DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION

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PREFACE

This study was performed to meet a need in the field of ion exchange demineralization. The development of a demineralization system simulation should aid system operators and designers in achieving optimum results or designs. The study also serves as a basis for further work by adding other design options or incorporating theoretical based models of resin performance.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Demineralization of water by means of synthetic ion exchange resins is a widely used industrial process (15). The process gained acceptance in the late nineteen forties and early nineteen fifties as resin manufacturers were able to produce ion exchange resins having high capacity and stability characteristics (1). Demineralization of water involves the removal of objectionable dissolved solids such as silica and salts of calcium, magnesium, and sodium by hydrogen or hydroxide exchange. Cation resins exchange hydrogen ions for calcium, magnesium, sodium, and other cations. Anion resins exchange hydroxide ions for sulfates, chlorides, and other anions as well as carbon dioxide and silica. These ion exchange processes are reversible. Exhausted resin exchange capacity is restored by regeneration. Regeneration is accomplished by an acid solution for cation resins or an alkali solution for anion resins. Systems employing a series of vessels containing fixed beds of either a single resin type or a mixture of cation and anion resins are the most common method of accomplishing demineralization. Water is demineralized until the exchange capacity of one or more of the beds is exhausted. The exhausted bed is removed from service, regenerated, and returned to service. Other systems using continuous regeneraton, moving beds, or stirred tanks are also utilized.

The design of fixed bed ion exchange demineralization systems for industrial use is not, in practice, a precise science. The complex behavior of the ion exchange resins, the variations in operating conditions from site to site, and the variety of design options available to the design engineer make comprehensive evaluation and rigorous design development impractical. To simplify the design process, resin manufacturers have provided tables and charts which allow the designer to estimate resin behavior in his specific application. The use of these charts bypasses determination of behavior by a more rigorous approach based upon chemical equilibria and kinetic theory. Applebaum (1) has documented the general approach taken in design of industrial demineralization systems. Although this approach greatly simplifies design, complete evaluation of the design options is not always possible because of the time consuming nature of the computations.

Ideally, the design of ion exchange demineralization systems should be based upon chemical equilibria and kinetic theory and the optimum choice of design options. If this is to be accomplished in a practical manner, computer calculation of the system performance is required. Modeling of the resin equilibria and kinetic behavior has been accomplished by a number of investigators (2, 13, 24, 28). However, computer modeling of ion exchange demineralization systems compatible with industrial practice has not been effectively accomplished.

The purpose of this study was to develop a computer program patterned after industrial practice for ion exchange demineralizer design. This program is designed to facilitate the evaluation of the various options available to the system designer. The scope of this work was to develop a computer program which will simulate system performance given the design conditions. The program will form a basis for further work to incorporate the theoretical models of chemical equilibria and behavior.

The program is limited to considering systems having up to nine vessels in series (including forced draft or vacuum degasifiers) and nine vessels in parallel. Resin selection is limited to the strong acid cation resin Dowex HCR-S, the strong base anion resin Dowex SBR-P, and the weak base resin Dowex WGR-2. Fixed beds of only a single resin type are considered. Only sulfuric acid and sodium hydroxide are considered as regenerant chemicals and only downflow regeneration are considered. Future work will allow the incorporation of other resin types, consideration of mixed beds of cation and anion resins, other regenerant chemicals, and upflow regeneration. However, the program in its initial form will facilitate evaluation of a large percentage of the most common demineralization system designs.

CHAPTER II

LITERATURE REVIEW

General Process Description

Ion Exchange Process

The history of the development of ion exchange as an industrial process is discussed by a number of authors, including Kunin (18) and Applebaum (1). The terms "demineralization" and "deionization" have come into common useage to distinguish the removal of dissolved solids from water by means of ion exchange from the removal by means of distillation or evaporation (23).

The process of cation exchange may be illustrated by the following reactions (25):

$$Ca^{+2} + 2RH \rightleftharpoons R_2Ca + 2H^+$$

$$MG^{+2} + 2RH \rightleftharpoons R_2Mg + 2H^+$$

$$Na^+ + RH \rightleftharpoons RNa + H^+$$

where R refers to an exchange site on a resin particle. These reactions are reversible, and the exhausted cation exchange resin is converted back to the hydrogen form by means of acids such as sulfuric or hydrochloric acid. The cation exchange process also neutralizes any alkalinity present in the water, converting hydroxide into water and carbonate and bicarbonate into carbon dioxide.

Similarly, the anion exchange process may be described by the following reactions (25):

$$SO_4^{-2} + 2ROH \rightleftharpoons R_2SO_4 + 2OH^-$$

$$Cl^- + ROH \rightleftharpoons RCl + OH^-$$

$$NO_3^- + ROH \rightleftharpoons RNO_3 + OH^-$$

$$HSiO_3^- + ROH \rightleftharpoons RHSiO_3 + OH^-$$

$$HCO_3^- + ROH \rightleftharpoons RHCO_3 + OH^-$$

where R refers to an exchange site on a resin particle. The exhausted resin may be converted back to hydroxide form by means of an alkali such as sodium hydroxide.

The conversion of exhausted resin back to hydrogen or hydroxide forms is called "regeneration," and the general steps to regenerate exhausted resin capacity are as follows. The resin bed is first backwashed to remove debris and broken resin beads or fines. The regenerant chemical is applied to the resin in sufficient quantity and contact time to achieve the desired resin operating performance. The regenerant is displaced from the resin by water. This step is termed the "displacement" or "slow rinse." This takes place at the same flow rate as the regenerant was applied. The resin is then rinsed at the service flow rate until acceptable water purity is obtained. This step is termed the "final" or "fast rinse." Following this step, the bed is placed back in service.

Ion Exchange Resin Types

The ion exchange resins most commonly employed in demineralization consist of beads of polystyrene of varying degrees of crosslinkage. Crosslinking is controlled by the amount of divinyl/benzene added to the polymer. Depending upon the type of resin, ionic groups are substituted on the resulting polymer matrix to form the active sites for ion exchange to take place. The functionality of the substituted ionic group determines the resin type. The capacity and kinetics of the resin are controlled by the bead size, degree of crosslinkage, and the number of exchange sites. For some applications, acrylic polymer resins are being utilized, particularly where organic removal is required.

In general, there are four basic resin types: strong acid cation resins having a sulfonic acid functionality, weak acid cation resins having a carboxylic acid functionality, strong base anion resins having a quaternary amine functionality, and weak base anion resins having generally a mixture of primary, secondary, and tertiary amine functionalities (3, 17). There are other types of resins and functional groups; however, the four described are the most common.

Lists of available resins from domestic and foreign manufacturers can be found in a variety of sources (1, 16, 17, 18). Product descriptions and performance information for specific resins are available from the resin manufacturer. In this study, weak acid resins will not be considered, as they have very limited use in water treatment (3). In general, the resins of a given type exhibit relatively the same performance characteristics regardless of the manufacturer. Therefore, in this study, the resins of one manufacturer will be used to represent the three relevant resin types. The strong acid cation resin will be Dowex HCR-S. The strong base anion resin will be Dowex SBR-P. The weak base anion resin will be Dowex WGR-2. These resins are manufactured by the Dow Chemical Company.

System Configurations

There are a variety of ways to configure a demineralization system. Marks (20) identifies 10 major system configurations. These 10 configurations do not represent all of the current designs utilized. The simplest demineralization systems consist of a single mixed bed exchanger vessel or a cation exchanger vessel followed by an anion exchanger vessel. The more complex configurations may use as many as six vessels in series, three pairs of cation and anion exchange vessels, and also include either a forced draft or vacuum degasifier (29). In addition, vessel size considerations may dictate the use of parallel vessels. No single arrangement of cation and anion vessels can be used universally.

Two typical demineralizer configurations are shown in Figures 1 and 2. In Figure 1, the system has a primary anion exchanger using strong base type resin, following a degasifier. This design is appropriate for a raw water having a relatively low percentage of strong base or mineral ions (i.e., sulfates, chlorides, and nitrates) compared to weak base ions (i.e., alkalinity, carbon dioxide, and silica). The degasifier reduces the carbon dioxide load to the strong base exchange resin allowing the use of a smaller vessel, less resin, and less regenerant chemical consumption. In Figure 2, the primary anion

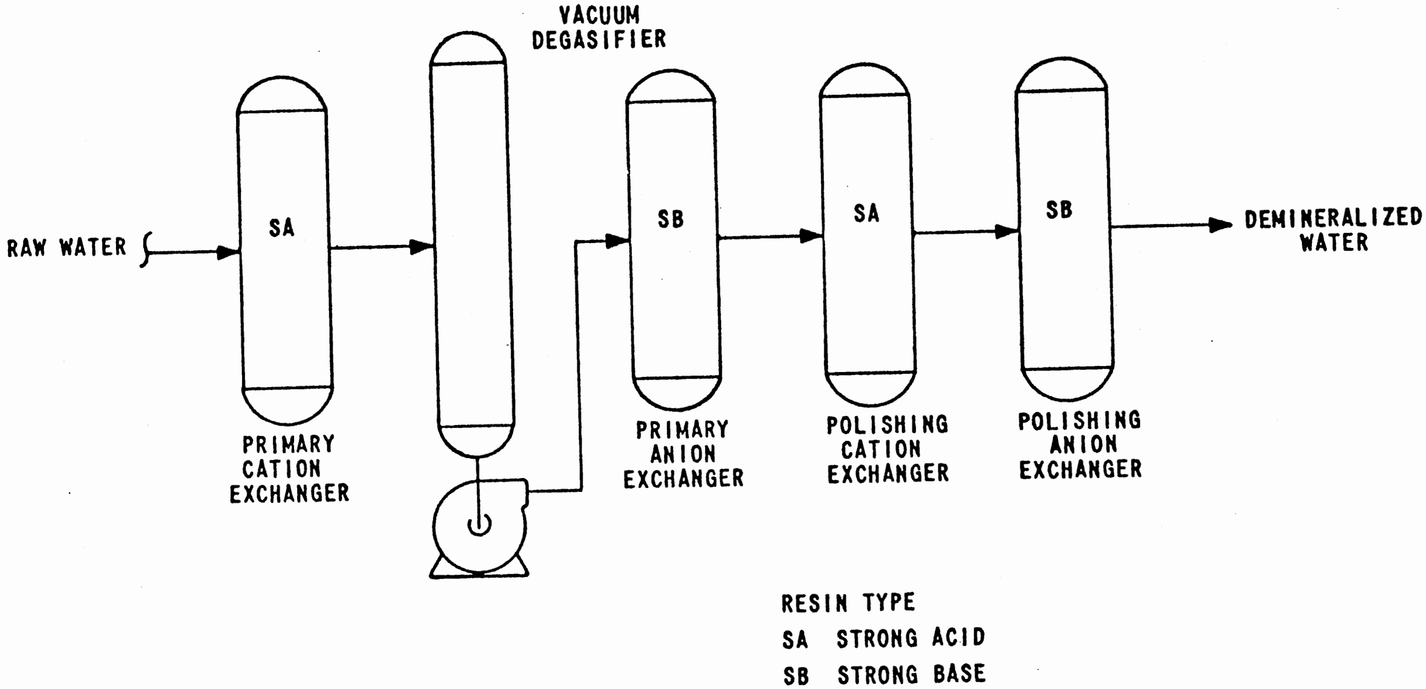

Figure 1. Demineralizer Arrangement With Degasifier Following Primary Cation Exchanger

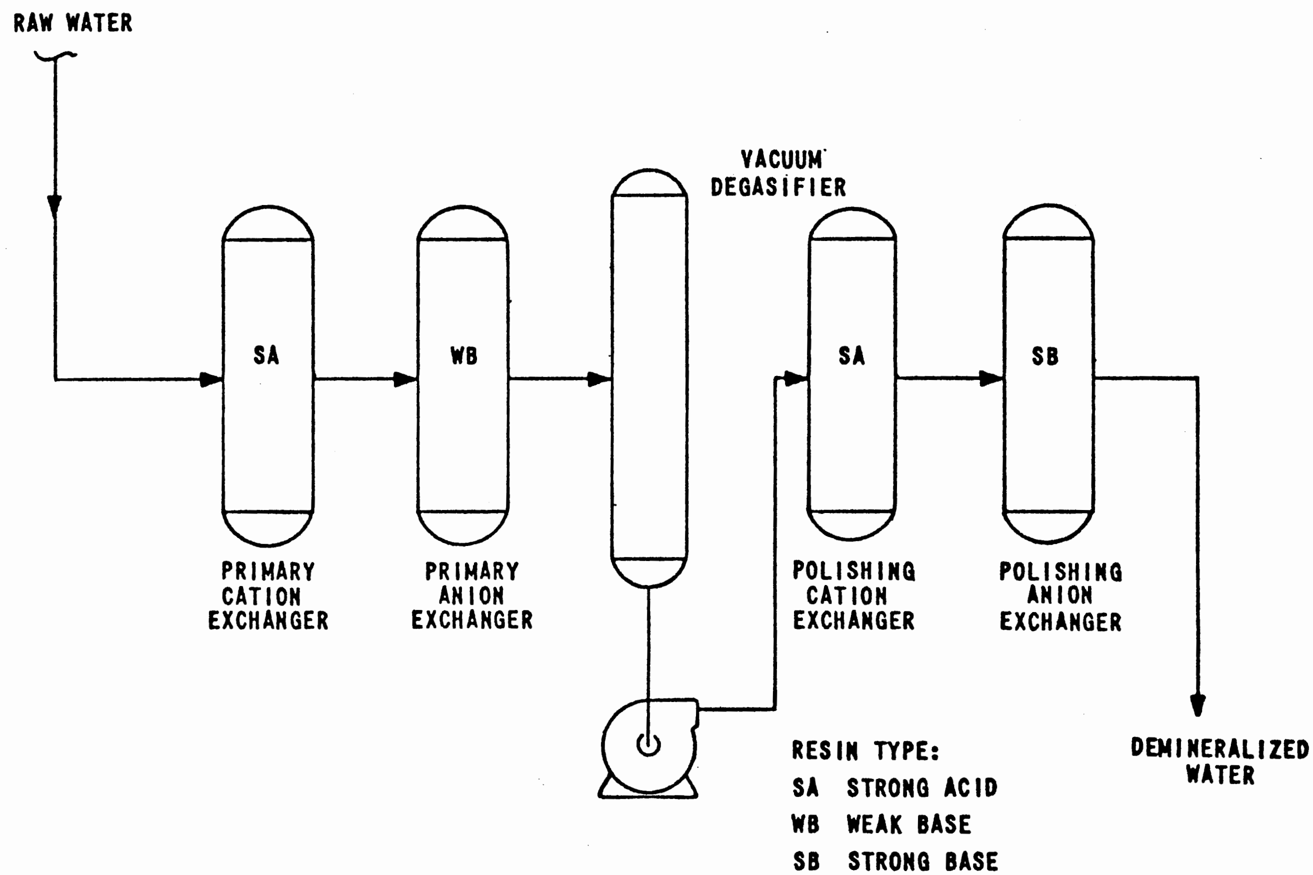

Figure 2. Demineralizer Arrangement With Degasifier Following Primary Exchangers

exchanger uses a weak base type resin. This design is most effective for a raw water containing a relatively high percentage of strong base ions. As carbon dioxide is not removed by the weak base resins being displaced from the exchange sites by the strong base ions, the degasifier may be located downstream. This location of the degasifier is preferred for corrosion considerations. In both systems, polishing cation and anion vessels are provided to reduce ion leakage to the purity levels required by the application. This comparison illustrates the considerations required to determine the optimum vessel configuration for a given application and the need for the numerous variations of system designs which are employed.

Resin Properties and Behavior

General Resin Behavior

Resin behavior is influenced by a great number of variables. The significant behavior characteristics for demineralization are the resin operating capacity, meaning the relative number of sites available for ion exchange, and the resin ion leakage, meaning the amount of impurities passing through or released by the resin. As mentioned previously, the resin particle size, crosslinkage, and ultimate capacity influence the operating capacity and leakage. Other factors which are significant include: operating characteristics such as system flow rate and dissolved solids composition, and regeneration characteristics such as the amount and flow rate of regenerant, and the method of regenerant application. Operating and regeneration temperature may also affect performance.

In order to minimize the number of variables which the system designer must optimize, the resin manufacturer has established specific operating conditions or ranges. This also insures the validity of the manufacturer's performance data for a given resin. Examples of manufacturer specified parameters include minimum and maximum system and regeneration flow rates, rinse rates and volumes, and regenerant application times.

Strong Acid Cation Resin

To illustrate strong acid cation resin behavior, Dowex HCR-S was selected. A summary of the physical and chemical properties of the resin is given in Table I. Table II provides a summary of the suggested operating conditions. A summary of capacity and leakage performance is provided in Table III. A more complete tabulation of capacity and leakage data is included as part of Appendix A. The order of selectivity for Dowex HCR-S is as follows: calcium, magnesium, potassium, sodium, and hydrogen in order of highest preference to lowest (6). When operating in the hydrogen cycle, sodium will be the first cation to be eluted. The service cycle is then normally terminated at or before sodium breakthrough.

Given the suggested operating conditions, the variation in capacity and leakage is negligible over the range of normal operating temperatures, 32 to 95°F (27). The capacities will vary with magnesium concentration, and should be corrected accordingly. A magnesium correction correlation developed from the data of Dow (4) is as

TABLE I

SOME PHYSICAL AND CHEMICAL PROPERTIES OF DOWEX HCR-S (5)

	Na^+ Form		H^+ Form
Water retention capacity	44-48%		50-56%
Density, lbs/cu ft	53		50
Minimum total capacity (Kgr $CaCO_3$/cu ft)	43.5		39.0
Original sphericity		93% minimum	
Wet screen mesh		Typical %	
+16		4.1	
+20		39.8	
+30		39.8	
+35		8.6	
+40		5.2	
+50		2.3	
-50		0.2	

TABLE II

RECOMMENDED OPERATING CONDITIONS FOR DOWEX HCR-S (5, 10)

Operating Conditions for Hydrogen Cycle	
Minimum bed depth	30 inches
Service flow rate	2-4 gpm/cu ft
Backwash bed expansion	50%
Regenerant level	Dependent upon leakage and capacity required (see Table III)
Regenerant concentration	4-10% hydrochloric acid 2-8% sulfuric acid
Regenerant flow rate	0.5-2.0 gpm/cu ft
Rinse water volume	40-100 gal/cu ft
Displacement rinse rate	Same as regenerant rate
Final rinse rate	Same as service rate

TABLE III

SOME REPRESENTATIVE CAPACITIES AND AVERAGE SODIUM LEAKAGES FOR DOWEX HCR-S (4)

Regenerant Level (66°BE H_2SO_4 Basis)		5.0 lb H_2SO_4/cu ft resin		10.0 lb H_2SO_4/cu ft resin	
Alkalinity %	Sodium %	Capacity* Kgr/cu ft	Na Leakage %	Capacity* Kgr/cu ft	Na Leakage %
0	20	17.7	2.15	23.9	0.5
	100	20.0	38.7	27.9	18.5
100	20	18.7	0	24.8	0
	100	24.0	0	31.0	0

*Basis 25% magnesium of non-sodium cations.

follows:

$$C_{Mg} = (m_m P_{mg} + b_m) P_{Na} + m_b P_{Mg} + b_b$$

where: C_{Mg} - capacity correction, Kgr as $CaCO_3$/cu ft

P_{Mg} - percent magnesium of non-sodium cations

P_{Na} - percent sodium of total cations

m_m = -0.0003

b_m = 0.03

m_b = 0.0075

b_b = -0.75

Capacity corrections must also be made for bed depths other than 30 inches and for service flow rates in excess of five gallons per minute per square foot of resin. Bed depth correction factors are shown in Table IV. Correction factors for service flow rate are shown in Table V.

TABLE IV

BED DEPTH CAPACITY CORRECTION FACTORS (4)

Bed Depth inches	Correction Factor %
18	71
24	88
30	100
36	107
42	111
48	114
54	117
60	119

TABLE V

CAPACITY CORRECTION FACTORS FOR SERVICE FLOW RATES ON A 30 INCH BED (4)

Flow Rate gpm/sq ft	Correction Factor %
5	100
20	65
50	25
100	0

After determination of the corrected capacity, the operating or throughput capacity may be determined by multiplying the corrected capacity by a throughput correction factor, F_{th}, where:

$$F_{th} = 100/(100 - \% \text{ Sodium Leakage}).$$

The backwash flow rate required varies with the required bed expansion and the water temperature. The relationship between backwash flow rate and bed expansion is given in Table VI.

Sulfuric acid is most commonly used as the regenerant chemical for cation resins because its cost is generally lower than hydrochloric acid. This study will consider only sulfuric acid as a regenerant. The use of sulfuric acid is complicated by the potential for fouling the resin with calcium sulfate where a significant percentage of the cation loading is calcium. The precipitation of calcium sulfate is minimized by gradually increasing the regenerant concentration and increasing the regenerant flow rate. The lower concentrations of acid at the start of regeneration prevent immediate elution of calcium from the resin. Since there is a certain time delay to form precipitates in a supersaturated solution, the higher flow rates cause the solution to leave the exchanger before precipitation occurs. The recommendations of Dow regarding acid concentrations and flow rates are given in Tables VII and VIII.

TABLE VI

EXPANSION CHARACTERISTICS OF DOWEX HCR-S (5)

Backwash Flow Rate* gpm/sq ft	Bed Expansion %
0.0	0.0
2.0	10.0
4.0	21.2
6.0	34.7
8.0	49.5
10.0	64.0
12.0	79.0
14.0	93.9
14.72	100.0

*Basis 77°F, to determine flow at temperature, t;

$$F_t = F_{77} (1 + 0.008 (t - 77))$$

where: F_t, F77 - Flow rate at temperature t and 77°F, respectively.

TABLE VII
RECOMMENDED CONCENTRATIONS OF SULFURIC ACID (11)

Sulfuric Acid lb/cu ft	lb/cu ft @2%	lb/cu ft @4%	lb/cu ft @6%	lb/cu ft @8%
4	2	2	-	-
6	2	2	2	-
8	2	2	2	2
10	2	2	3	3
12	2	2	4	4

TABLE VIII

RECOMMENDED REGENERANT FLOW RATES (11)

% Calcium of Total Cations as $CaCo_3$	Regeneration Flow Rate gpm/cu ft
0	0.5
25	0.5
50	1.0
75	1.5
100*	2.25

*When % calcium is high, the first 2lb/cu ft of H_2SO_4 should be at 0.5% H_2SO_4 concentration. The remainder of the acid is applied as described in Table V.

If the water being treated is sufficiently low in calcium such that calcium sulfate precipitation does not pose a problem, the regeneration flow rate can be at 0.5 gallons per minute per cubic foot of resin and the acid concentration may be eight percent. However, higher operating capacities will be achieved if acid concentrations are held below six percent.

Strong Base Anion Resin

Strong base anion resin behavior was chosen to be demonstrated by Dowex SBR-P. A summary of the physical and chemical properties of the resin are given in Table IX. Table X provides a summary of the recommended operating conditions. A summary of capacity and leakage performance is given in Table XI. A more complete tabulation of capacity and leakage data is included as part of Appendix A. The order of selectivity for Dowex SBR-P is as follows: nitrate, bisulfate, chloride, carbonic, hydroxide, in order of strongest to weakest preference (6). The weak acids of carbon dioxide and silica are eluted before any mineral acids. Silica leakage occurs first. The service cycle is normally terminated at or before silica breakthrough.

As was the case with the strong acid cation resin, the recommended operating conditions are such that temperature has a negligible effect upon capacity and leakage in the normal operating temperature range, silica excepted. Silica leakage is affected by operating temperature. Correction factors for silica leakage as a function of operating temperatures are given in Table XII. Silica leakage is also affected by the amount of sodium leakage from the upstream strong acid

TABLE IX

SOME PHYSICAL AND CHEMICAL PROPERTIES OF DOWEX SBR-P (7)

	Cl^- Form
Water retention capacity	53-60%
Density, lbs/cu ft	43
Typical total capacity	
Kgr $CaCO_3$/cu ft	27.3
Sphericity	90% minimum
Wet screen mesh	Typical %
+16	1.1
+20	37.4
+30	47.4
+35	10.5
+40	2.6
+50	1.0
-50	0.0

TABLE X

RECOMMENDED OPERATING CONDITIONS FOR DOWEX SBR-P (7)

Minimum bed depth	30 inches
Service flow rate	2-4 gpm/cu ft
Backwash bed expansion	50%
Regenerant level	Dependent upon leakage and capacity required (see Table XI)
Regenerant concentration	4% sodium hydroxide
Regenerant flow rate	0.25 to 1.0 gpm/cu ft (60 to 90 minute application time recommended (1))
Regenerant temperature	Ambient to 120°F
Rinse water volume	Approx. 50 gal/cu ft
Displacement rinse rate	Same as regenerant rate
Final rinse rate	Approx 1 gpm/cu ft

TABLE XI

SOME REPRESENTATIVE CAPACITIES AND AVERAGE SILICA LEAKAGES FOR DOWEX SBR-P (8)

Regenerant Temperature F	Regeneration Level* lb/cu ft	Capacity, Kgr $CaCo_3$/cu ft % Weak Acid of TEA** 20	50	80	Silica Leakage, ppm % Silica of TEA 20	50	80
75	5	13.6	14.5	15.5	0.06	0.21	0.378
	10	16.3	17.0	17.9	0.02	0.068	0.125
120	5	13.7	14.9	16.3	0.018	0.07	0.135
	10	16.6	17.5	18.5	0	0.018	0.043

*Basis 16 100% NaOH/cu ft

**TEA - Total Exchangeable Anions

cation exchanger. Silica leakage correction factors as a function of sodium leakage are given in Table XIII.

TABLE XII

SILICA LEAKAGE CORRECTION FACTORS FOR VARIOUS OPERATING TEMPERATURES (8)

Temperature °F	Correction Factor %
50	53.6
55	58.8
60	66.4
65	77.2
70	87.6
75	100.0
80	114.4
85	129.2
90	146.4

The capacity of the resin varies as a function of the chloride concentration and the rise in silica to the service run end point. Table XIV shows the capacity correction factors for chlorides. The capacity correction factor for silica rise to end point is given in Table XV.

The backwash flow rate required to produce a desired bed expansion varies with the water temperature. The relationship between water temperature, backwash flow rate, and bed expansion is given in Table XVI.

TABLE XIII

SILICA LEAKAGE CORRECTION FACTORS FOR SODIUM LEAKAGE (8)

Sodium Leakage ppm as $CaCo_3$	Correction Factor %
0	83.2
0.4	95.2
0.6	100.0
0.8	105.6
1.2	114.8
1.6	123.6
2.0	132.0
2.4	138.0
2.8	143.2
3.2	148.0

TABLE XIV

CAPACITY CORRECTION FACTOR FOR CHLORIDES (8)

% Chloride of Total Anions	Capacity Correction Factor %
0	100.0
10	95.5
20	92.5
30	89.5
40	87.0
50	85.5
60	83.0
70	81.5
80	80.5
90	79.0
100	78.0

TABLE XV

CAPACITY CORRECTION FACTOR FOR SILICA RISE TO END POINT (8)

Silica Rise to End Point mg/1 as SiO_2	Capacity Correction Factor %
0.0	0
0.1	91.0
0.2	94.0
0.3	95.0
0.4	96.0
0.5	97.0
0.6	98.0
0.7	98.75
0.8	99.0
0.9	99.5
1.0	100.0

TABLE XVI

EXPANSION CHARACTERISTICS OF DOWEX SBR-P (7)

Backwash Flow Rate* gpm/sq ft	Bed Expansion %
0	0
1	23.33
2	46.67
3	70.00
4	93.33

*Basis 77°F, to determine flow at temperature, t:

$$F_t = F_{77}(1 + 0.008\ (t - 77))$$

where: F_t, F_{77} - Flow rate at temperature t and 77°F, respectively.

Weak Base Anion Resin

Weak base anion resin behavior was chosen to be demonstrated by Dowex WGR-2. This resin has approximately 90 percent tertiary amine functional groups and 10 percent quaternary amine groups. A summary of the physical and chemical properties of the resin are given in Table XVII. Table XVIII provides a summary of the recommended operating conditions. A weak base resin is used primarily to remove the mineral acids found in the effluent of a cation exchanger. Weak acid anions such as those formed by the presence of dissolved carbon dioxide and silica are not generally removed by a weak base resin. The capacity of Dowex WGR-2 for sulfuric and hydrochloric acids is shown in Table XIX.

TABLE XVII

SOME PHYSICAL AND CHEMICAL PROPERTIES OF DOWEX WGR-2 (9)

	Free Base Form
Water retention capacity	Approx. 50%
Density	43
Operating capacity at	
5 lb NaOH/cu ft	
- HCl	25.0 Kgr $CaCO_3$/cu ft
- H_2SO_4	30.0 Kgr $CaCO_3$/cu ft
Wet screen mesh	Typical %
+20	8
+30	65
+35	20
+40	5
+50	2
-50	0

TABLE XVIII

RECOMMENDED OPERATING CONDITIONS FOR
DOWEX WGR-2 (9)

Bed depth	30-72 inches
Service flow rate	2 gpm/cu ft
Backwash bed expansion	50%
Regenerant level	Dependent upon capacity required (see Table XIX)
Regenerant concentration	4% sodium hydroxide or ammonium hydroxide
Regenerant flow rate	0.5 gpm/cu ft
Rinse water volume	25-100 gal/cu ft^3
Displacement rinse rate	same as regenerant rate
Final rinse rate	1 gpm/cu ft

TABLE XIX

CAPACITY OF DOWEX WGR-2 (9)

Regenerant Level lb NaOH/cu ft	Capacity, Kgr $CaCO_3$/cu ft	
	H_2SO_4	HCl
2	23.75	20.0
3	28.0	24.0
4	30.0	25.0
5	30.25	25.25

The service cycle is terminated at or prior to breakthrough of free mineral acidity. At the recommended operating conditions, temperature effects are minimal on capacity.

The backwash flow rate required to produce a desired bed expansion varies with the water temperature. The relationship between water temperature, backwash flow rate, and bed expansion is given in Table XX.

TABLE XX

EXPANSION CHARACTERISTICS OF DOWEX WGR-2 (9)

Backwash Flow Rate* gpm/sq ft	Bed Expansion %
0	0
1	8.7
2	18.7
3	28.7
4	38.7
5	48.7

*Basis 77°F, to determine flow at temperature, t:

$$F_t = F_{77} (1 + 0.008 (t - 77))$$

where: F_t, F_{77} - Flow rate at temperature t and 77°F, respectively.

System Design Considerations

Overall System Design

The results of any process design must be developed within the constraints of the structural and mechanical requirements (22). A complete demineralization system, in addition to a series of vessels containing beds of ion exchange resin, will require the necessary pretreatment equipment; supply pumps; regenerant storage, pumping and dilution equipment; control valves and control system; and waste collection and disposal facilities. Structural constraints may dictate equipment size and weight. A diagram, typical of a demineralization system, showing major equipment, is given in Figure 3.

The process information which is required for equipment design and economic evaluation is as follows. The system flow rate allows sizing of supply and transfer pumps, main flow and recycle piping, and control valves. The vessel size and resin volume allows design of the exchanger vessels and internal distributors and collectors. A typical exchanger vessel is shown in Figure 4. The regenerant flow rates and concentrations allow for sizing regenerant storage tanks, regenerant and dilution water pumps and piping, and waste collection and treatment facilities. The performance predictions allow for establishment of control setpoints and operating procedures. Capital costs may be determined from the overall design. Operating costs may be estimated from the consumption of water and regenerant chemicals, wastewater production, pump energy requirements, and labor and maintenance requirements. The overall design considerations given a process design are described by Applebaum (1). A method for determining relative economics of a demineralization system was described by Downing (12).

