# SUL-biSUL[T] Ion Exchange Process: Field Evaluation on Brackish Waters

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# SUL-biSUL[T] Ion Exchange Process: Field Evaluation on Brackish Waters

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UNITED STATES DEPARTMENT OF THE INTERIOR • Walter J. Hickel, Secretary
Carl L. Klein, Assistant Secretary for Water Quality and Research

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## FOREWORD

This is one of a continuing series of reports designed to present accounts of progress in saline water conversion and the economics of its application. Such data are expected to contribute to the long-range development of economical processes applicable to low-cost demineralization of sea and other saline water.

Except for minor editing, the data herein are as contained in a report submitted by the contractor. The data and conclusions given in the report are essentially those of the contractor and are not necessarily endorsed by the Department of the Interior.

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# I INTRODUCTION AND BACKGROUND

The initial research concerning the SUL-biSUL® process employed laboratory scale apparatus investigating the chemical reaction mechanisms of anion resin exhaustion and regeneration; subsequent preliminary studies employed pilot scale equipment investigating performance characteristics utilizing synthesized brackish water. An evaluation of the data collected during laboratory and pilot plant studies clearly indicated that potential commercial utilization did exist. The available technical information was, unfortunately, entirely inadequate to allow safe prediction of resin performance characteristics and, therefore, made equipment design impossible. Before a firm proposal of a SUL-biSUL® brackish water desalting plant could be prepared estimating the costs of capital investment (equipment design), chemical regenerants, product water quality and effluent waste considerations, additional research data was required.

Reliable SUL-biSUL® performance data was obtained by utilizing a specially designed mobile laboratory containing SUL-biSUL® process equipment and analytical laboratory to support the field studies. This mobile laboratory was operated at five OSW selected sites investigating the SUL-biSUL® ion exchange resin system as a suitable process for brackish water desalting. The equipment was designed as a research tool allowing sufficient latitude at the site to investigate the various modifications of the basic system.

The purpose of the research conducted under OSW contract was to obtain sufficient data to predict the capital and operating cost of both a 0.5 M gpd and 1.0 M gpd plant desalting brackish water.

## Limitations Of Conventional Ion Exchange

Increased emphasis on saline water conversion research has achieved encouraging progress; the possibilities of approach are numerous. Yet, no one process has been developed which is completely satisfactory for all water supplies.

To date, ion exchange processes have not found extensive application for brackish water desalting. The reason for this limitation is the economics - the cost and quantity of the regenerants required for ion exchange resin regeneration. The capital investment, labor and maintenance costs of ion exchange processes have always compared favorably with other existing systems. Ease of operation and product water qualities are comparable if not better than many systems. An ion exchange system is usually easier to build and more simple to operate than other water treating systems. However, ion exchange systems do require chemicals for operation and the cost of these chemicals has offset other advantages.

A typical two bed demineralizing system employs a cation resin exchanger in the hydrogen form and an anion exchanger either in the hydroxide or the free amine form. Regardless of the mechanics of regeneration, two separate regenerants are consumed. One of these regenerants is sulfuric acid - it is moderately priced and relatively efficient. The other is sodium hydroxide - it costs twice that of sulfuric acid and is sometimes less efficient.

The acid may be applied advantageously at moderately low regenerant levels. This helps obtain efficient acid utilization. The sodium hydroxide, on the other hand, must be applied at regenerant levels dictated by the effluent quantity and quality of the water produced by the cation exchanger; e.g., if we are to utilize the cation capacity achieved, we must have a sufficient supply of anion capacity available to complete the demineralization. Under these conditions, which do exist, the major portion of the total regenerant cost is contributed by the sodium hydroxide requirements of anion regeneration. If this anion regenerant cost could be either reduced or eliminated, ion exchange brackish water treatment could become feasible.

## The SUL-biSUL® Process

SUL-biSUL® is a new concept in ion exchange resin water treatment, designed and developed to economically treat high mineral content waters. The chemical principles of exhaustion and regeneration are completely different than those of the conventional resin system. The significant contribution of the SUL-biSUL® process desalting system applied to brackish water demineralization is the substantial reduction achieved in anion chemical regenerant cost.

SUL-biSUL® is a two bed ion exchange resin process, which in its simplest form employs a cation exchanger and an anion exchanger, but here its similarity to the conventional demineralizer ends. The cation exchange section of a SUL-biSUL® system employs low sulfuric acid regenerant levels at increased acid efficiencies. The anion unit operates in a new and unique manner which either completely eliminates or substantially reduces the chemical cost of anion regeneration.

The SUL-biSUL® system is applicable for the demineralization of brackish waters ranging in total dissolved minerals from 800 to 2000 ppm, and sometimes higher, depending on the chemical composition of the brackish water supply. When employed for the production of potable water, a final TDS (total dissolved solids) output of 500 ppm or less can be obtained. In most cases, the SUL-biSUL® will produce water of sufficient quality (50-250 ppm) to enable blending of the partially demineralized water with raw brackish water to produce a final TDS of 500 ppm, recommended by APHA. When employed for industrial demineralization, it can function as a primary demineralizer to be followed by a polishing unit such as a mixed bed deionizer.

Service Cycle

The first stage of demineralization in this process is performed by the strong acid cation exchanger in the hydrogen form. In this operation, the conventional method of converting dissolved mineral salts to their respective acids is paralleled (Figure 1). Although the performance of the cation exchange unit in the SUL-biSUL® process is essentially the same as in any conventional two bed demineralization system, special consideration on the maximum economy in acid regenerant levels (cost) is emphasized. Lower regenerant levels of acid are employed economically because cation (salt) leakage can be tolerated. The effluent of the cation unit (anion influent) is a stream of dilute mineral acid and a small amount of mineral salts. The function of the anion resin is to sorb (remove) these acids.

The distinguishing feature of the SUL-biSUL® process is the anion exchange unit. This unit contains a strong base anion exchanger in the sulfate salt form instead of the hydroxide anion exchanger or weak base anion exchanger of the type normally employed in conventional demineralizers. The physical mechanism of exhaustion in this process is not different than any conventional two bed demineralizer system; i.e., the raw water is first passed through the cation unit, then passed through the anion exchanger. The chemical mechanism of anion exhaustion, however, differs sufficiently from the conventional mechanism to merit special consideration. The following equations describe in simple chemical terms how this new method of anion exhaustion functions:

(A)

$$\begin{matrix} R \\ R \end{matrix} \Big> SO_4^{=} + H^+ A^- \longrightarrow \begin{matrix} R - HSO_4^- \\ R - A^- \end{matrix}$$

(R represents a positively charged anion exchange site)

By this reaction, divalent sulfate ions ($SO_4^{=}$) on the regenerated exchange sites are converted to monovalent bisulfate ions ($HSO_4^-$). This conversion frees one of the two exchange sites initially required to hold the divalent sulfate ion. The newly freed site is now capable of accepting an additional anion. This anion will be the anion portion of the exhausting acid (HA). The mechanism may be further illustrated as follows:

If HA above is in fact a mixture of sulfuric, hydrochloric and nitric acids in the cation exchange effluent, then

(B)

$$\begin{matrix} R \\ R \end{matrix} \Big> SO_4^{=} \quad + \quad H_2SO_4 \longrightarrow \begin{matrix} R - HSO_4^- \\ R - HSO_4^- \end{matrix}$$

$$\begin{matrix} R \\ R \end{matrix} \Big> SO_4^{=} \quad + \quad HCl \longrightarrow \begin{matrix} R - Cl^- \\ R - HSO_4^- \end{matrix}$$

$$\begin{matrix} R \\ R \end{matrix} \Big> SO_4^{=} \quad + \quad HNO_3 \longrightarrow \begin{matrix} R - NO_3^- \\ R - HSO_4^- \end{matrix}$$

Under ideal conditions, if all the sulfate ions on the regenerated resin exchange sites were converted to bisulfate ions, a maximum theoretical capacity would be one half on the total rated exchange capacity of the resin employed. In studies conducted thus far, this capacity has not been observed.

As shown in equations A and B, the anion capacity in the SUL-biSUL® process is dependent on the conversion of divalent sulfate ions to monovalent bisulfate ions. Two variables control or promote this conversion, namely, the concentration of hydrogen ions and the concentration of sulfate ions entering the anion exchange resin bed. The source of these two variables is governed by the chemical composition of the effluent stream leaving the cation exchange unit. This composition, in turn, is governed by the chemical composition of the brackish water supply. The greater the total dissolved mineral content of the brackish water, the greater will be the free mineral acidity effluent of the first bed or cation unit and the greater will be the SUL-biSUL® anion resin's capacity.

The variables controlling the conversion of divalent sulfate ions to monovalent bisulfate ions may be expressed and understood chemically by the following equation:

(C)

$$SO_4^{=} \quad + \quad H^{=} \rightleftharpoons HSO_4^-$$

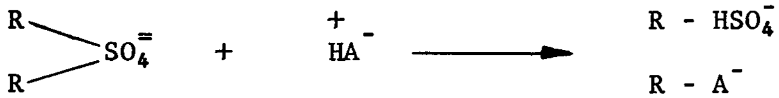
As the hydrogen ion concentration and sulfate ion concentration of the influent anion exhaustant are increased, the greater is the shift, to the right, in the sulfate-bisulfate equilibrium and the greater is the corresponding anion's capacity.

## Regenerant Cycle

The regeneration of the two exchange units in the SUL-biSUL® process, as in a conventional ion exchange system, is performed utilizing two separate regeneration techniques. The regeneration of the cation unit is accomplished using low levels of sulfuric acid in a conventional manner. The regeneration of the anion unit, however, is entirely new and merits special consideration.

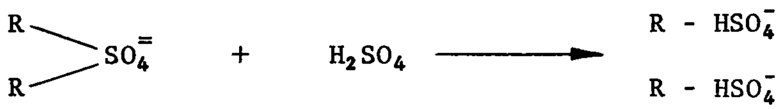
During exhaustion, for each molecule of acid (HA) exhausting the regenerated sulfate anion bed, one bisulfate ion is formed.

(D)




If the exhausting acid is sulfuric acid, two bisulfate ions are formed.

(E)

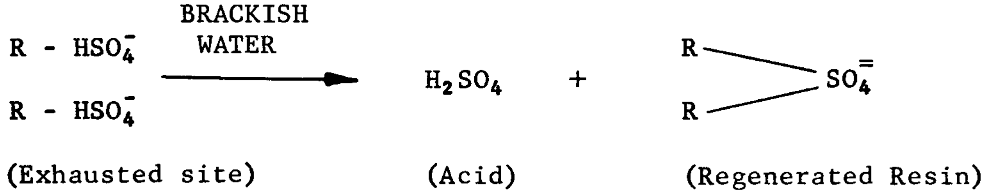



We conclude that regardless of the chemical composition of the raw water, at least 50% of the exhausted exchange sites are bisulfate ions (equation B). Since most waters contain some sulfate ions, we may further conclude that more than 50% of the exhausted sites are bisulfate ions. To regenerate the anion bed, then, we must cope primarily with bisulate ions.

Occuring simultaneously with bisulfate ion formation or acid sorption is the process of normal ion exchange. As chlorides and nitrates, present in the raw water, enter the anion bed during exhaustion they do displace some sulfates and bisulfates - ion exchange. In regenerating the bed back to the sulfate form, we must take all of the ions present on the exhausted exchange sites into consideration.

The simplest method of anion regeneration in the SUL-biSUL® process is to reverse the sulfate-bisulfate equilibrium; i.e., convert bisulfate ions back to sulfate ions releasing the sorbed acids which are then discharged from the bed.

(F)



With water supplies containing sulfate ions it is possible to regenerate the anion bed by merely rinsing the unit, either upflow or downflow, with brackish water.

With water supplies containing a substantial portion of sulfate ions, the rinse regeneration technique may be applied efficiently downflow. During this operation, bisulfate ions disassociate forming sulfate ions and hydrogen ions due to the neutral or alkaline pH of the raw water. Also, during rinse regeneration, ions other than sulfate ions are eluted from the bed by a process of selective ion exchange; the strong base anion exchange resin will selectively remove and hold sulfate ions in preference to chloride ions from dilute solutions.

