUMPS AND MOTORS	44065.89	14.2033	271961.93
VALVES AND PIPING	22994.02	7.4114	141912.44
INSTRUMENTS	8747.94	2.8196	53989.77
ELECTRICAL	19137.56	6.1684	118111.48
PRETREATMENT SYSTEM	77568.80	25.0020	478732.28
POSTTREATMENT SYSTEM	4576.65	1.4751	28245.77
SEA-WATER INTAKE	31609.65	10.1884	195085.62
SITE, BLDGS, CRANES	29570.40	9.5312	182500.00
POWER RECOV. TURBINE	19669.47	6.3399	121394.30
TOTAL CAPITAL	394116.35	127.0319	2519563.59
TOTAL INVESTMENT, \$DIR+IND			3516941.38
SPECIFIC INVESTMENT, \$/GPD			3.51694
MEMBRANE REPLACEMENT	190166.28	61.2945	

PRETREATMENT SYSTEM	77568.80	25.0020	478732.28
POSTTREATMENT SYSTEM	4576.65	1.4751	28245.77
SEA-WATER INTAKE	31609.65	10.1884	195085.62
SITE, BLDGS, CRANES	29570.40	9.5312	182500.00
POWER RECOV. TURBINE	19669.47	6.3399	121394.30

TOTAL CAPITAL	394116.35	127.0319	2519563.59
---------------	-----------	----------	------------

TOTAL INVESTMENT, \$DIR+IND			3516941.38
SPECIFIC INVESTMENT, \$/GPD			3.51694

MEMBRANE REPLACEMENT	190166.28	61.2945	
----------------------	-----------	---------	--

OPERATING COMPONENTS

POWER	122439.19	39.4647	
CHEMICALS	102361.47	32.9932	
OPERATING	113000.00	36.4222	
MAINT. + SUPPLIES	24618.59	7.9351	

TOTAL OPERATING	362419.25	116.8152	
-----------------	-----------	----------	--

TOTAL(CAP+RETUB+OP)	946701.89	305.1417	
---------------------	-----------	----------	--

COST FACTORS

COST OF POWER,C/KWHR	2.000000
ANNUAL CHARGE RATE	0.116079
INTEREST RATE	0.100000
HIGHER COST FACTOR	1.395853
PLANT LOAD FACTOR	0.850000
PLANT LIFE,YEARS	30.000000

PUMP AND MOTOR EFFICIENCY	
HIGH PRESSURE PUMP - 1ST STAGE	0.760
HIGH PRESSURE PUMP - 2ND STAGE	0.760
OTHER PUMPS	0.820
POWER RECOVERY TURBINE	0.650
MEMBRANE LIFETIME, YEARS	
FIRST STAGE	3.00
SECOND STAGE	3.00
LOG FLUX DECLINE RATE	
FIRST STAGE M FACTOR	-0.0300
SECOND STAGE M FACTOR	-0.0300
MEMBRANE REPLACEMENT COST, \$/GPD	
FIRST STAGE	0.34
SECOND STAGE	0.10

REVERSE OSMOSIS SEAWATER DESALTING PLANT - ROUTINE R075 PAGE 3

I SUMMARY OF PLANT DATA

GENERAL

PLANT CAPACITY, MGD	1.00
SEA WATER CONCENTRATION, PPM	35000.00
PRODUCT CONCENTRATION, PPM	500.00
PRODUCT RECOVERY	0.35
NO OF STAGES	2.00
YEAR CONSTRUCTION STARTED	1976.00
OCEAN TEMPERATURE, F	77.00

II DESCRIPTION OF PHYSICAL PLANT

	STAGE 1	STAGE 2	TOTAL
TOTAL PLANT AREA, SQ FT			5000.
NO OF TRAINS	1.	1.	2.
NO OF MODULES	172	16	188

III MEMBRANE PARAMETERS

	POLYAMIO - HOLLOW FIBER	
MEMBRANE TYPE	12.00	12.00
MODULE OUTSIDE DIAM., IN.		
SHELL DIMENSIONS		
OUTSIDE DIAM., IN.	13.50	13.50
LENGTH, IN.	48.00	48.00
NO. OF MODULES IN SHELL	1	1
MEMBRANE SURFACE, SQ.FT.	5000.00	6000.00
NOMINAL OPERATING PRESSURE, PSI	800.0	400.0
NOMINAL PRODUCT RECOVERY	0.3000	0.7500
NOMINAL REJECTION RATE	0.9850	0.9000
INITIAL PRODUCTIVITY, GPD/MODULE	10000.00	28000.00
REFERENCE FEED CONCENTRATION, PPM	30000.00	1500.00
REFERENCE FEED TEMPERATURE, F	77.00	77.00
MEMBRANE LIFE, YEARS,	3.00	3.00

IV ACTUAL OPERATING PARAMETERS

MODULE INLET PRESSURE, PSI	800.00	400.00
PRODUCT RECOVERY	0.3600	0.9000
SALT PASSAGE	0.0210	0.2036
MODULE PRODUCTIVITY, GPD		
INITIAL	7273.50	28595.23
END OF LIFETIME	5896.05	23179.88
WEIGHTED AVERAGE	6078.40	23896.78
TOTAL STAGE PRODUCTION, MGD	1.0432	0.3888
STAGE PRODUCT QUALITY, PPM	724.25	147.46
MODULE REJECTION RATE	0.9790	0.7964
BLENDING RATIO, 2ND STAGE/TOTAL		0.3888

FIRST STAGE FEED CONCENTRATION, PPM 34566.

V PUMPING PARAMETERS

	FLOW-GPM	HEAD-FT	POWER-KW
1ST STAGE HIGH PRESSURE	2012.2	1840.0	921.6
2ND STAGE HIGH PRESSURE	300.0	920.0	61.8
SEA-WATER DELIVERY	1982.2	138.0	63.1
PRODUCT	694.4	92.0	14.7
TOTAL			1076.2
POWER RECOVERY TURBINE	1287.8	1721.8	254.0
NUMBER OF PLANT CALLS 1 0			
TIME FOR THIS CASE 0.09 SECONDS			

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Internal Distribution

1. T. D. Anderson	15-39. S. A. Reed
2. S. J. Ball	40. M. W. Rosenthal
3. D. F. Cope	41. M. R. Sheldon
4. W. B. Cottrell	42. M. J. Skinner
5. F. L. Culler	43. I. Spiewak
6. G. G. Fee	44. J. J. Taylor
7. M. J. Goglia	45. D. B. Trauger
8. R. F. Hibbs	46. W. J. Wilcox
9. R. E. MacPherson	47-51. J. V. Wilson
10. W. J. McCarthy, Jr.	52-53. Central Research Library
11. J. W. Michel	54. Document Reference Section
12. J. S. Johnson	55-57. Laboratory Records Department
13. J. E. Jones Jr.	58. Laboratory Records, RC
14. H. Postma	

External Distribution

- 59-63. Pinhas Glueckstern, Desalting Dept., Mekoroth Water Co.,
9 Lincoln Street, Tel Aviv, Israel.
- 64-68. W. F. Savage, Advanced Concepts Evaluation Branch, U.S. Energy
Research and Development Administration, Washington, D.C. 20545
- 69-70. Director, Division of Nuclear Research and Applications, ERDA,
Washington, D.C. 20545
 - 71. Director, Reactor Division, ERDA, ORO
 - 72. Research and Technical Support Division, ERDA, ORO
 - 73. G. H. Corey, 6600 West 13th Ave., Denver, Colorado 80214
- 74-100. Technical Information Center, ERDA
- 101-110. Argonne Code Center