Vessel Design

Exchanger vessels used in demineralization are commonly of carbon

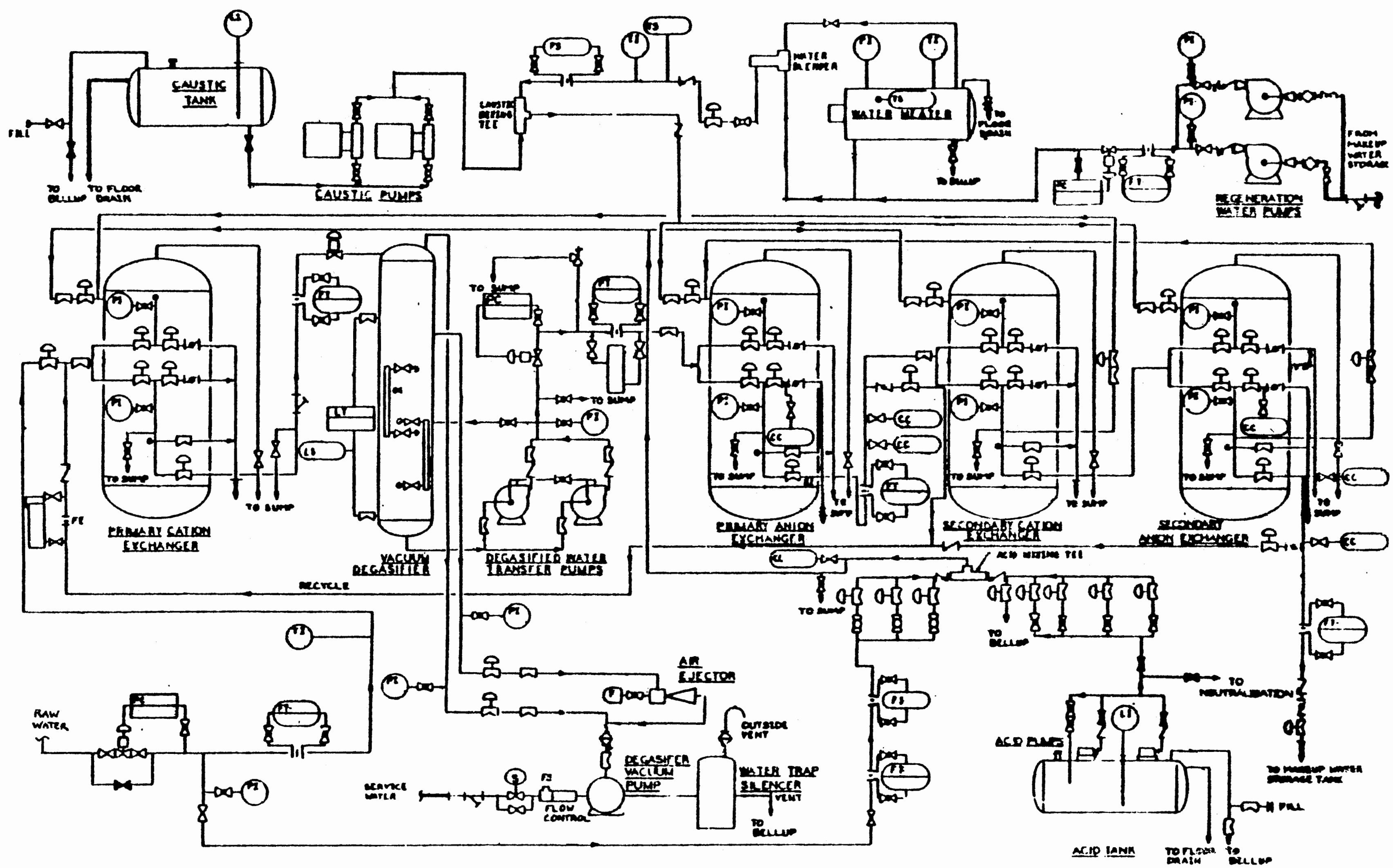

Figure 3. Typical Demineralization System Process Diagram

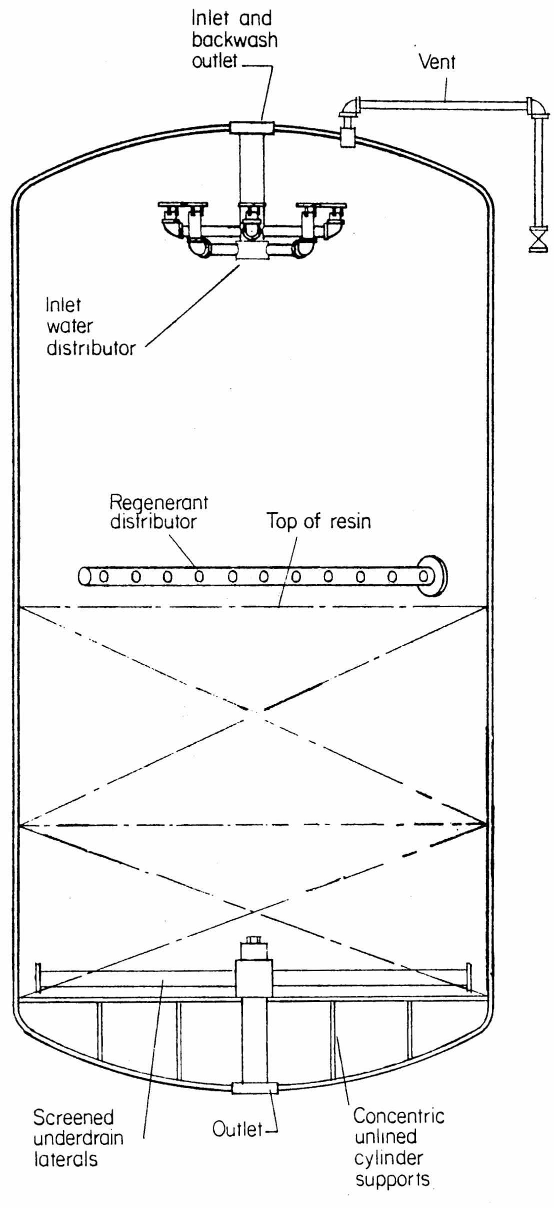

Figure 4. Typical Exchanger Vessel Design

steel construction with baked phenolic or vulcanized rubber linings. Stainless steel or Fiberglas Reinforced Plastic (FRP) vessels are used in some applications. The standard steel tank sizes range in outside diameter from 30 inches to 132 inches, increasing at 6 inch increments. The straight side ranges from 5 feet to 13 feet, increasing also in 6 inch increments. It is generally good engineering practice to hold exchanger vessels in series to the same straight side dimension to facilitate piping. The vessel straight side should be sufficient to allow for effective bed expansion during backwash.

The vessel distributors should be designed to provide uniform distribution. The regenerant distributor should be located above the resin bed in its most swollen state. The collector should be designed to minimize the amount of ineffective resin.

Some system designs require parallel vessels because of vessel size limitations or for operating flexibility. Parallel vessels are generally identical in design. Piping to parallel vessel should be such that uniform splitting of flow is obtained.

Other Design Options

Other design options not considered in this study include regenerant recovery, rinse water recycle, regeneration of vessels in series, upflow or counterflow regeneration, and mixed bed exchange vessels. These options should be given consideration in system design.

Regenerant recovery involves recovery, storage, and use of approximately the final third of the regenerant. The recovered regenerant is then applied during the first stage of the next regeneration. This results in a reduction in chemical consumption. These savings are offset by the additional tankage, piping, pumps, and controls.

Rinse water recycle involves recycling the final rinse water of an exchanger to the system inlet when the conductivity of the rinse water has dropped below the inlet water conductivity. One-third to one-half of the required rinse water may be saved, minimizing wastewater production.

Series regeneration of exchangers involves simultaneous regeneration of a downstream cation or anion exchanger with a corresponding upstream cation or anion exchanger. The regenerant volume is based upon that required for the upstream exchanger. Regenerant chemical consumption is reduced by this technique.

Upflow or counterflow regeneration occurs when the regenerant is applied in the opposite direction of the service flow (1, 21). This technique requires blocking water to be fed at the top of the vessel to hold the bed in place. Increased capacities and lower leakages result from this type of regeneration where the ions are easily eluted from the resin.

Mixed bed ion exchangers employ a mixture of cation and anion resins in a single vessel (19). The major advantage is the lower leakage resulting from the intimately mixed resin. The regeneration process requires hydraulic classification of the resins prior to regenerant chemical application. Following regeneration, the resins must be mixed again. Leakage from mixed bed exchangers is commonly a result of incomplete resin separation. Inert resin having an intermediate density between the two resins may be used to facilitate resin separation.

CHAPTER III

PERFORMANCE SIMULATION PROGRAM

General Features

A demineralization system performance program was developed to calculate the system throughput, runtime, and effluent quality, as well as the regeneration chemical and water requirements. This program requires the specification of the system design. The present version is limited to fixed bed exchangers containing a single resin type. The program is written in FORTRAN and a listing is provided in Appendix C.

The required system design input parameters are as follows:

Number of vessels in series,

Number and position of parallel vessels,

Type of vessel,

System flow rate,

Water analysis units,

Influent water analysis, and

Influent water temperature.

The required vessel design input parameters for each vessel are as follows:

Vessel outside diameter,

Vessel straight side,

Effective resin depth,

Vessel wall thickness,

Resin type,

Regenerant temperature (anion exchanger only),

Regeneration level, and

Capacity effectiveness.

If a vessel is a degasifier, the effluent carbon dioxide concentration must be specified.

The program is capable of simulating systems having up to nine vessels in series, including a degasifier, and nine vessels in parallel. The regenerant chemicals used are 66 degree Baumé (93%) sulfuric acid for cation resins and 50 percent sodium hydroxide. The resin types available include Dowex HCR-S strong acid cation resin, Dowex SBR-P strong base anion resin, and Dowex WGR-2 weak base anion resin.

The program output may be specified to be only an overall system summary or a complete output, including individual exchanger operating performance and regeneration. Examples of the program input and output are shown in Appendix D.

Overall Program Logic

The program follows the following sequence of steps:

1. Variables are declared, dimensioned, and initialized.

2. Input data are read. Water analysis data are converted to calcium carbonate equivalents (WATCON). Default variables are modified as necessary.

3. Vessel resin ratings, effluent analysis, and regeneration conditions are determined as follows:

a. Vessel type is determined. If vessel is a degasifier, water analysis is adjusted for carbon dioxide removed (DECON).

b. For cation and anion vessels, resin selection is made and rating parameters computed (CRESIN, ARESIN).

c. Resin capacities and leakages are determined. The water analysis is revised accordingly. Specific regeneration constraints are established for the resin selected (DHCRS, DSBRP, DWGR2).

d. Resin regeneration conditions are determined. Regenerant and regeneration flow rates, volumes, and application times are determined (CREGN, AREGN).

e. System and vessel throughputs and operating time are determined by water mass balance (MASBAL).

4. Output results are displayed in accordance with user preferences. Either a system performance summary or a complete summary, which includes vessel performances, may be selected.

The program subroutine organization is shown in Figure 5.

Subroutine Descriptions

WATCON

Subroutine WATCON performs two functions. The first is to convert the water analysis into units of milligram per liter as calcium carbonate from the units with which the analysis was entered. The second function is to check the electronegativity balance between the

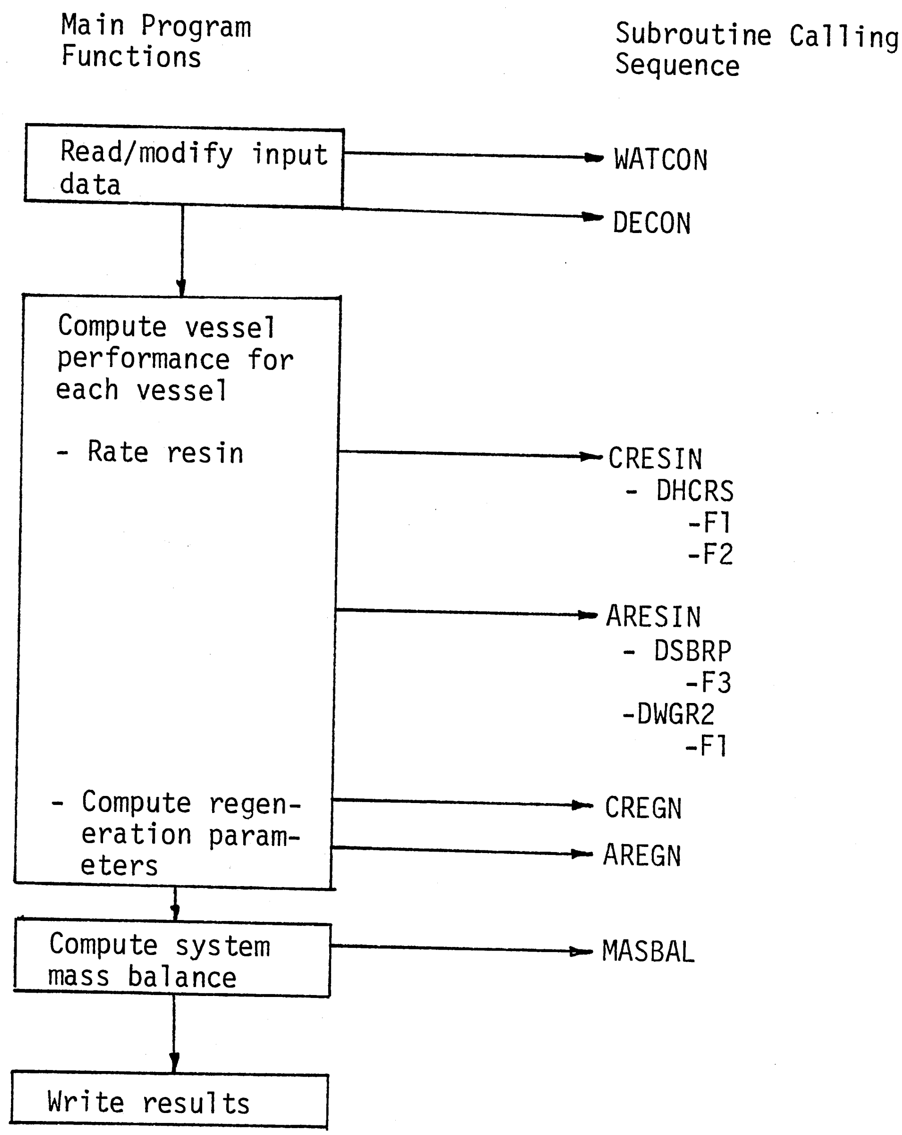

Figure 5. Program Organization

cations and anions. The sodium concentration is adjusted in order to compensate for any imbalance.

DECON

Subroutine DECON converts the degasifier effluent carbon dioxide entered into units of milligrams per liter of calcium carbonate. This value is stored in the water analysis array location corresponding to the degasifier effluent.

CRESIN

Subroutine CRESIN computes the parameters commonly used for cation resin rating. This subroutine calls the cation resin rating subroutine for cation resin selected. Presently, Dowex HCR-S is the only cation resin available. The subroutine is structured to call other cation resins as they are added in the future.

DHCRS

Subroutine DHCRS computes the resin capacity and sodium leakage ratings of Dowex HCR-S based upon the vessel influent water analysis. The resin rating procedure follows the method outlined in the Dow literature (4, 5, 11). A tabulation of the sodium leakage and capacity data taken from the Dow information is contained in Appendix A. A series of straight line equations was obtained by least squares regression of the leakage and capacity data. The sodium leakage is determined by linear interpolation of the straight line coefficients using the arbitrary function subroutine of Franks (14). The capacity is determined by computing the four capacities bounding the point of interest since there are two dependent variables. A bilinear interpolation in two variables is performed to determine the desired capacity. The subroutine used to compute the capacity is shown in Appendix C. The coefficients of the straight line equations for sodium leakage and capacity are given in Appendix B.

The alkalinity correction factors for sodium leakage were filled by least squares regression to the polynomial of the form:

$$F_{ALK} = A_0 + A_1 P_{ALK} + A_2 P_{ALK}^2 + A_3 P_{ALK}^3$$

where: F_{ALK} - Alkalinity correction factor

P_{ALK} - Percent alkalinity of the total anions

A_0 = 1.00

A_1 = -6.109762 x 10

A_2 = -8.64853 x 10

A_3 = -3.016536 x 10

This alkalinity factor is multiplied by the total anion concentration to yield a capacity correction factor.

The calculated capacity is corrected by the addition of the magnesium correction computed from the relationship described in Chapter II. The capacity is then corrected for flow rate and bed depth. The flow rate relationship developed from the information in Table V is given as:

$$F_{FR} = A_0 + A_1 q + A_2 q^2 + A_3 q^3$$

where: F_{FR} - Flow rate correction factor, percent, where $q > 5$ gpm/cu ft (F_{FR} = 100% where $q \leq 5$ gpm/cu ft

q - Flow rate, gpm/cu ft

$A_0 = 1.145102 \times 10^{2}$

$A_1 = -3.056652$

$A_2 = 3.15424 \times 10^{-2}$

$A_3 = -1.242690 \times 10^{-4}$

The bed depth correction derived from the data in Table IV is given as:

for h $\geq$ 18 inches,

$$F_{BD} = A_0 + A_1 h_{BD} + A_2 h_{BD}^2 + A_3 h_{BD}^3$$

where: F_{BD} - Bed depth correction factor, percent

h_{BD} - Bed depth, inches

$A_0 = -2.466667 \times 10^{1}$

$A_1 = 7.591991$

$A_2 = -1.433682 \times 10^{-1}$

$A_3 = 9.469697 \times 10^{-4}$

for h $<$ 18 inches,

$$F_{BD} = A_1 h_{BD}$$

where: $A_1 = 3.9444444 \times 10^{-2}$

The capacity is corrected for sodium leakage by the throughput correction factor described in Chapter II. The backwash flow rate is computed by linear interpolation from the data in Table VI. The regenerant flow rate is interpolated from the data in Table VIII. The backwash time is set at 5 minutes, unless the vessel is first in the series, in which case the backwash time is set at 10 minutes. This default condition may be changed if desired. The final rinse volume is computed based upon a requirement of 25 gallons per cubic foot of resin. This default may also be changed.

The subroutine computes the effluent water analysis from the sodium leakage. This computation assumes the removal of all cations except sodium and the neutralization of all alkalinity.

ARESIN

Subroutine ARESIN computes the parameters commonly used for anion resin rating. This subroutine calls the anion resin rating subroutine for the anion resin selected. Presently, Dowex SBR-P and WGR-2 are the only resins available. The subroutine is structured to allow the addition of other anion resin subroutines in the future.

DSBRP

Subroutine DSBRP computes the resin capacity and silica leakage ratings of Dowex SBR-P based upon the vessel influent water analysis. The resin rating procedure follows the method outlined in the Dow literature (7, 8). A tabulation of the silica leakage and capacity data taken from the Dow information is contained in Appendix A. The silica leakage and sodium leakage are determined by a bilinear interpolation in two variables from these data. The subroutine used to perform this interpolation is shown in Appendix C. Ratings at intermediate resin temperatures are obtained by interpolation of the ratings at the reference temperatures.

Silica leakage must be corrected for sodium leakage and operating temperature. The silica leakage correction factors for sodium leakage in Table XIII were fit to the quadratic below:

for $x_{NA} \leq 4.76$ mg/l as $CaCO_3$,

$$F_{NA} = A_0 + A_1 X_{NA} + A_2 X_{NA}^2$$

where: F_{NA} - Sodium leakage correction factor, percent

X_{NA} - Sodium leakage, mg/l as $CaCO_3$

A_0 = 83.7886

A_1 = 30.50159

A_2 = -3.203408

for $X_{NA} > 4.76$ mg/l as $CaCO_3$,

$$F_{NA} = 155.78489\%$$

The silica leakage correction factors for operating temperature in Table XII were fit to the polynomial below:

for $t \geq 50°F$,

$$F_t = A_0 + A_1 t + A_2 t^2 + A_3 t^3 + A_4 t^4$$

where: F_t - Temperature correction factor, percent

t - Temperature, °F

$A_0 = 4.801963 \times 10^{2}$

$A_1 = -2.547444 \times 10^{1}$

$A_2 = 5.330862 \times 10^{-1}$

$A_3 = -4.696193 \times 10^{-3}$

$A_4 = 1.622378 \times 10^{-5}$

for $t < 50°F$,

$$F_t = 50.0\%$$

Exchange capacity must be corrected for the chloride concentration and the rise in silica to the endpoint. The capacity correction factors for chloride concentration in Table XIV were fitted to the polynomial expression:

$$F_{CL} = A_0 + A_1 P_{CL} + A_2 P_{CL}^2 + A_3 P_{CL}^3$$

where: F_{CL} - Chloride correction factor

P_{CL} - Chloride percent of total anions

$A_0 = 9.981469 \times 10^{-1}$

$A_1 = -4.292541 \times 10^{-3}$

$A_2 = 3.210956 \times 10^{-5}$

$A_3 = -1.107226 \times 10^{-7}$

The capacity correction factors for silica rise to the endpoint in Table XV were fitted to the expression:

for $0.1 \leq x \leq 1.0$ mg/1 as SiO_2,

$$F_{SR} = A_0 + A_1 x_{SR} + A_2 x_{SR}^2 + A_3 x_{SR}^3$$

where: F_{SR} - Silica rise correction factor

x_{SR} - Silica rise to endpoint, mg/1 as SiO_2

$A_0 = 8.870000 \times 10^{-1}$

$A_1 = 2.895979 \times 10^{-1}$

$A_2 = -2.999709 \times 10^{-1}$

$A_3 = 1.238345 \times 10^{-1}$

for $x_{SR} < 0.1$ mg/1 as SiO_2,

$$F_{SR} = 9.1\ x_{SR}$$

for $x_{SR} > 1.0$ mg/1 as SiO_2,

$$F_{SR} = 1.0$$

The backwash rate is computed from the data in Table XVI by means of the linear expression:

$$q_{BW} = P_{BE}/23.33333$$

where: q_{BW} - Backwash rate, gpm/sq ft

P_{BE} - Percent bed expansion

The regenerant application time is set at 60 minutes. The backwash time is set at five minutes. The final rinse volume is computed based upon a requirement of 100 gallons per cubic foot of resin. These default parameters may be changed, if desired.

The subroutine computes the effluent water analysis from the silica leakage. This computation assumes removal of all anions except silica and chloride, and neutralization of all acidity. The chloride concentration is assumed to be equivalent to the sodium concentration.

DWGR2

Subroutine DWGR2 computes the resin capacity rating for Dowex WGR-2 based upon the vessel influent water analysis. The resin rating procedure is based upon the Dow capacity data shown in Table XIX. The capacity rating of the resin is interpolated from this data.

The backwash rate is computed from the data in Table XX by means of the relation given as:

$$q_{BW} = (P_{BE} + 1.3)/10.0$$

where: q_{BW} - Backwash rate, gpm/sq ft

P_{BE} - Percent bed expansion

The backwash time is set at five minutes. The regenerant flow rate is computed based upon 0.5 gallons per minute per cubic foot of resin. The final rinse volume is computed based upon a requirement of 75 gallons per minute per cubic foot of resin. These default parameters may be changed, if desired.

The subroutine computes the effluent water analysis. This computation assumes removal of all sulfates and nitrates. No removal of silica or carbon dioxide is assumed. Chloride concentration is assumed to be equivalent to the sodium concentration. All acidity is assumed to be neutralized.

CREGN

Subroutine CREGN calculates the volume, flow rate, and duration of each step of the regeneration process for vessels containing cation resins. Presently, 66 degree Baumé or 93 percent sulfuric acid is the only cation regenerant, although the subroutine is structured to allow the consideration of other regenerants in the future. If the influent water analysis indicates the presence of calcium, a stepwise regenerant application is followed as shown in Table VII. If no calcium is present, acid is assumed to be applied at a six percent concentration. The volumes of regenerant and dilution water, flow rate of regenerant, and the application time are determined from the dilution water flow rate provided by the resin rating subroutine and the regenerant level.

The backwash volume is calculated from the flow rate and duration. The displacement rinse volume is estimated by the following relationship:

$$V_{DR} = (V_R F_R + A_V h_D)\ F_V F_{DR}$$

where: V_{DR} - Displacement rinse volume, gallons

V_R - Resin volume, cubic feet

F_R - Resin void fraction (0.5)

A_V - Exchanger area, square feet

h_D - Height of distributor above resin, feet (0.75)

F_V - Volume conversion factor, cubic feet to gallons (7.48)

F_{DR} - Displacement rinse correction factor (1.5)

The values in parentheses are contained in the subroutine. The displacement rinse volume may be supplied directly, if known. The displacement rinse is assumed to be carried out at the regeneration water flow rate. The duration of the displacement rinse is determined from these quantities.

The final rinse is assumed to be performed at the service flow rate. The duration of the final rinse is determined from the flow rate and volume required.

AREGN

Subroutine AREGN calculates the volume, flow rate, and duration of each step of the regeneration process for vessels containing anion resins. Presently, 50 percent sodium hydroxide is the only anion regenerant, although the subroutine is structured to allow the consideration of other regenerants in the future.

The backwash volume is computed from the backwash flow rate and duration. The regenerant and regenerant dilution water volumes, flow rates, and durations are calculated from the dilution water flow rate or the duration supplied by the anion resin rating subroutine and the regenerant level.

The displacement rinse is assumed to be carried out at the regeneration water flow rate. The rinse volume is supplied directly or estimated by the method used in subroutine CREGN. These quantities allow the determination of the rinse duration.

The final rinse is assumed to be performed at the service flow rate. The duration of the final rinse is determined from the flow rate and volume required.

MASBAL

Subroutine MASBAL calculates the gross and net throughput, total regeneration chemical and dilution water volumes, and operating time between regenerations. Individual throughputs for each vessel are calculated.

Interpolation Functions

Linear interpolation function subroutines are called by several subroutines. Function F1 is a single dependent variable interpolation subroutine taken from Franks (14). Functions F2 and F3 are bilinear interpolation in two dependent variable subroutines.

Program Options

The program user is allowed to modify a number of the default parameters to more closely represent the application simulated. For any given vessel, the following defaults may be modified in the program edit mode:

Backwash duration,
Backwash bed expansion,
Anion regenerant application time,
Slow rinse volume, and
Fast rinse volume.

The edit mode will also provide a listing of current input parameters and default conditions. Input parameters may also be revised in this mode.

CHAPTER IV

PROGRAM VERIFICATION AND RESULTS

The simulation program developed underwent verification in the following manner. Since the ratings of the resins are the most significant part of the overall calculations, a series of comparisons were made between the resin ratings generated by the program with those determined from the resin literature. These resin ratings were also compared with the ratings of other manufacturers' equivalent resins. A series of performance comparisons were made with some demineralizer designs appearing in the open literature. The results of these comparisons are as follows.

Comparison of Calculated Resin Ratings With Literature Estimates

A summary of the resin ratings calculated by the simulation program compared to those estimated from the resin manufacturer's literature is shown in Table XXI for Dowex HCR-S or its equivalent. The comparison of ratings for Dowex SBR-P is shown in Table XXII, and the comparison of ratings for Dowex WGR-2 is shown in Table XXIII.

From these comparisons, the following general observations can be made. First, the calculated resin ratings appear to be in reasonable agreement with the Dow literature. The deviations appear to be within the range of the accuracy of the charts. Second, the capacities and

TABLE XXI

COMPARISON OF CALCULATED AND LITERATURE RESIN RATINGS FOR DOWEX HCR-S OR EQUIVALENT

Regen. Level lb/cu ft	Total Cations mg/l	Mg^{+2} %	Na+ %	Alkalinity %	Sodium Leakage, mg/l as $CaCO_3$ Dowex HCR-S Calc.	Dowex HCR-S Lit.	Amberlite IR-120 (26)	Capacity, Kgr $CaCO_3$/cu ft Dowex HCR-S Calc.	Dowex HCR-S Lit.	Amberlite IR-120 (26)
6.0	170	68.8	10.0	91.2	0.21	0.17	0.18	20.6	20.7	19.3
6.0	0.21	0.0	100.0	0.0	0.070	0.070	0.066	22.6	22.1	20.8
6.0	85	44.7	20.0	77.6	0.49	0.46	0.26	20.7	20.8	18.0
6.0	0.49	0.0	100.0	0.0	0.16	0.17	0.16	22.1	22.1	20.8
9.0	0.16	0.0	100.0	0.0	0.035	0.035	0.029	26.7	26.5	24.0

TABLE XXII

COMPARISON OF CALCULATED AND LITERATURE RESIN RATINGS FOR DOWEX SBR-P OR EQUIVALENT

Regen. Level lb/cu ft	Weak Acids %	SiO_2 %	Cl^- %	Sodium Leakage mg/l as $CaCO_3$	Silica Leakage, mg/l as SiO_3			Capacity, Kgr $CaCO_3$/cu ft		
					Dowex SBR-P Calc.	Dowex SBR-P Lit.	Amberlite IRA-402 (26)	Dowex SBR-P Calc.	Dowex SBR-P Lit.	Amberlite IRA-402 (26)
6.0	58.0	42.1	22.4	0.21	0.041	0.04	0.062	13.3	13.2	13.2
6.0	8.1	8.1	92.0	0.070	0.0052	0.005	0.02	16.8	16.7	15.1

TABLE XXIII

COMPARISON OF CALCULATED AND LITERATURE RESIN RATINGS FOR DOWEX WGR-2 OR EQUIVALENT

Regen. Level lb/cu ft	HCl, Capacity, Kgr, $CaCo_3$/cu ft			H_2SO_4 Capacity, Kgr $CaCO_3$/cu ft		
	Dowex WGR-2		Amberlite	Dowex WGR-2		Amberlite
	Calc.	Lit.	IRA-45 (26)	Calc.	Lit.	IRA-45 (26)
3.2	24.2	24.0	28.0	28.4	28.5	33.0

leakages appear to compare well with those of the equivalent resin performance. The exception to this appears to be with regard to the low silica leakage region for Dowex SBR-P and the capacity of Dowex WGR-2 with respect to IRA-45. The discrepancies in the low silica leakage region between Dowex SBR-P and IRA-402 could reflect a difference in resin properties; however, it is more likely that the difference lies in the manner in which the charts were drawn. The differences between Dowex WGR-2 and Amberlite IRA-45 are likely a result of the difference in properties of these two resins.

Comparison of Design Performances

Some of the demineralizer designs in the literature were evaluated. A six bed and a three bed demineralization system is described by Webb and Carr (29). These are operating demineralizers and the overall performance data was reported. The two systems are at the same site and their comparative performance was evaluated. The calculated performance estimate is compared with the reported performance in Table XXIV for the six bed system. The performance of the mixed bed in the three bed system was approximated by individual cation and anion exchanges. The performance comparison of the three bed system is shown in Table XXV. The six bed performance comparison shows reasonable agreement in throughput and leakage. The three bed performance comparison agrees reasonably in throughput. The comparison differs in leakage of sodium and silica. This reflects the improved leakage performance capability of the mixed bed exchanger. Copies of the performance calculations are shown in Appendix D.

TABLE XXIV

COMPARISON WITH SIX BED DEMINERALIZER PERFORMANCE
REPORTED BY WEBB AND CARR (29)

	Reported	Calculated
Throughput, gpd, net to storage	150,000	179,000*
Effluent conductivity, micromhos/cm	0.3	0.2**
Effluent silica, mg/l as $SiSO_2$	0.010	0.0021**

*Based upon original design water analysis and eight hours for regeneration.

**Based upon three bed design water analysis.

TABLE XXV

COMPARISON WITH THREE BED DEMINERALIZER PERFORMANCE
REPORTED BY WEBB AND CARR (29)

	Reported	Calculated
Throughput, gpd, net to storage	300,000	304,000*
Effluent conductivity, micromhos/cm	0.5	1.8
Effluent silica, mg/l as SiO_2	0.020	0.033

*Based upon eight hours for regeneration.

Applebaum (1) includes several demineralizer designs as examples. The performance of Case 1 was calculated and the results are shown in Table XXVI. The design is for a two bed demineralizer. The overall comparison of the designs indicates relatively good agreement. The differences in throughput arise from the different assumptions in the required regeneration and rinse volumes. Modification of the default regeneration and rinse parameters would allow the design to be more closely approximated.

TABLE XXVI

COMPARISON WITH CASE 1 DEMINERALIZER DESIGN
PROPOSED BY APPLEBAUM (1)

	Design	Calculated
Net throughput, gpd	383,000	345,000
Effluent conductivity, micromhos/cm	10.0	20.0
Effluent silica, mg/l as SiO	0.03	0.024
Capacity, Kgr CaCO /cu ft		
cation	13.6	13.6
anion	10.6	10.3
Cation regeneration volumes		
backwash, gal	2120	1487
sulfuric acid, gal 66 Be	19.3	20.0
dilution water, gal	1111	1286
displacement rinse, gal	265	527
final rinse, gal	2950	1469
Anion regeneration volumes		
backwash, gal	1070	197
sodium hydroxide, gal 50%	46	47
dilution water, gal	802	1139
displacement rinse, gal	265	527
final rinse, gal	2950	5877

CHAPTER V

PROGRAM APPLICATION AND DISCUSSION

Program Use

This simulation program will be useful in both modeling the performance of existing demineralizers and aiding in the design of new demineralizers. Since the program requires that a well defined design be provided, the present form is more readily useful in modeling existing designs to assess the effects of changes in water supply, operation, or design. In order to be used in system design, the designer must make some estimates concerning the configuration, loading, and operation of the system. Optimizing the design becomes a trial and error process. However, the program can still afford the system designer appreciable time savings in performance evaluation. Future modifications may allow some of the initial system design estimates to be performed by the program.

An example of the input dialogue is shown in Appendix D. The required system design input parameters are as follows:

Number of vessels in series,

Number and position of parallel vessels,

Type of vessel,

System flow rate,

Water analysis units,

Influent water analysis, and

Influent water temperature.

The required vessel design input parameters for each vessel are as follows:

Vessel outside diameter,

Vessel straight side,

Effective resin depth,

Vessel wall thickness,

Resin type,

Regenerant temperature (anion exchanger only),

Regeneration level, and

Capacity effectiveness.

If a vessel is a degasifier, the effluent carbon dioxide concentration must be specified.

The program user is allowed to modify a number of the default parameters to more closely represent the application simulated. For any given vessel, the following defaults may be modified in the program edit mode:

Backwash duration,

Backwash bed expansion,

Anion regenerant application time,

Slow rinse volume, and

Fast rinse volume.

As resin ratings are the most significant parameters, the program user has the ability to adjust the resin capacity by means of an effectiveness factor. This factor is chosen based upon the actual operating capacity in the case of an existing design or upon experience in a new design. This factor is widely variable and depends upon the resin age, characteristics, and operating practices.

Interpretation of Results

The program in its present form does not provide a total picture of the system performance, but does provide sufficient information to determine the complete system operating characteristics. The parameters which can be derived from the results include the system regeneration time, the vessel regeneration frequency, and the gross and net throughput per day.

The vessel regeneration frequency is determined by the program user from the vessel capacity utilization. A schedule of regeneration frequency may be established by comparing the percent capacity utilization for each vessel and by taking into consideration any vessels which may be regenerated in series.