The total cost of anion regeneration in the SUL-biSULⓉ process employing the rinse regeneration technique is equal to the cost of the available water, which in many cases is equal to the cost of pumping water. To this must be added the cost of acidic waste treatment of the water discharged during anion rinse regeneration.

## Three Bed SUL-biSULⓉ System

The three bed SUL-biSULⓉ system (the addition of a carboxylic cation exchanger) is advantageously employed on water supplies containing a substantial percentage of alkalinity (Figure 2). The advantage of utilizing waste acid from the strong cation unit for the regeneration of a weak acid exchanger is an established practice. Technical data describing the weak acid resin may be found in Rohm and Haas bulletin IE-117-67.

## Summary

Because of the versatility of the SUL-biSULⓉ system, many modifications of the basic process are possible. To achieve the best system combination, the component parts must be predictable. Of prime economic importance is cation regeneration controlling the majority of the chemical operating costs and product water quality. Other modifications are methods of further reducing operational costs and saving water. An accurate evaluation of the SUL-biSULⓉ system should include a complete investigation of all the modifications possible, including operating experience.

## II AREAS OF STUDY

### Strong Acid Cation Exchange Unit

During cation resin regeneration, maximum utilization of the sulfuric acid employed must be realized. If accomplished, three important effects will be observed:

1) Since the operating regenerant cost per 1,000 gallons of water treated is directly proportional to the sulfuric acid regenerant utilization (capacity), maximum capacity means economical product water.

2) The greater the degree of regenerant acid utilization, the lower is the cation metallic leakage during exhaustion. Product water quality is a function of cation regeneration.

3) All acid not utilized (exchanged) by the cation resin during regeneration is waste. Acidic waste disposal can be a significant consideration.

It is impossible to accurately predict the degree of regenerant acid utilization based on existing resin data. All cation resin technology presently available is limited by an influent metallic feed of approximately 600-800 ppm. In addition, this data was primarily developed for application in the area of demineralization, where low cation leakage is desirable. Consequently, low acid regenerant levels of 1 to 3 pounds per cubic foot have not been extensively investigated owing to the high resulting leakage observed.

With the SUL-biSUL® process, high cation leakage is desirable. Throughput capacity, accepting an average leakage of 80-300 ppm, must be interpreted as more water treated per Kgr. of capacity. Therefore, acid regenerant levels of 1 to 5 pounds per cubic foot can and were employed in order to achieve a high degree of regenerant acid utilization.

Because of the key role cation regeneration plays in the overall economics of the SUL-biSUL® process, a portion of Elgin's research program at test sites having an ample supply of natural brackish water was to study the effect of low sulfuric acid regenerant levels with respect to the resulting capacities and leakage performance characteristics. All data collected during these tests was reviewed and an attempt was made to correlate this data with the existing resin technology.

### Strong Base Anion Exchange Unit

The anion exchange unit in the SUL-biSUL® process is the unique part of the system. The chemical principals of exhaustion and regeneration are drastically different than those of conventional ion exchange systems. Therefore, a complete understanding of both the exhaustion and regeneration performance characteristics of the SUL-biSUL®

anion unit was required and had to be fully developed without the benefit of any existing ion exchange technology.

There are three essential considerations necessary for predicting the performance characteristics of the SUL-biSUL® anion exchange unit. They are, the capacity of the resin for free mineral acidity (cation effluent), the effect of variations in chemical composition of free mineral acidity (sulfate-chloride ratio) on anion resin capacity and raw water requirements for anion rinse regeneration as a function of raw water chemical composition.

Weak Acid Cation Exchange Unit

The three bed SUL-biSUL® system (addition of a weak acid cation exchanger) is most advantageously employed on water supplies containing a substantial percentage of alkalinity. The advantage of utilizing strong acid cation resin waste acid regenerant for the regeneration of a weak acid cation exchanger is an established practice. However, the exhaustion characteristics of a weak acid cation exchanger and the exhaustion characteristics of a strong acid cation resin utilizing an influent pretreated with a weak acid cation exchanger required study. The results of the studies were evaluated with respect to the cost of regenerant saved versus the increase capital investment required.

## III EQUIPMENT

All research studies were conducted in Elgin's Mobile SUL-biSUL® Pilot Plant. (See photograph in Appendix of report).

The SUL-biSUL® equipment contained in this mobile laboratory consists of one weak acid cation unit containing 3 cubic feet of resin, two strong acid cation exchangers containing 1-1/2 cubic feet of resin each, and two strong base anion exchangers containing 4 cubic feet of resin each. The two cation and anion units can be operated in series or individually and regenerated either upflow or downflow. All 61 valves are activated by semi-automatic controls, the status of each valve being indicated on a lighted graphic panel. (See photograph in Appendix of report).

Included in the trailer is a small laboratory equipped with the necessary instruments to operate and evaluate the performance of the equipment. Complete water analyses were made in Elgin's Analytical Laboratory.

The mobile unit is self-sustaining in that it carries its own electrical generator supplying sufficient power for lighting, instruments, air compressor, air conditioning and heating.

## IV EXPERIMENTAL PROCEDURES

### Strong Acid Cation Exchange Unit

Cation regeneration was accomplished by pumping a predetermined volume and concentration of sulfuric acid downflow through both strong acid cation exchange beds in series. Residual acid was flushed free from the bed at the regenerant flow rate, termination of this operation being determined conductometrically. The exact water requirements for acid rinse out were recorded by a water meter.

Exhaustion was conducted at rates of approximately 5 and 8 gpm per square foot of resin bed area. Periodic samples were taken throughout the exhaustion run to determine salt leakage (product water quality). Termination of the exhaustion run was determined conductometrically with the throughput volume being recorded by a water meter. Exhaustion cycles were repeated at each regenerant level until a minimum of two consecutive cycles were observed showing essentially identical results indicating performance characteristics under cyclic equilibrium.

### Summary Of Operating Parameters

| | |
|---|---|
| Regeneration level | 1 to 5 lbs. 66$^{o}$ Be' $H_2SO_4$ acid per cubic foot of resin. |
| Regeneration concentration | First 2 lbs/ft$^3$ applied as 2% solution. Any additional acid applied as 4% solution. |
| Regeneration rate | 1 gpm per cubic foot of resin. |
| Method of regeneration | Downflow through both cation units in series at a rate of 3 gpm. |
| Method of control | 3 gpm Dole valve located in effluent line. |
| Regenerant acid rinse out | 3 gpm rinse with raw water until effluent conductivity determined conductometrically at 500 micromhos higher than average conductivity observed during exhaustion cycle. |
| Exhaustion rate | 2.60 and 4.25 gpm. |
| Exhaustion rate control | Dole valve located in effluent line. Also monitored by flow rate meter. |

| | |
|---|---|
| Termination of exhaustion cycle | Decrease in effluent conductivity of 500 micromhos below average conductivity observed during exhaustion cycle. |
| Volume of water treated | Determined by water meter located on raw water influent line. |
| Resin capacity | Calculated from mineral analysis of raw water and exhaustion volume. |
| Water quality | Determined by periodic mineral analysis and drip sample of effluent in Elgin's Analytical Laboratory. |

Strong Base Anion Exchange Unit

Anion exhaustion was conducted at a rate of 2.60 and 4.25 gpm. A drip sample of the influent stream (effluent of cation unit) was taken to determine the average concentration of mineral acidity feed to the unit. The volume of exhaustant feed to this unit was recorded by a water meter. Termination of the cycle was determined conductometrically. Periodic water samples of the effluent were taken throughout the run and analyzed in Elgin's laboratory to indicate product water quality. Sufficient exhaustion runs were conducted to verify performance characteristics.

Raw water was employed for regeneration, downflow at various rates ranging from 6 to 12 gpm. Termination of rinse regeneration was determined conductometrically. The total volume of water consumed was recorded by a water meter.

Summary Of Operating Parameters

| | |
|---|---|
| Regenerant | Raw water. |
| Regenerant rate | 6 to 12 gpm. |
| Method of regeneration | Downflow through single unit employed in experiments. |
| Method of control | Dole valve located in effluent line. Also monitored by flow rate meter. |
| Termination of regeneration | When effluent conductivity was essentially equal to influent conductivity. |

| | |
|---|---|
| Exhaustion rate | 2.60 and 4.25 gpm. |
| Method of control | Dole valve located in effluent line. Also monitored by flow rate meter. |
| Termination of exhaustion | Rise in effluent conductivity of approximately 500 micromhos. |
| Volume of water treated | Determined by water meter. |
| Resin capacity | Calculated from mineral analysis of influent and exhaustion volume. |
| Water quality | Determined by periodic analysis and drip sample of effluent in Elgin's Analytical Laboratory. |

Weak Acid Cation Exchange Unit

Weak acid cation resin exhaustion was conducted at two different exhaustion rates - 3 and 8 gpm. Effluent water samples were taken throughout the run for analysis in the Elgin laboratories as well as sample analysis performed in the mobile laboratory. Termination of the service cycle was determined by an effluent alkalinity rise to 10% of the influent alkalinity.

Two regenerant levels of acid were employed - 22.1 and 32.0 lbs. (per 3 cubic feet of resin) of 66° Be' $H_2SO_4$. All regeneration was accomplished using 0.5% $H_2SO_4$ followed by 120 gallons of raw water rinse.

Summary Of Operating Parameters

| | |
|---|---|
| Regeneration level | 22.1 and 32.0 lbs. of 66° Be' $H_2SO_4$ per 3 cubic feet of resin. |
| Regeneration concentration | 0.5% $H_2SO_4$. |
| Regeneration rate | 1 gpm per cubic foot of resin. |
| Method of regeneration | Downflow. |
| Method of control | 3 gpm Dole valve located in effluent line. |
| Regeneration acid rinse out | 120 gallons (40 gals/$ft^3$). |
| Exhaustion rate | 3 and 8 gpm. |

| | |
|---|---|
| Exhaustion rate control | Dole valve located in effluent line. Also monitored by flow rate meter. |
| Termination of exhaustion cycle | Rise in effluent alkalinity to 10% of influent alkalinity. |
| Volume of water treated | Determined by water meter located on raw water influent. |
| Resin capacity | Calculated from mineral analysis of raw water and exhaustion volume. |
| Water quality | Determined by periodic mineral analysis and drip sample of effluent in Elgin's Analytical Laboratory. |

## V EXPERIMENTAL RESULTS

### Experimental Data - Strong Acid Cation Unit

SUL-biSUL® studies were conducted at five test sites. Only two of these, Webster, South Dakota, and Dalpra Farms, Colorado, had natural brackish water supplies allowing a complete study of cation performance characteristics.

At the remaining test sites, it was necessary to synthesize brackish water in a 5000 gallon tank. The inherent problems in attempting to synthesize brackish water of various chemical compositions, along with the insufficient supply of small storage tanks did not afford the opportunity to attain cyclic equilibrium during cation exhaustion studies. Because of the above limitations, the data collected at Wrightsville Beach, and Roswell during cation exhaustion studies was insufficient to attempt correlation or interpretation with the two natural brackish water test sites.

Exhaustion and regeneration cycles were conducted at each regenerant level until performance characteristics in cyclic equilibrium were observed. Cyclic equilibrium is defined as a minimum of two consecutive cycles showing essentially identical characteristics of capacity and leakage. The following is a summary of cation performance characteristics data collected at both Webster, South Dakota and Dalpra Farms, Colorado:

### Webster, South Dakota

Table I summarizes the average cation capacity and leakage data collected.

Table II summarizes the data justifying the figures presented in Table I.

Table III summarizes the regenerant acid requirements per thousand gallons of water treated with respect to various regenerant levels.

Table IV summarizes the performance characteristics of all cation exhaustion studies conducted.

### Dalpra Farms, Colorado

Table V summarizes the average cation capacity and leakage data collected.

Table VI summarizes the data justifying the figures presented in Table V.

Table VII summarizes the regenerant acid requirements per thousand gallons of water treated with respect to various regenerant levels.

Table VIII summarizes the performance characteristics of all cation exhaustion studies conducted.

Discussion And Summary Of Experimental Data

Figure 3 shows the typical effluent conductivity characteristics of a strong acid cation exhaustion cycle. As shown, the initial conductivity is very high due to the concentrated regenerant acid, decreases as the acid is rinsed out of the resin bed and remains fairly constant throughout the exhaustion run. Breakthrough is that point at which the resin loses its ability to convert mineral salts to mineral acids. At this point (end of exhaustion run), the effluent conductivity decreases sharply due to the difference in conductivity between mineral salt leaking through the resin bed where it had previously been converted to mineral acid. This method of determining (salt) breakthrough capacities is considered to be very sensitive and accurate, as substantiated by a comparison of the data presented in Tables IV and VIII showing that a minimum of experimental error in pilot equipment was experienced.

At Webster, South Dakota, the bulk of the cation performance studies were conducted at a regenerant level of two pounds of acid per cubic foot of resin or less. This decision was based on the fact that both good resin capacity and excellent water quality were obtained at this regenerant level. Although the three and four pound per cubic foot regenerant levels were briefly investigated, the time involved for more extensive studies was not justified. It was considered more prudent to direct our efforts towards the lower economic regenerant levels of 1 and 1.5 pounds of acid per cubic foot. In reviewing the data from Table III, since water quality at all regenerant levels is excellent, an evaluation of the most desirable regenerant level to be employed at Webster, South Dakota, must be based on its effect on plant design and equipment.

The Dalpra Farms cation performance studies were conducted at regenerant levels of 3, 4 and 5 pounds of acid per cubic foot of resin. The high sodium content and low total hardness in the raw water supply dictated a decision not to employ an acid regenerant level of less than 3 pounds per cubic foot of resin. Tables V and VI show excellent capacities are achieved at the regenerant levels studied. Table VII shows the acid regenerant required. The high sodium content of the raw water accounts for the high cation leakage, greater than 500 ppm total dissolved mineral salts in the product water. The data also indicates that an increase to 5.5-6.0 pounds of acid per cubic foot of resin would produce a water acceptable to the suggested Public Health potable water standards of 500 ppm total dissolved minerals.

Comparison of Figure 4 and Table I show that increasing regenerant levels increases capacity and water quality but decreases the efficiency (per pound) of acid utilization at Webster, South Dakota. The comparison of Figure 5 and Table V shows essentially identical performance characteristics were observed at Dalpra Farms, Colorado. Comparison of Figures 4 and 5 and Tables I and V dramatizes the effect of high sodium content or increased resin capacity and leakage characteristics.

Table II summarizes the effect of increasing the cation exhaustion rate from 2.6 gallons per minute to 4.25 gallons per minute. As shown, no appreciable change in operating capacity was observed within experimental error. This study was conducted for application in design considerations.

The average strong acid cation exchange capacities and leakage data at various acid regenerant levels obtained from the two natural brackish water sites at Webster, South Dakota and Dalpra Farms, Colorado are presented in Table IX. Conventional published data for the strong acid cation was obtained from the Rohm and Haas technical bulletin IE-108-68. Elgin's observed capacity was corrected for leakage by subtracting the kilograins of capacity utilized if the amount of leakage had been exchanged by the resin.

Various mathematical interpretations were evaluated in order to arrive at a correction factor or correlation between the observed and Rohm and Haas predicted capacities and leakage. Though the observed and predicted capacity data were in relatively good agreement at Dalpra Farms by correcting the observed capacity for leakage the same method did not hold true for Webster. Similarly, the observed and predicted leakage data were also in disagreement; Webster was 150% higher than predicted and Dalpra Farms was approximately 22% higher.

The Webster site had a low sodium content (18.8%) and a TDS of 1082 ppm, whereas Dalpra Farms had a very high sodium content (89.3%) and a TDS of 2160 ppm. The fact that only these two sites were natural brackish waters and varied so greatly may account for the difficulty in finding a correlation or trend.

At this time, we feel that the study of cation performance characteristics should be extended to other levels of TDS and percent chemical composition of various brackish supplies and is definitely required before a correlation or trend may be firmly established.

The possible reuse of waste acid for cation regeneration and its effect on performance characteristics and economics of operation in the SUL-biSUL® process also should be investigated.

Anion capacity is a predictable quantity provided that the cation effluent FMA level (anion influent exhaustant) is known.

Because cation performance characteristics are not predictable from a brackish water analysis, laboratory or field tests studying its performance characteristics are required before a water treatment plant can be designed. These studies would not necessarily require pilot equipment as was employed at the Webster and Dalpra Farms test sites but could employ laboratory scale equipment to obtain the necessary cation design parameters.

## Experimental Data - Strong Base Anion Unit

There are three essential considerations necessary for predicting the performance characteristics of the SUL-biSUL® anion exchange unit. They are, the capacity of the resin for free mineral acidity (cation effluent), the effect of variations in chemical composition of free mineral acidity (sulfate-chloride ratio) on anion resin capacity and raw water requirements for anion rinse regeneration as a function of raw water chemical composition.

The SUL-biSUL® anion resin capacity for free mineral acidity was observed at all test sites and thoroughly studied at the Wrightsville Beach test site. Figure 6 graphically summarizes the correlation between influent free mineral acidity concentrations and anion resin capacity. Figure 7 shows the typical anion effluent conductivity characteristics during exhaustion.

Figure 8 indicates the effect of sulfate-chloride chemical composition variations on the anion resin capacities that would be predicted from Figure 6.

Water requirements for anion rinse regeneration were extensively studied at the Roswell, New Mexico, test site. These studies consisted of varying the synthetic raw water alkalinity while holding the free mineral acidity content (after cation treatment) relatively constant. Figure 9 graphically summarizes the effect of raw water alkalinity on anion rinse regeneration requirements. The typical anion effluent conductivity characteristics during raw water rinse regeneration are shown in Figure 10. Table X summarizes the experimental data collected at Roswell. It will be noted in exhaustion runs 38-58 that when the influent alkalinity content is held constant and the influent free mineral acidity concentration is varied, the volume of water required for anion rinse regeneration remains relatively constant.

It is also interesting to note in Figures 11-15 (data summarized in Table X), that the effluent conductivity during anion rinse regeneration is directly proportional to the influent free mineral acidity exhaustant concentration, i.e., as the anion bed was exhausted with higher concentrations of free mineral acidity resulting in higher anion capacities, the effluent conductivity during anion rinse regeneration also increased but the volume of water required for rinse regeneration remain relatively constant.

As shown in Table XI, the rate of rinse regeneration can be increased from 6 gpm to 12 gpm with no appreciable change in the volume of raw water required. Rinse regeneration flow rate is an important consideration for equipment design - the anion unit must be regenerated in less time than it takes for exhaustion. This fact has significance in systems where double and triple units are employed for the production of a constant flow of product water.

## Discussion And Summary Of Results

From studies of the anion unit in the SUL-biSUL® process employing both natural brackish water supplies and synthesized brackish waters, the following are indicated:

1) Within acceptable experimental error, there is a direct relationship between influent FMA and a corresponding operating anion capacity when the system is employed for desalting brackish waters high in sulfate - low in chloride.

2) The SUL-biSUL® anion capacity and influent free mineral acidity relationship follows a predictable trend.

3) The effect of variations in the sulfate-chloride ratio on anion capacity follows a predictable trend.

4) Product water quality is a function of cation resin metallic leakage.

5) The volume of water required for anion rinse regeneration is a predictable quantity dependent upon the raw water alkalinity.

6) The anion rinse regeneration flow rate can be increased to 3 gpm per cubic foot of resin with no affect on anion operating capacity. It is conceivable that anion rinse regeneration flow rates could be increased significantly higher than 3 gpm per cubic foot of resin.

From the experimental data, the following observations should also be noted:

1) Over rinse regenerating (employing more rinse water than is required) does not result in any detrimental affects on the anion resin bed.

2) Anion rinse regeneration can be accurately and easily automated with simple conductivity equipment.

3) SUL-biSUL® anion resin performance is definitely predictable within limited experimental error.

Lime slurry regeneration of the anion unit was also briefly studied. The results of these studies quickly indicated that lime slurry feed was extremely difficult to control due to the formation of both calcium sulfate and calcium carbonate (raw water temporary hardness) precipitation in the pilot equipment. In addition to these difficulties, the time required for lime slurry regeneration and rinse out exceeded the time required for exhaustion - an important consideration. From an equipment and operational point of view, lime slurry regeneration was not considered practical and no additional studies were conducted. Further advancements in ion exchange equipment design may allow future utilization of this anion regeneration technique.

## Experimental Data - Weak Acid Cation Unit

Only the Webster, South Dakota, test site had a sufficient supply of brackish water to allow weak acid cation resin performance characteristics studies. The following is a summary of the data collected:

Figure 16 summarizes the TDS (product water quality) and free mineral acidity effluent characteristics of the weak acid cation exchange unit.

Figure 17 summarizes the TDS and free mineral acidity effluent characteristics of the weak acid cation exchange unit used as an exhaustant for the strong acid cation exchange unit.

Table XII summarizes all of the data collected employing the weak acid cation exchange unit.

Table XIII summarizes the acid requirements per thousand gallons of water treated employing a weak acid cation exchange unit.

## Discussion And Summary Of Experimental Data

During runs number 24-30 in Table XII, we experienced difficulty in obtaining reproducible results (cyclic equilibrium). Since the weak acid cation exchange unit, in actual operation, will be regenerated with an excess of waste acid supplied by the strong acid cation exchange unit, a decision was made to consistently regenerate the unit with a fixed amount of acid. The level selected was equal to the maximum capacity of the resin (60 $Kgr/ft^3$) regenerated at 120% of stoichiometric (32 lbs. per 3 cubic foot of resin). Exhaustion runs number 31, 32 and 33 show reproducible results at this fixed regenerant level.

As will be noted in Table XII, the calculated capacity of the strong acid cation exchange unit is higher than the results obtained during two bed SUL-biSUL® studies. This higher capacity is due to the lower TDS feed from the weak acid cation exchange unit and a higher percentage of sodium contained in the feed owing to the ability of the weak acid cation exchange resin to selectively remove hardness from the raw water supply over sodium. The average TDS influent to the strong acid cation exchange unit was assumed at 670 ppm for capacity calculations.

As indicated in Table XIII, incorporating a weak acid cation exchange unit into the SUL-biSUL® system has a definite effect on the economics of the product water. The third bed, a weak acid cation exchanger, added to the basic SUL-biSUL® system has the following advantages:

1) Decreases the total influent cation load to the strong acid cation exchange unit.

2) Increases the sodium to hardness ratio of the influent stream to the strong acid cation exchanger due to the selectivity of the weak acid cation exchange resin for hardness over sodium.

3) The effect of 1) and 2) increases the capacity of the strong acid cation exchange unit.

4) The carboxylic exchanger provides additional cation capacity at no additional operating cost since it can be regenerated with waste acid from the strong acid cation exchange unit.