The regeneration time may be determined by the individual vessel regeneration times and frequency, taking into account steps which can be performed simultaneously (i.e., regenerant application can take place for a cation exchanger and an anion exchanger simultaneously). A sequence of regeneration steps is established, and from this the system regeneration time may be determined.

The gross and net throughput per day of the system may be determined from the summation of the vessel regeneration water requirements, the service cycle and the system regeneration time, and the net throughput per regeneration. The total cycle time, service and regeneration, and the gross and net system throughput per regeneration are determined. Throughput may be converted to a daily basis by means of the cycle time.

The mechanical design of the system is supported by the program results. From the flow rate information, pipe and valve sizes may be determined and pumps may be sized. Regenerant storage tanks and water heating sizing may be performed. Regenerant waste volumes and neutralization requirements may be estimated.

Program Features and Limitations

The program in its present form represents a significant improvement over manual computation. The program has the flexibility to allow a user to tailor the design to fit his application. The program also provides a faster, more reproducible, and possibly more accurate means of interpolating resin ratings from the manufacturer's data. This is supported by the comparative results shown in Chapter IV.

The program is limited in a number of ways. The program cannot be used in a straightforward manner in design. The designer must approxiamte the design and optimize by trial and error.

Resin selection is limited. Only resins from one manufacturer are represented. The ratings generated must also be corrected by the user by the use of the resin effectiveness to reflect operating conditions, resin age, and deterioration.

The regeneration of cation resins is limited to sulfuric acid. Hydrochloric acid is used as regenerant, although not as commonly as sulfuric.

Cocurrent or downflow regeneration is assumed. Current practice sometimes finds countercurrent or upflow regeneration being applied.

Improved capacity and leakage performance results from this technique where ions are easily eluted. Individual vessel regeneration is the only mode assumed. In many applications, regeneration of vessels in series results in substantial savings in regenerant consumption.

The program only considers fixed beds of a single resin type. Fixed beds of cation and anion mixtures called "mixed beds" have been widely used. Mixed bed exchangers exhibit superior leakage performance.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to develop a computer program patterned after industrial practice to simulate ion exchange demineralizer operation. The program is designed to aid the program user in evaluation of a number of possible demineralization system options, and will estimate the system performance for a given design and set of operation conditions.

The program has the following constraints. The maximum system configuration size is nine vessels in series, inclusive of a forced draft or vacuum degasifier, and nine vessels in parallel. The minimum system configuration size is a two bed system of a cation exchanger followed by an anion exchanger. The available resins consist of Dowex HCR-S, strong acid cation resin; Dowex SBR-P, strong base anion resin; and Dowex WGR-2, weak base anion resin. Only fixed beds of a single type of exchange resin are considered. The regenerants are sulfuric acid for cation regeneration and sodium hydroxide for anion regeneration. Regenerant is assumed to be applied cocurrent to the service flow or downflow. Despite these constraints, evaluation of a large percentage of the most common system designs is possible with this program.

The program was developed and evaluated and the following conclusions can be made as a result of this study.

The comparison of the resin ratings determined from the manufacturer's literature with those estimated by the program shows reasonable agreement. The comparison of the performance estimates calculated by the program with operating performance results and other performance predictions appears to be reasonable, particularly in view of the inaccuracies and uncertainties inherent in an industrial operating environment.

The program has the advantage of generating resin ratings quicker and with more reproducible results than can be obtained by using the charts contained in the manufacturer's literature. Changes in system operation and design may easily be evaluated as a result. The program is a useful tool in the evaluation of existing systems and the design of new systems.

The following recommendations are made for further work as a result of this study. The program should be enhanced in the following ways:

1. Mixed bed exchanger simulation should be incorporated.

2. Hydrochloric acid should be included as a regenerant for cation regeneration.

3. Countercurrent and series regeneration options should be added.

4. Additional resin types should be incorporated into the data base.

5. Regeneration wastes should be characterized and the neutralization requirements determined.

6. To facilitate system design, the program should provide initial vessel size estimates.

Areas of further study which were identified as a result of this study are as follows:

1. A means should be developed in which the equilibria and kinetic theories may be used to predict resin performance for industrial ion exchange systems.

2. The range of the resin effectiveness factors should be determined for various resin types based upon operating experience.

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APPENDIXES

APPENDIX A

RESIN RATING DATA

RESIN RATING DATA

The resin rating data used by the simulation program, either by means of linear correlations or by interpolating functions, are provided herein. The Dowex HCR-S sodium leakage data are given in Table XXVII. The leakage data are based upon a water containing no alkalinity. The Dowex HCR-S capacity data are given in Table XXVIII. The capacity data are based upon a calcium to magnesium concentration ratio of 3:1. The Dowex SBR-P silica leakage data are given in Table XXIX. The leakage data are based upon a water at 75°F and specific conductance of three micromhos per centimeter. The Dowex SBR-P capacity data are given in Table XXX. The capacity data are based upon a water containing no chlorides and operation to a silica rise of one part per million.

TABLE XXVII

DOWEX HCR-S SODIUM LEAKAGE RATING DATA (4)

Regeneration Level lb 66°Be H_2SO_4/cu ft	Sodium Leakage, Percent of Corrected Total Mineral Anions							
	Percent Sodium of Total Cations							
	20	40	50	60	70	80	90	100
3	3.4	6.2	9.3	13.9	19.5	28.0	--	--
4	2.7	5.0	7.6	11.4	16.0	23.25	--	--
5	2.15	4.2	6.3	9.5	13.45	19.6	--	--
6	1.7	3.5	5.3	7.9	11.3	16.5	24.2	--
7	1.35	3.0	4.3	6.6	9.4	13.9	20.7	--
8	1.0	2.5	3.7	5.4	7.9	11.75	17.6	25.1
9	0.75	2.0	3.0	4.4	6.45	9.8	14.7	21.7
10	0.5	1.5	2.4	3.5	5.25	8.0	12.3	18.5
12	--	0.9	1.3	1.9	3.05	5.0	7.9	13.2
14	--	--	--	0.6	1.2	2.5	4.4	8.9

TABLE XXVIII

DOWEX HCR-S CAPACITY RATING DATA (4)

Regeneration Level lb 66° Be H_2SO_4/cu ft	Percent Alkalinity	Capacity, Kgr $CaCO_3$/cu ft — Percent Sodium of Total Cations					
		0	20	40	60	80	100
2	0	--	--	--	--	--	--
	50	--	--	--	--	--	12.9
	100	--	--	--	--	13.4	14.7
3	0	12.9	13.0	13.3	12.8	11.3	14.2
	50	12.9	13.7	13.9	14.4	13.8	17.1
	100	12.9	14.2	14.7	16.4	17.4	18.9
4	0	15.1	15.7	16.1	15.9	15.1	17.4
	50	15.1	16.2	16.8	17.3	17.2	20.1
	100	15.1	16.8	17.6	19.1	20.1	21.8
5	0	16.9	17.7	18.3	18.3	18.0	20.0
	50	16.9	18.1	18.9	19.8	19.9	22.3
	100	16.9	18.7	19.8	21.4	22.3	24.0
6	0	18.5	19.4	20.1	20.2	20.5	22.1
	50	18.5	19.9	20.9	21.6	22.0	24.2
	100	18.5	20.3	21.6	22.9	24.1	25.9

TABLE XXVIII (Continued)

Regeneration Level lb 66° Be H_2SO_4/cu ft	Percent Alkalinity	Capacity, Kgr $CaCO_3$/cu ft — Percent Sodium of Total Cations: 0	20	40	60	80	100
7	0	19.8	20.7	21.6	21.9	22.5	23.9
	50	19.8	21.2	22.2	23.0	23.9	25.9
	100	19.8	21.7	23.0	24.5	25.7	27.5
8	0	20.8	21.9	22.9	23.4	24.3	25.4
	50	20.8	22.3	23.7	24.4	25.6	27.3
	100	20.8	22.8	24.2	25.8	27.0	28.8
9	0	21.8	22.9	24.0	24.6	25.9	26.6
	50	21.8	23.5	24.8	25.8	26.9	28.4
	100	21.8	23.9	25.5	26.9	28.1	30.0
10	0	22.6	23.9	25.2	25.9	27.3	27.9
	50	22.6	24.4	25.9	26.8	28.1	29.6
	100	22.6	24.8	26.5	27.9	29.2	31.0
12	0	24.1	25.5	26.8	27.8	29.7	29.9
	50	24.1	26.0	27.7	28.5	30.3	31.4
	100	24.1	26.3	28.1	29.6	31.0	33.0

TABLE XXVIII (Continued)

Regeneration Level lb 66° Be H_2SO_4/cu ft	Percent Alkalinity	Capacity, Kgr $CaCo_3$/cu ft — Percent Sodium of Total Cations					
		0	20	40	60	80	100
14	0	25.3	--	28.4	29.5	--	31.6
	50	25.3	--	29.1	30.2	--	32.6
	100	25.3	--	29.8	31.0	--	34.5

TABLE XXIX

DOWEX SBR-P SILICA LEAKAGE RATING DATA (8)

Regen. Temp °F	Regen. Level lb NaOH/cu ft	Silica Leakage, Parts per Million SiO_2										
		Percent Silica of Total Anions										
		0	10	20	30	40	50	60	70	80	90	100
75	3.5	0	0.060	0.145	0.270	0.445	--	--	--	--	--	--
	5.0	0	0.025	0.060	0.105	0.145	0.210	0.270	0.3275	0.3775	0.4225	0.4575
	7.5	0	0.020	0.0375	0.0575	0.075	0.105	0.130	0.155	0.170	0.1875	0.200
	10	0	0.0075	0.020	0.0325	0.045	0.0675	0.0850	0.1075	0.125	0.140	0.150
95	3.5	0	0.060	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.60
	5.0	0	0.020	0.040	0.060	0.085	0.11	0.14	0.16	0.21	-.25	0.30
	7.5	0	0.015	0.025	0.000	0.055	0.070	0.085	0.10	0.12	0.135	0.15
	10	0	0.010	0.020	0.025	0.0325	0.045	0.060	0.075	0.090	0.11	0.125
120	3.5	0	0.025	0.06	0.10	0.15	0.195	0.24	0.28	--	--	--
	5.0	0	0.0075	0.0175	0.030	0.045	0.070	0.0975	0.12	0.135	0.145	0.15
	7.5	0	0.005	0.010	0.015	0.025	0.035	0.045	0.060	0.0725	0.0875	0.10
	10	0	0	0	0.005	0.010	0.0175	0.025	0.035	0.0425	0.0525	0.0625

TABLE XXX

DOWEX SBR-P CAPACITY RATING DATA (8)

Regeneration Level lb NaOH/cu ft	Capacity, Kgr $CaCO_3$/cu ft							
	Mixed Anions				Weak Acid Anions			
	Percent Weak Acids	Temperature, °F 75	95	120	Percent Silica	Temperature, °F 75	95	120
3.5	0	11.13	--	--	0	16.5	16.57	16.53
	10	11.53	--	--	10	16.2	16.5	16.47
	20	11.90	--	12.1	20	15.83	16.33	16.33
	30	12.23	12.23	12.5	30	15.33	16.13	16.3
	40	12.53	12.77	12.9	40	14.73	15.8	16.2
	50	12.86	13.2	13.3	50	14.1	15.2	16.07
	60	13.23	13.6	13.7	60	13.5	14.67	15.83
	70	13.53	14.0	14.1	70	12.87	14.2	15.6
	80	13.93	14.47	14.6	80	12.2	13.8	15.3
	90	14.47	14.87	15.1	90	11.6	13.4	15.07
	100	15.0	15.33	15.7	100	11.0	13.0	14.8
7.5	0	14.67	14.3	14.5	0	18.72	18.8	18.7
	10	14.96	14.77	14.93	10	18.67	18.67	18.7
	20	15.23	15.13	15.4	20	18.50	18.63	18.7
	30	15.50	15.5	15.8	30	18.23	18.57	18.7

TABLE XXX (Continued)

Regeneration Level lb NaOH/cu ft	Capacity, Kgr $CaCO_3$/cu ft							
	Mixed Anions				Weak Acid Anions			
	Percent Weak Acids	Temperature, °F 75	95	120	Percent Silica	Temperature, °F 75	95	120
	40	15.80	15.83	16.13	40	17.90	18.47	18.7
	50	16.00	16.17	16.53	50	17.50	18.3	18.7
	60	16.30	16.5	16.9	60	17.07	18.07	18.7
	70	16.67	16.83	17.3	70	16.67	17.73	18.7
	80	17.00	17.27	17.67	80	16.20	17.3	18.7
	90	17.50	17.67	18.1	90	15.80	17.0	18.7
	100	18.03	13.13	18.6	100	15.33	16.83	18.7
5.0	0	12.87	12.77	12.9	0	17.83	17.84	18.27
	10	13.23	13.27	13.27	10	17.67	17.84	18.2
	20	13.60	13.77	13.67	20	17.47	17.83	18.17
	30	13.90	14.1	14.07	30	17.07	17.73	18.13
	40	14.17	14.43	14.5	40	16.67	17.53	18.1
	50	14.50	14.77	14.9	50	16.1	17.2	18.0
	60	14.80	15.07	15.3	60	15.47	16.87	17.9
	70	15.10	15.4	15.8	70	14.8	16.5	17.8
	80	15.47	15.77	16.3	80	14.1	16.1	17.6

TABLE XXX (Continued)

Regeneration Level lb NaOH/cu ft	Capacity, Kgr $CaCO_3$/cu ft — Mixed Anions: Percent Weak Acids	Mixed Anions: Temperature, °F 75	95	120	Weak Acid Anions: Percent Silica	Weak Acid Anions: Temperature, °F 75	95	120
	90	15.90	16.13	16.9	90	13.5	15.8	17.4
	100	16.37	16.6	17.67	100	12.87	15.5	17.2
10.0	0	15.87	15.57	15.9	0	--	19.3	19.2
	10	16.07	15.9	16.3	10	--	19.2	19.2
	20	16.33	16.23	16.6	20	--	19.1	19.2
	30	16.56	16.5	16.9	30	18.84	19.07	19.2
	40	16.83	16.8	17.2	40	18.59	19.0	19.2
	50	17.00	17.07	17.53	50	18.28	18.9	19.2
	60	17.27	17.33	17.87	60	17.90	18.73	19.2
	70	17.57	17.6	18.2	70	17.53	18.4	19.2
	80	17.93	17.97	18.5	80	17.13	17.93	19.2
	90	18.43	18.4	18.8	90	16.83	17.6	19.2
	100	18.97	18.9	19.1	100	16.43	17.3	19.2

APPENDIX B

DOWEX HCR-S LINEAR CORRELATION COEFFICIENTS

DOWEX HCR-S LINEAR CORRELATION COEFFICIENTS

The Dowex HCR-S sodium leakage rating data were fit to the following model:

$$P_{NAL} = (\text{Ln } R - b)/m$$

where: P_{NAL} - Percent sodium leakage of corrected total anions

R - Regeneration level, lb 66° Be H_2SO_4/cu ft

m, b - Coefficients interpolated from Table XXXI

The Dowex HCR-S capacity rating data were fit to the following model:

$$\text{Cap} = (\text{LnR} - b)/m$$

where: Cap - Capacity, Kgr $CaCO_3$/cu ft

R - Regeneration level, lb 66° BeH_2SO_4/cu ft

m, b - Coefficients interpolated from Table XXXII

TABLE XXXI

DOWEX HCR-S SODIUM LEAKAGE CORRELATION COEFFICIENTS

Percent Sodium of Total Cations	m	b
0	-1.243*	2.503*
20	-0.4142	2.503
40	-0.2629	2.719
50	-0.1745	2.715
60	-0.1157	2.707
70	-0.08441	2.743
80	-0.06028	2.787
90	-0.04237	2.825
100	-0.03445	2.943

*Estimated

TABLE XXXII

DOWEX HCR-S CAPACITY CORRELATION COEFFICIENTS

Percent Sodium of Total Cations	m			b		
	Percent Alkalinity			Percent Alkalinity		
	0	50	100	0	50	100
0	0.1232	0.1231	0.1231	-0.4836	-0.4836	-0.4836
20	0.1113	0.1122	0.1143	-0.3579	-0.4332	-0.5296
40	0.1021	0.1009	0.1030	-0.2589	-0.3055	-0.4232
60	0.09210	0.09773	0.1051	-0.07632	-0.3120	-0.6274
80	0.07521	0.08387	0.1018	-0.2512	-0.05823	-0.6672
100	0.08824	0.09712	0.09893	-0.1556	-0.5628	-0.7571

APPENDIX C

PROGRAM LISTING

```
                   *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       37       562 FORMAT(/5X,'ENTER USER NAME (25 CHARACTERS MAXIMUM)',
                      1        /5X,1H?)
ISN       38           READ(NI,520)(UNAME(I),I=1,6)
ISN       39           IF(ECHO)WRITE(NO,5520)(UNAME(I),I=1,6)
ISN       41           WRITE(NO,563)
ISN       42       563 FORMAT(/5X,'ENTER DATE (20 CHARACTERS MAXIMUM)',
                      1        /5X,1H?)
ISN       43           READ(NI,520)(DATE(I),I=1,5)
ISN       44           IF(ECHO)WRITE(NO,5520)(DATE(I),I=1,5)
ISN       46           WRITE(NO,601)
ISN       47       601 FORMAT(//1X,'****ENTER SYSTEM DESIGN DATA****',//)
ISN       48       100 WRITE(NO,1602)
ISN       49      1602 FORMAT(5X,'ENTER NUMBER OF VESSELS IN SERIES ',
                      1       '(9 MAXIMUM)',/5X,1H?)
ISN       50           READ(NI,500)NV
ISN       51       500 FORMAT(I1)
ISN       52           IF(ECHO)WRITE(NO,5500)NV
ISN       54      5500 FORMAT(1X,I1)
ISN       55           IF(NV.LE.0) GO TO 100
ISN       56           WRITE(NO,602)
ISN       57       602 FORMAT(/5X,'ENTER NUMBER OF VESSELS IN SERIES WITH ',
                      1       'PARALLEL VESSELS',/5X,1H?)
ISN       58           READ(NI,500)LL
ISN       59           IF(ECHO)WRITE(NO,5500)LL
ISN       61           IF(LL.LE.0) GO TO 109
ISN       62       101 WRITE(NO,603)
ISN       63       603 FORMAT(/5X,'ENTER POSITIONS OF PARALLEL VESSELS',/
                      1       10X,'(EXAMPLE: 1,2,3,  )',/
                      2       10X,'(          -FIRST THREE POSITIONS HAVE ',
                      3       'PARALLEL VESSELS)',/5X,1H?)
ISN       64           READ(NI,500)(LLP(I),I=1,LL)
ISN       65           IF(ECHO)WRITE(NO,5500)(LLP(I),I=1,LL)
ISN       67           DO 103 I=1,LL
ISN       68           IF(LLP(I).LE.NV) GO TO 102
ISN       69           WRITE(NO,604)
ISN       70       604 FORMAT(1X,'****INVALID VESSEL POSITION****',/)
ISN       71           GO TO 101
ISN       72       102 LLPI=LLP(I)
ISN       73           WRITE(NO,605)LLPI
ISN       74       605 FORMAT(/5X,'ENTER NUMBER OF PARALLEL VESSELS IN ',
                      1       'POSITION ',I1,' (9 MAXIMUM)',/5X,1H?)
ISN       75           READ(NI,500)IVES(LLPI,2)
ISN       76           IF(ECHO)WRITE(NO,5500)IVES(LLPI,2)
ISN       78       103 CONTINUE
ISN       79       109 WRITE(NO,606)
ISN       80       606 FORMAT(5X,'ENTER VESSEL TYPE',/10X,'CX-CATION EXCHANGER',
                      1       /10X,'AX-ANION EXCHANGER'/10X,
                      2       'FG-FORCED DRAFT DEGASIFIER',
                      3       /10X,'VG-VACUUM DEGASIFIER',/)
ISN       81           DO 115 I=1,NV
ISN       82       110 WRITE(NO,607)I
ISN       83       607 FORMAT(5X,'POSITION ',I1,2H ?)
ISN       84           READ(NI,502)CMD
ISN       85           IF(ECHO)WRITE(NO,5502)CMD
ISN       87      5502 FORMAT(1X,A2)
ISN       88       502 FORMAT(A2)
```

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                  *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       89            DO 111 J=1,6
ISN       90            IF(CMD.EQ.VT(J)) GO TO 112
ISN       91        111 CONTINUE
ISN       92            WRITE(NO,608)
ISN       93        608 FORMAT(1X,'****INVALID VESSEL TYPE****',/1X,
                       1      'ENTER VT FOR LIST OF VESSEL TYPES',/)
ISN       94            GO TO 110
ISN       95        112 IF(J.NE.1) GO TO 113
ISN       96            WRITE(NO,606)
ISN       97            GO TO 110
ISN       98        113 IF(J.GE.5) GO TO 114
ISN       99            IF(J.EQ.2)IVES(I,1)=1
ISN      101            IF(J.EQ.3)IVES(I,1)=2
ISN      103            IF(J.NE.4) GO TO 115
ISN      104            IVES(I,1)=3
ISN      105            IMB=IMB+1
ISN      106            IVES(I,7)=IMB
ISN      107            GO TO 115
ISN      108        114 IF(J.EQ.5) IVES(I,1)=-1
ISN      110            IF(J.EQ.6) IVES(I,1)=-2
ISN      112        115 CONTINUE
                  C     WRITE(NO,609)
                  C 609 FORMAT(/5X,'ENTER REGENERATION MODES',/10X,
                  C    1      'INDICATE IF INDIVIDUAL OR SERIES '
                  C    2      ,'REGENERATION IS PERFORMED',/10X,
                  C    3      '0-INDIVIDUAL',/10X,'N-SERIES WHERE N IS ',
                  C    4      'POSITION OF VESSEL WITH WHICH SERIES ',/12X,
                  C    5      'REGENERATION IS PERFORMED',/)
                  C     DO 125 I=1,NV
                  C     IF(IVES(I,1).LE.0) GO TO 125
                  C     IF(IVES(I,5).GT.0) GO TO 125
                  C     WRITE(NO,610)I
                  C 610 FORMAT(5X,'VESSEL ',I1,2H ?)
                  C     READ(NI,500)IVES(I,5)
                  C     IF(ECHO)WRITE(NO,5500)IVES(I,5)
                  C     J=IVES(I,5)
                  C     IVES(J,5)=I
                  C 125 CONTINUE
ISN      113            WRITE(NO,611)
ISN      114        611 FORMAT(/5X,'ENTER SYSTEM FLOW RATE(GPM)',
                       1      /5X,1H?)
ISN      115            READ(NI,510)QSYS
ISN      116        510 FORMAT(F10.0)
ISN      117            IF(ECHO)WRITE(NO,5510)QSYS
ISN      119       5510 FORMAT(1X,E12.5)
ISN      120        130 WRITE(NO,612)
ISN      121        612 FORMAT(/5X,'ENTER WATER ANALYSIS UNITS',/10X,
                       1      '1-MG/L AS SUCH',/10X,'2-MG/L AS CACO3',
                       2      /10X,'3-MEQ/L',/5X,1H?)
ISN      122            READ(NI,500)IWAU
ISN      123            IF(ECHO)WRITE(NO,5500)IWAU
ISN      125            IF(IWAU.LT.1.OR.IWAU.GT.3) GO TO 130
ISN      126            WRITE(NO,613)
ISN      127        613 FORMAT(/5X,'ENTER INFLUENT WATER ANALYSIS')
ISN      128            DO 140 I=2,14
ISN      129            WRITE(NO,614)IONS(I-1)
```

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                  *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN      130        614 FORMAT(5X,A4,2H ?)
ISN      131            READ(NI,510)WAN(1,I)
ISN      132            IF(ECHO)WRITE(NO,5510)WAN(1,I)
ISN      134        140 CONTINUE
ISN      135            IF(SUBI)WRITE(NO,6650)
ISN      137       6650 FORMAT(1X,'WATCON')
ISN      138            CALL WATCON(IWAU,WAN,CNA)
ISN      139            IF(SUBI)WRITE(NO,6650)
ISN      141            IF(CNA.LE.0) GO TO 141
ISN      142            WRITE(NO,615)CNA
ISN      143        615 FORMAT(/5X,'SODIUM ADJUSTED TO',F10.2,'TO BALANCE')
ISN      144        141 WRITE(NO,616)
ISN      145        616 FORMAT(/5X,'ENTER INFLUENT TEMPERATURE(F)',
                       1        /5X,1H?)
ISN      146            READ(NI,510)WAN(1,15)
ISN      147            IF(ECHO)WRITE(NO,5510)WAN(1,15)
ISN      149            ICR=1
                  C     WRITE(NO,617)
                  C 617 FORMAT(/5X,'ENTER CATION RESIN REGENERANT',
                  C    1        /10X,'1-SULFURIC ACID',/10X,
                  C    2        '2-HYDROCHLORIC ACID',/5X,1H?)
                  C     READ(NI,500)ICR
                  C     IF(ECHO)WRITE(NO,5500)ICR
ISN      150            IAR=-1
ISN      151            WRITE(NO,625)
ISN      152        625 FORMAT(//1X,'****ENTER VESSEL DESIGN DATA****',//)
ISN      153            IBW=0
ISN      154            DO 200 J=1,NV
ISN      155            IF(IVES(J,1).LE.0) GO TO 190
ISN      156            IND=IVES(J,1)-2
ISN      157            VES(J,25)=5.0
ISN      158            IF(IBW.EQ.0)VES(J,25)=10.0
ISN      160            IBW=1
ISN      161            WRITE(NO,626)J
ISN      162        626 FORMAT(/1X,'*** VESSEL ',I1,' ***')
ISN      163            WRITE(NO,627)
ISN      164        627 FORMAT(/5X,'ENTER VESSEL DIAMETER (INCHES)',
                       1        /5X,1H?)
ISN      165            READ(NI,510)VES(J,1)
ISN      166            IF(ECHO)WRITE(NO,5510)VES(J,1)
ISN      168            WRITE(NO,628)
ISN      169        628 FORMAT(/5X,'ENTER VESSEL SIDE SHEET (INCHES)',
                       1        /5X,1H?)
ISN      170            READ(NI,510)VES(J,2)
ISN      171            IF(ECHO)WRITE(NO,5510)VES(J,2)
ISN      173            WRITE(NO,629)
ISN      174        629 FORMAT(/5X,'ENTER EFFECTIVE RESIN DEPTH (INCHES)',
                       1        /5X,1H?)
ISN      175            READ(NI,510)VES(J,5)
ISN      176            IF(ECHO)WRITE(NO,5510)VES(J,5)
ISN      178            WRITE(NO,630)
ISN      179        630 FORMAT(/5X,'ENTER INEFFECTIVE RESIN DEPTH (INCHES)',
                       1        /5X,1H?)
ISN      180            READ(NI,510)VES(J,4)
ISN      181            IF(ECHO)WRITE(NO,5510)VES(J,4)
ISN      183            WRITE(NO,631)
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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN     184       631 FORMAT(/5X,'ENTER VESSEL WALL THICKNESS (INCHES)',
                     1       /5X,1H?)
ISN     185       143 READ(NI,510)VES(J,7)
ISN     186           IF(ECHO)WRITE(NO,5510)VES(J,7)
                C     IF(IND.NE.1) GO TO 44
                C     IMB=IVES(J,7)
                C     WRITE(NO,632)
                C 632 FORMAT(/5X,'ENTER CATION/ANION RESIN RATIO',
                C    1       /5X,1H?)
                C     READ(NI,510)MBV(IMB,1)
                C     IF(ECHO)WRITE(NO,5510)MBV(IMB,1)
ISN     188        44 IF(IND)144,147,144
ISN     189       144 WRITE(NO,633)(CAT(L),L=1,2)
ISN     190       633 FORMAT(/5X,'ENTER ',A4,A2,' RESIN TYPE',/10X,
                C    1       '100-LIST OF GENERIC RESIN TYPE CODES',/10X,
                     2       '200-LIST OF DOWEX RESIN TYPE CODES',/5X,1H?)
                C    3       '300-LIST OF AMBERLITE RESIN TYPE CODES',/10X,
                C    4       '400-LIST OF IONAC RESIN TYPE CODES',/10X,
                C    5       '500-LIST OF DUOLITE RESIN TYPE CODES',/5X,1H?)
ISN     191      1144 READ(NI,503)IVES(J,3)
ISN     192           IF(ECHO)WRITE(NO,5503)IVES(J,3)
ISN     194      5503 FORMAT(1X,I3)
ISN     195       503 FORMAT(I3)
ISN     196           IRES=IVES(J,3)
ISN     197       145 IRES=IRES-100
ISN     198           IF(DIAG)WRITE(NO,6600)IRES
ISN     200      6600 FORMAT(1X,'IRES = ',I3)
ISN     201           IF(IRES.GT.100) GO TO 145
ISN     202           IF(IRES.GT.0) GO TO 1145
ISN     203           WRITE(NO,6633)
ISN     204      6633 FORMAT(/5X,'DOWEX RESIN TYPE CODES',
                     1        /10X,'201 - DOWEX HCR-S',
                     2        /10X,'221 - DOWEX SBR-P',
                     3        /10X,'241 - DOWEX WGR-2',
                     4        /5X,1H?)
ISN     205           GO TO 1144
ISN     206      1145 IF(IRES.LT.20) GO TO 146
ISN     207           GO TO 144
ISN     208       146 IVES(J,6)=ICR
ISN     209           GO TO 150
ISN     210       147 WRITE(NO,633)(ANI(L),L=1,2)
ISN     211           READ(NI,503)IVES(J,3)
ISN     212           IF(ECHO)WRITE(NO,5503)IVES(J,3)
ISN     214           IRES=IVES(J,3)
ISN     215       148 IRES=IRES-100
ISN     216           IF(DIAG)WRITE(NO,6600)IRES
ISN     218           IF(IRES.GT.100) GO TO 148
ISN     219           IF(IRES.GE.20) GO TO 149
ISN     220           GO TO 147
ISN     221       149 IVES(J,6)=IAR
ISN     222           WRITE(NO,634)
ISN     223       634 FORMAT(/5X,'ENTER REGENERANT TEMPERATURE(F)',
                     1       /5X,1H?)
ISN     224           READ(NI,510)VES(J,31)
ISN     225           IF(ECHO)WRITE(NO,5510)VES(J,31)
ISN     227       150 IF(IND.NE.0)WRITE(NO,635)(CAT(L),L=1,2)
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                  *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN     229             IF(IND.EQ.0)WRITE(NO,635)(ANI(L),L=1,2)                            00002760
ISN     231         635 FORMAT(/5X,'ENTER ',A4,A2,' RESIN REGENERANT LEVEL',               00002770
                       1        ' (LB/CU FT)',/5X,1H?)                                     00002780
ISN     232             READ(NI,510)VES(J,10)                                              00002790
ISN     233             IF(ECHO)WRITE(NO,5510)VES(J,10)                                    00002800
ISN     235             IF(IND.NE.0)WRITE(NO,636)(CAT(L),L=1,2)                            00002810
ISN     237             IF(IND.EQ.0)WRITE(NO,636)(ANI(L),L=1,2)                            00002820
ISN     239         636 FORMAT(/5X,'ENTER ',A4,A2,' RESIN CAPACITY EFFECTIVENESS',         00002830
                       1        ' (PERCENT)',/5X,1H?)                                      00002840
ISN     240             READ(NI,510)VES(J,12)                                              00002850
ISN     241             IF(ECHO)WRITE(NO,5510)VES(J,12)                                    00002860
ISN     243             VES(J,6)=PI*(VES(J,1)/2.0-VES(J,7))**2/144.0                       00002870
ISN     244             VES(J,3)=VES(J,6)*VES(J,5)/12.0                                    00002880
                  C     IF(IND.NE.1) GO TO 200                                             00002890
                  C 154 WRITE(NO,633)(ANI(L),L=1,2)                                        00002900
                  C     READ(NI,503)IMBV(IMB,1)                                            00002910
                  C     IF(ECHO)WRITE(NO,5503)IMBV(IMB,1)                                  00002920
                  C     IRES=IMBV(IMB,1)                                                   00002930
                  C 155 IRES=IRES-100                                                      00002940
                  C     IF(DIAG)WRITE(NO,6600)IRES                                         00002950
                  C     IF(IRES.GT.100) GO TO 155                                          00002960
                  C     IF(IRES.GE.20) GO TO 156                                           00002970
                  C     GO TO 154                                                          00002980
                  C 156 IMBV(IMB,2)=IAR                                                    00002990
                  C     WRITE(NO,634)                                                      00003000
                  C     READ(NI,510)VES(J,31)                                              00003010
                  C     IF(ECHO)WRITE(NO,5510)VES(J,31)                                    00003020
                  C     WRITE(NO,635)ANI                                                   00003030
                  C     READ(NI,510)MBV(IMB,4)                                             00003040
                  C     IF(ECHO)WRITE(NO,5510)MBV(IMB,4)                                   00003050
                  C     WRITE(NO,636)ANI                                                   00003060
                  C     READ(NI,510)MBV(IMB,6)                                             00003070
                  C     IF(ECHO)WRITE(NO,5510)MBV(IMB,6)                                   00003080
                  C     MBV(IMB,3)=VES(J,3)/(MBV(IMB,1)+1.0)                               00003090
                  C     MBV(IMB,2)=VES(J,3)-MBV(IMB,3)                                     00003100
ISN     245             GO TO 200                                                          00003110
ISN     246         190 WRITE(NO,638)                                                      00003120
ISN     247         638 FORMAT(/5X,'ENTER DEGASIFIER EFFLUENT CO2',                        00003130
                       1        ' CONCENTRATION',/5X,1H?)                                  00003140
ISN     248             READ(NI,510)WAN(J+1,14)                                            00003150
ISN     249             IF(ECHO)WRITE(NO,5510)WAN(J+1,14)                                  00003160
ISN     251             IF(SUBI)WRITE(NO,6660)                                             00003170
ISN     253        6660 FORMAT(1X,'DECON')                                                 00003180
ISN     254             CALL DECON(IWAU,WAN,J)                                             00003190
ISN     255             IF(SUBI)WRITE(NO,6660)                                             00003200
ISN     257         200 CONTINUE                                                           00003210
ISN     258             WRITE(NO,641)                                                      00003220
ISN     259         641 FORMAT(1X,'RUN CURRENT CASE OR EDIT',/5X,                          00003230
                       1        '1-RUN',/5X,'2-EDIT',/1X,1H?)                              00003240
ISN     260             READ(NI,500)IOP                                                    00003250
ISN     261             IF(ECHO)WRITE(NO,5500)IOP                                          00003260
ISN     263             IF(IOP.NE.1) GO TO 4000                                            00003270
ISN     264        1000 DO 1200 J=1,NV                                                     00003280
ISN     265             IF(IVES(J,2))1015,1015,1010                                        00003290
ISN     266        1010 VP=IVES(J,2)                                                       00003300
ISN     267             VES(J,29)=QSYS/VP                                                  00003310
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                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       268          GO TO 1020                                                         00003320
ISN       269     1015 IVES(J,2)=1                                                        00003330
ISN       270          VES(J,29)=QSYS                                                     00003340
ISN       271     1020 IF(IVES(J,1))1100,1100,1025                                        00003350
ISN       272     1025 IND=IVES(J,1)-2                                                    00003360
ISN       273          IF(IND)1030,1040,1050                                              00003370
ISN       274     1030 IF(SUBI)WRITE(NO,6670)                                             00003380
ISN       276     6670 FORMAT(1X,'CRESIN')                                                00003390
ISN       277          CALL CRESIN(J)                                                     00003400
ISN       278          IF(SUBI)WRITE(NO,6680)                                             00003410
ISN       280     6680 FORMAT(1X,'CRESIN',/1X,'CREGN')                                    00003420
ISN       281          CALL CREGN(J)                                                      00003430
ISN       282          IF(SUBI)WRITE(NO,6690)                                             00003440
ISN       284     6690 FORMAT(1X,'CREGN')                                                 00003450
ISN       285          GO TO 1200                                                         00003460
ISN       286     1040 IF(SUBI)WRITE(NO,6700)                                             00003470
ISN       288     6700 FORMAT(1X,'ARESIN')                                                00003480
ISN       289          CALL ARESIN(J)                                                     00003490
ISN       290          IF(SUBI)WRITE(NO,6710)                                             00003500
ISN       292     6710 FORMAT(1X,'ARESIN',/1X,'AREGN')                                    00003510
ISN       293          CALL AREGN(J)                                                      00003520
ISN       294          IF(SUBI)WRITE(NO,6720)                                             00003530
ISN       296     6720 FORMAT(1X,'AREGN')                                                 00003540
ISN       297          GO TO 1200                                                         00003550
ISN       298     1050 CONTINUE                                                           00003560
ISN       299          GO TO 1200                                                         00003570
ISN       300     1100 JP=J+1                                                             00003580
ISN       301          CO2=WAN(JP,14)                                                     00003590
ISN       302          DO 1105 I=1,15                                                     00003600
ISN       303          WAN(JP,I)=WAN(J,I)                                                 00003610
ISN       304     1105 CONTINUE                                                           00003620
ISN       305          WAN(JP,14)=CO2                                                     00003630
ISN       306          IND=IVES(JP,1)-2                                                   00003640
ISN       307          IF(IND)1200,1110,1200                                              00003650
ISN       308     1110 DO 1111 K=7,12                                                     00003660
ISN       309          TDS=TDS+WAN(JP,K)                                                  00003670
ISN       310     1111 CONTINUE                                                           00003680
ISN       311          WAN(JP,1)=TDS                                                      00003690
ISN       312          GO TO 1200                                                         00003700
ISN       313     1200 CONTINUE                                                           00003710
ISN       314          IF(SUBI)WRITE(NO,6730)                                             00003720
ISN       316     6730 FORMAT(1X,'MASBAL')                                                00003730
ISN       317          CALL MASBAL(NV,TOP,QG,QN,TA,TC)                                    00003740
ISN       318          IF(SUBI)WRITE(NO,6730)                                             00003750
ISN       320          IF(.NOT.DIAG) GO TO 3000                                           00003760
ISN       321          WRITE(NO,2600)                                                     00003770
ISN       322     2600 FORMAT(/5X,'WAN',/)                                                00003780
ISN       323          DO 2010 I=1,15                                                     00003790
ISN       324          WRITE(NO,2601)I,WAN(1,I)                                           00003800
ISN       325     2601 FORMAT(5X,I2,5X,E12.6)                                             00003810
ISN       326     2010 CONTINUE                                                           00003820
ISN       327          DO 2100 J=1,NV                                                     00003830
ISN       328          K=J+1                                                              00003840
ISN       329          WRITE(NO,2602)J                                                    00003850
ISN       330     2602 FORMAT(/5X,'VESSEL ',I1,//)                                        00003860
ISN       331          WRITE(NO,2603)                                                     00003870
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                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN   332      2603 FORMAT(5X,'IVES',/)
ISN   333           DO 2605 I=1,8
ISN   334           WRITE(NO,2604)I,IVES(J,I)
ISN   335      2604 FORMAT(5X,I1,5X,I3)
ISN   336      2605 CONTINUE
ISN   337           WRITE(NO,2606)
ISN   338      2606 FORMAT(/5X,'VES',/)
ISN   339           DO 2608 I=1,32
ISN   340           WRITE(NO,2607)I,VES(J,I)
ISN   341      2607 FORMAT(5X,I2,5X,E12.6)
ISN   342      2608 CONTINUE
ISN   343           WRITE(NO,2600)
ISN   344           DO 2609 I=1,15
ISN   345           WRITE(NO,2601)I,WAN(K,I)
ISN   346      2609 CONTINUE
ISN   347      2100 CONTINUE
ISN   348           WRITE(NO,2620)TOP
ISN   349      2620 FORMAT(/5X,'TOP=',F10.2)
              C     GO TO 4000
ISN   350           NV1=NV+1
ISN   351      3000 DO 3001 I=1,NV1
ISN   352           CALL CONWAT(IWAU,WAN,I)
ISN   353      3001 CONTINUE
ISN   354      3002 IPG=IPG+1
ISN   355           CALL HEADG(IPG)
ISN   356           WRITE(NO,3600)
ISN   357      3600 FORMAT(5X,'**** OUTPUT SELECTION ****',//5X,
                   1        'ENTER OUTPUT TYPE',/10X,'0 - COMPLETE',
                   2        /10X,'1 - SYSTEM DESIGN',/10X,'2 - SYSTEM ',
                   3        'PERFORMANCE',/10X,'3 - VESSEL DESIGN',/10X,
                   4        '4 - VESSEL PERFORMANCE',/10X,'5 - EDIT INPUT',
                   5        ' DATA',/10X,'6 - EXIT PROGRAM',/5X,1H?)
ISN   358           READ(NI,500)IOT
ISN   359           IF(ECHO)WRITE(NO,5500)IOT
ISN   361           IF(IOT.EQ.0) GO TO 3005
ISN   362           GO TO(3010,3100,3200,3300,4000,5000),IOT
ISN   363      3005 COUT=.TRUE.
ISN   364      3010 IPG=IPG+1
ISN   365           CALL HEADG(IPG)
ISN   366           WRITE(NO,3601)
ISN   367      3601 FORMAT(5X,'**** OVERALL SYSTEM DESIGN ****',//)
ISN   368           WRITE(NO,3602)QSYS
ISN   369      3602 FORMAT(5X,'SYSTEM FLOW RATE',10X,F6.1,' GPM')
ISN   370           WRITE(NO,3603)(WUNIT(IWAU,I),I=1,4)
ISN   371      3603 FORMAT(/5X,'INFLUENT WATER ANALYSIS',7X,4A4,/)
ISN   372           DO 3020 I=2,14
ISN   373           WRITE(NO,3604)IONS(I-1),WAN(1,I)
ISN   374      3604 FORMAT(10X,A4,21X,F10.4)
ISN   375      3020 CONTINUE
ISN   376           WRITE(NO,3605)WAN(1,15)
ISN   377      3605 FORMAT(/5X,'INFLUENT TEMPERATURE',6X,F6.1,' F')
ISN   378           WRITE(NO,3606)
ISN   379      3606 FORMAT(/5X,'SYSTEM CONFIGURATION',/)
ISN   380           DO 3030 I=1,NV
ISN   381           IVT=IVES(I,1)+3
ISN   382           GO TO(3021,3022,3023,3023,3024,3025),IVT
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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN      383      3021 WRITE(NO,3607)I                                                        00004440
ISN      384      3607 FORMAT(10X,'VESSEL ',I1,12X,'VACUUM DEGASIFIER')                       00004450
ISN      385           GO TO 3030                                                             00004460
ISN      386      3022 WRITE(NO,3608)I                                                        00004470
ISN      387      3608 FORMAT(10X,'VESSEL ',I1,12X,'FORCED DRAFT DEGASIFIER')                 00004480
ISN      388           GO TO 3030                                                             00004490
ISN      389      3023 WRITE(NO,3609)I                                                        00004500
ISN      390      3609 FORMAT(10X,'VESSEL ',I1,12X,'CATION EXCHANGER')                        00004510
ISN      391           GO TO 3030                                                             00004520
ISN      392      3024 WRITE(NO,3610)I                                                        00004530
ISN      393      3610 FORMAT(10X,'VESSEL ',I1,12X,'ANION EXCHANGER')                         00004540
ISN      394           GO TO 3030                                                             00004550
ISN      395      3025 WRITE(NO,3611)I                                                        00004560
ISN      396      3611 FORMAT(10X,'VESSEL ',I1,12X,'MIXED BED EXCHANGER')                     00004570
ISN      397      3030 CONTINUE                                                               00004580
ISN      398           WRITE(NO,3612)                                                         00004590
ISN      399      3612 FORMAT(/5X,'NUMBER OF VESSELS IN PARALLEL',/)                          00004600
ISN      400           DO 3040 I=1,NV                                                         00004610
ISN      401           WRITE(NO,3613)I,IVES(I,2)                                              00004620
ISN      402      3613 FORMAT(10X,'VESSEL ',I1,12X,I1)                                        00004630
ISN      403      3040 CONTINUE                                                               00004640
ISN      404           WRITE(NO,3614)                                                         00004650
ISN      405      3614 FORMAT(/5X,'REGENERANT CHEMICALS',/10X,                                00004660
                     1         'CATION RESIN',8X,'93 PERCENT SULFURIC ',                      00004670
                     2         'ACID',/10X,'ANION RESIN',9X,'50 PERCENT ',                    00004680
                     3         'SODIUM HYDROXIDE')                                            00004690
ISN      406           IF(COUT) GO TO 3100                                                    00004700
ISN      407           GO TO 3002                                                             00004710
ISN      408      3100 IPG=IPG+1                                                              00004720
ISN      409           CALL HEADG(IPG)                                                        00004730
ISN      410           WRITE(NO,3620)                                                         00004740
ISN      411      3620 FORMAT(5X,'**** OVERALL SYSTEM PERFORMANCE ****',//)                   00004750
ISN      412           WRITE(NO,3621)QG,QN,TOP                                                00004760
ISN      413      3621 FORMAT(5X,'THROUGHPUT',9X,'GALLONS PER REGENERATION',                  00004770
                     1         /10X,'GROSS',11X,F10.0,/10X,'NET',13X,F10.0,                   00004780
                     2         //5X,'OPERATING TIME',11X,F7.2,' HOURS')                       00004790
ISN      414           WRITE(NO,3622)(WUNIT(IWAU,I),I=1,4)                                    00004800
ISN      415      3622 FORMAT(/5X,'EFFLUENT WATER ANALYSIS',7X,4A4,/)                         00004810
ISN      416           DO 3110 I=2,14                                                         00004820
ISN      417           WRITE(NO,3604)IONS(I-1),WAN(NV+1,I)                                    00004830
ISN      418      3110 CONTINUE                                                               00004840
ISN      419           WRITE(NO,3623)TA,TC                                                    00004850
ISN      420      3623 FORMAT(/5X,'TOTAL REGENERANT',3X,'GALLONS PER ',                       00004860
                     1         'REGENERATION',/10X,'ACID',18X,F6.2,                           00004870
                     2         /10X,'CAUSTIC',15X,F6.2)                                       00004880
ISN      421           IF(COUT) GO TO 3220                                                    00004890
ISN      422           GO TO 3002                                                             00004900
ISN      423      3200 WRITE(NO,3630)NV                                                       00004910
ISN      424      3630 FORMAT(/5X,'ENTER VESSEL NUMBER OR NUMBERS',                           00004920
                     1         /10X,'FORMATS - N OR',/18X,'- N M',                            00004930
                     2         /10X,'WHERE:  N - INITIAL VESSEL',                             00004940
                     3         /18X,'M - FINAL VESSEL',                                       00004950
                     4         /10X,'EXAMPLE:  1 ',I1,' - OUTPUT FOR ALL ',                   00004960
                     5         'VESSELS',/5X,1H?)                                             00004970
ISN      425           READ(NI,3500)IVI,IVF                                                   00004980
ISN      426      3500 FORMAT(I1,1X,I1)                                                       00004990
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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN     427            IF(ECHO)WRITE(NO,3560)IVI,IVF
ISN     429       3560 FORMAT(1X,I1,1X,I1)
ISN     430            IF(IVF.NE.0) GO TO 3210
ISN     431            IVF=IVI
ISN     432            GO TO 3230
ISN     433       3210 IF(IVI.GT.IVF) GO TO 3200
ISN     434            GO TO 3230
ISN     435       3220 IVI=1
ISN     436            IVF=NV
ISN     437       3230 DO 3290 I=IVI,IVF
ISN     438            IPG=IPG+1
ISN     439            CALL HEADG(IPG)
ISN     440            WRITE(NO,3640)I
ISN     441       3640 FORMAT(5X,'**** VESSEL ',I1,' DESIGN****',//)
ISN     442            IF(IVES(I,1).LT.0) GO TO 3280
ISN     443            WRITE(NO,3641)VES(I,1),VES(I,7),VES(I,2),VES(I,6),VES(I,24)
ISN     444       3641 FORMAT(5X,'OUTSIDE DIAMETER (INCHES)',11X,F10.1,
                      1        //5X,'WALL THICKNESS (INCHES)',15X,F10.3,
                      2        //5X,'STRAIGHT SIDE (INCHES)',14X,F10.1,
                      3        //5X,'AREA (SQUARE FEET)',19X,F10.2,
                      4        //5X,'FLOW RATE PER VESSEL (GPM)',10X,F10.1)
ISN     445            IF(IVES(I,3).EQ.201)IRES=1
ISN     447            IF(IVES(I,3).EQ.221)IRES=2
ISN     449            IF(IVES(I,3).EQ.241)IRES=3
ISN     451            WRITE(NO,3642)(RESIN(IRES,J),J=1,2)
ISN     452       3642 FORMAT(/5X,'RESIN TYPE',29X,'DOWEX ',2A4)
ISN     453            TVOL=VES(I,6)*(VES(I,4)+VES(I,5))/12.0
ISN     454            WRITE(NO,3643)VES(I,5),VES(I,3),VES(I,4),TVOL,VES(I,12)
ISN     455       3643 FORMAT(/5X,'EFFECTIVE RESIN DEPTH (INCHES)',6X,F10.1,
                      1        //5X,'EFFECTIVE RESIN VOLUME (CU FT)',6X,F10.1,
                      2        //5X,'INEFFECTIVE RESIN DEPTH (INCHES)',4X,F10.1,
                      3        //5X,'TOTAL RESIN VOLUME (CU FT)',10X,F10.1,
                      4        //5X,'CAPACITY EFFECTIVENESS (PERCENT)',4X,F10.1)
ISN     456            IF(IVES(I,1).EQ.1)WRITE(NO,3644)VES(I,10)
ISN     458       3644 FORMAT(/5X,'REGENERANT LEVEL (LB 93% H2SO4/CU FT)',5X,
                      1        F4.1)
ISN     459            IF(IVES(I,1).EQ.2)WRITE(NO,3645)VES(I,10)
ISN     461       3645 FORMAT(/5X,'REGENERANT LEVEL (LB 100% NAOH/CU FT)',5X,
                      1        F4.1)
ISN     462            IF(IVES(I,1).EQ.2)WRITE(NO,3646)VES(I,31)
ISN     464       3646 FORMAT(/5X,'REGENERATION TEMPERATURE (F)',8X,F10.1)
ISN     465            GO TO 3290
ISN     466       3280 IF(IVES(I,1).EQ.-1)WRITE(NO,3650)(WUNIT(IWAU,J),J=1,4),
                      1                                    WAN(I+1,14)
ISN     468       3650 FORMAT(5X,'FORCED DRAFT DEGASIFIER',14X,4A4,
                      1        //5X,'EFFLUENT CARBON DIOXIDE',17X,F10.4)
ISN     469            IF(IVES(I,1).EQ.-2)WRITE(NO,3651)(WUNIT(IWAU,J),J=1,4),
                      1                                     WAN(I+1,14)
ISN     471       3651 FORMAT(5X,'VACUUM DEGASIFIER',20X,4A4,
                      1        //5X,'EFFLUENT CARBON DIOXIDE',17X,F10.4)
ISN     472       3290 CONTINUE
ISN     473            IF(COUT) GO TO 3320
ISN     474            GO TO 3002
ISN     475       3300 WRITE(NO,3630)
ISN     476            READ(NI,3500)IVI,IVF
ISN     477            IF(ECHO)WRITE(NO,3560)IVI,IVF
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ISN      479           IF(IVF.NE.0) GO TO 3310                                           00005560
ISN      480           IVF=IVI                                                           00005570
ISN      481           GO TO 3320                                                        00005580
ISN      482      3310 IF(IVI.GT.IVF) GO TO 3300                                         00005590
ISN      483      3320 DO 3390 I=IVI,IVF                                                 00005600
ISN      484           IPG=IPG+1                                                         00005610
ISN      485           CALL HEADG(IPG)                                                   00005620
ISN      486           WRITE(NO,3660)I                                                   00005630
ISN      487      3660 FORMAT(5X,'**** VESSEL ',I1,' PERFORMANCE****',//)                00005640
ISN      488           IF(IVES(I,1).LT.0) GO TO 3380                                     00005650
ISN      489           UTIL=VES(I,9)/VES(I,8)*R100                                       00005660
ISN      490           WRITE(NO,3661)VES(I,13),VES(I,8),VES(I,9),UTIL,VES(I,14)          00005670
ISN      491      3661 FORMAT(5X,'CAPACITY:',/10X,'RESIN (KGR AS CACO3/CU FT)',          00005680
                     1        6X,F10.2,/10X,'VESSEL (KGR AS CACO3)',11X,F10.2,           00005690
                     2        /10X,'LOAD (KGR AS CACO3)',13X,F10.2,/10X,                 00005700
                     3        'UTILIZATION (PERCENT)',11X,F10.2,/5X,                     00005710
                     4        'THROUGHPUT (GAL/REGEN)',13X,F10.0)                        00005720
ISN      492           WRITE(NO,3662)(WUNIT(IWAU,J),J=1,4)                               00005730
ISN      493      3662 FORMAT(/5X,'EFFLUENT WATER ANALYSIS',7X,4A4,/)                    00005740
ISN      494           DO 3330 J=2,14                                                    00005750
ISN      495           WRITE(NO,3604)IONS(J-1),WAN(I+1,J)                                00005760
ISN      496      3330 CONTINUE                                                          00005770
ISN      497           WRITE(NO,3663)                                                    00005780
ISN      498      3663 FORMAT(/5X,'REGENERATION SUMMARY:',//12X,                         00005790
                     1        'STEP',16X,'FLOW',10X,'VOLUME',8X,                         00005800
                     2        'DURATION',/31X,'(GPM)',11X,'(GAL)',9X,                    00005810
                     3        '(MIN)',/)                                                 00005820
ISN      499           WRITE(NO,3664)VES(I,20),VES(I,15),VES(I,25)                       00005830
ISN      500      3664 FORMAT(5X,'BACKWASH',13X,F10.1,5X,F10.0,5X,F10.2)                 00005840
ISN      501           WRITE(NO,3665)                                                    00005850
ISN      502      3665 FORMAT(5X,'REGN APPLICATION',/10X,'REGENERANT')                   00005860
ISN      503           IVTP=IVES(I,1)                                                    00005870
ISN      504           GO TO(3340,3350),IVTP                                             00005880
ISN      505      3340 IF(VES(I,22).LT.0) GO TO 3345                                     00005890
ISN      506           WRITE(NO,3666)VES(I,22),VES(I,17),VES(I,26)                       00005900
ISN      507      3666 FORMAT(15X,'AT 6% H2SO4',F10.1,5X,F10.0,5X,F10.2)                 00005910
ISN      508           WRITE(NO,3667)VES(I,21),VES(I,16),VES(I,26)                       00005920
ISN      509      3667 FORMAT(10X,'DILUTION WATER',2X,F10.1,5X,F10.0,5X,F10.2)           00005930
ISN      510           GO TO 3360                                                        00005940
ISN      511      3345 WRITE(NO,3668)RQ(I,1),RVOL(I,1),TSTEP(I,1)                        00005950
ISN      512      3668 FORMAT(15X,'AT 2% H2SO4',F10.1,5X,F10.0,5X,F10.2)                 00005960
ISN      513           IF(ISTEP(I).LT.2) GO TO 3346                                      00005970
ISN      514           WRITE(NO,3669)RQ(I,2),RVOL(I,2),TSTEP(I,2)                        00005980
ISN      515      3669 FORMAT(15X,'AT 4% H2SO4',F10.1,5X,F10.0,5X,F10.2)                 00005990
ISN      516           IF(ISTEP(I).LT.3) GO TO 3346                                      00006000
ISN      517           WRITE(NO,3666)RQ(I,3),RVOL(I,3),TSTEP(I,3)                        00006010
ISN      518           IF(ISTEP(I).LT.4) GO TO 3346                                      00006020
ISN      519           WRITE(NO,3670)RQ(I,4),RVOL(I,4),TSTEP(I,4)                        00006030
ISN      520      3670 FORMAT(15X,'AT 8% H2SO4',F10.1,5X,F10.0,5X,F10.2)                 00006040
ISN      521      3346 WRITE(NO,3671)                                                    00006050
ISN      522      3671 FORMAT(10X,'DILUTION WATER')                                      00006060
ISN      523           WRITE(NO,3668)VES(I,21),DVOL(I,1),TSTEP(I,1)                      00006070
ISN      524           IF(ISTEP(I).LT.2) GO TO 3360                                      00006080
ISN      525           WRITE(NO,3669)VES(I,21),DVOL(I,2),TSTEP(I,2)                      00006090
ISN      526           IF(ISTEP(I).LT.3) GO TO 3360                                      00006100
ISN      527           WRITE(NO,3666)VES(I,21),DVOL(I,3),TSTEP(I,3)                      00006110
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                   *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN     528           IF(ISTEP(I).LT.4) GO TO 3360                                          00006120
ISN     529           WRITE(NO,3670)VES(I,21),DVOL(I,4),TSTEP(I,4)                          00006130
ISN     530           GO TO 3360                                                            00006140
ISN     531      3350 WRITE(NO,3672)VES(I,22),VES(I,17),VES(I,26)                           00006150
ISN     532      3672 FORMAT(15X,'AT 3% NAOH',1X,F10.1,5X,F10.0,5X,F10.2)                   00006160
ISN     533           WRITE(NO,3671)                                                        00006170
ISN     534           WRITE(NO,3672)VES(I,21),VES(I,16),VES(I,26)                           00006180
ISN     535      3360 WRITE(NO,3673)VES(I,23),VES(I,18),VES(I,27)                           00006190
ISN     536      3673 FORMAT(5X,'SLOW RINSE',11X,F10.1,5X,F10.0,5X,F10.2)                   00006200
ISN     537           WRITE(NO,3674)VES(I,24),VES(I,19),VES(I,28)                           00006210
ISN     538      3674 FORMAT(5X,'FAST RINSE',11X,F10.1,5X,F10.0,5X,F10.2)                   00006220