TABLE I

STRONG ACID CATION RESIN PERFORMANCE CHARACTERISTICS AT VARIOUS REGENERANT LEVELS

| Regenerant Level lbs. 66° Be' $H_2SO_4/ft^3$ Resin | Average Capacity Kilograins/$ft^3$ | Average Leakage ppm as $CaCO_3$ (Product Water Quality) |
|---|---|---|
| 1.0 | 4.82 | 135 |
| 1.5 | 6.19 | 86 |
| 2.0 | 7.55 | 57 |
| 3.0 | 9.28 | 51 |
| 4.0 | 11.22 | - |

TABLE II

CATION EXHAUSTION DATA FOR VARIOUS REGENERANT LEVELS

| REGENERANT LEVEL LBS. OF $66^{o}$ Be' $H_2SO_4$ ACID/$FT^3$ | EXHAUSTION FLOW RATE GPM | RUN NO. | EXHAUSTION VOLUME IN GALLONS | RESIN CAPACITY Kgr/$ft^3$ | CATION LEAKAGE PPM AS $CaCO_3$ (DRIP SAMPLES) | REGENERANT RINSE OUT VOLUME IN GALLONS |
|---|---|---|---|---|---|---|
| 1.0 | 2.6 | 9 | 225 | 4.72 | 138 | 63 |
| | 2.6 | 10 | 226 | 4.74 | 130 | 69 |
| | 2.6 | 12 | 232 | 4.87 | 136 | 62 |
| | 2.6 | 14 | 235 | 4.93 | 136 | 48 |
| 1.5 | 2.6 | 11 | 295 | 6.19 | 78 | 44 |
| | 2.6 | 15 | 293 | 6.15 | 101 | 62 |
| | 2.6 | 16 | 297 | 6.23 | 80 | 62 |
| 2.0 | 2.6 | 5 | 354 | 7.42 | 51 | 68 |
| | 2.6 | 6 | 355 | 7.45 | 59 | 65 |
| | 2.6 | 17 | 372 | 7.80 | 65 | 51 |
| | 2.6 | 18 | 365 | 7.66 | 58 | 46 |
| | 4.25 | 19 | 360 | 7.55 | 61 | 66 |
| | 4.25 | 20 | 360 | 7.55 | 55 | 60 |
| | 4.25 | 22 | 355 | 7.45 | 52 | 61 |
| 3.0 | 2.6 | 7 | 430 | 9.02 | 52 | 60 |
| | 2.6 | 8 | 457 | 9.58 | 49 | 68 |
| 4.0 | 2.6 | 23 | 535 | 11.22 | - | - |

## TABLE III

## ACID REQUIREMENTS PER 1000 GALLONS OF TREATED WATER FOR VARIOUS REGENERANT LEVELS

| Regeneration Level lbs. of $66^{o}$ Be' $H_2SO_4$ Acid/$ft^3$ | Cation Resin Capacity in Kgr. (Average) | Gal/$ft^3$ Treated | $Ft^3$ Resin Required Per 1000 Gallons Treated | Lbs. Acid Required Per 1000 Gallons Treated |
|---|---|---|---|---|
| 1.0 | 4.82 | 76.5 | 13.07 | 13.07 |
| 1.5 | 6.19 | 98.4 | 10.16 | 15.24 |
| 2.0 | 7.55 | 120 | 8.34 | 16.68 |
| 3.0 | 9.28 | 148 | 6.76 | 20.38 |
| 4.0 | 11.22 | 178 | 5.62 | 22.48 |

## TABLE IV

## MASTER DATA SHEET FOR CATION RUNS
## (TWO BED SUL-biSUL® STUDIES)

| Run No. | Regenerant Level in Lbs. $66^{o}$ Be' $H_2SO_4$ Acid/$ft^3$ | Rinse Out Volume in Gallons | Exhaustion Rate in GPM | Exhaustion Volume in Gallons | Capacity in Kgr/$ft^3$ | FMA in ppm as $CaCO_3$ (Drip Sample) | Leakage in ppm as $CaCO_3$ (Drip Sample) |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 65 | 2.6 | 477 | 10.00 | 678 | - |
| 2 | 2 | 65 | 2.6 | 375 | 7.87 | - | - |
| 3 | 2 | 69 | 2.6 | 340 | 7.13 | 668 | 42 |
| 4 | 2 | 62 | 2.6 | 308 | 6.46 | 676 | 56 |
| 5 | 2 | 68 | 2.6 | 354 | 7.42 | 664 | 51 |
| 6 | 2 | 65 | 2.6 | 355 | 7.45 | - | 59 |
| 7 | 3 | 60 | 2.6 | 430 | 9.02 | - | 52 |
| 8 | 3 | 68 | 2.6 | 457 | 9.58 | 672 | 49 |
| 9 | 1 | 63 | 2.6 | 225 | 4.72 | 598 | 138 |
| 10 | 1 | 69 | 2.6 | 226 | 4.74 | 610 | 130 |
| 11 | 1.5 | 44 | 2.6 | 295 | 6.19 | 658 | 78 |
| 12 | 1 | 62 | 2.6 | 232 | 4.87 | 598 | 136 |
| 13 | 1 | 40 | 2.6 | 234 | 4.91 | 608 | 126 |
| 14 | 1 | 48 | 2.6 | 235 | 4.93 | 604 | 136 |
| 15 | 1.5 | 62 | 2.6 | 293 | 6.15 | - | 101 |
| 16 | 1.5 | 62 | 2.6 | 297 | 6.23 | 656 | 80 |
| 17 | 2 | 51 | 2.6 | 372 | 7.80 | 696 | 65 |
| 18 | 2 | 46 | 2.6 | 365 | 7.66 | 680 | 58 |
| 19 | 2 | 66 | 3.5 | 360 | 7.55 | 686 | 61 |
| 20 | 2 | 60 | 4.25 | 360 | 7.55 | 688 | 55 |
| 21 | 2 | 71 | 4.25 | 335 | 7.03 | 690 | 52 |
| 22 | 2 | 61 | 4.25 | 355 | 7.45 | 690 | 52 |
| 23 | 4 | 62 | 2.6 | 535 | 11.22 | - | - |

TABLE V

STRONG ACID CATION RESIN PERFORMANCE CHARACTERISTICS AT VARIOUS REGENERANT LEVELS

| Regenerant Level Lbs. 66° Be' $H_2SO_4$ Acid/$ft^3$ Resin | Average Capacity Kgr/$ft^3$ | Average Leakage ppm as $CaCO_3$ (Product Water Quality) |
|---|---|---|
| 3 | 18.3 | 739 |
| 4 | 19.6 | 691 |
| 5 | 21.7 | 542 |

TABLE VI

STRONG ACID CATION EXHAUSTION DATA FOR VARIOUS REGENERANT LEVELS

| Regenerant Level lbs. of 66° Be' $H_2SO_4$ Acid/$ft^3$ | Exhaustion Flow Rate GPM | Run No. | Exhaustion Volume in Gallons | Resin Capacity Kgr/$ft^3$ | Cation Leakage ppm as $CaCO_3$ (Drip Samples) | Regenerant Rinse Out Volume in Gallons |
|---|---|---|---|---|---|---|
| 3 | 3 | 6 | 451 | 19.01 | 889 | |
| 3 | 3 | 7 | 435 | 18.33 | 781 | 51 |
| 3 | 3 | 8 | 433 | 18.25 | 667 | 50 |
| 3 | 3 | 9 | 432 | 18.21 | 675 | 61 |
| 3 | 3 | 10 | 430 | 18.12 | 503 | 60 |
| 4 | 3 | 11 | 467 | 19.68 | 507 | 62 |
| 4 | 3 | 12 | 483 | 20.36 | 556 | 59 |
| 4 | 3 | 13 | 468 | 19.72 | 585 | 59 |
| 4 | 3 | 14 | 459 | 19.34 | 560 | 59 |
| 4 | 3 | 15 | 458 | 19.30 | | 57 |
| 4 | 3 | 16 | 457 | 19.26 | 511 | 54 |
| 4 | 3 | 17 | 469 | 19.76 | 515 | 57 |
| 4 | 3 | 18 | 462 | 19.47 | 504 | 55 |
| 4 | 3 | 19 | 474 | 19.98 | 470 | 58 |
| 5 | 3 | 20 | 491 | 20.69 | 340 | 55 |
| 5 | 3 | 21 | 517 | 21.79 | 367 | 53 |
| 5 | 3 | 22 | 503 | 21.20 | 362 | 54 |
| 5 | 3 | 23 | 534 | 22.50 | 388 | 48 |
| 5 | 3 | 24 | 502 | 21.16 | 400 | 56 |
| 5 | 3 | 25 | 521 | 21.96 | 380 | 55 |
| 5 | 3 | 26 | 510 | 21.49 | 399 | 55 |
| 5 | 3 | 27 | 506 | 21.32 | 420 | 50 |
| 5 | 3 | 28 | | | | 74 |
| 5 | 3 | 29 | 516 | 21.75 | 419 | 52 |
| 5 | 3 | 30 | 544 | 22.93 | 416 | 50 |
| 5 | 3 | 31 | 519 | 21.87 | 411 | 53 |
| 5 | 3 | 32 | 536 | 22.59 | 368 | 53 |

## TABLE VII

## ACID REQUIREMENTS PER 1000 GALLONS OF TREATED WATER FOR VARIOUS REGENERANT LEVELS

| Regeneration Level lbs. of $66^{o}$ Be' $H_2SO_4$ Acid/$ft^3$ | Cation Resin Capacity in Kgr. (Average) | Gal/$ft^3$ Treated | $Ft^3$ Resin Required Per 1000 Gallons Treated | Lbs. Acid Required Per 1000 Gallons Treated |
|---|---|---|---|---|
| 3 | 18.3 | 144.5 | 6.92 | 20.76 |
| 4 | 19.6 | 155.1 | 6.45 | 25.80 |
| 5 | 21.7 | 172.1 | 5.81 | 29.05 |

TABLE VIII

MASTER DATA SHEET FOR CATION RUNS

(TWO BED SUL-biSUL® STUDIES)

| Run No. | Regenerant Level in Lbs. 66° Be' $H_2SO_4$ Acid/ft$^3$ | Rinse Out Volume in Gallons | Exhaustion Rate in GPM | Exhaustion Volume in Gallons | Capacity in Kgr/ft$^3$ | FMA in ppm as $CaCO_3$ (Drip Samples) | Leakage in ppm as $CaCO_3$ (Drip Samples) |
|---|---|---|---|---|---|---|---|
| 6 | 3 | - | 3 | 451 | 19.01 | 992 | 889 |
| 7 | 3 | 51 | 3 | 435 | 18.33 | 1100 | 781 |
| 8 | 3 | 50 | 3 | 433 | 18.25 | 1063 | 667 |
| 9 | 3 | 61 | 3 | 432 | 18.21 | 1108 | 675 |
| 10 | 3 | 60 | 3 | 430 | 18.12 | 1227 | 503 |
| 11 | 4 | 62 | 3 | 467 | 19.68 | 1211 | 507 |
| 12 | 4 | 59 | 3 | 483 | 20.36 | 1235 | 556 |
| 13 | 4 | 59 | 3 | 468 | 19.72 | 1292 | 585 |
| 14 | 4 | 59 | 3 | 459 | 19.34 | 1268 | 560 |
| 15 | 4 | 57 | 3 | 458 | 19.30 | - | - |
| 16 | 4 | 54 | 3 | 457 | 19.26 | 1305 | 511 |
| 17 | 4 | 57 | 3 | 469 | 19.76 | 1223 | 515 |
| 18 | 4 | 55 | 3 | 462 | 19.47 | 1284 | 504 |
| 19 | 4 | 58 | 3 | 474 | 19.98 | 1268 | 470 |
| 20 | 5 | 55 | 3 | 491 | 20.69 | 1411 | 340 |
| 21 | 5 | 53 | 3 | 517 | 21.79 | 1373 | 367 |
| 22 | 5 | 54 | 3 | 503 | 21.20 | 1430 | 362 |
| 23 | 5 | 48 | 3 | 534 | 22.50 | 1340 | 388 |
| 24 | 5 | 56 | 3 | 502 | 21.16 | 1410 | 400 |
| 25 | 5 | 55 | 3 | 521 | 21.96 | 1370 | 380 |
| 26 | 5 | 55 | 3 | 510 | 21.49 | 1381 | 399 |
| 27 | 5 | 50 | 3 | 506 | 21.32 | 1400 | 420 |
| 28 | 5 | 74 | 3 | - | - | - | - |
| 29 | 5 | 52 | 3 | 516 | 21.75 | 1381 | 419 |
| 30 | 5 | 50 | 3 | 544 | 22.93 | 1322 | 416 |
| 31 | 5 | 53 | 3 | 519 | 21.87 | 1389 | 411 |
| 32 | 5 | 53 | 3 | 536 | 22.59 | 1355 | 368 |

## TABLE IX

### OBSERVED AND PREDICTED CAPACITY OF STRONG ACID CATION UNIT AT VARIOUS ACID REGENERANT LEVELS

| Regen.Level Lbs. 66° Be' $H_2SO_4$ Acid/$ft^3$ Resin | Test Site | Observed Average Total Capacity Kgr/$ft^3$ | Observed Leakage In ppm As $CaCO_3$ | Observed Capacity Less Observed Leakage Kgr/$ft^3$ | Rohm & Haas Predicted Capacity Kgr/$ft^3$ | Rohm & Haas Predicted Leakage In ppm As $CaCO_3$ |
|---|---|---|---|---|---|---|
| 2 | Webster | 7.6 | 57 | 7.2 | 8.3 | 21 |
| 3 | Webster | 9.3 | 51 | 8.8 | 10.2 | 21 |
| 3 | Dalpra | 18.2 | 730 | 12.1 | 11.8 | 560 |
| 4 | Dalpra | 19.6 | 540 | 14.8 | 14.4 | 420 |
| 5 | Dalpra | 21.7 | 400 | 17.8 | 16.4 | 310 |

## TABLE X

SUMMARY OF ANION RINSE REGENERATION REQUIREMENTS

| Batch | Run | Average Influent FMA (exhaustant) in ppm as $CaCO_3$ | Total Volume of Water Consumed in Gallons | Gallons of Rinse Water Per $ft^3$ Resin | Influent Test Water Alkalinity in ppm as $CaCO_3$ |
|---|---|---|---|---|---|
| 1 | 3, 4 | 1393 | 466 | 116.5 | 80 |
| 2 | 5, 9 | 1492 | 456 | 114.0 | 86 |
| 3 | 11,12, 13,14 | 1591 | 367 | 91.7 | 275 |
| 4 | 16,17 | 1334 | 351 | 87.75 | 316 |
| 5 | 22,23 | 1506 | 302 | 75.5 | 495 |
| 6 | 27,28 | 1512 | 270 | 67.5 | 744 |
| 7 | 30,32 | 1357 | 241 | 60.25 | 1064 |
| 8 | 35,37 | 1362 | 221.5 | 55.3 | 1292 |
| 9 | 38,39 | 3063 | 219 | 54.75 | 1333 |
| 10 | 44,45 | 2245 | 257.5 | 64.4 | 757 |
| 11 | 48,50 | 1681 | 254 | 63.5 | 757 |
| 12 | 51,53 | 1143 | 256 | 64.0 | 761 |
| 13 | 56,57, 58 | 562 | 248 | 62.0 | 724 |

TABLE XI

ANION CAPACITY AND RINSE REGENERATION DATA

| Run No. | Exhaustion Rate in GPM | Anion Raw Water Rinse Regenerant Rate in GPM | Anion Raw Water Rinse Regeneration Volume in Gallons | Anion Exhaustion Volume in Gallons | FMA Level PPM as $CaCO_3$ | Anion Capacity In $Kgr/ft^3$ |
|---|---|---|---|---|---|---|
| 3 | 2.6 | 12 | 306 | 317 | 668 | 3.09 |
| 5 | 2.6 | 10 | 280 | 319 | 664 | 3.10 |
| 17 | 2.6 | 10 | 286 | 300 | 696 | 3.05 |
| 18 | 2.6 | 6 | 284 | 285 | 680 | 2.83 |
| 19 | 3.5 | 6 | 285 | 305 | 686 | 3.06 |
| 20 | 4.25 | 10 | 285 | 285 | 688 | 2.87 |
| 21 | 4.25 | 10 | 285 | 285 | 690 | 2.88 |
| 22 | 4.25 | 10 | 285 | 290 | 690 | 2.93 |

TABLE XII

MASTER DATA FOR WEAK ACID CATION UNIT

| RUN NO. | REGENERANT LEVEL IN LBS. OF 66° Be' $H_2SO_4$ ACID PER/$FT^3$ | ACID RINSE OUT VOLUME | EXHAUSTION FLOW RATE IN GPM | EXHAUSTION VOLUME IN GALLONS | CAPACITY IN KGR/$FT^3$ |
|---|---|---|---|---|---|
| 24 | * | - | 3 | 6190 | 44.7(?) |
| 25 | 7.37 | - | 3 | - | - |
| 26 | 7.37 | - | 3 | 8210 | 59.2(?) |
| 27 | 10.67 | 150 | 9 | 4790 | 34.6(?) |
| 28 | 10.67 | 150 | 6.4 | 7100 | 51.2(?) |
| 29 | 10.67 | 120 | 6.4 | 7050 | 50.9(?) |
| 30 | 10.67 | - | 3 | - | - |
| | (SAC) 2.0 | 75 | 3 | - | - |
| 31 | 10.67 | 109 | 8 | 5670 | 40.9 |
| | (SAC) 2.0 | 109 | 3 | 641 | 8.37 |
| 32 | 10.67 | 119 | 8 | 5680 | 41.0 |
| | (SAC) 2.0 | 119 | 3 | 639 | 8.35 |
| 33 | 10.67 | 122 | 8 | 5765 | 41.6 |
| | (SAC) 2.0 | 122 | 3 | 639 | 8.35 |

* 270 gallons from anion rinse regeneration

TABLE XIII

ACID REQUIREMENTS PER 1000 GALLONS OF RAW WATER TREATED EMPLOYING THREE BED SUL-biSUL® SYSTEM

| CYCLE NO. | RESIN CAPACITY IN KGR/FT$^3$ | GALS/FT$^3$ TREATED | FT$^3$ RESIN REQUIRED PER 1000 GALS. TREATED | POUNDS ACID REQUIRED PER 1000 GALS. TREATED |
|---|---|---|---|---|
| 31 | 8.37 | 213.7 | 4.68 | 9.36 |
| 32 | 8.35 | 213.0 | 4.69 | 9.38 |
| 33 | 8.35 | 213.0 | 4.69 | 9.38 |
| Average | 8.36 | 213.2 | 4.69 | 9.37 |