ISN     539      3380 IF(IVES(I,1).EQ.-1)WRITE(NO,3650)(WUNIT(IWAU,J),J=1,4),               00006230
                     1                                  WAN(I+1,14)                         00006240
ISN     541           IF(IVES(I,1).EQ.-2)WRITE(NO,3651)(WUNIT(IWAU,J),J=1,4),               00006250
                     1                                  WAN(I+1,14)                         00006260
ISN     543      3390 CONTINUE                                                              00006270
ISN     544           GO TO 3002                                                            00006280
ISN     545      4000 CONTINUE                                                              00006290
ISN     546           WRITE(NO,4600)                                                        00006300
ISN     547      4600 FORMAT(//1X,'****EDIT MENU****',//5X,                                 00006310
                     1        'O - RUN CURRENT CASE',/5X,                                   00006320
                     2        '1 - LIST PROBLEM IDENTIFICATION',/5X,                        00006330
                     3        '2 - LIST SYSTEM DESIGN DATA',/5X,                            00006340
                     4        '3 - LIST VESSEL DESIGN DATA',/5X,                            00006350
                     5        '4 - LIST VESSEL DESIGN DEFAULTS',/5X,                        00006360
                C    6        '5 - EDIT PROBLEM IDENTIFICATION',/5X,                        00006370
                C    7        '6 - EDIT SYSTEM DESIGN DATA',/5X,                            00006380
                C    8        '7 - EDIT VESSEL DESIGN DATA',/5X,                            00006390
                     9        '8 - EDIT VESSEL DESIGN DEFAULTS',/5X,                        00006400
                     0        '9 - NEW PROBLEM',/5X,1H?)                                    00006410
ISN     548           READ(NI,500)IEM                                                       00006420
ISN     549           IF(ECHO)WRITE(NO,5500)IEM                                             00006430
ISN     551           IF(IEM.EQ.0)GO TO 1000                                                00006440
ISN     552           GO TO(4010,4020,4030,4040,4100,4200,4300,4400,10),IEM                 00006450
ISN     553      4010 WRITE(NO,4605)                                                        00006460
ISN     554      4605 FORMAT(/5X,'****PROBLEM IDENTIFICATION****')                          00006470
ISN     555           WRITE(NO,4606)(TITLE(I),I=1,10),(IDNUM(J),J=1,4)                      00006480
ISN     556      4606 FORMAT(/5X,'TITLE: ',10A4,//5X,'ID NO: ',4A4)                         00006490
ISN     557           WRITE(NO,4607)(UNAME(I),I=1,6),(DATE(J),J=1,5)                        00006500
ISN     558      4607 FORMAT(/5X,'USER NAME: ',6A4,//5X,'DATE: ',5A4)                       00006510
ISN     559           WRITE(NO,4610)                                                        00006520
ISN     560      4610 FORMAT(//1X,'****ENTER SELECTION****',/5X,                            00006530
                     1        'O - RETURN TO EDIT MENU',/5X,                                00006540
                     2        '1 - RUN CURRENT CASE',/1X,1H?)                               00006550
ISN     561           READ(NI,500)ISL                                                       00006560
ISN     562           IF(ECHO)WRITE(NO,5500)ISL                                             00006570
ISN     564           ISL=ISL+1                                                             00006580
ISN     565           GO TO (4000,1000),ISL                                                 00006590
ISN     566      4020 WRITE(NO,4611)                                                        00006600
ISN     567      4611 FORMAT(/5X,'****SYSTEM DESIGN DATA****',/)                            00006610
ISN     568           WRITE(NO,3602)QSYS                                                    00006620
ISN     569           WRITE(NO,3603)(WUNIT(IWAU,I),I=1,4)                                   00006630
ISN     570           DO 4021 I=2,14                                                        00006640
ISN     571           WRITE(NO,3604)IONS(I-1),WAN(1,I)                                      00006650
ISN     572      4021 CONTINUE                                                              00006660
ISN     573           WRITE(NO,3605)WAN(1,15)                                               00006670
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ISN      574         WRITE(NO,3606)                                                    00006680
ISN      575         DO 4027 I=1,NV                                                    00006690
ISN      576         IVT=IVES(I,1)+3                                                   00006700
ISN      577         GO TO (4022,4023,4025,4026),IVT                                   00006710
ISN      578    4022 WRITE(NO,3607)I                                                   00006720
ISN      579         GO TO 4027                                                        00006730
ISN      580    4023 WRITE(NO,3608)I                                                   00006740
ISN      581         GO TO 4027                                                        00006750
ISN      582    4024 WRITE(NO,3609)I                                                   00006760
ISN      583         GO TO 4027                                                        00006770
ISN      584    4025 WRITE(NO,3610)I                                                   00006780
ISN      585         GO TO 4027                                                        00006790
ISN      586    4026 WRITE(NO,3611)I                                                   00006800
ISN      587    4027 CONTINUE                                                          00006810
ISN      588         WRITE(NO,3612)                                                    00006820
ISN      589         DO 4028 I=1,NV                                                    00006830
ISN      590         WRITE(NO,3613)I,IVES(I,2)                                         00006840
ISN      591    4028 CONTINUE                                                          00006850
ISN      592         WRITE(NO,4610)                                                    00006860
ISN      593         READ(NI,500)ISL                                                   00006870
ISN      594         IF(ECHO)WRITE(NO,5500)ISL                                         00006880
ISN      596         ISL=ISL+1                                                         00006890
ISN      597         GO TO (4000,1000),ISL                                             00006900
ISN      598    4030 WRITE(NO,3630)NV                                                  00006910
ISN      599         READ(NI,3500)IVI,IVF                                              00006920
ISN      600         IF(ECHO)WRITE(NO,3560)IVI,IVF                                     00006930
ISN      602         IF(IVF.NE.0)GO TO 4031                                            00006940
ISN      603         IVF=IVI                                                           00006950
ISN      604         GO TO 4032                                                        00006960
ISN      605    4031 IF(IVI.GT.IVF)GO TO 4030                                          00006970
ISN      606    4032 DO 4039 I=IVI,IVF                                                 00006980
ISN      607         WRITE(NO,3640)I                                                   00006990
ISN      608         IF(IVES(I,1).LT.0)GO TO 4038                                      00007000
ISN      609         WRITE(NO,4620)VES(I,1),VES(I,7),VES(I,2)                          00007010
ISN      610    4620 FORMAT(5X,'OUTSIDE DIAMETER(INCHES)',11X,F10.1,                   00007020
                    1      //5X,'WALL THICKNESS(INCHES)',15X,F10.3,                    00007030
                    2      //5X,'STRAIGHT SIDE(INCHES)',14X,F10.1)                     00007040
ISN      611         IF(IVES(I,3).EQ.201)IRES=1                                        00007050
ISN      613         IF(IVES(I,3).EQ.221)IRES=2                                        00007060
ISN      615         IF(IVES(I,3).EQ.241)IRES=3                                        00007070
ISN      617         WRITE(NO,3642)(RESIN(IRES,J),J=1,2)                               00007080
ISN      618         WRITE(NO,4621)VES(I,5),VES(I,4),VES(I,12)                         00007090
ISN      619    4621 FORMAT(/5X,'EFFECTIVE RESIN DEPTH(INCHES)',6X,F10.1,              00007100
                    1      //5X,'INEFFECTIVE RESIN DEPTH(INCHES)',4X,F10.1,            00007110
                    2      //5X,'CAPCITY EFFECTIVENESS(PERCENT)',4X,F10.1)             00007120
ISN      620         IF(IVES(I,1).EQ.1)WRITE(NO,3644)VES(I,10)                         00007130
ISN      622         IF(IVES(I,1).EQ.2)WRITE(NO,3645)VES(I,10)                         00007140
ISN      624         IF(IVES(I,1).EQ.2)WRITE(NO,3646)VES(I,31)                         00007150
ISN      626         GO TO 4039                                                        00007160
ISN      627    4038 IF(IVES(I,1).EQ.-1)WRITE(NO,3650)(WUNIT(IWAU,J),J=1,4),           00007170
                    1                                        WAN(I+1,14)               00007180
ISN      629         IF(IVES(I,1).EQ.-2)WRITE(NO,3651)(WUNIT(IWAU,J),J=1,4),           00007190
                    1                                        WAN(I+1,14)               00007200
ISN      631    4039 CONTINUE                                                          00007210
ISN      632         WRITE(NO,4610)                                                    00007220
ISN      633         READ(NI,500)ISL                                                   00007230
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ISN       634              IF(ECHO)WRITE(NO,5500)ISL
ISN       636              ISL=ISL+1
ISN       637              GO TO (4000,1000),ISL
ISN       638         4040 WRITE(NO,3630)NV
ISN       639              READ(NI,3500)IVI,IVF
ISN       640              IF(ECHO)WRITE(NO,3560)IVI,IVF
ISN       642              IF(IVF.NE.0) GO TO 4041
ISN       643              IVF=IVI
ISN       644              GO TO 4042
ISN       645         4041 IF(IVI.GT.IVF) GO TO 4040
ISN       646         4042 DO 4060 I=IVI,IVF
ISN       647              WRITE(NO,4630)I
ISN       648         4630 FORMAT(5X,'****VESSEL ',I1,' DEFAULTS****',//)
ISN       649              IF(IVES(I,1).LT.0) GO TO 4060
ISN       650         4631 FORMAT(5X,'BACKWASH TIME(MIN): ',25X,F10.1)
ISN       651              IF(IVES(I,3).EQ.201)IRES=1
ISN       653              IF(IVES(I,3).EQ.221)IRES=2
ISN       655              IF(IVES(I,3).EQ.241)IRES=3
ISN       657              GO TO (4043,4044,4045),IRES
ISN       658         4043 BDEX=50.0
ISN       659              FRV=25.0*VES(I,3)
ISN       660              GO TO 4046
ISN       661         4044 BDEX=50.0
ISN       662              FRV=100.0*VES(I,3)
ISN       663              APTM=60.0
ISN       664              GO TO 4046
ISN       665         4045 BDEX=50.0
ISN       666              FRV=75.0*VES(I,3)
ISN       667         4046 IF(VES(I,30).NE.0)BDEX=VES(I,30)
ISN       669              WRITE(NO,4632)BDEX
ISN       670         4632 FORMAT(/5X,'BED EXPANSION(%):',28X,F10.1)
ISN       671              IF(IRES.NE.2) GO TO 4047
ISN       672              IF(VES(I,26).NE.0)APTM=VES(I,26)
ISN       674              WRITE(NO,4633)APTM
ISN       675         4633 FORMAT(/5X,'ANION REGENERANT APPLICATION TIME(MIN): ',
                         1        5X,F10.1)
ISN       676         4047 IF(VES(I,18).NE.0)GO TO 4048
ISN       677              SRV=(VES(I,3)/2.0+0.75*VES(I,6))*1.5*7.48
ISN       678              GO TO 4049
ISN       679         4048 SRV=VES(I,18)
ISN       680         4049 WRITE(NO,4634)SRV
ISN       681         4634 FORMAT(/5X,'SLOW RINSE VOLUME(GAL):',21X,F10.1)
ISN       682              IF(VES(I,19).NE.0)FRV=VES(I,19)
ISN       684              WRITE(NO,4635)FRV
ISN       685         4635 FORMAT(/5X,'FAST RINSE VOLUME(GAL):',21X,F10.1)
ISN       686         4060 CONTINUE
ISN       687              WRITE(NO,4610)
ISN       688              READ(NI,500)ISL
ISN       689              IF(ECHO)WRITE(NO,5500)ISL
ISN       691              ISL=ISL+1
ISN       692              GO TO (4000,1000),ISL
ISN       693         4100 CONTINUE
ISN       694         4200 CONTINUE
ISN       695         4300 CONTINUE
ISN       696         4400 WRITE(NO,3630)NV
ISN       697              READ(NI,3500)IVI,IVF
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ISN    698          IF(ECHO)WRITE(NO,3560)IVI,IVF                                       00007800
ISN    700          IF(IVF.NE.0)GO TO 4401                                              00007810
ISN    701          IVF=IVI                                                             00007820
ISN    702          GO TO 4402                                                          00007830
ISN    703     4401 IF(IVI.GT.IVF) GO TO 4400                                           00007840
ISN    704     4402 DO 4500 I=IVI,IVF                                                   00007850
ISN    705          IF(IVES(I,1).LT.0) GO TO 4500                                       00007860
ISN    706     4403 WRITE(NO,4650)I                                                     00007870
ISN    707     4650 FORMAT(5X,'****EDIT VESSEL ',I1,' DEFAULTS****',                    00007880
                   1       /10X,'1 - CHANGE BACKWASH TIME',                             00007890
                   2       /10X,'2 - CHANGE BACKWASH BED EXPANSION',                    00007900
                   3       /10X,'3 - CHANGE SLOW RINSE VOLUME',                         00007910
                   4       /10X,'4 - CHANGE FAST RINSE VOLUME')                         00007920
ISN    708          IF(IVES(I,1).EQ.2)WRITE(NO,4651)                                    00007930
ISN    710     4651 FORMAT(10X,'5 - CHANGE ANION REGENERANT APPLICATION TIME')          00007940
ISN    711          READ(NI,500)ISL                                                     00007950
ISN    712          IF(ECHO)WRITE(NO,5500)ISL                                           00007960
ISN    714          GO TO (4410,4420,4430,4440,4450),ISL                                00007970
ISN    715     4410 WRITE(NO,4655)                                                      00007980
ISN    716     4655 FORMAT(/5X,'ENTER BACKWASH TIME(MINUTES)',/5X,1H?)                  00007990
ISN    717          READ(NI,510)VES(I,25)                                               00008000
ISN    718          IF(ECHO)WRITE(NO,5510)VES(I,25)                                     00008010
ISN    720          GO TO 4460                                                          00008020
ISN    721     4420 WRITE(NO,4656)                                                      00008030
ISN    722     4656 FORMAT(/5X,'ENTER BACKWASH BED EXPANSION(PERCENT)',/5X,1H?)         00008040
ISN    723          READ(NI,510)VES(I,30)                                               00008050
ISN    724          IF(ECHO)WRITE(NO,5510)VES(I,30)                                     00008060
ISN    726          GO TO 4460                                                          00008070
ISN    727     4430 WRITE(NO,4657)                                                      00008080
ISN    728     4657 FORMAT(/5X,'ENTER SLOW RINSE VOLUME(GALLONS)',/5X,1H?)              00008090
ISN    729          READ(NO,510)VES(I,18)                                               00008100
ISN    730          IF(ECHO)WRITE(NO,5510)VES(I,18)                                     00008110
ISN    732          GO TO 4460                                                          00008120
ISN    733     4440 WRITE(NO,4658)                                                      00008130
ISN    734     4658 FORMAT(/5X,'ENTER FAST RINSE VOLUME(GALLONS)',/5X,1H?)              00008140
ISN    735          READ(NI,510)VES(I,19)                                               00008150
ISN    736          IF(ECHO)WRITE(NO,5510)VES(I,19)                                     00008160
ISN    738          GO TO 4460                                                          00008170
ISN    739     4450 WRITE(NO,4659)                                                      00008180
ISN    740     4659 FORMAT(/5X,'ENTER REGENERANT APPLICATION TIME(MINUTES)',            00008190
                   1        /5X,1H?)                                                    00008200
ISN    741          READ(NI,510)VES(I,26)                                               00008210
ISN    742          IF(ECHO)WRITE(NO,5510)VES(I,26)                                     00008220
ISN    744     4460 WRITE(NO,4665)                                                      00008230
ISN    745     4665 FORMAT(//1X,'****ENTER SELECTION****',/5X,                          00008240
                   1        '0 - CONTINUE TO EDIT DEFAULTS',/5X,                        00008250
                   2        '1 - RETURN TO EDIT MENU',/5X,                              00008260
                   3        '2 - RUN CURRENT CASE',/1X,1H?)                             00008270
ISN    746          READ(NI,500)ISL                                                     00008280
ISN    747          IF(ECHO)WRITE(NO,5500)ISL                                           00008290
ISN    749          ISL=ISL+1                                                           00008300
ISN    750          GO TO (4470,4000,1000),ISL                                          00008310
ISN    751     4470 WRITE(NO,4666)                                                      00008320
ISN    752     4666 FORMAT(//1X,'****ENTER SELECTION****',/5X,                          00008330
                   1        '0 - SAME VESSEL',/5X,                                      00008340
                   2        '1 - NEXT VESSEL',/1X,1H?)                                  00008350
```

```
                *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN       753          READ(NI,500)ISL                                                00008360
ISN       754          IF(ECHO)WRITE(NO,5500)ISL                                      00008370
ISN       756          ISL=ISL+1                                                      00008380
ISN       757          GO TO (4403,4500),ISL                                          00008390
ISN       758     4500 CONTINUE                                                       00008400
ISN       759     5000 STOP                                                           00008410
ISN       760          END                                                            00008420

*** VS FORTRAN ERROR MESSAGES ***

IFX0030I    CNTL     0(I)          TRMFLG HAS BEEN SPECIFIED BUT SYSTERM IS NOT A TERMINAL. TRMFLG CANCELED.

*STATISTICS*   SOURCE STATEMENTS = 668, PROGRAM SIZE = 39060 BYTES, PROGRAM NAME = MAIN    PAGE:     1.

*STATISTICS* 1 DIAGNOSTIC GENERATED. SEVERITY CODE IS 0.

****** END OF COMPILATION 1 ******
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LEVEL 1.3.0 (MAY 1983)            VS FORTRAN          DATE: NOV 18, 1983     TIME: 15:48:12                   PAGE:    17

OPTIONS IN EFFECT:   NOLIST NOMAP NOXREF NOGOSTMT NODECK    SOURCE NOTERM    OBJECT FIXED  NOTEST NOTRMFLG    SRCFLG NOSYM
                       OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          BLOCK DATA                                                                00008430
ISN        2          DIMENSION IVES(9,8),VES(9,32),MBV(2,20),                                  00008440
                     1          WAN(10,15),IMBV(2,5),ISTEP(9),RQ(9,4),                          00008450
                     2          RVOL(9,4),DVOL(9,4),TSTEP(9,4)                                  00008460
ISN        3          COMMON /DESD/WAN,VES,IVES                                                 00008470
ISN        4          COMMON /DESM/MBV,IMBV                                                     00008480
ISN        5          COMMON /STEP/ISTEP,RQ,RVOL,DVOL,TSTEP                                     00008490
ISN        6          COMMON /IO/NI,NO,IOUT                                                     00008500
ISN        7          DATA WAN/150*0.0/                                                         00008510
ISN        8          DATA VES/288*0.0/                                                         00008520
ISN        9          DATA IVES/72*0/                                                           00008530
ISN       10          DATA MBV/40*0.0/                                                          00008540
ISN       11          DATA IMBV/10*0/                                                           00008550
ISN       12          DATA NI,NO,IOUT/5,6,1/                                                    00008560
ISN       13          DATA ISTEP/9*0/                                                           00008570
ISN       14          END                                                                       00008580

*STATISTICS*    SOURCE STATEMENTS = 14, PROGRAM SIZE = 0 BYTES, PROGRAM NAME = BLKDT#     PAGE:    17.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 2 ******
```

```
OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)      CHARLEN(500)     SDUMP

               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       1          SUBROUTINE WATCON (IWAU,WAN,CNA)                                00008590
ISN       2          LOGICAL QL                                                      00008600
ISN       3          DIMENSION WAN(10,15),CFS(13)                                    00008610
ISN       4          COMMON/IO/NI,NO,IOUT                                            00008620
ISN       5          DATA CFE,CFS/50.0,50.0,2.5,4.11,2.17,1.28,2.94,1.67,            00008630
                    1             0.82,1.04,1.41,0.81,0.835,1.14/                    00008640
ISN       6          QL=.FALSE.                                                      00008650
ISN       7          IF(IOUT GE.5)QL=.TRUE.                                          00008660
ISN       9          CNA=0                                                           00008670
ISN      10          IND=IWAU-2                                                      00008680
ISN      11          IF(IND)100,120,110                                              00008690
ISN      12      100 DO 101 I=2,14                                                   00008700
ISN      13          WAN(1,I)=WAN(1,I)*CFS(I-1)                                      00008710
ISN      14      101 CONTINUE                                                        00008720
ISN      15          GO TO 120                                                       00008730
ISN      16      110 DO 111 I=2,14                                                   00008740
ISN      17          WAN(1,I)=WAN(1,I)*CFE                                           00008750
ISN      18      111 CONTINUE                                                        00008760
ISN      19      120 CAT=WAN(1,2)+WAN(1,3)+WAN(1,4)+WAN(1,5)+WAN(1,6)                00008770
ISN      20          ANI=WAN(1,7)+WAN(1,8)+WAN(1,9)+WAN(1,10)+WAN(1,11)              00008780
                    1     +WAN(1,12)                                                 00008790
ISN      21          DIF=ANI-CAT                                                     00008800
ISN      22          IF(DIF.LE.1.0) GO TO 130                                        00008810
ISN      23          IF(DIF.GE.-1.0) GO TO 130                                       00008820
ISN      24          WAN(1,5)=WAN(1,5)+DIF                                           00008830
ISN      25          CNA=WAN(1,5)                                                    00008840
ISN      26          IF(IND) 121,130,122                                             00008850
ISN      27      121 CNA=WAN(1,5)/CFS(4)                                             00008860
ISN      28          GO TO 130                                                       00008870
ISN      29      122 CNA=WAN(1,5)/CFE                                                00008880
ISN      30      130 IF(QL)WRITE(NO,600)(WAN(1,I),I=1,15)                            00008890
ISN      32      600 FORMAT(1X,E12.5)                                                00008900
ISN      33          RETURN                                                          00008910
ISN      34          END                                                             00008920

*STATISTICS*  SOURCE STATEMENTS = 32, PROGRAM SIZE = 1944 BYTES, PROGRAM NAME = WATCON    PAGE:    18.

*STATISTICS*   NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 3 ******
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LEVEL 1.3.0 (MAY 1983)           VS FORTRAN          DATE: NOV 18, 1983     TIME: 15:48:13                     PAGE:   19

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                    OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)     SDUMP

               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       1          SUBROUTINE DECON (IWAU,WAN,J)                                    00008930
ISN       2          LOGICAL QL                                                       00008940
ISN       3          DIMENSION WAN(10,15)                                             00008950
ISN       4          COMMON/IO/NI,NO,IOUT                                             00008960
ISN       5          DATA CFS,CFE/1.14,50.0/                                          00008970
ISN       6          QL=.FALSE.                                                       00008980
ISN       7          IF(IOUT.GE.5)QL=.TRUE.                                           00008990
ISN       9          I=J+1                                                            00009000
ISN      10          IND=IWAU-2                                                       00009010
ISN      11          IF(IND)100,120,110                                               00009020
ISN      12      100 WAN(I,14)=WAN(J,14)*CFS                                          00009030
ISN      13          GO TO 120                                                        00009040
ISN      14      110 WAN(I,14)=WAN(J,14)*CFE                                          00009050
ISN      15      120 IF(QL)WRITE(NO,600)(WAN(I,J),J=1,15)                             00009060
ISN      17      600 FORMAT(1X,E12.5)                                                 00009070
ISN      18          RETURN                                                           00009080
ISN      19          END                                                              00009090

*STATISTICS*   SOURCE STATEMENTS = 17, PROGRAM SIZE = 1122 BYTES, PROGRAM NAME = DECON    PAGE:    19.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 4 ******
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OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                     OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

                    *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          SUBROUTINE CRESIN (J)                                                 00009100
ISN        2          LOGICAL OL                                                            00009110
ISN        3          DIMENSION WAN(10,15),IVES(9,8),VES(9,32)                              00009120
ISN        4          COMMON/IO/NI,NO,IOUT                                                  00009130
ISN        5          COMMON/DESD/WAN,VES,IVES                                              00009140
ISN        6          COMMON/CWAT/TC,ALK,TMA,PNA,PALK,PMG,PCA,PMGN                          00009150
ISN        7          OL=.FALSE.                                                            00009160
ISN        8          IF(IOUT.GE.5)OL=.TRUE.                                                00009170
ISN       10          R100=100.0                                                            00009180
ISN       11          TC=WAN(J,2)+WAN(J,3)+WAN(J,4)+WAN(J,5)+WAN(J,6)                       00009190
ISN       12          PNA=(WAN(J,5)+WAN(J,6))/TC*R100                                       00009200
ISN       13          PMG=WAN(J,4)/TC*R100                                                  00009210
ISN       14          PCA=WAN(J,3)/TC*R100                                                  00009220
ISN       15          TH=WAN(J,3)+WAN(J,4)                                                  00009230
ISN       16          IF(TH.GT.0.0)  GO TO 50                                               00009240
ISN       17          PMGN=0.0                                                              00009250
ISN       18          GO TO 51                                                              00009260
ISN       19       50 PMGN=WAN(J,4)/TH*R100                                                 00009270
ISN       20       51 ALK=WAN(J,7)+WAN(J,8)+WAN(J,9)                                        00009280
ISN       21          TMA=ALK+WAN(J,10)+WAN(J,11)+WAN(J,12)                                 00009290
ISN       22          PALK=ALK/TMA*R100                                                     00009300
ISN       23          IR=IVES(J,3)                                                          00009310
ISN       24          IF(OL)WRITE(NO,601)TC,ALK,TMA,PNA,                                    00009320
                     1             PALK,PMG,PCA,PMGN,IR                                     00009330
ISN       26      601 FORMAT(1X,'TC= ',E12.5,/1X,'ALK= ',E12.5,/1X,                         00009340
                     1      'TMA= ',E12.5,/1X,'PNA= ',E12.5,/1X,'PALK= ',                   00009350
                     2      E12.5,/1X,'PMG= ',E12.5,/1X,'PCA= ',E12.5,/1X,                  00009360
                     3      'PMGN= ',E12.5,/1X,'IR= ',I3)                                   00009370
ISN       27          I=IR/100                                                              00009380
ISN       28          GO TO(100,200,300,400),I                                              00009390
ISN       29      100 I=(IR-100)/10+1                                                       00009400
ISN       30          GO TO (101,110),I                                                     00009410
ISN       31      101 CONTINUE                                                              00009420
ISN       32      110 CONTINUE                                                              00009430
ISN       33          GO TO 1000                                                            00009440
ISN       34      200 I=(IR-200)/10+1                                                       00009450
ISN       35          GO TO (201,203,211),I                                                 00009460
ISN       36      201 IF(OL)WRITE(NO,602)                                                   00009470
ISN       38      602 FORMAT(1X,'DHCRS')                                                    00009480
ISN       39          CALL DHCRS(J)                                                         00009490
ISN       40          IF(OL)WRITE(NO,602)                                                   00009500
ISN       42          GO TO 999                                                             00009510
ISN       43      203 CONTINUE                                                              00009520
ISN       44      211 CONTINUE                                                              00009530
ISN       45          GO TO 1000                                                            00009540
ISN       46      300 I=(IR-300)/10+1                                                       00009550
ISN       47          GO TO (301,311),I                                                     00009560
ISN       48      301 CONTINUE                                                              00009570
ISN       49      311 CONTINUE                                                              00009580
ISN       50          GO TO 1000                                                            00009590
ISN       51      400 I=(IR-400)/10+1                                                       00009600
ISN       52          GO TO 401                                                             00009610
ISN       53      401 CONTINUE                                                              00009620
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OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG    SRCFLG NOSYM
                     OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)        CHARLEN(500)      SDUMP

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       1           SUBROUTINE DHCRS(J)                                                  00009700
ISN       2           REAL NCAP                                                            00009710
ISN       3           LOGICAL QL                                                           00009720
ISN       4           DIMENSION WAN(10,15),IVES(9,8),VES(9,32),DNAL(9),                    00009730
                     1DML(9),DBL(9),DPNC(6),DPAC(3),DMC(6,3),DBC(6,3),                     00009740
                     2DCT(5),DFT(5),DBW(9),DBE(9)                                          00009750
ISN       5           COMMON/IO/NI,NO,IOUT                                                 00009760
ISN       6           COMMON/DESD/WAN,VES,IVES                                             00009770
ISN       7           COMMON/CWAT/TC,ALK,TMA,PNA,PALK,PMG,PCA,PMGN                         00009780
ISN       8           DATA DNAL/0.0,20.0,40.0,50.0,60.0,70.0,80.0,                         00009790
                     190.0,100.0/                                                          00009800
ISN       9           DATA DML/-1.243,-0.4142,-0.2629,-0.1745,-0.1157,                     00009810
                     1-0.08441,-0.06028,-0.04237,-0.03445/                                 00009820
ISN      10           DATA DBL/2.503,2.503,2.719,2.715,2.707,2.743,                        00009830
                     12.787,2.825,2.943/                                                   00009840
ISN      11           DATA A1,A2,A3,A4/1.000814,-6.109762E-3,                              00009850
                     1-8.648535E-6,-3.016536E-7/                                           00009860
ISN      12           DATA DPNC/0.0,20.0,40.0,60.0,80.0,100.0/                             00009870
ISN      13           DATA DPAC/0.0,50.0,100.0/                                            00009880
ISN      14           DATA DMC/0.1232112,0.1113266,0.1020957,0.0921048,                    00009890
                     10.0752088,0.0882422,0.1232112,0.1122203,0.1008939,                   00009900
                     20.0977334,0.0838716,0.0971294,0.1232112,0.1143136,                   00009910
                     30.1029766,0.0977334,0.0838716,0.0971294/                             00009920
ISN      15           DATA DBC/-0.4836166,-0.357857,-0.258914,-0.0763162,                  00009930
                     1-0.2511519,-0.1556087,-0.4836166,-0.4331589,                         00009940
                     2-0.3055134,-0.3119608,-0.0582378,-0.5628272,                         00009950
                     3-0.4836166,-0.5296028,-0.4232008,-0.6274264,                         00009960
                     4-0.6671997,-0.7571206/                                               00009970
ISN      16           DATA PM,BP,PPM,BPP/-0.0003,0.03,0.0075,-0.75/                        00009980
ISN      17           DATA B1,B2,B3,B4/-2.466667E+1,7.591991,                              00009990
                     1-1.433682E-1,9.469697E-4/                                            00010000
ISN      18           DATA FF1,FF2,FF3,FF4/1.145102E+2,-3.056652,3.154240E-2,              00010010
                     1-1.242690E-4/                                                        00010020
ISN      19           DATA DCT/0.0,25.0,50.0,75.0,100.0/                                   00010030
ISN      20           DATA DFT/0.5,0.5,1.0,1.5,2.25/                                       00010040
ISN      21           DATA DBW/0.0,2.0,4.0,6.0,8.0,10.0,12.0,14.0,14.72/                   00010050
ISN      22           DATA DBE/0.0,10.0,21.2,34.7,49.5,64.0,79.0,93.9,                     00010060
                     1100.0/                                                               00010070
ISN      23           TDS=0.0                                                              00010080
ISN      24           QL=.FALSE.                                                           00010090
ISN      25           IF(IOUT.GE.5) QL=.TRUE.                                              00010100
ISN      27           DO 1 K=2,6                                                           00010110
ISN      28           TDS=TDS+WAN(J,K)                                                     00010120
ISN      29         1 CONTINUE                                                             00010130
ISN      30           WAN(J,1)=TDS                                                         00010140
ISN      31           DO 2 I=1,15                                                          00010150
ISN      32           WAN(J+1,I)=WAN(J,I)                                                  00010160
ISN      33         2 CONTINUE                                                             00010170
ISN      34           R100=100.0                                                           00010180
ISN      35           RL=VES(J,10)                                                         00010190
ISN      36           RLL=ALOG(RL)                                                         00010200
ISN      37           IF(PNA.NE.0.0)GO TO 3                                                00010210
ISN      38           PNAL=0.0                                                             00010220
```

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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       54          GO TO 1000                                                        00009630
ISN       55      999 RETURN                                                            00009640
ISN       56     1000 WRITE (NO,600)J                                                   00009650
ISN       57      600 FORMAT(5X,'****SELECT ANOTHER CATION RESIN****',                  00009660
                     1        /5X,'**** FOR VESSEL ',I1,'****')                         00009670
ISN       58          RETURN                                                            00009680
ISN       59          END                                                               00009690

*STATISTICS*   SOURCE STATEMENTS = 55, PROGRAM SIZE = 3224 BYTES, PROGRAM NAME = CRESIN    PAGE:   20.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 5 ******
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                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN    39          TNAL=0.0                                                              00010230
ISN    40          GO TO 4                                                               00010240
ISN    41        3 FA=A1+PALK*(A2+PALK*(A3+PALK*A4))                                     00010250
ISN    42          CM=F1(PNA,9,DNAL,DML)                                                 00010260
ISN    43          CB=F1(PNA,9,DNAL,DBL)                                                 00010270
ISN    44          PNAL=(RLL-CB)/CM                                                      00010280
ISN    45          TNAL=FA*TMA*PNAL/R100                                                 00010290
ISN    46          IF(QL)WRITE(NO,610)PNAL,FA                                            00010300
ISN    48          PNAL=TNAL*R100/TC                                                     00010310
ISN    49        4 WAN(J+1,5)=TNAL                                                       00010320
ISN    50          IF(PMGN.GT.0.0) GO TO 5                                               00010330
ISN    51          CMG=0.0                                                               00010340
ISN    52          GO TO 6                                                               00010350
ISN    53        5 CMG=(PM*PNA+BP)*PMGN+PPM*PNA+BPP                                      00010360
ISN    54        6 GCAP=F2(PNA,PALK,6,3,DPNC,DPAC,DMC,DBC,RLL)+CMG                       00010370
ISN    55          FTP=R100/(R100-PNAL)                                                  00010380
ISN    56          IF(VES(J,5).GT.18.0) GO TO 10                                         00010390
ISN    57          FBD=(VES(J,5)/18.0)*0.71                                              00010400
ISN    58          GO TO 20                                                              00010410
ISN    59       10 IF(VES(J,5).GT.60.0) GO TO 15                                         00010420
ISN    60          X=VES(J,5)                                                            00010430
ISN    61          FBD=(B1+X*(B2+X*(B3+X*B4)))/R100                                      00010440
ISN    62          GO TO 20                                                              00010450
ISN    63       15 FBD=1.2                                                               00010460
ISN    64       20 AREA=VES(J,6)                                                         00010470
ISN    65          QPA=VES(J,29)/AREA                                                    00010480
ISN    66          IF(QPA.GT.5.0) GO TO 30                                               00010490
ISN    67          FSR=1.0                                                               00010500
ISN    68          GO TO 40                                                              00010510
ISN    69       30 FSR=(FF1+QPA*(FF2+QPA*(FF3+QPA*FF4)))/R100                            00010520
ISN    70       40 FEF=VES(J,12)/R100                                                    00010530
ISN    71          CCAP=GCAP*FBD*FSR*FTP                                                 00010540
ISN    72          IF(QL)WRITE(NO,610)GCAP,CCAP,FBD,FSR,FTP,CMG                          00010550
ISN    74      610 FORMAT(1X,E12.5)                                                      00010560
ISN    75          VES(J,11)=CCAP                                                        00010570
ISN    76          NCAP=CCAP*FEF                                                         00010580
ISN    77          VES(J,13)=NCAP                                                        00010590
ISN    78          CAP=VES(J,3)*NCAP                                                     00010600
ISN    79          VES(J,8)=CAP                                                          00010610
ISN    80          IF(VES(J,30).GT.0.0) GO TO 50                                         00010620
ISN    81          VES(J,30)=50.0                                                        00010630
ISN    82       50 BWRA=F1(VES(J,30),9,DBE,DBW)*(1.0+0.008*(WAN(J,15)                    00010640
                 1       -77.0))                                                         00010650
ISN    83          BWR=BWRA*AREA                                                         00010660
ISN    84          IF(QL)WRITE(NO,610)BWRA,BWR                                           00010670
ISN    86          VES(J,20)=BWR                                                         00010680
ISN    87          RR=F1(PCA,5,DCT,DFT)*VES(J,3)                                         00010690
ISN    88          VES(J,21)=RR                                                          00010700
ISN    89          JP=J+1                                                                00010710
ISN    90          WAN(JP,2)=TMA-TNAL-ALK                                                00010720
ISN    91          WAN(JP,3)=0.0                                                         00010730
ISN    92          WAN(JP,4)=0.0                                                         00010740
ISN    93          WAN(JP,14)=WAN(J,14)+WAN(J,8)/2.0+WAN(J,9)                            00010750
ISN    94          WAN(JP,8)=0.0                                                         00010760
ISN    95          WAN(JP,9)=0.0                                                         00010770
ISN    96          WAN(JP,7)=0.0                                                         00010780
```

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LEVEL 1.3.0 (MAY 1983)           VS FORTRAN          DATE: NOV 18, 1983    TIME: 15:48:13      NAME: DHCRS   PAGE:   24

               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       97         IF(VES(J,19).GT.0.0) GO TO 100                                            00010790
ISN       98         FRV=25.0*VES(J,3)                                                         00010800
ISN       99         VES(J,19)=FRV                                                             00010810
ISN      100     100 RETURN                                                                    00010820
ISN      101         END                                                                       00010830

*STATISTICS*   SOURCE STATEMENTS = 97, PROGRAM SIZE = 5806 BYTES, PROGRAM NAME = DHCRS    PAGE:   22.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 6 ******
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OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)      CHARLEN(500)     SDUMP

                  *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          SUBROUTINE ARESIN (J)                                                00010840
ISN        2          DIMENSION WAN(10,15),IVES(9,8),VES(9,32)                             00010850
ISN        3          COMMON /IO/NI,NO,IOUT                                                00010860
ISN        4          COMMON /DESD/WAN,VES,IVES                                            00010870
ISN        5          COMMON /AWAT/TA,TMA,PSI,PCLM,PWA,PCLT                                00010880
ISN        6          R100=100.0                                                           00010890
ISN        7          TMA=WAN(J,10)+WAN(J,11)+WAN(J,12)                                    00010900
ISN        8          TWA=WAN(J,13)+WAN(J,14)                                              00010910
ISN        9          ERR=WAN(J,7)+WAN(J,8)+WAN(J,9)                                       00010920
ISN       10          IF(ERR)1001,1,1001                                                   00010930
ISN       11        1 TA=TWA+TMA                                                           00010940
ISN       12          PWA=TWA/TA*R100                                                      00010950
ISN       13          PSI=WAN(J,13)/TA*R100                                                00010960
ISN       14          PCLM=(WAN(J,11)+WAN(J,12))/TMA*R100                                  00010970
ISN       15          PCLT=(WAN(J,11)+WAN(J,12))/TA*R100                                   00010980
ISN       16          IR=IVES(J,3)                                                         00010990
ISN       17          IF(IOUT.EQ.5)WRITE(NO,601)TA,TMA,PSI,PCLM,                           00011000
                     1             PWA,PCLT,IR                                             00011010
ISN       19      601 FORMAT(1X,'TA= ',E12.5,/1X,'TMA= ',E12.5,/1X,                        00011020
                     1      'PSI= ',E12.5,/1X,'PCLM= ',E12.5,/1X,                          00011030
                     2      'PWA= ',E12.5,/1X,'PCLT= ',E12.5/1X,                           00011040
                     3      'IR= ',I3)                                                     00011050
ISN       20          I=IR/100                                                             00011060
ISN       21          GO TO (100,200,300,400),I                                            00011070
ISN       22      100 I=(IR-100)/10-1                                                      00011080
ISN       23          GO TO (120,130,140),I                                                00011090
ISN       24      120 CONTINUE                                                             00011100
ISN       25      130 CONTINUE                                                             00011110
ISN       26      140 CONTINUE                                                             00011120
ISN       27          GO TO 1000                                                           00011130
ISN       28      200 I=(IR-200)/10-1                                                      00011140
ISN       29          GO TO (221,231,240),I                                                00011150
ISN       30      221 IF(IOUT.EQ.5)WRITE(NO,602)                                           00011160
ISN       32      602 FORMAT(1X,'DSBRP')                                                   00011170
ISN       33          CALL DSBRP(J)                                                        00011180
ISN       34          IF(IOUT.EQ.5)WRITE(NO,602)                                           00011190
ISN       36          GO TO 999                                                            00011200
ISN       37      231 CONTINUE                                                             00011210
ISN       38          GO TO 1000                                                           00011220
ISN       39      240 I=IR-240                                                             00011230
ISN       40          GO TO (241,242),I                                                    00011240
ISN       41      241 IF(IOUT.EQ.5)WRITE(NO,603)                                           00011250
ISN       43      603 FORMAT(1X,'DWGR2')                                                   00011260
ISN       44          CALL DWGR2(J)                                                        00011270
ISN       45          IF(IOUT.EQ.5)WRITE(NO,603)                                           00011280
ISN       47          GO TO 999                                                            00011290
ISN       48      242 CONTINUE                                                             00011300
ISN       49          GO TO 1000                                                           00011310
ISN       50      300 I=(IR-300)/10-1                                                      00011320
ISN       51          GO TO (321,331,341),I                                                00011330
ISN       52      321 CONTINUE                                                             00011340
ISN       53      331 CONTINUE                                                             00011350
ISN       54      341 CONTINUE                                                             00011360
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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN      55          GO TO 1000                                                        00011370
ISN      56      400 I=(IR-400)/10-1                                                   00011380
ISN      57          GO TO 421                                                         00011390
ISN      58      421 CONTINUE                                                          00011400
ISN      59          GO TO 1000                                                        00011410
ISN      60      999 RETURN                                                            00011420
ISN      61     1000 WRITE(NO,600)J                                                    00011430
ISN      62      600 FORMAT(5X,'****SELECT ANOTHER ANION RESIN****',                   00011440
                    1        /5X,'****FOR VESSEL',I1,'****')                           00011450
ISN      63     1001 CONTINUE                                                          00011460
ISN      64          RETURN                                                            00011470
ISN      65          END                                                               00011480

*STATISTICS*   SOURCE STATEMENTS = 60, PROGRAM SIZE = 3326 BYTES, PROGRAM NAME = ARESIN    PAGE:   25.

*STATISTICS*   NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 7 ******
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OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)      CHARLEN(500)     SDUMP

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       1          SUBROUTINE DSBRP(J)                                                 00011490
ISN       2          REAL NCAP                                                           00011500
ISN       3          LOGICAL QL                                                          00011510
ISN       4          DIMENSION WAN(10,15),IVES(9,8),VES(9,32),DPX(11),                   00011520
                    1          DSL75(11,4),DSL95(11,4),DSL12(11,4),                      00011530
                    2          DCM75(11,4),DCM95(11,4),DCM12(11,4),                      00011540
                    3          DCW75(11,4),DCW95(11,4),DCW12(11,4),                      00011550
                    4          DRTP(3),DRG(4)                                            00011560
ISN       5          COMMON/IO/NI,NO,IOUT                                                00011570
ISN       6          COMMON/DESD/WAN,VES,IVES                                            00011580
ISN       7          COMMON/AWAT/TA,TMA,PSI,PCLM,PWA,PCLT                                00011590
ISN       8          DATA BWM/23.33333/                                                  00011600
ISN       9          DATA DRG/3.5,5.0,7.5,10.0/                                          00011610
ISN      10          DATA DPX/0.0,10.0,20.0,30.0,40.0,50.0,60.0,                         00011620
                    1         70.0,80.0,90.0,100.0/                                      00011630
ISN      11          DATA DSL75/0.0,0.06,0.145,0.270,0.445,0.85,                         00011640
                    2           1.10,1.25,1.40,1.50,1.60,0.0,0.025,                      00011650
                    3           0.06,0.105,0.145,0.210,0.270,0.3275,                     00011660
                    4           0.3775,0.4225,0.4575,0.0,0.02,0.0375,                    00011670
                    5           0.0575,0.075,0.105,0.130,0.155,0.170,                    00011680
                    6           0.1875,0.200,0.0,0.0075,0.02,0.0325,                     00011690
                    7           0.045,0.0675,0.0850,0.1075,0.125,0.140,                  00011700
                    8           0.150/                                                   00011710
ISN      12          DATA DSL95/0.0,0.06,0.12,0.18,0.24,0.30,0.36,0.42,                  00011720
                    1           0.48,0.54,0.60,0.0,0.02,0.04,0.06,0.085,                 00011730
                    2           0.11,0.14,0.17,0.21,0.25,0.30,0.0,0.015,                 00011740
                    3           0.025,0.04,0.055,0.07,0.085,0.1,0.12,                    00011750
                    4           0.135,0.15,0.0,0.01,0.02,0.025,0.0325,                   00011760
                    5           0.045,0.06,0.075,0.090,0.11,0.125/                       00011770
ISN      13          DATA DSL12/0.0,0.025,0.06,0.1,0.15,0.195,0.24,                      00011780
                    1           0.28,0.315,0.345,0.375,0.0,0.0075,0.0175,                00011790
                    2           0.03,0.045,0.07,0.0975,0.12,0.135,0.145,                 00011800
                    3           0.15,0.0,0.005,0.01,0.015,0.025,0.035,                   00011810
                    4           0.045,0.06,0.0725,0.0875,0.1,0.0,0.0,                    00011820
                    5           0.0,0.005,0.01.0.0175,0.025,0.035,                       00011830
                    6           0.0425,0 0525,0.0625/                                    00011840
ISN      14          DATA DCM75/11.13,11.53,11.90,12.23,12.53,12.86,13.23,               00011850
                    1           13.53,13.93,14.47,15.1,12.87,13.23,13.60,                00011860
                    2           13.90,14.17,14.5,14.8,15.1,15.47,15.9,16.37,             00011870
                    3           14.67,14.96,15.23,15.5,15.8,16.0,16.3,16.67,             00011880
                    4           17.0,17.5,18.03,15.87,16.07,16.33,16.56,                 00011890
                    5           16.83,17.0,17.27,17.57,17.93,18.43,18.97/                00011900
ISN      15          DATA DCM95/10.1,10.9,11.6,12.23,12.77,13.2,13.6,14.0,               00011910
                    1           14.47,14.87,15.33,12.77,13.27,13.77,14.1,                00011920
                    2           14.43,14.77,15.07,15.4,15.77,16.13,16.6,                 00011930
                    3           14.3,14.77,15.13,15.5,15.83,16.17,16.5,                  00011940
                    4           16.83,17.27,17.67,18.13,15.57,15.9,                      00011950
                    5           16.23,16.5,16.8,17.07,17.33,17.6,17.97,                  00011960
                    6           18.4,18.9/                                               00011970
ISN      16          DATA DCM12/11.1,11.67,12.1,12.5,12.9,13.3,13.7,14.1,                00011980
                    1           14.6,15.1,15.7,12.9,13.27,13.67,14.07,                   00011990
                    2           14.5,14.9,15.3,15.8,16.3,16.9,17.67,14.5,                00012000
                    3           14.93,15.4,15.8,16.3,16.53,16.9,17.3,17.67,              00012010
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                  *....*...1.........2.........3.........4.........5.........6.........7.*.......8
                    4          18.1,18.6,15.9,16.3,16.6,16.9,17.2,17.2,
                    5          17.53,17.87,18.2,18.5,19.1/
ISN      17          DATA DCW75/16.5,16.2,15.83,15.33,14.73,14.1,13.5,
                    1          12.87,12.2,11.6,11.0,17.83,17.67,17.47,17.07,
                    2          16.67,16.1,15.47,14.8,14.1,13.5,12.87,18.72,
                    3          18.67,18.50,18.23,17.90,17.50,17.07,16.67,16.2,
                    4          15.8,15.33,19.3,19.2,19.1,18.84,18.59,18.28,
                    5          17.90,17.53,17.13,16.83,16.43/
ISN      18          DATA DCW95/16.57,16.5,16.33,16.13,15.8,15.2,14.67,
                    1          14.2,13.8,13.4,13.0,17.84,17.84,17.83,17.73,
                    2          17.53,17.2,16.87,16.5,16.1,15.8,15.5,18.8,
                    3          18.67,18.63,18.57,18.47,18.3,18.07,17.73,
                    4          17.3,17.0,16.83,19.3,19.2,19.1,19.07,19.0,
                    5          18.9,18.73,18.4,17.93,17.6,17.3/
ISN      19          DATA DCW12/16.53,16.47,16.33,16.3,16.2,16.07,15.83,
                    1          15.6,15.3,15.07,14.8,18.27,18.2,18.17,18.13,
                    2          18.1,18.0,17.9,17.8,17.6,17.4,17.2,11*18.7,
                    3          11*19.2/
ISN      20          DATA C1,C2,C3,C4/9.981469E-1,-4.292541E-3,3.210956E-5,
                    1                    -1.107226E-7/
ISN      21          DATA S1,S2,S3,S4/8.87E-1,2.895979E-1,-2.999709E-1,
                    2                    1.238345E-1/
ISN      22          DATA SNL1,SNL2,SNL3/8.317886E+1,3.050159E+1,-3.203408/
ISN      23          DATA T1,T2,T3,T4,T5/4.801963E+2,-2.547444E+1,
                    1                         5.330862E-1,-4.696193E-3,1.622378E-5/
ISN      24          DATA DRTP/75.0,95.0,120.0/
ISN      25          QL=.FALSE.
ISN      26          IF(IOUT.GE.5) QL=.TRUE.
ISN      28          ICAP=0
ISN      29          R100=100.0
ISN      30          RL=VES(J,10)
ISN      31          IF(RL.GT.10.0)RL=10.0
ISN      33          TDS=0.0
ISN      34          DO 1 I=1,15
ISN      35          WAN(J+1,I)=WAN(J,I)
ISN      36        1 CONTINUE
ISN      37          DO 2 K=7,14
ISN      38          TDS=TDS+WAN(J,K)
ISN      39        2 CONTINUE
ISN      40          WAN(J,1)=TDS
ISN      41          TNAL=WAN(J,5)
ISN      42          RGTP=VES(J,31)
ISN      43          IF(RGTP.LT.75.0) GO TO 105
ISN      44          IF(RGTP.GT.120.0) GO TO 105
ISN      45          DO 10 I=2,3
ISN      46          IM=I-1
ISN      47          IF(RGTP.LT.DRTP(I)) GO TO 15
ISN      48       10 CONTINUE
ISN      49       15 IF((TMA-TNAL/TA).LT.0.05)ICAP=1
ISN      51          IF(IM.NE.1) GO TO 20
ISN      52          SL1=F3(PSI,RL,11,4,DPX,DRG,DSL75)
ISN      53          SL2=F3(PSI,RL,11,4,DPX,DRG,DSL95)
ISN      54          RDT=(RGTP-75.0)/20.0
ISN      55          IF(ICAP)16,16,17
ISN      56       16 CP1=F3(PWA,RL,11,4,DPX,DRG,DCM75)
ISN      57          CP2=F3(PWA,RL,11,4,DPX,DRG,DCM95)
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                    *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        58            GO TO 25                                                                00012580
ISN        59         17 CP1=F3(PSI,RL,11,4,DPX,DRG,DCW75)                                       00012590
ISN        60            CP2=F3(PSI,RL,11,4,DPX,DRG,DCW95)                                       00012600
ISN        61            GO TO 25                                                                00012610
ISN        62         20 SL1=F3(PSI,RL,11,4,DPX,DRG,DSL95)                                       00012620
ISN        63            SL2=F3(PSI,RL,11,4,DPX,DRG,DSL12)                                       00012630
ISN        64            RDT=(RGTP-95.0)/25.0                                                    00012640
ISN        65            IF(ICAP)21,21,22                                                        00012650
ISN        66         21 CP1=F3(PWA,RL,11,4,DPX,DRG,DCM95)                                       00012660
ISN        67            CP2=F3(PWA,RL,11,4,DPX,DRG,DCM12)                                       00012670
ISN        68            GO TO 25                                                                00012680
ISN        69         22 CP1=F3(PSI,RL,11,4,DPX,DRG,DCW95)                                       00012690
ISN        70            CP2=F3(PSI,RL,11,4,DPX,DRG,DCW12)                                       00012700
ISN        71         25 DSL=SL2-SL1                                                             00012710
ISN        72            DCP=CP2-CP1                                                             00012720
ISN        73            IF(QL)WRITE(NO,610)ICAP,IM                                              00012730
ISN        75        610 FORMAT(1X,I1)                                                           00012740
ISN        76            IF(QL)WRITE(NO,611)SL1,SL2,CP1,CP2,RDT                                  00012750
ISN        78        611 FORMAT(1X,E12.5)                                                        00012760
ISN        79            TSL=RDT*DSL+SL1                                                         00012770
ISN        80            GCAP=RDT*DCP+CP1                                                        00012780
ISN        81            IF(ICAP)26,26,27                                                        00012790
ISN        82         26 FCC=C1+PCLT*(C2+PCLT*(C3+PCLT*C4))                                      00012800
ISN        83            GO TO 30                                                                00012810
ISN        84         27 FCC=1.0                                                                 00012820
ISN        85         30 SREP=VES(J,32)                                                          00012830
ISN        86            IF(SREP.GT.0.0) GO TO 31                                                00012840
ISN        87            SREP=0.1                                                                00012850
ISN        88            VES(J,32)=SREP                                                          00012860
ISN        89         31 IF(SREP-0.1)32,33,33                                                    00012870
ISN        90         32 RDX=SREP/0.1                                                            00012880
ISN        91            FCS=RDX*0.91                                                            00012890
ISN        92            GO TO 35                                                                00012900
ISN        93         33 IF(SREP-1.0)133,34,34                                                   00012910
ISN        94        133 FCS=S1+SREP*(S2+SREP*(S3+SREP*S4))                                      00012920
ISN        95            GO TO 35                                                                00012930
ISN        96         34 FCS=1.0                                                                 00012940
ISN        97         35 IF(TNAL.LE.4.76) GO TO 135                                              00012950
ISN        98            FSN=1.55785                                                             00012960
ISN        99            GO TO 235                                                               00012970
ISN       100        135 FSN=(SNL1+TNAL*(SNL2+TNAL*SNL3))/R100                                   00012980
ISN       101        235 TP=WAN(J,15)                                                            00012990
ISN       102            IF(TP.GE.50.0) GO TO 36                                                 00013000
ISN       103            FST=0.5                                                                 00013010
ISN       104            GO TO 37                                                                00013020
ISN       105         36 FST=(T1+TP*(T2+TP*(T3+TP*(T4+TP*T5))))/R100                             00013030
ISN       106         37 CSL=TSL*FSN*FST                                                         00013040
ISN       107            CCAP=GCAP*FCC*FCS                                                       00013050
ISN       108            IF(QL)WRITE(NO,611)TSL,FSN,FST,GCAP,FCC,FCS                             00013060
ISN       110            VES(J,11)=CCAP                                                          00013070
ISN       111            FEF=VES(J,12)/R100                                                      00013080
ISN       112            NCAP=CCAP*FEF                                                           00013090
ISN       113            VES(J,13)=NCAP                                                          00013100
ISN       114            CAP=VES(J,3)*NCAP                                                       00013110
ISN       115            VES(J,8)=CAP                                                            00013120
ISN       116            IF(VES(J,30).GT.0.0) GO TO 38                                           00013130
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                       *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN      117          VES(J,30)=50.0                                                    00013140
ISN      118       38 BWRA=VES(J,30)/BWM*(1.0+0.008*(TP-77.0))                          00013150
ISN      119          BWR=BWRA*VES(J,6)                                                 00013160
ISN      120          VES(J,20)=BWR                                                     00013170
ISN      121          IF(VES(J,26))40,40,41                                             00013180
ISN      122       40 VES(J,26)=60.0                                                    00013190
ISN      123       41 I=J+1                                                             00013200
ISN      124          WAN(I,2)=0.0                                                      00013210
ISN      125          WAN(I,10)=0.0                                                     00013220
ISN      126          WAN(I,11)=TNAL                                                    00013230
ISN      127          WAN(I,12)=0.0                                                     00013240
ISN      128          WAN(I,13)=CSL                                                     00013250
ISN      129          WAN(I,14)=0.0                                                     00013260
ISN      130          IF(VES(J,19).GT.0.0) GO TO 110                                    00013270
ISN      131          VES(J,19)=100.0*VES(J,3)                                          00013280
ISN      132          GO TO 110                                                         00013290
ISN      133      105 WRITE(NO,600)                                                     00013300
ISN      134      600 FORMAT(5X,'****REGENERATION TEMPERATURE OUT ',                    00013310
                     1       'OF BOUNDS****')                                           00013320
ISN      135      110 RETURN                                                            00013330
ISN      136          END                                                               00013340

*STATISTICS*   SOURCE STATEMENTS = 130, PROGRAM SIZE = 8462 BYTES, PROGRAM NAME = DSBRP    PAGE:   27.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 8 ******
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OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          SUBROUTINE DWGR2(J)                                                       00013350
ISN        2          REAL NCAP                                                                 00013360
ISN        3          LOGICAL QL                                                                00013370
ISN        4          DIMENSION WAN(10,15),VES(9,8),IVES(9,32),DRL(4),                          00013380
                     1          DCPC(4),DCPS(4)                                                 00013390
ISN        5          COMMON/IO/NI,NO,IOUT                                                      00013400
ISN        6          COMMON/DESD/WAN,VES,IVES                                                  00013410
ISN        7          COMMON/AWAT/TA,TMA,PSI,PCLM,PWA,PCLT                                      00013420
ISN        8          DATA DRL/2,3,4,5/                                                         00013430
ISN        9          DATA DCPC/23.75,28.0,30.0,30.25/                                          00013440
ISN       10          DATA DCPS/20.0,24.0,25.0,25.25/                                           00013450
ISN       11          DATA BWM,BWB/10.0,-1.3/                                                   00013460
ISN       12          TNAL=WAN(J,5)                                                             00013470
ISN       13          QL=.FALSE.                                                                00013480
ISN       14          IF(IOUT.GE.5) QL=.TRUE.                                                   00013490
ISN       16          R100=100.0                                                                00013500
ISN       17          RL=VES(J,10)                                                              00013510
ISN       18          IF(RL.GT.5.0)RL=5.0                                                       00013520
ISN       20          TDS=0.0                                                                   00013530
ISN       21          DO 1 I=1,15                                                               00013540
ISN       22          WAN(J+1,I)=WAN(J,I)                                                       00013550
ISN       23        1 CONTINUE                                                                  00013560
ISN       24          DO 2 K=7,12                                                               00013570
ISN       25          TDS=TDS+WAN(J,K)                                                          00013580
ISN       26        2 CONTINUE                                                                  00013590
ISN       27          WAN(J,1)=TDS                                                              00013600
ISN       28          SA=WAN(J,10)                                                              00013610
ISN       29          TEA=TMA-TNAL                                                              00013620
ISN       30          FSA=SA/TEA                                                                00013630
ISN       31          FCA=1.0-FSA                                                               00013640
ISN       32          CPS=F1(RL,4,DRL,DCPS)                                                     00013650
ISN       33          CPC=F1(RL,4,DRL,DCPC)                                                     00013660
ISN       34          IF(QL)WRITE(NO,610)FSA,FCA,CPS,CPC                                        00013670
ISN       36      610 FORMAT(1X,E12.5)                                                          00013680
ISN       37          GCAP=FSA*CPS+FCA*CPC                                                      00013690
ISN       38          FEF=VES(J,12)/R100                                                        00013700
ISN       39          NCAP=GCAP*FEF                                                             00013710
ISN       40          VES(J,11)=GCAP                                                            00013720
ISN       41          VES(J,13)=NCAP                                                            00013730
ISN       42          CAP=VES(J,3)*NCAP                                                         00013740
ISN       43          VES(J,8)=CAP                                                              00013750
ISN       44          TP=WAN(J,15)                                                              00013760
ISN       45          IF(VES(J,30).GT.0.0) GO TO 6                                              00013770
ISN       46          VES(J,30)=50.0                                                            00013780
ISN       47        6 BWRA=(VES(J,30)-BWB)/BWM*(1.0+0.008*(TP-77.0))                            00013790
ISN       48          BWR=BWRA*VES(J,6)                                                         00013800
ISN       49          VES(J,20)=BWR                                                             00013810
ISN       50          IF(VES(J,26))10,10,11                                                     00013820
ISN       51       10 VES(J,21)=0.5*VES(J,3)                                                    00013830
ISN       52       11 I=J+1                                                                     00013840
ISN       53          WAN(I,2)=0.0                                                              00013850
ISN       54          WAN(I,10)=0.0                                                             00013860
ISN       55          WAN(I,11)=TNAL                                                            00013870
```

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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN       56          WAN(I,12)=0.0                                                   00013880
ISN       57          IF(VES(J,19).GT.0.0) GO TO 110                                  00013890
ISN       58          VES(J,19)=75.0*VES(J,3)                                         00013900
ISN       59      110 RETURN                                                          00013910
ISN       60          END                                                             00013920
```

STATISTICS   SOURCE STATEMENTS = 57, PROGRAM SIZE = 3288 BYTES, PROGRAM NAME = DWGR2   PAGE: 31.

STATISTICS   NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 9 ******

```
OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

                  *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN      1          SUBROUTINE CREGN(J)                                              00013930
ISN      2          LOGICAL QL                                                       00013940
ISN      3          DIMENSION WAN(10,15),IVES(9,8),VES(9,32),RQ(9,4),                00013950
                 1            RVOL(9,4),DVOL(9,4),TSTEP(9,4),ISTEP(9)                00013960
ISN      4          COMMON/IO/NI,NO,IOUT                                             00013970
ISN      5          COMMON/DESD/WAN,VES,IVES                                         00013980
ISN      6          COMMON/STEP/ISTEP,RQ,RVOL,DVOL,TSTEP                             00013990
ISN      7          DATA SRV2,SRV4,SRV6,SRV8/4*0.0/                                  00014000
ISN      8          DATA T2,T4,T6,T8/4*0.0/                                          00014010
ISN      9          DATA SWV2,SWV4,SWV6,SWV8/4*0.0/                                  00014020
ISN     10          DATA RHOS,RHOC/15.2,2.88/                                        00014030
ISN     11          DATA RHO2,RHO4,RHO6,RHO8/0.1689,0.3422,0.5200,                   00014040
                 1      0.7025/                                                      00014050
ISN     12          QL=.FALSE.                                                       00014060
ISN     13          IF(IOUT.GE.5) QL=.TRUE.                                          00014070
ISN     15          QS=VES(J,29)                                                     00014080
ISN     16          AREA=VES(J,6)                                                    00014090
ISN     17          VOL=VES(J,3)                                                     00014100
ISN     18          VES(J,15)=VES(J,20)*VES(J,25)                                    00014110
ISN     19          IF(IVES(J,6)-2) 10,20,30                                         00014120
ISN     20       10 RL=VES(J,10)                                                     00014130
ISN     21          TAW=RL*VOL                                                       00014140
ISN     22          TAV=TAW/RHOS                                                     00014150
ISN     23          IF(WAN(J,3).GT.0.5) GO TO 11                                     00014160
ISN     24          NSTEP=1                                                          00014170
ISN     25          QRW=VES(J,21)                                                    00014180
ISN     26          SRV6=TAW/RHO6                                                    00014190
ISN     27          SWW6=TAW*0.94/0.06                                               00014200
ISN     28          SWV6=SWW6/8.34                                                   00014210
ISN     29          T6=SWV6/QRW                                                      00014220
ISN     30          QA6=TAV/T6                                                       00014230
ISN     31          GO TO 15                                                         00014240
ISN     32       11 STEP=1.0                                                         00014250
ISN     33          ISTEP(J)=1                                                       00014260
ISN     34          IF(RL.LT.4.0) GO TO 12                                           00014270
ISN     35          STEP=2.0                                                         00014280
ISN     36          ISTEP(J)=2                                                       00014290
ISN     37          IF(RL.LT.6.0) GO TO 12                                           00014300
ISN     38          STEP=3.0                                                         00014310
ISN     39          ISTEP(J)=3                                                       00014320
ISN     40          IF(RL.LT.8.0) GO TO 12                                           00014330
ISN     41          STEP=4.0                                                         00014340
ISN     42          ISTEP(J)=4                                                       00014350
ISN     43       12 IF(QL)WRITE(NO,610)STEP                                          00014360
ISN     45      610 FORMAT(1X,E12.5)                                                 00014370
ISN     46          IF(RL.LE.8.0) GO TO 13                                           00014380
ISN     47          F24=4.0/RL                                                       00014390
ISN     48          F68=1.0-F24                                                      00014400
ISN     49          SAW=(TAW*F24)/2.0                                                00014410
ISN     50          SAV=(TAV*F24)/2.0                                                00014420
ISN     51          SAW6=(TAW*F68)/2.0                                               00014430
ISN     52          SAV6=(TAV*F68)/2.0                                               00014440
ISN     53          SAW8=SAW6                                                        00014450
```

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                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN       54          SAV8=SAV6
ISN       55          GO TO 14
ISN       56       13 SAW=TAW/STEP
ISN       57          SAV=TAV/STEP
ISN       58          SAV6=SAV
ISN       59          SAW6=SAW
ISN       60          SAV8=SAV
ISN       61          SAW8=SAW
ISN       62       14 QRW=VES(J,21)
ISN       63          SRV2=SAW/RHO2
ISN       64          SWW2=SAW*49.0
ISN       65          SWV2=SWW2/8.34
ISN       66          T2=SWV2/QRW
ISN       67          QA2=SAV/T2
ISN       68          IF(STEP.LT.2.0) GO TO 15
ISN       69          SRV4=SAW/RHO4
ISN       70          SWW4=SAW*24.0
ISN       71          SWV4=SWW4/8.34
ISN       72          T4=SWV4/QRW
ISN       73          QA4=SAV/T4
ISN       74          IF(STEP.LT.3.0) GO TO 15
ISN       75          SRV6=SAW6/RHO6
ISN       76          SWW6=SAW6*0.94/0.06
ISN       77          SWV6=SWW6/8.34
ISN       78          T6=SWV6/QRW
ISN       79          QA6=SAV6/T6
ISN       80          IF(STEP.LT.4.0) GO TO 15
ISN       81          SRV8=SAW8/RHO8
ISN       82          SWW8=SAW8*0.92/0.08
ISN       83          SWV8=SWW8/8.34
ISN       84          T8=SWV8/QRW
ISN       85          QA8=SAV8/T8
ISN       86       15 TTR=T2+T4+T6+T8
ISN       87          TRV=SRV2+SRV4+SRV6+SRV8
ISN       88          TWV=SWV2+SWV4+SWV6+SWV8
ISN       89          IF(QL)WRITE(NO,610)T2,T4,T6,T8,SWV2,SWV4,SWV6,SWV8
ISN       91          VES(J,22)=-1.0
ISN       92          IF(NSTEP.EQ.1) VES(J,22)=QA6
ISN       94          GO TO 40
ISN       95       20 CONTINUE
ISN       96       30 CONTINUE
ISN       97       40 SRV=VES(J,18)
ISN       98          IF(SRV.GT.0.0) GO TO 41
ISN       99          SRV=(VOL/2.0+0.75*AREA)*1.5*7.48
ISN      100          VES(J,18)=SRV
ISN      101       41 TSR=SRV/QRW
ISN      102          QFR=VES(J,24)
ISN      103          IF(QFR.GT.0.0) GO TO 42
ISN      104          QFR=QS
ISN      105       42 TFR=VES(J,19)/QFR
ISN      106          VES(J,16)=TWV
ISN      107          VES(J,17)=TAV
ISN      108          VES(J,23)=QRW
ISN      109          VES(J,24)=QFR
ISN      110          VES(J,26)=TTR
ISN      111          VES(J,27)=TSR
```

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                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN     112          VES(J,28)=TFR                                                   00015020
ISN     113          VES(J,14)=VES(J,8)/WAN(J,1)*17100.0                             00015030
ISN     114          RQ(J,1)=QA2                                                     00015040
ISN     115          RQ(J,2)=QA4                                                     00015050
ISN     116          RQ(J,3)=QA6                                                     00015060
ISN     117          RQ(J,4)=QA8                                                     00015070
ISN     118          RVOL(J,1)=SAV                                                   00015080
ISN     119          RVOL(J,2)=SAV                                                   00015090
ISN     120          RVOL(J,3)=SAV6                                                  00015100
ISN     121          RVOL(J,4)=SAV8                                                  00015110
ISN     122          DVOL(J,1)=SWV2                                                  00015120
ISN     123          DVOL(J,2)=SWV4                                                  00015130
ISN     124          DVOL(J,3)=SWV6                                                  00015140
ISN     125          DVOL(J,4)=SWV8                                                  00015150
ISN     126          TSTEP(J,1)=T2                                                   00015160
ISN     127          TSTEP(J,2)=T4                                                   00015170
ISN     128          TSTEP(J,3)=T6                                                   00015180
ISN     129          TSTEP(J,4)=T8                                                   00015190
ISN     130          RETURN                                                          00015200
ISN     131          END                                                             00015210

*STATISTICS*  SOURCE STATEMENTS = 127, PROGRAM SIZE = 6202 BYTES, PROGRAM NAME = CREGN   PAGE:   33.

*STATISTICS*  NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 10 ******
```

```
OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                       OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN      1          SUBROUTINE AREGN(J)                                                00015220
ISN      2          LOGICAL QL                                                         00015230
ISN      3          DIMENSION WAN(10,15),IVES(9,8),VES(9,32)                           00015240
ISN      4          COMMON/IO/NI,NO,IOUT                                               00015250
ISN      5          COMMON/DESD/WAN,VES,IVES                                           00015260
ISN      6          DATA RHON,RHO3/6.25,0.26/                                          00015270
ISN      7          QL=.FALSE.                                                         00015280
ISN      8          IF(IOUT.GE.5) QL=.TRUE.                                            00015290
ISN     10          QS=VES(J,29)                                                       00015300
ISN     11          AREA=VES(J,6)                                                      00015310
ISN     12          VOL=VES(J,3)                                                       00015320
ISN     13          VES(J,15)=VES(J,20)*VES(J,25)                                      00015330
ISN     14          RL=VES(J,10)                                                       00015340
ISN     15          TCW=RL*VOL                                                         00015350
ISN     16          TCV=TCW/RHON                                                       00015360
ISN     17          TRV=TCW/RHO3                                                       00015370
ISN     18          TWW=TCW*0.97/0.03                                                  00015380
ISN     19          TWV=TWW/8.34                                                       00015390
ISN     20          IF(VES(J,21).LE.0.0) GO TO 30                                      00015400
ISN     21          QRW=VES(J,21)                                                      00015410
ISN     22          TTR=TWV/QRW                                                        00015420
ISN     23          GO TO 35                                                           00015430
ISN     24       30 TTR=VES(J,26)                                                      00015440
ISN     25          QRW=TWV/TTR                                                        00015450
ISN     26       35 QC=TCV/TTR                                                         00015460
ISN     27          SRV=VES(J,18)                                                      00015470
ISN     28          IF(SRV.GT.0.0) GO TO 41                                            00015480
ISN     29         -SRV=(VOL/2.0+0.75*AREA)*1.5*7.48                                   00015490
ISN     30          VES(J,18)=SRV                                                      00015500
ISN     31       41 TSR=SRV/QRW                                                        00015510
ISN     32          QFR=VES(J,24)                                                      00015520
ISN     33          IF(QFR.GT.0.0) GO TO 42                                            00015530
ISN     34          QFR=QS                                                             00015540
ISN     35       42 TFR=VES(J,19)/QFR                                                  00015550
ISN     36          VES(J,16)=TWV                                                      00015560
ISN     37          VES(J,17)=TCV                                                      00015570
ISN     38          VES(J,21)=QRW                                                      00015580
ISN     39          VES(J,22)=QC                                                       00015590
ISN     40          VES(J,23)=QRW                                                      00015600
ISN     41          VES(J,24)=QS                                                       00015610
ISN     42          VES(J,26)=TTR                                                      00015620
ISN     43          VES(J,27)=TSR                                                      00015630
ISN     44          VES(J,28)=TFR                                                      00015640
ISN     45          VES(J,14)=VES(J,8)/WAN(J,1)*17100.0                                00015650
ISN     46          RETURN                                                             00015660
ISN     47          END                                                                00015670

*STATISTICS*   SOURCE STATEMENTS = 46, PROGRAM SIZE = 2494 BYTES, PROGRAM NAME = AREGN    PAGE:   36.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 11 ******
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```
OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                       OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       1          SUBROUTINE MASBAL(NV,TOP,QG,QN,TA,TC)
ISN       2          LOGICAL QL
ISN       3          DIMENSION WAN(10,15),IVES(9,8),VES(9,32),ICAT(5),
                    1           IAN(5),RVES(10)
ISN       4          COMMON/IO/NI,NO,IOUT
ISN       5          COMMON/DESD/WAN,VES,IVES
ISN       6          DATA ICAT,IAN/10*0/
ISN       7          DATA TADW,TCDW/2*0.0/
ISN       8          DATA RVES/10*0.0/
ISN       9          J=0
ISN      10          K=0
ISN      11          TA=0.0
ISN      12          TC=0.0
ISN      13          QL=.FALSE.
ISN      14          IF(IOUT.GE.5) QL=.TRUE.
ISN      16          DO 10 I=1,NV
ISN      17          IF(IVES(I,1).LT.0) GO TO 10
ISN      18          IF(IVES(I,1)-2)1,2,3
ISN      19        1 J=J+1
ISN      20          ICAT(J)=I
ISN      21          GO TO 10
ISN      22        2 K=K+1
ISN      23          IAN(K)=I
ISN      24          GO TO 10
ISN      25        3 IDG=I
ISN      26       10 CONTINUE
ISN      27          DO 12 I=1,5
ISN      28          IF(ICAT(I))15,15,11
ISN      29       11 J=ICAT(I)
ISN      30          VP=IVES(J,2)
ISN      31          TA=TA+VES(J,17)*VP
ISN      32          TADW=TADW+VES(J,16)*VP+VES(J,18)*VP
ISN      33       12 CONTINUE
ISN      34       15 DO 17 I=1,5
ISN      35          IF (IAN(I))20,20,16
ISN      36       16 J=IAN(I)
ISN      37          VP=IVES(J,2)
ISN      38          TC=TC+VES(J,17)*VP
ISN      39          TCDW=TCDW+VES(J,16)*VP+VES(J,18)*VP
ISN      40       17 CONTINUE
ISN      41       20 RVES(NV+1)=TCDW
ISN      42          IF(QL)WRITE(NO,610)TA,TADW,TC,TCDW
ISN      44          DO 30 I=1,NV
ISN      45          J=NV-I+1
ISN      46          K=J+1
ISN      47          VP=IVES(J,2)
ISN      48          RVES(J)=RVES(K)+VES(J,15)*VP+VES(J,19)*VP
ISN      49       30 CONTINUE
ISN      50          VP=IVES(1,2)
ISN      51          RVES(1)=RVES(2)+TADW+VES(1,15)*VP+VES(1,19)*VP
ISN      52          CAPLMT=VES(1,14)*VP-RVES(2)
ISN      53          DO 40 I=2,NV
ISN      54          IF(IVES(I,1))40,40,35
```

```
                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       55      35 VP=IVES(I,2)                                                  00016210
ISN       56         CAPNET=VES(I,14)*VP-RVES(I+1)                                 00016220
ISN       57         IF(CAPNET.GE.CAPLMT) GO TO 40                                 00016230
ISN       58         CAPLMT=CAPNET                                                 00016240
ISN       59         J=I                                                           00016250
ISN       60      40 CONTINUE                                                      00016260
ISN       61         NV1=NV+1                                                      00016270
ISN       62         IF(QL)WRITE(NO,610)(RVES(I),I=1,NV1),CAPLMT                   00016280
ISN       64     610 FORMAT(1X,E12.5)                                              00016290
ISN       65         DO 50 I=1,NV                                                  00016300
ISN       66         VP=IVES(I,2)                                                  00016310
ISN       67         VES(I,14)=(CAPLMT+RVES(I+1))/VP                               00016320
ISN       68         VES(I,9)=VES(I,14)*WAN(I,1)/17100.0                           00016330
ISN       69      50 CONTINUE                                                      00016340
ISN       70         TOP=VES(J,14)/VES(J,29)/60.0                                  00016350
ISN       71         VP1=IVES(1,2)                                                 00016360
ISN       72         QG=VES(1,14)*VP1+RVES(1)                                      00016370
ISN       73         VPN=IVES(NV,2)                                                00016380
ISN       74         QN=VES(NV,14)*VPN-RVES(NV+1)                                  00016390
ISN       75         IF(QL)WRITE(NO,610)QG,QN                                      00016400
ISN       77         RETURN                                                        00016410
ISN       78         END                                                           00016420

*STATISTICS*  SOURCE STATEMENTS = 74, PROGRAM SIZE = 4388 BYTES, PROGRAM NAME = MASBAL    PAGE:   37.