FIG. I

PARTIALLY EXHAUSTED SYSTEM

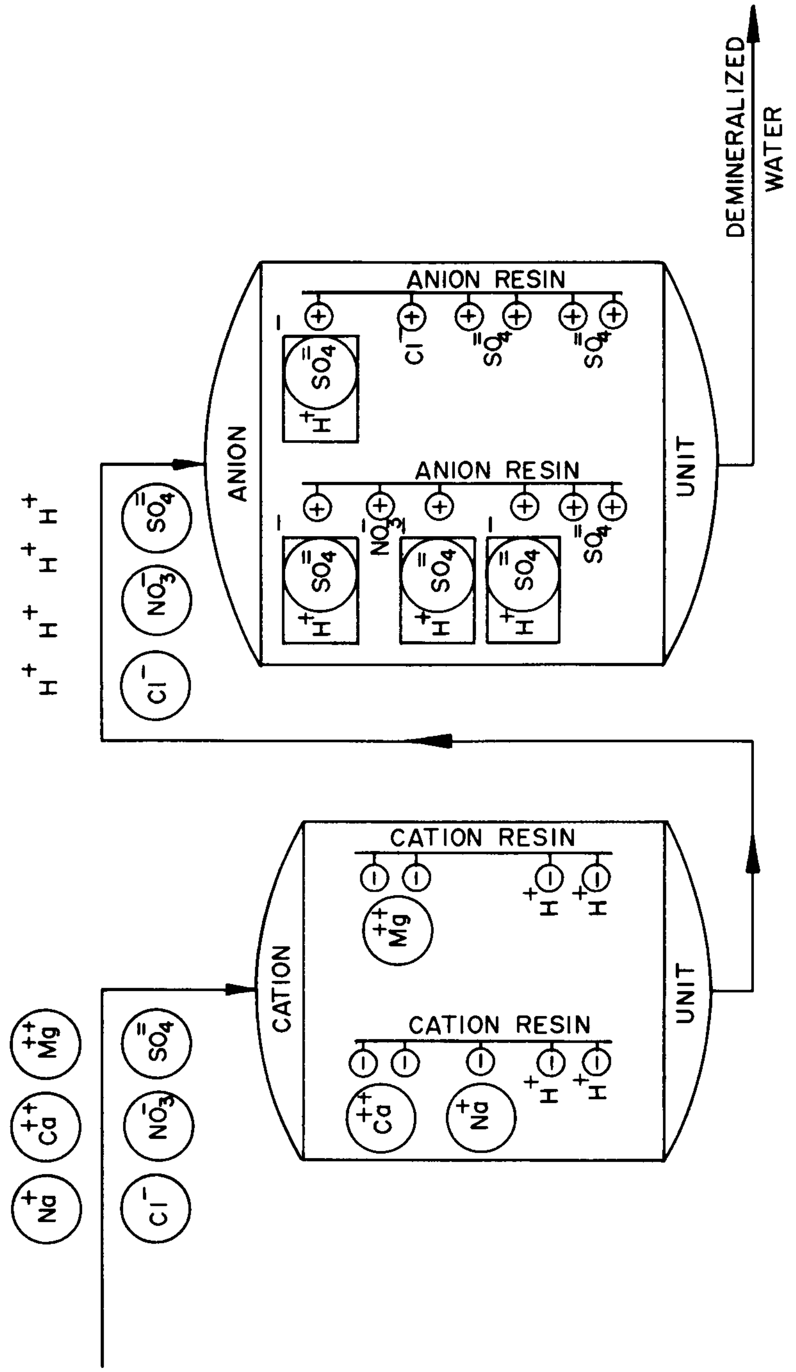


FIG. 2

## THREE BED SUL-bi SUL(T) SYSTEM

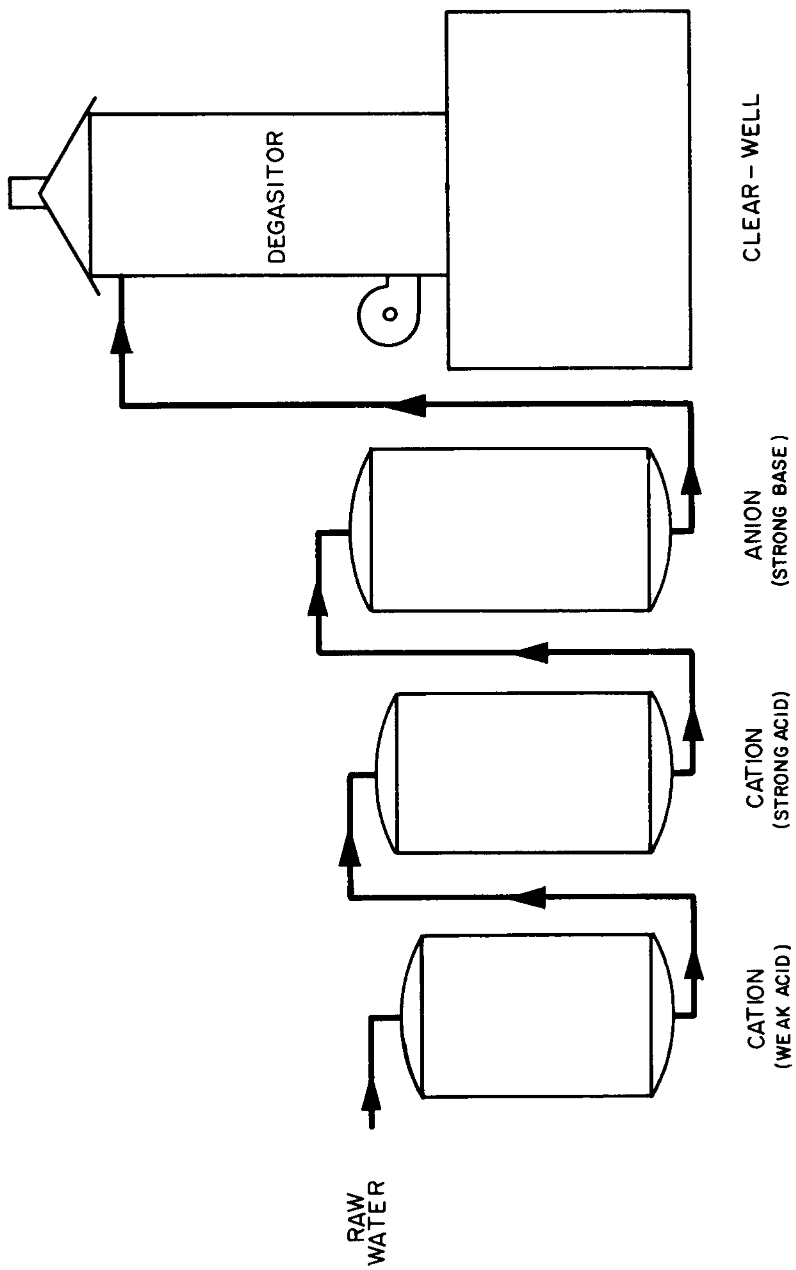


FIG. 3

TYPICAL CATION EFFLUENT CONDUCTIVITY CHARACTERISTICS DURING EXHAUSTION

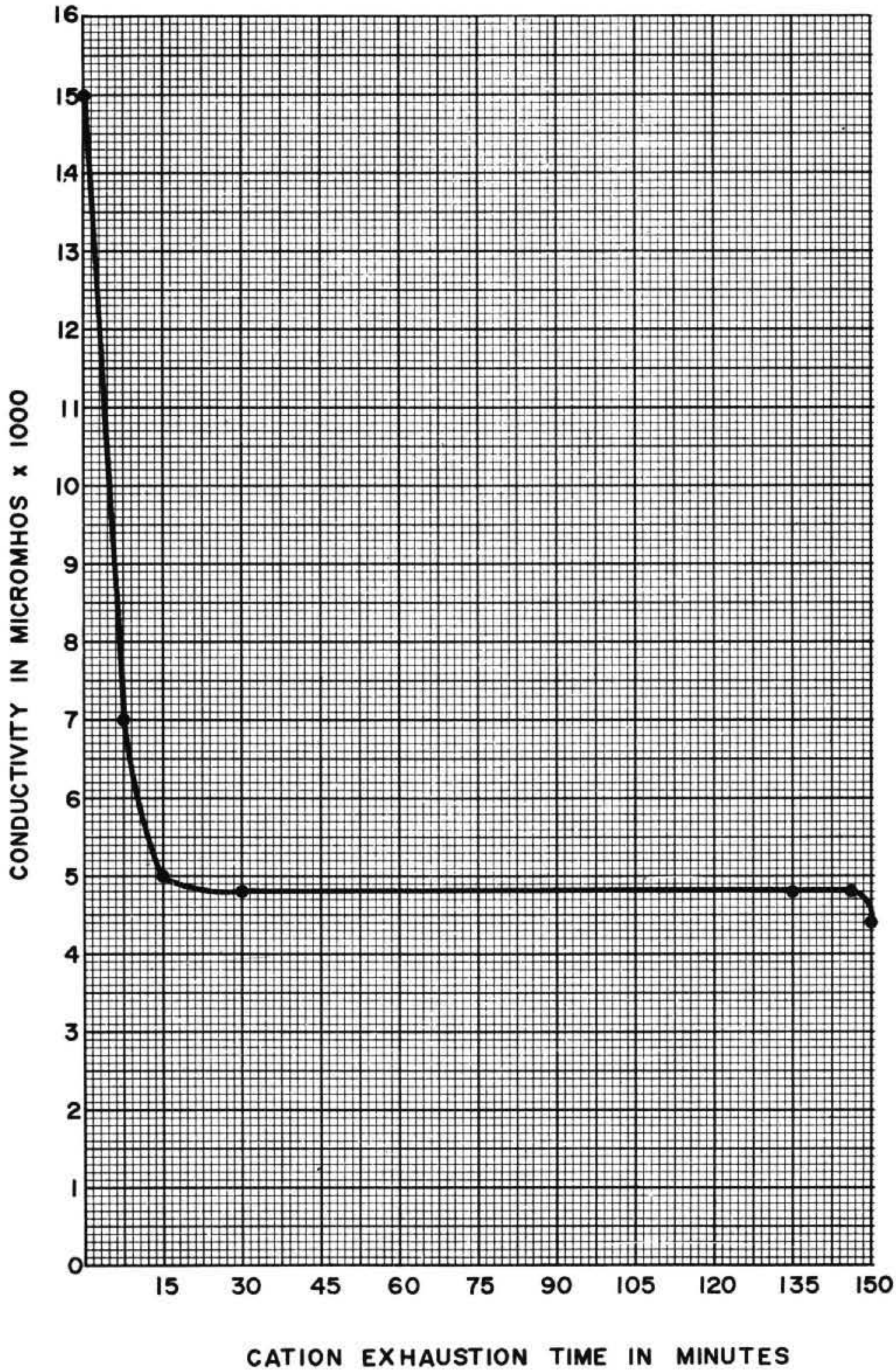


FIG. 4

REGENERANT ACID EFFICIENCY
AS A FUNCTION OF REGENERANT LEVEL

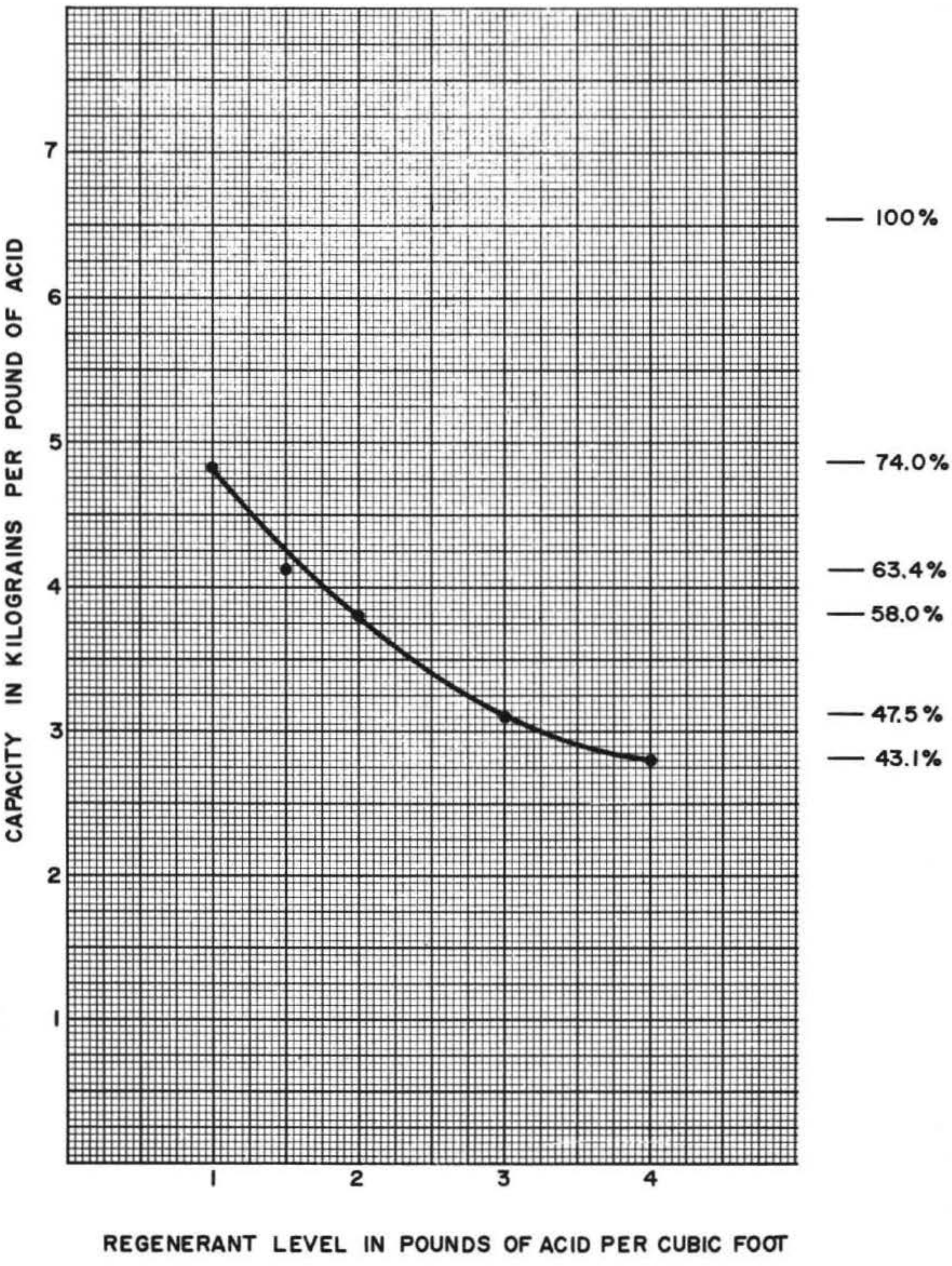
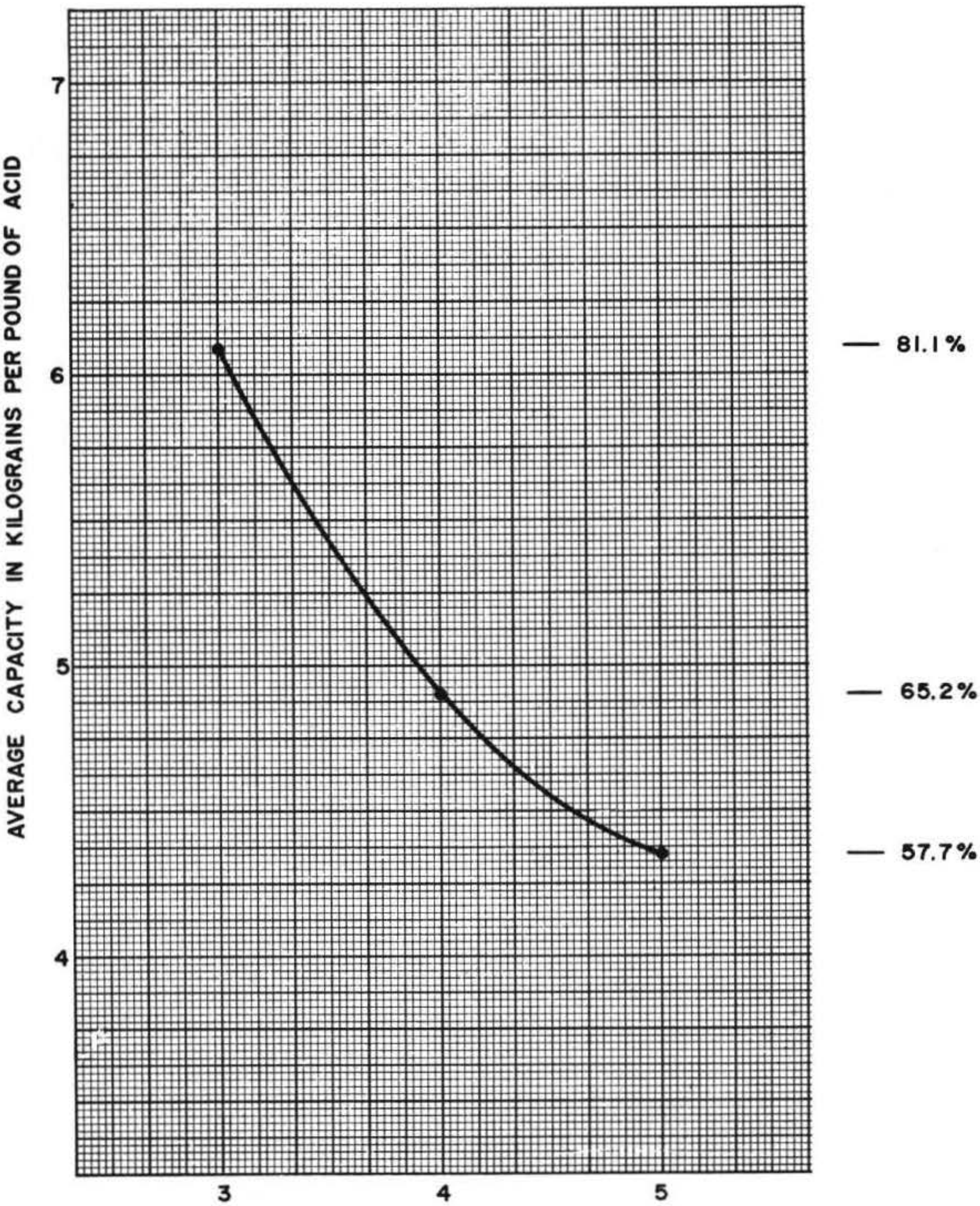