*STATISTICS*   NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 12 ******
```

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LEVEL 1.3.0 (MAY 1983)           VS FORTRAN          DATE: NOV 18, 1983     TIME: 15:48:16                 PAGE:   39

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK    SOURCE NOTERM    OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)      CHARLEN(500)     SDUMP

                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          FUNCTION F1(A,N,X,Y)                                                   00016430
ISN        2          DIMENSION X(N),Y(N)                                                    00016440
ISN        3          COMMON/IO/NI,NO,IOUT                                                   00016450
ISN        4          IF(IOUT.EQ.5)WRITE(NO,600)                                             00016460
ISN        6      600 FORMAT(1X,'F1')                                                        00016470
ISN        7          IF(A-X(1))3,3,1                                                        00016480
ISN        8        1 IF(A-X(N))4,2,2                                                        00016490
ISN        9        2 F1=Y(N)                                                                00016500
ISN       10          RETURN                                                                 00016510
ISN       11        3 F1=Y(1)                                                                00016520
ISN       12          RETURN                                                                 00016530
ISN       13        4 DO 5 I=2,N                                                             00016540
ISN       14          IM=I-1                                                                 00016550
ISN       15          IF(A.LT.X(I)) GO TO 6                                                  00016560
ISN       16        5 CONTINUE                                                               00016570
ISN       17        6 RDX=(A-X(IM))/(X(I)-X(IM))                                             00016580
ISN       18          DY=Y(I)-Y(IM)                                                          00016590
ISN       19          F1=Y(IM)+RDX*DY                                                        00016600
ISN       20          RETURN                                                                 00016610
ISN       21          END                                                                    00016620

*STATISTICS*   SOURCE STATEMENTS = 20, PROGRAM SIZE = 1480 BYTES, PROGRAM NAME = F1     PAGE:    39.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 13 ******
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```
OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG    SRCFLG NOSYM
                      OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)        CHARLEN(500)     SDUMP

                     *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       1           FUNCTION F2(A,B,N,M,X,Y,ZM,ZB,ZX)
ISN       2           LOGICAL QL
ISN       3           DIMENSION X(N),Y(M),ZM(N,M),ZB(N,M),Z(2,2)
ISN       4           COMMON/IO/NI,NO,IOUT
ISN       5           QL=.FALSE.
ISN       6           IF(IOUT.GE.5) QL=.TRUE.
ISN       8           IF(QL)WRITE(NO,600)
ISN      10       600 FORMAT(1X,'F2')
ISN      11           IF((A.LE.X(1)).AND.(B.LE.Y(1))) GO TO 100
ISN      12           IF((A.LE.X(1)).AND.(B.GE.Y(M))) GO TO 110
ISN      13           IF((A.GE.X(N)).AND.(B.LE.Y(1))) GO TO 120
ISN      14           IF((A.GE.X(N)).AND.(B.GE.Y(M))) GO TO 130
ISN      15           IF(A.LE.X(1)) GO TO 200
ISN      16           IF(A.GE.X(N)) GO TO 210
ISN      17           IF(B.LE.Y(1)) GO TO 240
ISN      18           IF(B.GE.Y(M)) GO TO 250
ISN      19           DO 10 I=2,N
ISN      20           IM=I-1
ISN      21           IF(A.LT.X(I)) GO TO 15
ISN      22        10 CONTINUE
ISN      23        15 DO 20 J=2,M
ISN      24           JM=J-1
ISN      25           IF(B.LT.Y(J)) GO TO 25
ISN      26        20 CONTINUE
ISN      27        25 DO 40 II=1,2
ISN      28           I=IM+II-1
ISN      29           DO 30 JJ=1,2
ISN      30           J=JM+JJ-1
ISN      31           Z(II,JJ)=(ZX-ZB(I,J))/ZM(I,J)
ISN      32           IF(QL)WRITE(NO,610)ZB(I,J),ZM(I,J)
ISN      34       610 FORMAT(1X,E12.5,5X,E12.5)
ISN      35        30 CONTINUE
ISN      36        40 CONTINUE
ISN      37           RDX=(A-X(IM))/(X(I)-X(IM))
ISN      38           RDY=(B-Y(JM))/(Y(J)-(JM))
ISN      39           DZ1=Z(1,2)-Z(1,1)
ISN      40           DZ2=Z(2,2)-Z(2,1)
ISN      41           F2=RDY*(RDX*(DZ2-DZ1)+DZ1)+RDX*(Z(2,1)-Z(1,1))+Z(1,1)
ISN      42           IF(QL)WRITE(NO,611)X(IM),X(I),Y(JM),Y(J),Z(1,1),Z(1,2),
                     1          Z(2,1),Z(2,2)
ISN      44       611 FORMAT(1X,E12.5)
ISN      45           RETURN
ISN      46       100 F2=(ZX-ZB(1,1))/ZM(1,1)
ISN      47           RETURN
ISN      48       110 F2=(ZX-ZB(1,M))/ZM(1,M)
ISN      49           RETURN
ISN      50       120 F2=(ZX-ZB(N,1))/ZM(N,1)
ISN      51           RETURN
ISN      52       130 F2=(ZX-ZB(N,M))/ZM(N,M)
ISN      53           RETURN
ISN      54       200 I=1
ISN      55           GO TO 215
ISN      56       210 I=N
```

```
LEVEL 1.3.0 (MAY 1983)          VS FORTRAN          DATE: NOV 18, 1983    TIME: 15:48:16      NAME: F2       PAGE:    41

                    *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        57      215 DO 220 J=2,M                                                         00017160
ISN        58          JM=J-1                                                               00017170
ISN        59          IF(B.LT.Y(J)) GO TO 225                                              00017180
ISN        60      220 CONTINUE                                                             00017190
ISN        61      225 DO 230 JJ=1,2                                                        00017200
ISN        62          J=JM+JJ-1                                                            00017210
ISN        63          Z(1,JJ)=(ZX-ZB(I,J))/ZM(I,J)                                         00017220
ISN        64      230 CONTINUE                                                             00017230
ISN        65          RDY=(B-Y(JM))/(Y(J)-Y(JM))                                           00017240
ISN        66          DZ1=Z(1,2)-Z(1,1)                                                    00017250
ISN        67          F2=RDY*DZ1+Z(1,1)                                                    00017260
ISN        68          RETURN                                                               00017270
ISN        69      240 J=1                                                                  00017280
ISN        70          GO TO 255                                                            00017290
ISN        71      250 J=M                                                                  00017300
ISN        72      255 DO 260 I=2,M                                                         00017310
ISN        73          IM=I-1                                                               00017320
ISN        74          IF (A.LT.X(I)) GO TO 265                                             00017330
ISN        75      260 CONTINUE                                                             00017340
ISN        76      265 DO 270 II=1,2                                                        00017350
ISN        77          I=IM+II-1                                                            00017360
ISN        78          Z(1,II)=(ZX-ZB(I,J))/ZM(I,J)                                         00017370
ISN        79      270 CONTINUE                                                             00017380
ISN        80          RDX=(A-X(IM))/(X(I)-X(IM))                                           00017390
ISN        81          DZ1=Z(1,2)-Z(1,1)                                                    00017400
ISN        82          F2=RDX*DZ1+Z(1,1)                                                    00017410
ISN        83          RETURN                                                               00017420
ISN        84          END                                                                  00017430

*STATISTICS*   SOURCE STATEMENTS = 80, PROGRAM SIZE = 5402 BYTES, PROGRAM NAME = F2     PAGE:    40.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 14 ******
```

```
               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN      56           GO TO 255                                                               00017970
ISN      57       250 J=M                                                                     00017980
ISN      58       255 DO 260 I=2,N                                                            00017990
ISN      59           IM=I-1                                                                  00018000
ISN      60           IF(A.LT.X(I)) GO TO 265                                                 00018010
ISN      61       260 CONTINUE                                                                00018020
ISN      62       265 RDX=(A-X(IM))/(X(I)-X(IM))                                              00018030
ISN      63           DZ1=Z(I,J)-Z(IM,J)                                                      00018040
ISN      64           F3=RDX*DZ1+Z(IM,J)                                                      00018050
ISN      65           RETURN                                                                  00018060
ISN      66           END                                                                     00018070

*STATISTICS*   SOURCE STATEMENTS = 63, PROGRAM SIZE = 4344 BYTES, PROGRAM NAME = F3    PAGE:    42.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 15 ******
```

```
OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                    OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)      SDUMP

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          FUNCTION F3(A,B,N,M,X,Y,Z)                                         00017440
ISN        2          LOGICAL QL                                                         00017450
ISN        3          DIMENSION X(N),Y(M),Z(N,M)                                         00017460
ISN        4          COMMON/IO/NI,NO,IOUT                                               00017470
ISN        5          QL=.FALSE.                                                         00017480
ISN        6          IF(IOUT.GE.5) QL=.TRUE.                                            00017490
ISN        8          IF(QL)WRITE(NO,600)                                                00017500
ISN       10      600 FORMAT(1X,'F3')                                                    00017510
ISN       11          IF((A.LE.X(1)).AND.(B.LE.Y(1))) GO TO 100                          00017520
ISN       12          IF((A.LE.X(1)).AND.(B.GE.Y(M))) GO TO 110                          00017530
ISN       13          IF((A.GE.X(N)).AND.(B.LE.Y(1))) GO TO 120                          00017540
ISN       14          IF((A.GE.X(N)).AND.(B.GE.Y(M))) GO TO 130                          00017550
ISN       15          IF(A.LE.X(1)) GO TO 200                                            00017560
ISN       16          IF(A.GE.X(N)) GO TO 210                                            00017570
ISN       17          IF(B.LE.Y(1)) GO TO 240                                            00017580
ISN       18          IF(B.GE.Y(M)) GO TO 250                                            00017590
ISN       19          DO 10 I=2,N                                                        00017600
ISN       20          IM=I-1                                                             00017610
ISN       21          IF(A.LT.X(I)) GO TO 15                                             00017620
ISN       22       10 CONTINUE                                                           00017630
ISN       23       15 DO 20 J=2,M                                                        00017640
ISN       24          JM=J-1                                                             00017650
ISN       25          IF(B.LT.Y(J)) GO TO 25                                             00017660
ISN       26       20 CONTINUE                                                           00017670
ISN       27       25 RDX=(A-X(IM))/(X(I)-X(IM))                                         00017680
ISN       28          RDY=(B-Y(JM))/(Y(J)-Y(JM))                                         00017690
ISN       29          DZ1=Z(IM,J)-Z(IM,JM)                                               00017700
ISN       30          DZ2=Z(I,J)-Z(I,JM)                                                 00017710
ISN       31          F3=RDY*(RDX*(DZ2-DZ1)+DZ1)+RDX*(Z(I,JM)-Z(IM,JM))+Z(IM,JM)         00017720
ISN       32          IF(QL)WRITE(NO,610)X(IM),X(I),Y(JM),Y(J),Z(IM,JM),Z(IM,J),         00017730
                 1              Z(I,JM),Z(I,J)                                           00017740
ISN       34      610 FORMAT(1X,E12.5)                                                   00017750
ISN       35          RETURN                                                             00017760
ISN       36      100 F3=Z(1,1)                                                          00017770
ISN       37          RETURN                                                             00017780
ISN       38      110 F3=Z(1,M)                                                          00017790
ISN       39          RETURN                                                             00017800
ISN       40      120 F3=Z(N,1)                                                          00017810
ISN       41          RETURN                                                             00017820
ISN       42      130 F3=Z(N,M)                                                          00017830
ISN       43          RETURN                                                             00017840
ISN       44      200 I=1                                                                00017850
ISN       45          GO TO 215                                                          00017860
ISN       46      210 I=N                                                                00017870
ISN       47      215 DO 220 J=2,M                                                       00017880
ISN       48          JM=J-1                                                             00017890
ISN       49          IF(B.LT.Y(J)) GO TO 225                                            00017900
ISN       50      220 CONTINUE                                                           00017910
ISN       51      225 RDY=(B-Y(JM))/(Y(J)-Y(JM))                                         00017920
ISN       52          DZ1=Z(I,J)-Z(I,JM)                                                 00017930
ISN       53          F3=RDY*DZ1+Z(I,JM)                                                 00017940
ISN       54          RETURN                                                             00017950
ISN       55      240 J=1                                                                00017960
```

```
LEVEL 1.3.0 (MAY 1983)          VS FORTRAN          DATE: NOV 18, 1983     TIME: 15:48:17                    PAGE:    44

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                       OPT(0) LANGLVL(66) NOFIPS    FLAG(I)  NAME(MAIN  )  LINECOUNT(60)        CHARLEN(500)      SDUMP

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          SUBROUTINE CONWAT(IWAU,WAN,I)                                           00018080
ISN        2          LOGICAL QL                                                              00018090
ISN        3          DIMENSION WAN(10,15),CFS(13)                                            00018100
ISN        4          COMMON/IO/NI,NO,IOUT                                                    00018110
ISN        5          DATA CFE,CFS/50.0,50.0,2.5,4.11,2.17,1.28,2.94,1.67,                    00018120
                     1             0.82,1.04,1.41,0.81,0.835,1.14/                            00018130
ISN        6          QL=.FALSE.                                                              00018140
ISN        7          IF(IOUT.GE.5)QL=.TRUE.                                                  00018150
ISN        9          CNA=0                                                                   00018160
ISN       10          IND=IWAU-2                                                              00018170
ISN       11          IF(IND)100,120,110                                                      00018180
ISN       12      100 DO 101 I=2,14                                                           00018190
ISN       13          WAN(1,I)=WAN(1,I)/CFS(I-1)                                              00018200
ISN       14      101 CONTINUE                                                                00018210
ISN       15          GO TO 120                                                               00018220
ISN       16      110 DO 111 I=2,14                                                           00018230
ISN       17          WAN(1,I)=WAN(1,I)/CFE                                                   00018240
ISN       18      111 CONTINUE                                                                00018250
ISN       19      120 IF(QL)WRITE(NO,600)(WAN(1,I),I=1,15)                                    00018260
ISN       21      600 FORMAT(1X,E12.5)                                                        00018270
ISN       22          RETURN                                                                  00018280
ISN       23          END                                                                     00018290

*STATISTICS*   SOURCE STATEMENTS = 21, PROGRAM SIZE = 1386 BYTES, PROGRAM NAME = CONWAT     PAGE:   44.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 16 ******
```

```
LEVEL 1.3.0 (MAY 1983)          VS FORTRAN          DATE: NOV 18, 1983    TIME: 15:48:17                PAGE:    45

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG    SRCFLG NOSYM
                     OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)      CHARLEN(500)      SDUMP

               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1          SUBROUTINE HEADG(IPG)                                              00018300
ISN        2          DIMENSION TITLE(10),IDNUM(4),UNAME(6),DATE(5)                      00018310
ISN        3          COMMON/IO/NI,NO,IOUT                                               00018320
ISN        4          COMMON/HDG/TITLE,IDNUM,UNAME,DATE                                  00018330
ISN        5          WRITE(NO,600)                                                      00018340
ISN        6      600 FORMAT(1H1,/5X,70(1H_),//5X,'DEMINERALIZATION SYSTEM PERF',        00018350
                 1         'ORMANCE ','SIMULATION',4X,'VERSION:  830901-1.0')            00018360
ISN        7          WRITE(NO,601)(TITLE(I),I=1,10),(IDNUM(J),J=1,4)                    00018370
ISN        8      601 FORMAT(/5X,10A4,3X,'ID NO: ',4A4)                                  00018380
ISN        9          WRITE(NO,602)(UNAME(I),I=1,6),(DATE(J),J=1,5),IPG                  00018390
ISN       10      602 FORMAT(5X,'USER NAME: ',6A4,'DATE: ',5A4,'PAGE: ',I2)              00018400
ISN       11          WRITE(NO,603)                                                      00018410
ISN       12      603 FORMAT(5X,70(1H_),///)                                             00018420
ISN       13          RETURN                                                             00018430
ISN       14          END                                                                00018440

*STATISTICS*   SOURCE STATEMENTS = 14, PROGRAM SIZE = 1128 BYTES, PROGRAM NAME = HEADG    PAGE:    45.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 17 ******
```

APPENDIX D

PERFORMANCE PROGRAM OUTPUT

PERFORMANCE PROGRAM OUTPUT

Four output listings are included as a part of this Appendix. The cases represented by these listingsinclude simulations of the following: three and six bed demineralizer performance reported by Webb and Carr (29), and a two bed system proposed as Case 1 in Applebaum (1). The input dialogue for Applebaum Case 1 is provided as an example of the form in which input is provided to the program. Two performance simulations were made on the six bed demineralizer of Webb and Carr. One simulation used the original design water analysis as a basis and the other three bed demineralizer design water analysis. The listings may be identified as follows:

A-1.1 Applebaum Case 1 two bed demineralizer,

W-3.1 Webb and Carr three bed demineralizer,

W-6.1 Webb and Carr six bed demineralizer (original design water analysis)

W-6.2 Webb and Carr six bed demineralizer (three bed demineralizer design water analysis).

```
*  *  *  *  *  *  *  *  *  *  *  *  *  *
*   DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION  *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
*   VERSION:  830901-1.0                           *
*   BY: A.J.WILSON                                 *
*  *  *  *  *  *  *  *  *  *  *  *  *  *

**** ENTER PROBLEM IDENTIFICATION ****
    ENTER TITLE (40 CHARACTERS MAXIMUM)
    ?
APPLEBAUM CASE 1
    ENTER PROBLEM ID NUMBER (15 CHARACTERS MAXIMUM)
    ?
A-1.1
    ENTER USER NAME (25 CHARACTERS MAXIMUM)
    ?
A.J.WILSON
    ENTER DATE (20 CHARACTERS MAXIMUM)
    ?
NOVEMBER 21, 1983

****ENTER SYSTEM DESIGN DATA****

    ENTER NUMBER OF VESSELS IN SERIES (9 MAXIMUM)
    ?
3
    ENTER NUMBER OF VESSELS IN SERIES WITH PARALLEL VESSELS
    ?
0
    ENTER VESSEL TYPE
         CX-CATION EXCHANGER
         AX-ANION EXCHANGER
         FG-FORCED DRAFT DEGASIFIER
         VG-VACUUM DEGASIFIER

    POSITION 1 ?
CX
    POSITION 2 ?
FG
    POSITION 3 ?
AX

    ENTER SYSTEM FLOW RATE(GPM)
    ?
 0.26600E+03
    ENTER WATER ANALYSIS UNITS
```

```
          1-MG/L AS SUCH
          2-MG/L AS CACO3
          3-MEQ/L
     ?
2

     ENTER INFLUENT WATER ANALYSIS
     H+    ?
 0.00000E+00
     CA++ ?
 0.35000E+02
     MG++ ?
 0.22000E+02
     NA+  ?
 0.55000E+02
     K+   ?
 0.00000E+00
     OH-  ?
 0.00000E+00
     CO3= ?
 0.69000E+02
     HCO3 ?
 0.00000E+00
     SO4= ?
 0.21000E+02
     CL-  ?
 0.22000E+02
     NO3- ?
 0.00000E+00
     SIO2 ?
 0.61790E+01
     CO2  ?
 0.00000E+00

     ENTER INFLUENT TEMPERATURE(F)
     ?
 0.50000E+02

****ENTER VESSEL DESIGN DATA****


*** VESSEL 1 ***

     ENTER VESSEL DIAMETER (INCHES)
     ?
 0.66000E+02

     ENTER VESSEL SIDE SHEET (INCHES)
     ?
 0.60000E+02

     ENTER EFFECTIVE RESIN DEPTH (INCHES)
     ?
 0.30000E+02

     ENTER INEFFECTIVE RESIN DEPTH (INCHES)
     ?
 0.30000E+01

     ENTER VESSEL WALL THICKNESS (INCHES)
     ?
 0.17500E+00

     ENTER CATION RESIN TYPE
```

```
          200-LIST OF DOWEX RESIN TYPE CODES
     ?
201

     ENTER CATION RESIN REGENERANT LEVEL (LB/CU FT)
     ?
 0.50000E+01

     ENTER CATION RESIN CAPACITY EFFECTIVENESS (PERCENT)
     ?
 0.80000E+02

     ENTER DEGASIFIER EFFLUENT CO2 CONCENTRATION
     ?
 0.57000E+01

*** VESSEL 3 ***

     ENTER VESSEL DIAMETER (INCHES)
     ?
 0.66000E+02

     ENTER VESSEL SIDE SHEET (INCHES)
     ?
 0.60000E+02

     ENTER EFFECTIVE RESIN DEPTH (INCHES)
     ?
 0.30000E+02

     ENTER INEFFECTIVE RESIN DEPTH (INCHES)
     ?
 0.30000E+01

     ENTER VESSEL WALL THICKNESS (INCHES)
     ?
 0.17500E+00

     ENTER ANION  RESIN TYPE
          200-LIST OF DOWEX RESIN TYPE CODES
     ?
221

     ENTER REGENERANT TEMPERATURE(F)
     ?
 0.75000E+02

     ENTER ANION  RESIN REGENERANT LEVEL (LB/CU FT)
     ?
 0.50000E+01

     ENTER ANION  RESIN CAPACITY EFFECTIVENESS (PERCENT)
     ?
 0.95000E+02
RUN CURRENT CASE OR EDIT
     1-RUN
     2-EDIT
?
2

****EDIT MENU****

     0 - RUN CURRENT CASE
     1 - LIST PROBLEM IDENTIFICATION
     2 - LIST SYSTEM DESIGN DATA
```

```
    3 - LIST VESSEL DESIGN DATA
    4 - LIST VESSEL DESIGN DEFAULTS
    8 - EDIT VESSEL DESIGN DEFAULTS
    9 - NEW PROBLEM
    ?
1

    ****PROBLEM IDENTIFICATION****

    TITLE: APPLEBAUM CASE 1

    ID NO: A-1.1

    USER NAME: A.J.WILSON

    DATE: NOVEMBER 21, 1983


****ENTER SELECTION****
    0 - RETURN TO EDIT MENU
    1 - RUN CURRENT CASE
?
0

****EDIT MENU****

    0 - RUN CURRENT CASE
    1 - LIST PROBLEM IDENTIFICATION
    2 - LIST SYSTEM DESIGN DATA
    3 - LIST VESSEL DESIGN DATA
    4 - LIST VESSEL DESIGN DEFAULTS
    8 - EDIT VESSEL DESIGN DEFAULTS
    9 - NEW PROBLEM
    ?
2

    ****SYSTEM DESIGN DATA****

    SYSTEM FLOW RATE            266.0 GPM

    INFLUENT WATER ANALYSIS        MG/L AS CACO3

         H+                           0.0000
         CA++                        35.0000
         MG++                        22.0000
         NA+                         55.0000
         K+                           0.0000
         OH-                          0.0000
         CO3=                        69.0000
         HCO3                         0.0000
         SO4=                        21.0000
         CL-                         22.0000
         NO3-                         0.0000
         SIO2                         6.1790
         CO2                          0.0000

    INFLUENT TEMPERATURE         50.0 F

    SYSTEM CONFIGURATION

         VESSEL 1             CATION EXCHANGER
         VESSEL 2             FORCED DRAFT DEGASIFIER
         VESSEL 3             ANION EXCHANGER

    NUMBER OF VESSELS IN PARALLEL
```

```
         VESSEL 1              0
         VESSEL 2              0
         VESSEL 3              0

****ENTER SELECTION****
    0 - RETURN TO EDIT MENU
    1 - RUN CURRENT CASE
?
0

****EDIT MENU****

    0 - RUN CURRENT CASE
    1 - LIST PROBLEM IDENTIFICATION
    2 - LIST SYSTEM DESIGN DATA
    3 - LIST VESSEL DESIGN DATA
    4 - LIST VESSEL DESIGN DEFAULTS
    8 - EDIT VESSEL DESIGN DEFAULTS
    9 - NEW PROBLEM
    ?
3

    ENTER VESSEL NUMBER OR NUMBERS
         FORMATS - N OR
                 - N M
         WHERE:  N - INITIAL VESSEL
                 M - FINAL VESSEL
         EXAMPLE:  1 3 - OUTPUT FOR ALL VESSELS
    ?
1 3
    **** VESSEL 1 DESIGN****

    OUTSIDE DIAMETER(INCHES)                 66.0

    WALL THICKNESS(INCHES)                    0.175

    STRAIGHT SIDE(INCHES)                    60.0

    RESIN TYPE                             DOWEX HCR-S

    EFFECTIVE RESIN DEPTH(INCHES)            30.0

    INEFFECTIVE RESIN DEPTH(INCHES)           3.0

    CAPCITY EFFECTIVENESS(PERCENT)          80.0

    REGENERANT LEVEL (LB 93% H2SO4/CU FT)      5.0
    **** VESSEL 2 DESIGN****

    FORCED DRAFT DEGASIFIER               MG/L AS CACO3

    EFFLUENT CARBON DIOXIDE                      5.7000
    **** VESSEL 3 DESIGN****

    OUTSIDE DIAMETER(INCHES)                 66.0

    WALL THICKNESS(INCHES)                    0.175

    STRAIGHT SIDE(INCHES)                    60.0
```

```
    RESIN TYPE                                DOWEX SBR-P

    EFFECTIVE RESIN DEPTH(INCHES)               30.0

    INEFFECTIVE RESIN DEPTH(INCHES)              3.0

    CAPCITY EFFECTIVENESS(PERCENT)             95.0

    REGENERANT LEVEL (LB 100% NAOH/CU FT)        5.0

    REGENERATION TEMPERATURE (F)                75.0

****ENTER SELECTION****
    0 - RETURN TO EDIT MENU
    1 - RUN CURRENT CASE
?
0

****EDIT MENU****

    0 - RUN CURRENT CASE
    1 - LIST PROBLEM IDENTIFICATION
    2 - LIST SYSTEM DESIGN DATA
    3 - LIST VESSEL DESIGN DATA
    4 - LIST VESSEL DESIGN DEFAULTS
    8 - EDIT VESSEL DESIGN DEFAULTS
    9 - NEW PROBLEM
    ?
4

    ENTER VESSEL NUMBER OR NUMBERS
         FORMATS - N OR
                 - N M
         WHERE:  N - INITIAL VESSEL
                 M - FINAL VESSEL
         EXAMPLE:  1 3 - OUTPUT FOR ALL VESSELS
    ?
1 3
    ****VESSEL 1 DEFAULTS****


    BED EXPANSION(%):                                    50.0

    SLOW RINSE VOLUME(GAL):                             527.5

    FAST RINSE VOLUME(GAL):                            1469.2
    ****VESSEL 2 DEFAULTS****

    ****VESSEL 3 DEFAULTS****


    BED EXPANSION(%):                                    50.0

    ANION REGENERANT APPLICATION TIME(MIN):              60.0

    SLOW RINSE VOLUME(GAL):                             527.5

    FAST RINSE VOLUME(GAL):                            5876.7

****ENTER SELECTION****
```

```
    O - RETURN TO EDIT MENU
    1 - RUN CURRENT CASE
?
O

****EDIT MENU****

    O - RUN CURRENT CASE
    1 - LIST PROBLEM IDENTIFICATION
    2 - LIST SYSTEM DESIGN DATA
    3 - LIST VESSEL DESIGN DATA
    4 - LIST VESSEL DESIGN DEFAULTS
    8 - EDIT VESSEL DESIGN DEFAULTS
    9 - NEW PROBLEM
    ?
8

    ENTER VESSEL NUMBER OR NUMBERS
         FORMATS - N OR
                 - N M
         WHERE:  N - INITIAL VESSEL
                 M - FINAL VESSEL
         EXAMPLE:  1 3 - OUTPUT FOR ALL VESSELS
    ?
1 3
    ****EDIT VESSEL 1 DEFAULTS****
         1 - CHANGE BACKWASH TIME
         2 - CHANGE BACKWASH BED EXPANSION
         3 - CHANGE SLOW RINSE VOLUME
         4 - CHANGE FAST RINSE VOLUME
1

    ENTER BACKWASH TIME(MINUTES)
    ?
 O.10000E+02

****ENTER SELECTION****
    O - CONTINUE TO EDIT DEFAULTS
    1 - RETURN TO EDIT MENU
    2 - RUN CURRENT CASE
?
O

****ENTER SELECTION****
    O - SAME VESSEL
    1 - NEXT VESSEL
?
1
    ****EDIT VESSEL 3 DEFAULTS****
         1 - CHANGE BACKWASH TIME
         2 - CHANGE BACKWASH BED EXPANSION
         3 - CHANGE SLOW RINSE VOLUME
         4 - CHANGE FAST RINSE VOLUME
         5 - CHANGE ANION REGENERANT APPLICATION TIME
5

    ENTER REGENERANT APPLICATION TIME(MINUTES)
    ?
 O.90000E+02

****ENTER SELECTION****
    O - CONTINUE TO EDIT DEFAULTS
```

```
    1 - RETURN TO EDIT MENU
    2 - RUN CURRENT CASE
?
2
```

```
DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION:  830901-1.0

APPLEBAUM CASE 1                                  ID NO: A-1.1
USER NAME: A.J.WILSON               DATE: NOVEMBER 21, 1983   PAGE:  1
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**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
       0 - COMPLETE
       1 - SYSTEM DESIGN
       2 - SYSTEM PERFORMANCE
       3 - VESSEL DESIGN
       4 - VESSEL PERFORMANCE
       5 - EDIT INPUT DATA
       6 - EXIT PROGRAM
?
0
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**** OVERALL SYSTEM DESIGN ****

SYSTEM FLOW RATE 266.0 GPM

INFLUENT WATER ANALYSIS MG/L AS CACO3

H+	0.0000
CA++	35.0000
MG++	22.0000
NA+	55.0000
K+	0.0000
OH-	0.0000
CO3=	69.0000
HCO3	0.0000
SO4=	21.0000
CL-	22.0000
NO3-	0.0000
SIO2	6.1790
CO2	0.0000

INFLUENT TEMPERATURE 50.0 F

SYSTEM CONFIGURATION

VESSEL 1	CATION EXCHANGER
VESSEL 2	FORCED DRAFT DEGASIFIER
VESSEL 3	ANION EXCHANGER

NUMBER OF VESSELS IN PARALLEL

VESSEL 1	1
VESSEL 2	1
VESSEL 3	1

REGENERANT CHEMICALS

CATION RESIN	93 PERCENT SULFURIC ACID
ANION RESIN	50 PERCENT SODIUM HYDROXIDE

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

APPLEBAUM CASE 1 ID NO. A-1.1
USER NAME: A.J.WILSON DATE: NOVEMBER 21, 1983 PAGE: 3

**** OVERALL SYSTEM PERFORMANCE ****

THROUGHPUT	GALLONS PER REGENERATION	
GROSS	134518.	
NET	114266.	
OPERATING TIME	7.64 HOURS	
EFFLUENT WATER ANALYSIS		MG/L AS CACO3
H+		0.0000
CA++		0.0000
MG++		0.0000
NA+		3.5384
K+		0.0000
OH-		0.0000
CO3=		0.0000
HCO3		0.0000
SO4=		0.0000
CL-		3.5384
NO3-		0.0000
SIO2		0.0238
CO2		0.0000
TOTAL REGENERANT	GALLONS PER REGENERATION	
ACID	19.33	
CAUSTIC	47.01	

**** VESSEL 1 DESIGN****

OUTSIDE DIAMETER (INCHES)	66.0
WALL THICKNESS (INCHES)	0.175
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	23.51
FLOW RATE PER VESSEL (GPM)	266.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	58.8
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	64.6
CAPACITY EFFECTIVENESS (PERCENT)	80.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	5.0

**** VESSEL 2 DESIGN****

FORCED DRAFT DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

**** VESSEL 3 DESIGN****

OUTSIDE DIAMETER (INCHES)	66.0
WALL THICKNESS (INCHES)	0.175
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	23.51
FLOW RATE PER VESSEL (GPM)	266.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	58.8
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	64.6
CAPACITY EFFECTIVENESS (PERCENT)	95.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	5.0
REGENERATION TEMPERATURE (F)	75.0

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

APPLEBAUM CASE 1 ID NO: A-1.1
USER NAME: A.J.WILSON DATE: NOVEMBER 21, 1983 PAGE: 7

**** VESSEL 1 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	13.60
VESSEL (KGR AS CACO3)	799.11
LOAD (KGR AS CACO3)	799.11
UTILIZATION (PERCENT)	100.00
THROUGHPUT (GAL/REGEN)	122007.

EFFLUENT WATER ANALYSIS MG/L AS CACO3

H+	39.4615
CA++	0.0000
MG++	0.0000
NA+	3.5384
K+	0.0000
OH-	0.0000
CO3=	0 0000
HCO3	0.0000
SO4=	21.0000
CL-	22.0000
NO3-	0.0000
SIO2	6.1790
CO2	34.5000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	148.7	1487.	10.00
REGN APPLICATION			
REGENERANT			
AT 2% H2SO4	0.4	10.	23.50
AT 4% H2SO4	0.8	10.	11.51
DILUTION WATER			
AT 2% H2SO4	36.7	863.	23.50
AT 4% H2SO4	36.7	423.	11.51
SLOW RINSE	36.7	527.	14.36
FAST RINSE	266.0	1469.	5.52

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION   VERSION: 830901-1.0

APPLEBAUM CASE 1   ID NO: A-1.1
USER NAME: A.J.WILSON   DATE: NOVEMBER 21, 1983   PAGE: 8

**** VESSEL 2 PERFORMANCE****

FORCED DRAFT DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION. 830901-1.0

APPLEBAUM CASE 1 ID NO: A-1.1
USER NAME: A.J.WILSON DATE: NOVEMBER 21, 1983 PAGE: 9

**** VESSEL 3 PERFORMANCE****

CAPACITY.

RESIN (KGR AS CACO3/CU FT)	10.31
VESSEL (KGR AS CACO3)	605.72
LOAD (KGR AS CACO3)	372.06
UTILIZATION (PERCENT)	61.43
THROUGHPUT (GAL/REGEN)	115933.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	3.5384
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	3.5384
NO3-	0.0000
SIO2	0.0238
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	39.5	197.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	0.5	47.	90.00
DILUTION WATER			
AT 3% NAOH	12.7	1139.	90.00
SLOW RINSE	12.7	527.	41.67
FAST RINSE	266.0	5877.	22.09

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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION.  830901-1.0

APPLEBAUM CASE 1                                ID NO: A-1.1
USER NAME: A.J.WILSON                DATE: NOVEMBER 21, 1983    PAGE: 10

**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
     0 - COMPLETE
     1 - SYSTEM DESIGN
     2 - SYSTEM PERFORMANCE
     3 - VESSEL DESIGN
     4 - VESSEL PERFORMANCE
     5 - EDIT INPUT DATA
     6 - EXIT PROGRAM
?
6
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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION:  830901-1.0

WEBB AND CARR THREE BED                        ID NO: W-3.1
USER NAME: A.J.WILSON                DATE: NOVEMBER 3, 1983     PAGE:  1
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**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
     0 - COMPLETE
     1 - SYSTEM DESIGN
     2 - SYSTEM PERFORMANCE
     3 - VESSEL DESIGN
     4 - VESSEL PERFORMANCE
     5 - EDIT INPUT DATA
     5 - EXIT PROGRAM
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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

WEBB AND CARR THREE BED ID NO: W-3.1
USER NAME: A.J.WILSON DATE: NOVEMBER 3, 1983 PAGE: 2

**** OVERALL SYSTEM DESIGN ****

SYSTEM FLOW RATE 270.0 GPM

INFLUENT WATER ANALYSIS MG/L AS CACO3

H+	0.0000
CA++	30.0000
MG++	38.0000
NA+	17.0000
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	66.0000
SO4=	4.0000
CL-	14.0000
NO3-	1.0000
SIO2	1.6700
CO2	0.0000

INFLUENT TEMPERATURE 55.0 F

SYSTEM CONFIGURATION

VESSEL 1	CATION EXCHANGER
VESSEL 2	VACUUM DEGASIFIER
VESSEL 3	ANION EXCHANGER
VESSEL 4	CATION EXCHANGER
VESSEL 5	ANION EXCHANGER

NUMBER OF VESSELS IN PARALLEL

VESSEL 1	1
VESSEL 2	1
VESSEL 3	1
VESSEL 4	1
VESSEL 5	1

REGENERANT CHEMICALS

CATION RESIN	93 PERCENT SULFURIC ACID
ANION RESIN	50 PERCENT SODIUM HYDROXIDE

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION   VERSION: 830901-1.0

WEBB AND CARR THREE BED   ID NO: W-3.1
USER NAME: A.J.WILSON   DATE: NOVEMBER 3, 1983   PAGE: 3

**** OVERALL SYSTEM PERFORMANCE ****

THROUGHPUT	GALLONS PER REGENERATION
GROSS	539660.
NET	491215.

OPERATING TIME   30.75 HOURS

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.3310
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.3310
NO3-	0.0000
SIO2	0.0329
CO2	0.0000

TOTAL REGENERANT	GALLONS PER REGENERATION
ACID	52.40
CAUSTIC	80.71

**** VESSEL 1 DESIGN****

OUTSIDE DIAMETER (INCHES)	96.0
WALL THICKNESS (INCHES)	0.750
STRAIGHT SIDE (INCHES)	96.0
AREA (SQUARE FEET)	48.71
FLOW RATE PER VESSEL (GPM)	270.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	48.0
EFFECTIVE RESIN VOLUME (CU FT)	194.8
INEFFECTIVE RESIN DEPTH (INCHES)	5.0
TOTAL RESIN VOLUME (CU FT)	215.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	3.5

**** VESSEL 2 DESIGN****

VACUUM DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

**** VESSEL 3 DESIGN****

OUTSIDE DIAMETER (INCHES)	78.0
WALL THICKNESS (INCHES)	0.750
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	31.92
FLOW RATE PER VESSEL (GPM)	270.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	79.8
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	87.8
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	5.0
REGENERATION TEMPERATURE (F)	120.0

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

WEBB AND CARR THREE BED ID NO: W-3.1
USER NAME: A.J.WILSON DATE: NOVEMBER 3, 1983 PAGE: 7

**** VESSEL 4 DESIGN****

OUTSIDE DIAMETER (INCHES)	42.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	9.17
FLOW RATE PER VESSEL (GPM)	270.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	22.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	25.2
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	5.0

**** VESSEL 5 DESIGN****

OUTSIDE DIAMETER (INCHES)	48.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	12.05
FLOW RATE PER VESSEL (GPM)	270.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	30.1
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	33.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	3.5
REGENERATION TEMPERATURE (F)	120.0

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

WEBB AND CARR THREE BED ID NO: W-3.1

USER NAME: A.J.WILSON DATE: NOVEMBER 3, 1983 PAGE: 9

**** VESSEL 1 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	16.28
VESSEL (KGR AS CACO3)	3172.15
LOAD (KGR AS CACO3)	2517.27
UTILIZATION (PERCENT)	79.36
THROUGHPUT (GAL/REGEN)	508415.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	18.1455
CA++	0.0000
MG++	0.0000
NA+	0.8545
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	4.0000
CL-	14.0000
NO3-	1.0000
SIO2	1.6700
CO2	66.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	323.8	3238.	10.00
REGN APPLICATION			
REGENERANT			
AT 2% H2SO4	1.5	45.	29.13
DILUTION WATER			
AT 2% H2SO4	137.5	4006.	29.13
SLOW RINSE	137.5	1503.	10.93
FAST RINSE	270.0	4871.	18.04

**** VESSEL 2 PERFORMANCE****

VACUUM DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION   VERSION: 830901-1.0

WEBB AND CARR THREE BED   ID NO: W-3.1
USER NAME: A.J.WILSON   DATE: NOVEMBER 3, 1983   PAGE: 11

**** VESSEL 3 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	9.63
VESSEL (KGR AS CACO3)	768.21
LOAD (KGR AS CACO3)	766.20
UTILIZATION (PERCENT)	100.00
THROUGHPUT (GAL/REGEN)	498153.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.8545
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.8545
NO3-	0.0000
SIO2	0.0030
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	56.4	282.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	1.1	64.	60.00
DILUTION WATER			
AT 3% NAOH	25.8	1547.	60.00
SLOW RINSE	25.8	716.	27.78
FAST RINSE	270.0	7980.	29.55

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION   VERSION: 830901-1.0

WEBB AND CARR THREE BED   ID NO: W-3.1
USER NAME: A.J.WILSON   DATE: NOVEMBER 3, 1983   PAGE: 12

**** VESSEL 4 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	14.25
VESSEL (KGR AS CACO3)	326.66
LOAD (KGR AS CACO3)	24.85
UTILIZATION (PERCENT)	7.61
THROUGHPUT (GAL/REGEN)	497275.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.5235
CA++	0.0000
MG++	0.0000
NA+	0.3310
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.8545
NO3-	0.0000
SIO2	0.0030
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	61.0	305.	5.00
REGN APPLICATION			
REGENERANT			
AT 6% H2SO4	0.4	8.	47.92
DILUTION WATER	11.5	4222.	47.92
SLOW RINSE	11.5	206.	17.95
FAST RINSE	270.0	573.	2.12

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION   VERSION: 830901-1.0

WEBB AND CARR THREE BED   ID NO: W-3.1
USER NAME: A.J.WILSON   DATE: NOVEMBER 3, 1983   PAGE: 13

**** VESSEL 5 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	7.15
VESSEL (KGR AS CACO3)	215.38
LOAD (KGR AS CACO3)	24.78
UTILIZATION (PERCENT)	11.51
THROUGHPUT (GAL/REGEN)	484157.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.3310
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.3310
NO3-	0.0000
SIO2	0.0329
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	21.3	106.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	0.3	17.	60.00
DILUTION WATER			
AT 3% NAOH	6.8	409.	60.00
SLOW RINSE	6.8	270.	39.69
FAST RINSE	270.0	3012.	11.16

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**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
     0 - COMPLETE
     1 - SYSTEM DESIGN
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     3 - VESSEL DESIGN
     4 - VESSEL PERFORMANCE
     5 - EDIT INPUT DATA
     6 - EXIT PROGRAM
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6
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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION:  830901-1.0

WEBB AND CARR SIX BED                          ID NO: W-6.1
USER NAME: A.J.WILSON                 DATE: NOVEMBER 4, 1983     PAGE:  1

**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
     0 - COMPLETE
     1 - SYSTEM DESIGN
     2 - SYSTEM PERFORMANCE
     3 - VESSEL DESIGN
     4 - VESSEL PERFORMANCE
     5 - EDIT INPUT DATA
     6 - EXIT PROGRAM
?
0
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**** OVERALL SYSTEM DESIGN ****

SYSTEM FLOW RATE 175.0 GPM

INFLUENT WATER ANALYSIS MG/L AS CACO3

H+	0.0000
CA++	35.0000
MG++	81.0000
NA+	142.0000
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	94.0000
SO4=	6.0000
CL-	157.0000
NO3-	1.0000
SIO2	5.0100
CO2	0.0000

INFLUENT TEMPERATURE 55.0 F

SYSTEM CONFIGURATION

VESSEL 1	CATION EXCHANGER
VESSEL 2	VACUUM DEGASIFIER
VESSEL 3	ANION EXCHANGER
VESSEL 4	CATION EXCHANGER
VESSEL 5	ANION EXCHANGER
VESSEL 6	CATION EXCHANGER
VESSEL 7	ANION EXCHANGER

NUMBER OF VESSELS IN PARALLEL

VESSEL 1	1
VESSEL 2	1
VESSEL 3	1
VESSEL 4	1
VESSEL 5	1
VESSEL 6	1
VESSEL 7	1

REGENERANT CHEMICALS

CATION RESIN	93 PERCENT SULFURIC ACID
ANION RESIN	50 PERCENT SODIUM HYDROXIDE

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830601-1.0

WEBB AND CARR SIX BED ID NO: W-6.1
USER NAME: A.J.WILSON DATE: NOVEMBER 4, 1983 PAGE: 3

**** OVERALL SYSTEM PERFORMANCE ****

THROUGHPUT	GALLONS PER REGENERATION
GROSS	279009.
NET	222179.

OPERATING TIME 21.80 HOURS

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.8922
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.8922
NO3-	0.0000
SIO2	0.0002
CO2	0.0000

TOTAL REGENERANT	GALLONS PER REGENERATION
ACID	92.91
CAUSTIC	91.70

**** VESSEL 1 DESIGN****

OUTSIDE DIAMETER (INCHES)	90.0
WALL THICKNESS (INCHES)	C.750
STRAIGHT SIDE (INCHES)	96.0
AREA (SQUARE FEET)	42.72
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	48.0
EFFECTIVE RESIN VOLUME (CU FT)	170.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	181.6
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	6.0

**** VESSEL 2 DESIGN****

VACUUM DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

**** VESSEL 3 DESIGN****

OUTSIDE DIAMETER (INCHES)	72.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	84.0
AREA (SQUARE FEET)	27.49
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX WGR-2
EFFECTIVE RESIN DEPTH (INCHES)	42.0
EFFECTIVE RESIN VOLUME (CU FT)	96.2
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	103.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	3.2
REGENERATION TEMPERATURE (F)	120.0

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

WEBB AND CARR SIX BED ID NO: W-6.1
USER NAME: A.J.WILSON DATE: NOVEMBER 4, 1983 PAGE: 7

**** VESSEL 4 DESIGN****

OUTSIDE DIAMETER (INCHES)	48.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	12.05
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	30.1
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	33.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	6.0

**** VESSEL 5 DESIGN****

OUTSIDE DIAMETER (INCHES)	48.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	12.05
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	30.1
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	33.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	5.0
REGENERATION TEMPERATURE (F)	120.0

**** VESSEL 6 DESIGN****

OUTSIDE DIAMETER (INCHES)	42.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	9.17
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	22.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	25.2
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	9.0

**** VESSEL 7 DESIGN****

OUTSIDE DIAMETER (INCHES)	42.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	9.17
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	22.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	25.2
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	5.0
REGENERATION TEMPERATURE (F)	120.0

**** VESSEL 1 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	23.37
VESSEL (KGR AS CACO3)	3593.52
LOAD (KGR AS CACO3)	3635.67
UTILIZATION (PERCENT)	91.04
THROUGHPUT (GAL/REGEN)	240969.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	151.6874
CA++	0.0000
MG++	0.0000
NA+	12.3126
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	6.0000
CL-	157.0000
NO3-	1.0000
SIO2	6.0100
CO2	94.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	284.0	2840.	10.00
REGN APPLICATION			
RECENERANT			
AT 2% H2SO4	1.0	22.	23.50
AT 4% H2SO4	2.0	22.	11.51
AT 6% H2SO4	3.0	22.	7.51
DILUTION WATER			
AT 2% H2SO4	85.4	2008.	23.50
AT 4% H2SO4	85.4	983.	11.51
AT 6% H2SO4	85.4	642.	7.51
SLOW RINSE	85.4	1318.	15.43
FAST RINSE	175.0	4272.	24.41

**** VESSEL 2 PERFORMANCE****

VACUUM DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

**** VESSEL 3 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	25.41
VESSEL (KGR AS CACO3)	2445.26
LOAD (KGR AS CACO3)	2236.26
UTILIZATION (PERCENT)	91.45
THROUGHPUT (GAL/REGEN)	233171.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	12.3126
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	12.3126
NO3-	0.0000
SIO2	5.0100
CO2	5.7000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	116.2	581.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	2.0	49.	24.81
DILUTION WATER			
AT 3% NAOH	48.1	1194.	24.81
SLOW RINSE	48.1	771.	16.03
FAST RINSE	175.0	7217.	41.24

**** VESSEL 4 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	22.71
VESSEL (KGR AS CACO3)	684.07
LOAD (KGR AS CACO3)	167.06
UTILIZATION (PERCENT)	24.42
THROUGHPUT (GAL/REGEN)	232017.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	8.1946
CA++	0.0000
MG++	0.0000
NA+	4.1179
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	12.3126
NO3-	0.0000
SIO2	5.0100
CO2	5.7000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	80.1	401.	5.00
REGN APPLICATION			
REGENERANT			
AT 6% H2SO4	0.5	12.	57.55
DILUTION WATER	15.1	3331.	57.55
SLOW RINSE	15.1	270.	17.95
FAST RINSE	175.0	753.	4.30

**** VESSEL 5 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	10.23
VESSEL (KGR AS CACO3)	308.18
LOAD (KGR AS CACO3)	308.18
UTILIZATION (PERCENT)	100.00
THROUGHPUT (GAL/REGEN)	228899.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	4.1179
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	4.1179
NO3-	0.0000
SIO2	0.0179
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	21.3	106.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	0.4	24.	60.00
DILUTION WATER			
AT 3% NAOH	9.7	584.	60.00
SLOW RINSE	9.7	270.	27.78
FAST RINSE	175.0	3012.	17.21

**** VESSEL 6 PERFORMANCE****

CAPACITY:	
RESIN (KGR AS CACO3/CU FT)	20.39
VESSEL (KGR AS CACO3)	467.27
LOAD (KGR AS CACO3)	54.91
UTILIZATION (PERCENT)	11.75
THROUGHPUT (GAL/REGEN)	228021.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	3.2257
CA++	0.0000
MG++	0.0000
NA+	0.8922
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	4.1179
NO3-	0.0000
SIO2	0.0179
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	61.0	305.	5.00
REGN APPLICATION			
REGENERANT			
AT 6% H2SO4	0.4	14.	68.82
DILUTION WATER	11.5	3379.	68.82
SLOW RINSE	11.5	206.	17.95
FAST RINSE	175.0	573.	3.27

**** VESSEL 7 PERFORMANCE****

CAPACITY:	
RESIN (KGR AS CACO3/CU FT)	8.26
VESSEL (KGR AS CACO3)	189.71
LOAD (KGR AS CACO3)	54.56
UTILIZATION (PERCENT)	28.77
THROUGHPUT (GAL/REGEN)	225648.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.8922
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.8922
NO3-	0.0000
SIO2	0.0002
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	16.2	81.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	0.3	18.	60.00
DILUTION WATER			
AT 3% NAOH	7.4	444.	60.00
SLOW RINSE	7.4	206.	27.78
FAST RINSE	175.0	2292.	13.10

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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION:  830901-1.0

WEBB AND CARR SIX BED                        ID NO: W-6.1
USER NAME: A.J.WILSON               DATE: NOVEMBER 4, 1983     PAGE: 18
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**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
      0 - COMPLETE
      1 - SYSTEM DESIGN
      2 - SYSTEM PERFORMANCE
      3 - VESSEL DESIGN
      4 - VESSEL PERFORMANCE
      5 - EDIT INPUT DATA
      6 - EXIT PROGRAM
?
6
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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION:  830901-1.0

WEBB AND CARR SIX BED                          ID NO: W-6.2
USER NAME: A.J.WILSON                  DATE: NOVEMBER 4, 1983     PAGE:  1
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**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
     0 - COMPLETE
     1 - SYSTEM DESIGN
     2 - SYSTEM PERFORMANCE
     3 - VESSEL DESIGN
     4 - VESSEL PERFORMANCE
     5 - EDIT INPUT DATA
     6 - EXIT PROGRAM
?
0
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**** OVERALL SYSTEM DESIGN ****

SYSTEM FLOW RATE 175.0 GPM

INFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	30.0000
MG++	38.0000
NA+	17.0000
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	66.0000
SO4=	4.0000
CL-	14.0000
NO3-	1.0000
SIO2	1.6700
CO2	0.0000

INFLUENT TEMPERATURE 55.0 F

SYSTEM CONFIGURATION

VESSEL 1	CATION EXCHANGER
VESSEL 2	VACUUM DEGASIFIER
VESSEL 3	ANION EXCHANGER
VESSEL 4	CATION EXCHANGER
VESSEL 5	ANION EXCHANGER
VESSEL 6	CATION EXCHANGER
VESSEL 7	ANION EXCHANGER

NUMBER OF VESSELS IN PARALLEL

VESSEL 1	1
VESSEL 2	1
VESSEL 3	1
VESSEL 4	1
VESSEL 5	1
VESSEL 6	1
VESSEL 7	1

REGENERANT CHEMICALS

CATION RESIN	93 PERCENT SULFURIC ACID
ANION RESIN	50 PERCENT SODIUM HYDROXIDE

**** OVERALL SYSTEM PERFORMANCE ****

THROUGHPUT	GALLONS PER REGENERATION
GROSS	773428.
NET	716598.

OPERATING TIME   70.04 HOURS

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.0352
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.0352
NO3-	0.0000
SIO2	0.0021
CO2	0.0000

TOTAL REGENERANT	GALLONS PER REGENERATION
ACID	92.91
CAUSTIC	91.70

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION   VERSION: 830901-1.0

WEBB AND CARR SIX BED   ID NO: W-6.2
USER NAME: A.J.WILSON   DATE: NOVEMBER 4, 1983   PAGE: 4

**** VESSEL 1 DESIGN****

OUTSIDE DIAMETER (INCHES)	90.0
WALL THICKNESS (INCHES)	0.750
STRAIGHT SIDE (INCHES)	96.0
AREA (SQUARE FEET)	42.72
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	48.0
EFFECTIVE RESIN VOLUME (CU FT)	170.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	181.6
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	6.0

**** VESSEL 2 DESIGN****

VACUUM DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

**** VESSEL 3 DESIGN****

OUTSIDE DIAMETER (INCHES)	72.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	84.0
AREA (SQUARE FEET)	27.49
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX WGR-2
EFFECTIVE RESIN DEPTH (INCHES)	42.0
EFFECTIVE RESIN VOLUME (CU FT)	96.2
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	103.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	3.2
REGENERATION TEMPERATURE (F)	120.0

**** VESSEL 4 DESIGN****

OUTSIDE DIAMETER (INCHES)	48.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	12.05
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	30.1
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	33.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	6.0

**** VESSEL 5 DESIGN****

OUTSIDE DIAMETER (INCHES)	48.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	80.0
AREA (SQUARE FEET)	12.05
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	30.1
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	33.1
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	5.0
REGENERATION TEMPERATURE (F)	120.0

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

WEBB AND CARR SIX BED ID NO: W-6.2
USER NAME: A.J.WILSON DATE: NOVEMBER 4, 1983 PAGE: 9

**** VESSEL 6 DESIGN****

OUTSIDE DIAMETER (INCHES)	42.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	9.17
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX HCR-S
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	22.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	25.2
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 93% H2SO4/CU FT)	9.0

**** VESSEL 7 DESIGN****

OUTSIDE DIAMETER (INCHES)	42.0
WALL THICKNESS (INCHES)	0.500
STRAIGHT SIDE (INCHES)	60.0
AREA (SQUARE FEET)	9.17
FLOW RATE PER VESSEL (GPM)	175.0
RESIN TYPE	DOWEX SBR-P
EFFECTIVE RESIN DEPTH (INCHES)	30.0
EFFECTIVE RESIN VOLUME (CU FT)	22.9
INEFFECTIVE RESIN DEPTH (INCHES)	3.0
TOTAL RESIN VOLUME (CU FT)	25.2
CAPACITY EFFECTIVENESS (PERCENT)	90.0
REGENERANT LEVEL (LB 100% NAOH/CU FT)	5.0
REGENERATION TEMPERATURE (F)	120.0

DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION VERSION: 830901-1.0

WEBB AND CARR SIX BED ID NO: W-6.2
USER NAME: A.J.WILSON DATE: NOVEMBER 4, 1983 PAGE: 11

**** VESSEL 1 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	21.39
VESSEL (KGR AS CACO3)	3655.44
LOAD (KGR AS CACO3)	3655.44
UTILIZATION (PERCENT)	100.00
THROUGHPUT (GAL/REGEN)	735388.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	18.5139
CA++	0.0000
MG++	0.0000
NA+	0.4861
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	4.0000
CL-	14.0000
NO3-	1.0000
SIO2	1.6700
CO2	66.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	284.0	2840.	10.00
REGN APPLICATION			
REGENERANT			
AT 2% H2SO4	1.4	22.	16.65
AT 4% H2SO4	2.8	22.	8.15
AT 6% H2SO4	4.2	22.	5.32
DILUTION WATER			
AT 2% H2SO4	120.6	2008.	16.65
AT 4% H2SO4	120.6	983.	8.15
AT 6% H2SO4	120.6	642.	5.32
SLOW RINSE	120.6	1318.	10.93
FAST RINSE	175.0	4272.	24.41

**** VESSEL 2 PERFORMANCE****

VACUUM DEGASIFIER	MG/L AS CACO3
EFFLUENT CARBON DIOXIDE	5.7000

**** VESSEL 3 PERFORMANCE****

CAPACITY:	
RESIN (KGR AS CACO3/CU FT)	24.74
VESSEL (KGR AS CACO3)	2381.05
LOAD (KGR AS CACO3)	808.43
UTILIZATION (PERCENT)	33.95
THROUGHPUT (GAL/REGEN)	727590.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.4861
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.4861
NO3-	0.0000
SIO2	1.6700
CO2	5.7000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	116.2	581.	5.00
REGN APPLICATION			
REGENERANT			
AT 3% NAOH	2.0	49.	24.81
DILUTION WATER			
AT 3% NAOH	48.1	1194.	24.81
SLOW RINSE	48.1	771.	16.03
FAST RINSE	175.0	7217.	41.24

**** VESSEL 4 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	22.71
VESSEL (KGR AS CACO3)	684.07
LOAD (KGR AS CACO3)	20.65
UTILIZATION (PERCENT)	3.02
THROUGHPUT (GAL/REGEN)	726437.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.3235
CA++	0.0000
MG++	0.0000
NA+	0.1626
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.4861
NO3-	0.0000
SIO2	1.6700
CO2	5.7000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	80.1	401.	5.00
REGN APPLICATION			
REGENERANT			
AT 6% H2SO4	0.5	12.	47.34
DILUTION WATER	15.1	3331.	47.34
SLOW RINSE	15.1	270.	17.85
FAST RINSE	175.0	753.	4.30

**** VESSEL 5 PERFORMANCE****

CAPACITY:	
RESIN (KGR AS CACO3/CU FT)	13.74
VESSEL (KGR AS CACO3)	414.00
LOAD (KGR AS CACO3)	332.31
UTILIZATION (PERCENT)	80.27
THROUGHPUT (GAL/REGEN)	723318.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.1626
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.1626
NO3-	0.0000
SIO2	0.0099
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	21.3	106.	5.00
REGN APPLICATION			
REGENERANT AT 3% NAOH	0.4	24.	60 00
DILUTION WATER AT 3% NAOH	9.7	584.	60.00
SLOW RINSE	9.7	270.	27.78
FAST RINSE	175.0	3012.	17.21

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DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION     VERSION:  830901-1.0

WEBB AND CARR SIX BED                        ID NO: W-6.2
USER NAME: A.J.WILSON               DATE: NOVEMBER 4, 1983     PAGE: 16
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**** VESSEL 6 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	20.39
VESSEL (KGR AS CACO3)	467.27
LOAD (KGR AS CACO3)	6.87
UTILIZATION (PERCENT)	1.47
THROUGHPUT (GAL/REGEN)	722440.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.1274
CA++	0.0000
MG++	0.0000
NA+	0.0352
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.1626
NO3-	0.0000
SIO2	0.0099
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	61.0	305.	5.00
REGN APPLICATION			
REGENERANT			
AT 6% H2SO4	0.4	14.	58.61
DILUTION WATER	11.5	3379.	58.61
SLOW RINSE	11.5	206.	17.95
FAST RINSE	175.0	573.	3.27

**** VESSEL 7 PERFORMANCE****

CAPACITY:

RESIN (KGR AS CACO3/CU FT)	14.98
VESSEL (KGR AS CACO3)	343.38
LOAD (KGR AS CACO3)	7.26
UTILIZATION (PERCENT)	2.11
THROUGHPUT (GAL/REGEN)	720067.

EFFLUENT WATER ANALYSIS	MG/L AS CACO3
H+	0.0000
CA++	0.0000
MG++	0.0000
NA+	0.0352
K+	0.0000
OH-	0.0000
CO3=	0.0000
HCO3	0.0000
SO4=	0.0000
CL-	0.0352
NO3-	0.0000
SIO2	0.0021
CO2	0.0000

REGENERATION SUMMARY:

STEP	FLOW (GPM)	VOLUME (GAL)	DURATION (MIN)
BACKWASH	16.2	81.	5.00
REGN APPLICATION			
REGENERANT AT 3% NAOH	0.3	18.	60.00
DILUTION WATER AT 3% NAOH	7.4	444.	60.00
SLOW RINSE	7.4	206.	27.78
FAST RINSE	175.0	2292.	13.10

```
**** OUTPUT SELECTION ****

ENTER OUTPUT TYPE
     0 - COMPLETE
     1 - SYSTEM DESIGN
     2 - SYSTEM PERFORMANCE
     3 - VESSEL DESIGN
     4 - VESSEL PERFORMANCE
     5 - EDIT INPUT DATA
     6 - EXIT PROGRAM
 ?
6
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LEVEL 1.3.0 (MAY 1983)            VS FORTRAN           DATE: NOV 18, 1983    TIME: 15:48:10                   PAGE:     1

REQUESTED OPTIONS (EXECUTE): LANGLVL(66),NOTERM

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF NOGOSTMT NODECK   SOURCE NOTERM   OBJECT FIXED  NOTEST NOTRMFLG   SRCFLG NOSYM
                     OPT(0) LANGLVL(66) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)       CHARLEN(500)     SDUMP

               *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN     1            LOGICAL ECHO,DIAG,SUBI,COUT
ISN     2            DIMENSION IVES(9,8),VES(9,32),MBV(2,20),WAN(10,15),
                    1          VT(6),IONS(13),LLP(9),CAT(2),ANI(2),
                    2          IMBV(2,5),WUNIT(3,4),TITLE(10),IDNUM(4),UNAME(6),
                    3          DATE(5),RESIN(3,2),RQ(9,4),RVOL(9,4),DVOL(9,4),
                    4          TSTEP(9,4),ISTEP(9)
ISN     3            COMMON/IO/NI,NO,IOUT
ISN     4            COMMON/DESD/WAN,VES,IVES
ISN     5            COMMON/DESM/MBV,IMBV
ISN     6            COMMON/HDG/TITLE,IDNUM,UNAME,DATE
ISN     7            COMMON/STEP/ISTEP,RQ,RVOL,DVOL,TSTEP
ISN     8            DATA VT/2HVT,2HCX,2HAX,2HMX,2HFG,2HVG/
ISN     9            DATA IONS/4HH+   ,4HCA++,4HMG++,4HNA+ ,4HK+   ,
                    1          4HOH-  ,4HCO3=,4HHCO3,4HSO4=,4HCL-  ,
                    2          4HNO3-,4HSIO2,4HCO2 /
ISN    10            DATA CAT,ANI/4HCATI,2HON,4HANIO,2HN /
ISN    11            DATA ECHO,DIAG,SUBI/3*.TRUE./,COUT/.FALSE./
ISN    12            DATA WUNIT(1,1),WUNIT(1,2),WUNIT(1,3),WUNIT(1,4)/
                    1     4HMG/L,4H AS ,4HSUCH,4H    /
ISN    13            DATA WUNIT(2,1),WUNIT(2,2),WUNIT(2,3),WUNIT(2,4)/
                    1     4HMG/L,4H AS ,4HCACO,4H3   /
ISN    14            DATA WUNIT(3,1),WUNIT(3,2),WUNIT(3,3),WUNIT(3,4)/
                    1     4HMEQ/,4HL   ,4H    ,4H    /
ISN    15            DATA RESIN(1,1),RESIN(1,2)/4HHCR-,4HS   /
ISN    16            DATA RESIN(2,1),RESIN(2,2)/4HSBR-,4HP   /
ISN    17            DATA RESIN(3,1),RESIN(3,2)/4HWGR-,4H2   /
ISN    18         10 IMB=0
ISN    19            IPG=0
ISN    20            PI=3.141593
ISN    21            R100=100.0
ISN    22            WRITE (NO,600)
ISN    23        600 FORMAT(1H1,//,5X,1H*,13(3X,1H*),//,5X,1H*,3X,
                    1       'DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION',
                    2       2X,1H*,//,5X,1H*,13(3X,1H*),//,5X,1H*,3X,
                    3       'VERSION:  830901-1.0',28X,1H*,//,5X,1H*,
                    4       3X,'BY: A.J.WILSON',34X,1H*,//,5X,1H*,
                    5       13(3X,1H*),///)
ISN    24            WRITE(NO,560)
ISN    25        560 FORMAT(1X,'**** ENTER PROBLEM IDENTIFICATION ****',
                    1        //5X,'ENTER TITLE (40 CHARACTERS MAXIMUM)',
                    2        /5X,1H?)
ISN    26            READ(NI,520)(TITLE(I),I=1,10)
ISN    27        520 FORMAT(15A4)
ISN    28            IF(ECHO)WRITE(NO,5520)(TITLE(I),I=1,10)
ISN    30       5520 FORMAT(1X,15A4)
ISN    31            WRITE(NO,561)
ISN    32        561 FORMAT(/5X,'ENTER PROBLEM ID NUMBER (15 CHARACTERS ',
                    1        'MAXIMUM)',/5X,1H?)
ISN    33            READ(NI,520)(IDNUM(I),I=1,4)
ISN    34            IF(ECHO)WRITE(NO,5520)(IDNUM(I),I=1,4)
ISN    36            WRITE(NO,562)
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2

VITA

Andrew James Wilson

Candidate for the Degree of

Doctor of Philosophy

Thesis: DEMINERALIZATION SYSTEM PERFORMANCE SIMULATION

Major Field: Chemical Engineering

Biographical:

Personal Data: Born in St. Joseph, Missouri, August 13, 1951, the son of Mr. and Mrs. James W. Wilson; married to Priscilla R. Logan on June 25, 1976.

Education: Graduated from Raytown South High School, Raytown, Missouri, in May, 1969; received Bachelor of Science degree in Chemical Engineering from University of Missouri-Rolla in 1974; enrolled as special student at Calvary Bible College in 1975; received Master of Science in Chemical Engineering from the University of Missouri-Columbia in 1979; received Doctor of Philosophy in Chemical Engineering from Oklahoma State University in December, 1983.

Professional Experience: Cooperative Engineer, Phillips Petroleum, 1970-73; Process Engineer, Phillips Petroleum, 1974; Chemical Engineer, Black and Veatch Consulting Engineers, 1976-81.