FIG. 5

REGENERANT ACID EFFICIENCY AS A FUNCTION OF REGENERANT LEVEL




CATION REGENERANT LEVEL IN POUNDS OF ACID PER CUBIC FOOT

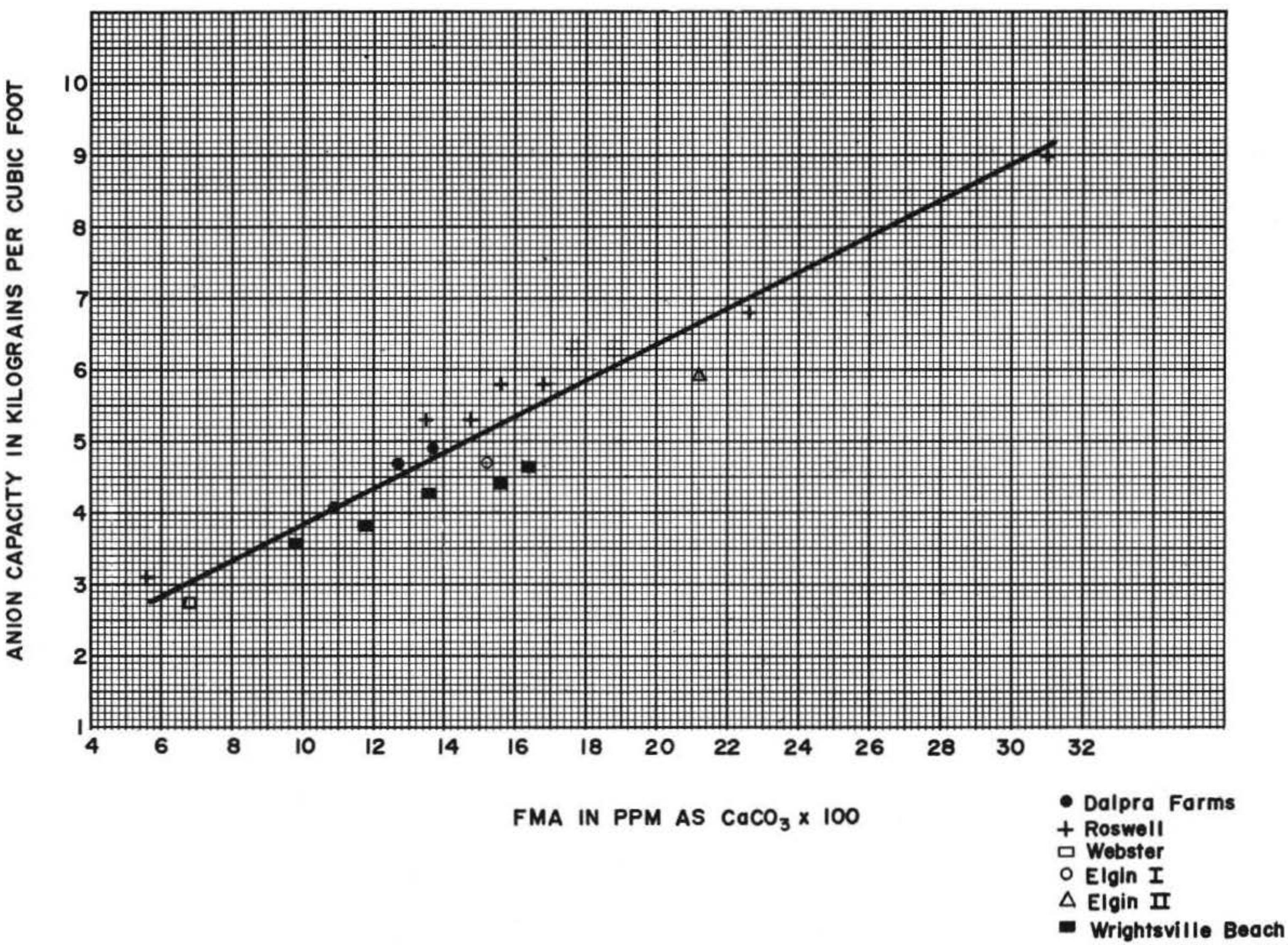



FIG. 6

EFFECT OF INFLUENT FMA ON ANION CAPACITY

FIG. 7

TYPICAL ANION EFFLUENT CONDUCTIVITY CHARACTERISTICS DURING EXHAUSTION

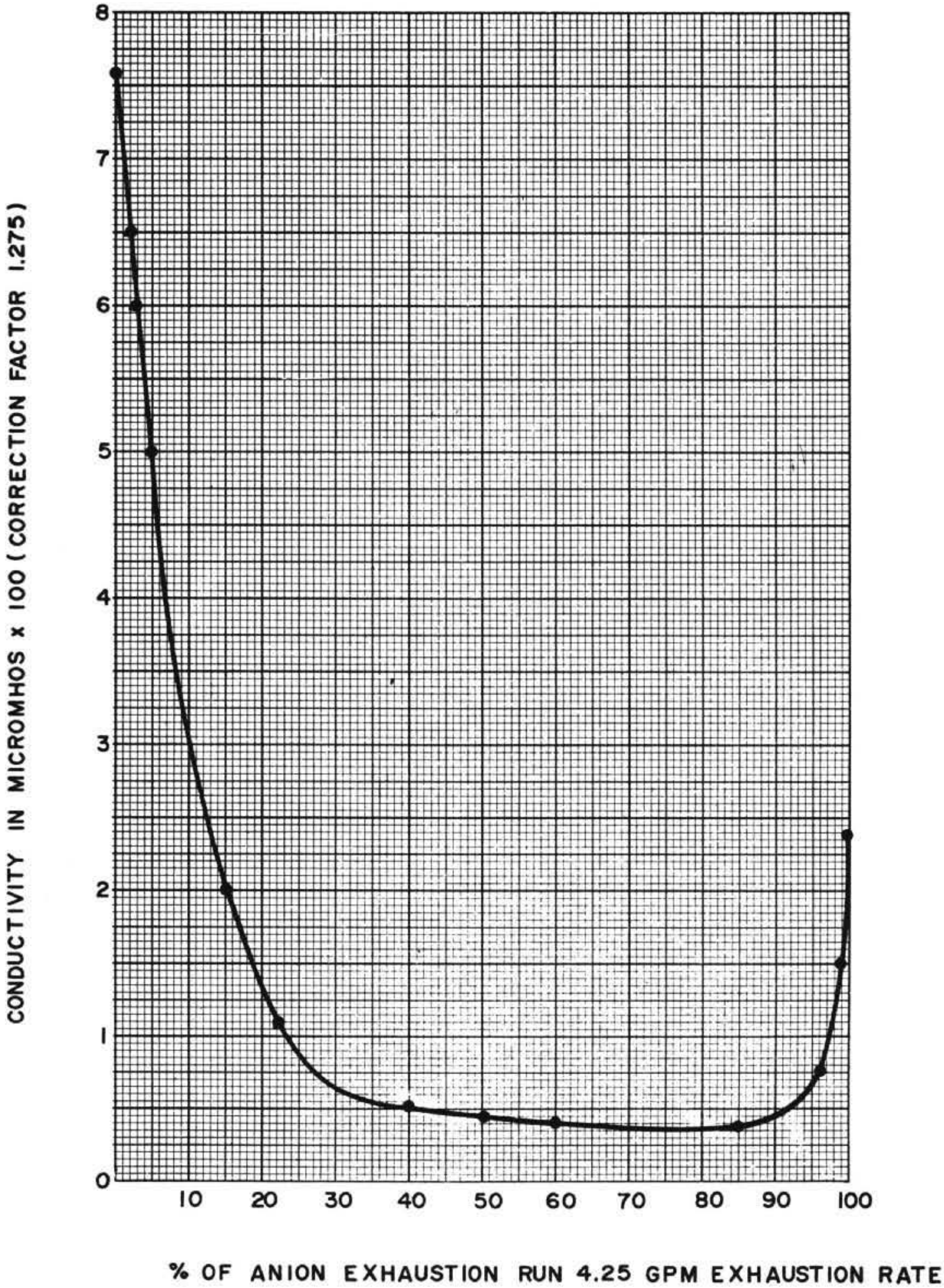


FIG. 8

**EFFECT OF SULFATE-TO-CHLORIDE IONIC VARIATIONS ON ANION CAPACITY**

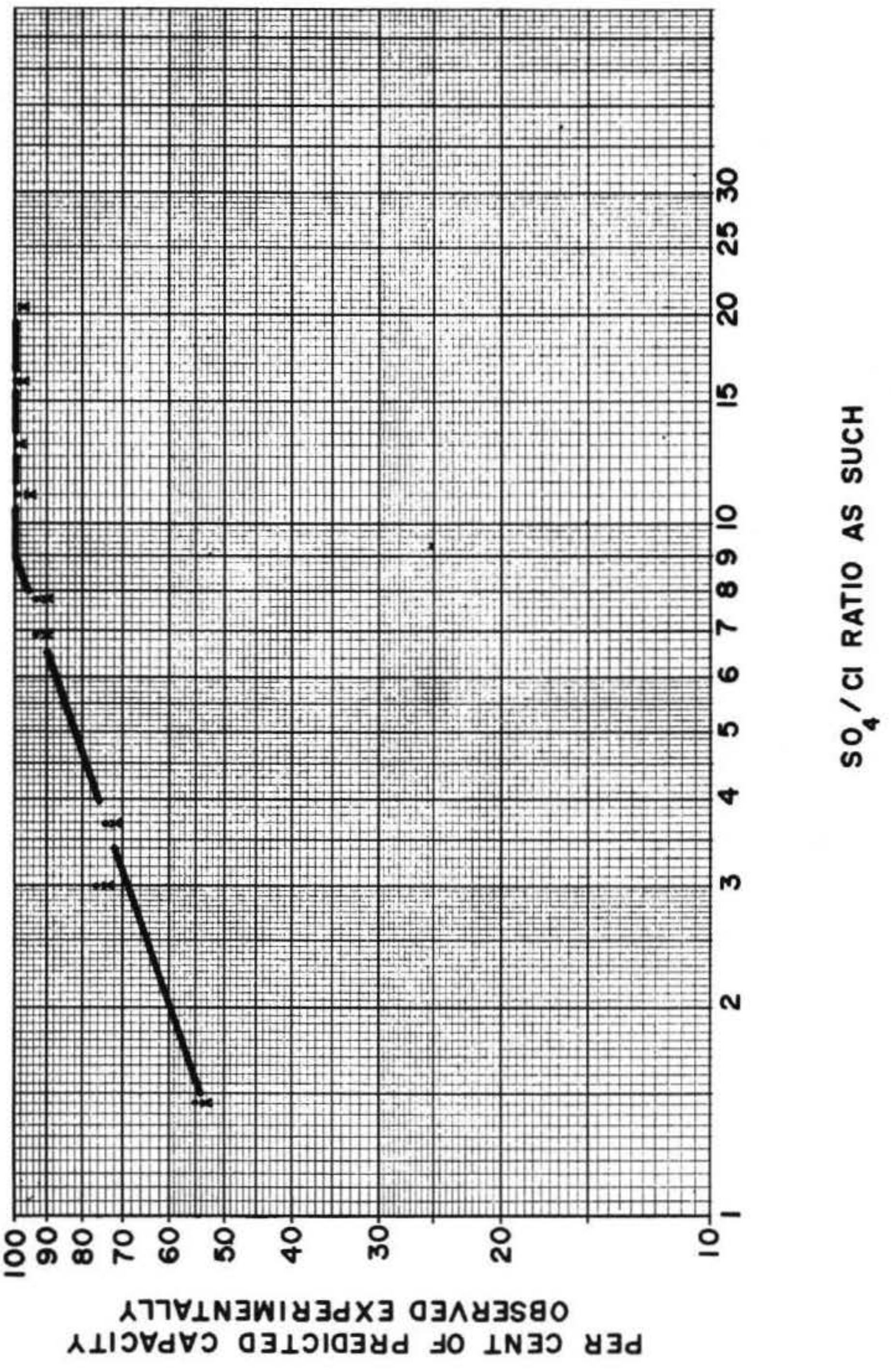


FIG. 9

WATER REQUIREMENTS FOR ANION RINSE REGENERATION AS A FUNCTION OF INFLUENT TEST WATER ALKALINITY

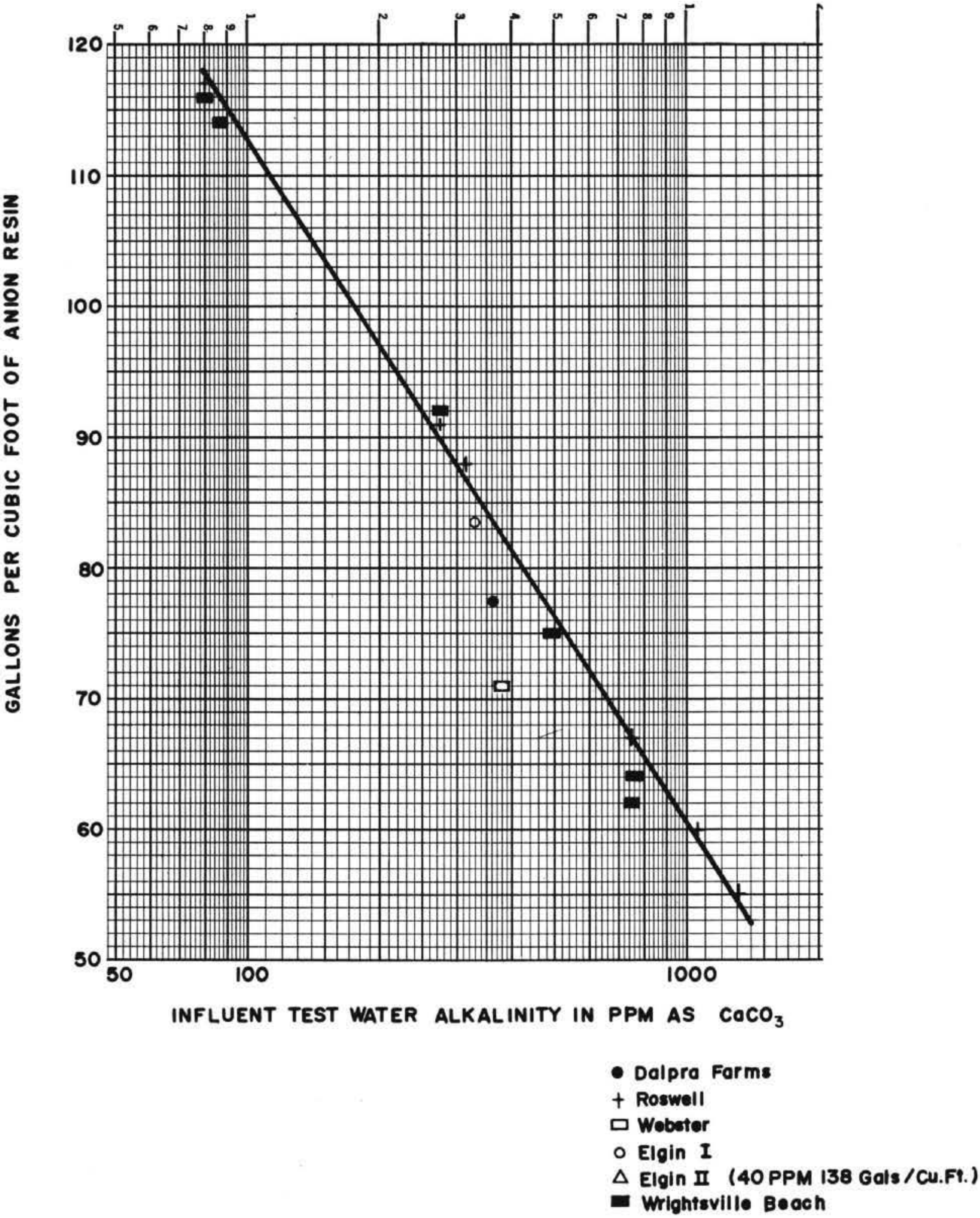


FIG. 10

TYPICAL ANION EFFLUENT CONDUCTIVITY CHARACTERISTICS DURING RAW WATER REGENERATION

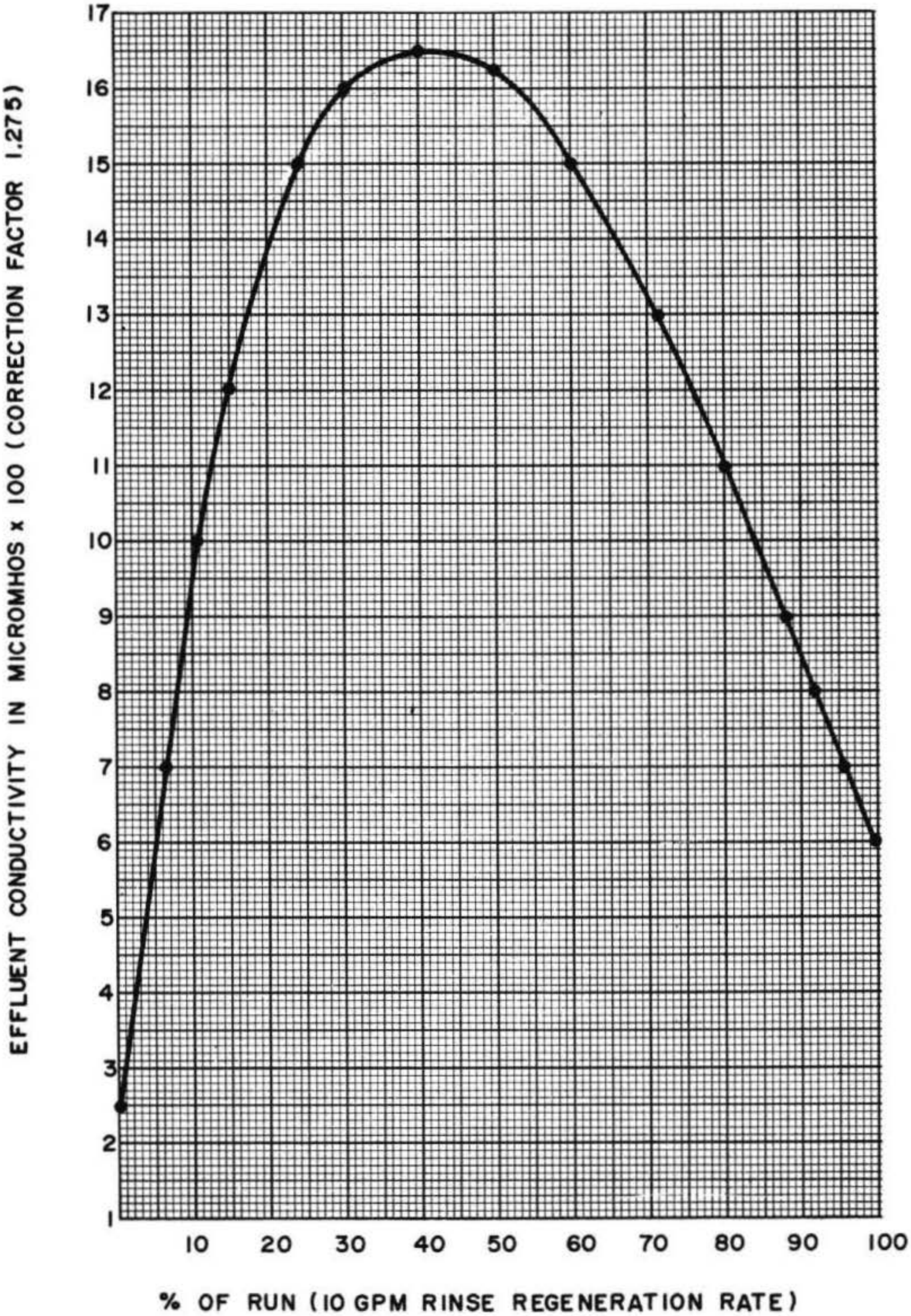


FIG. 11

AVERAGE EFFLUENT CONDUCTIVITY CHARACTERISTICS
DURING ANION RINSE REGENERATION

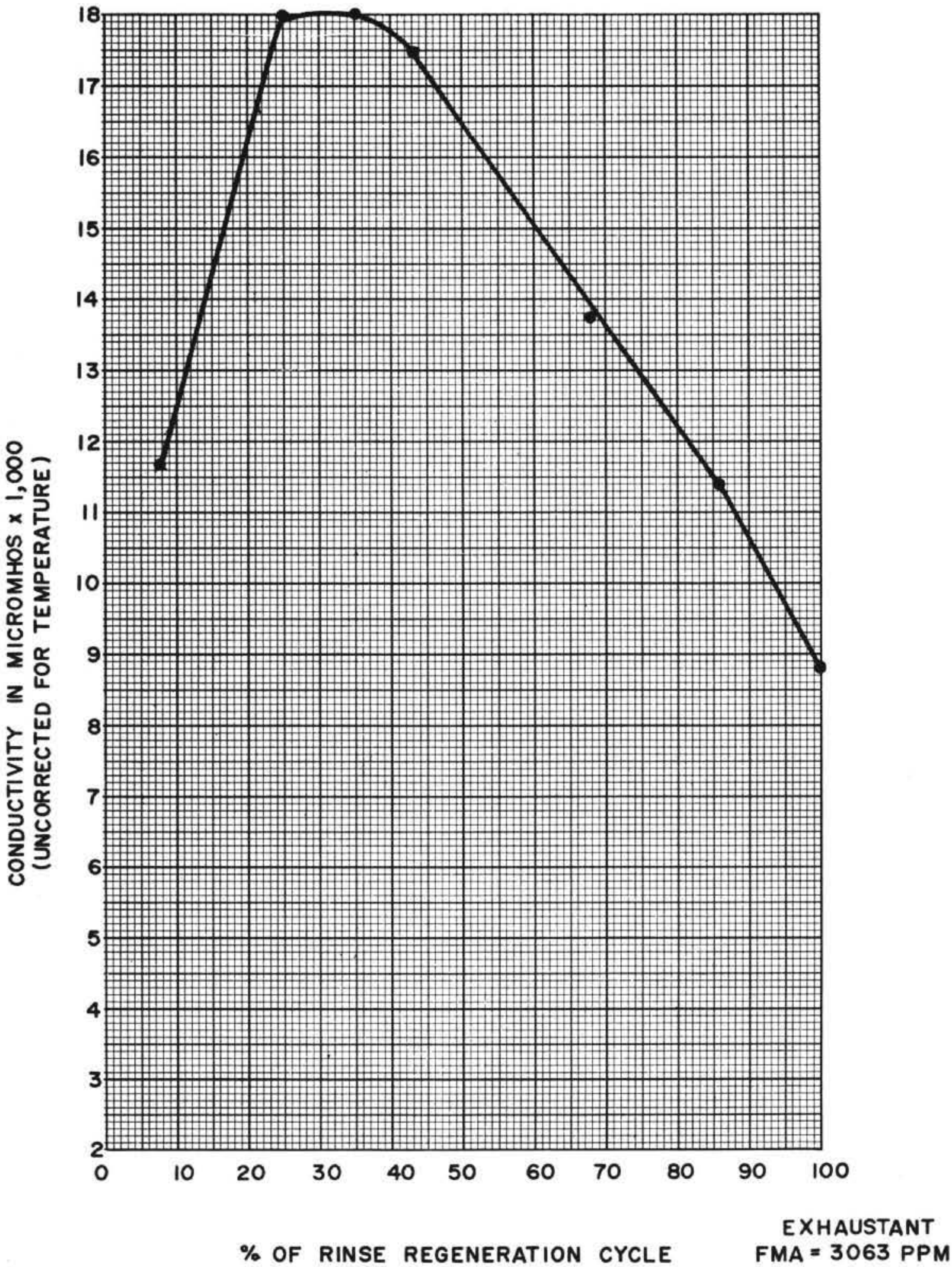


FIG. 12

AVERAGE EFFLUENT CONDUCTIVITY CHARACTERISTICS
DURING ANION RINSE REGENERATION

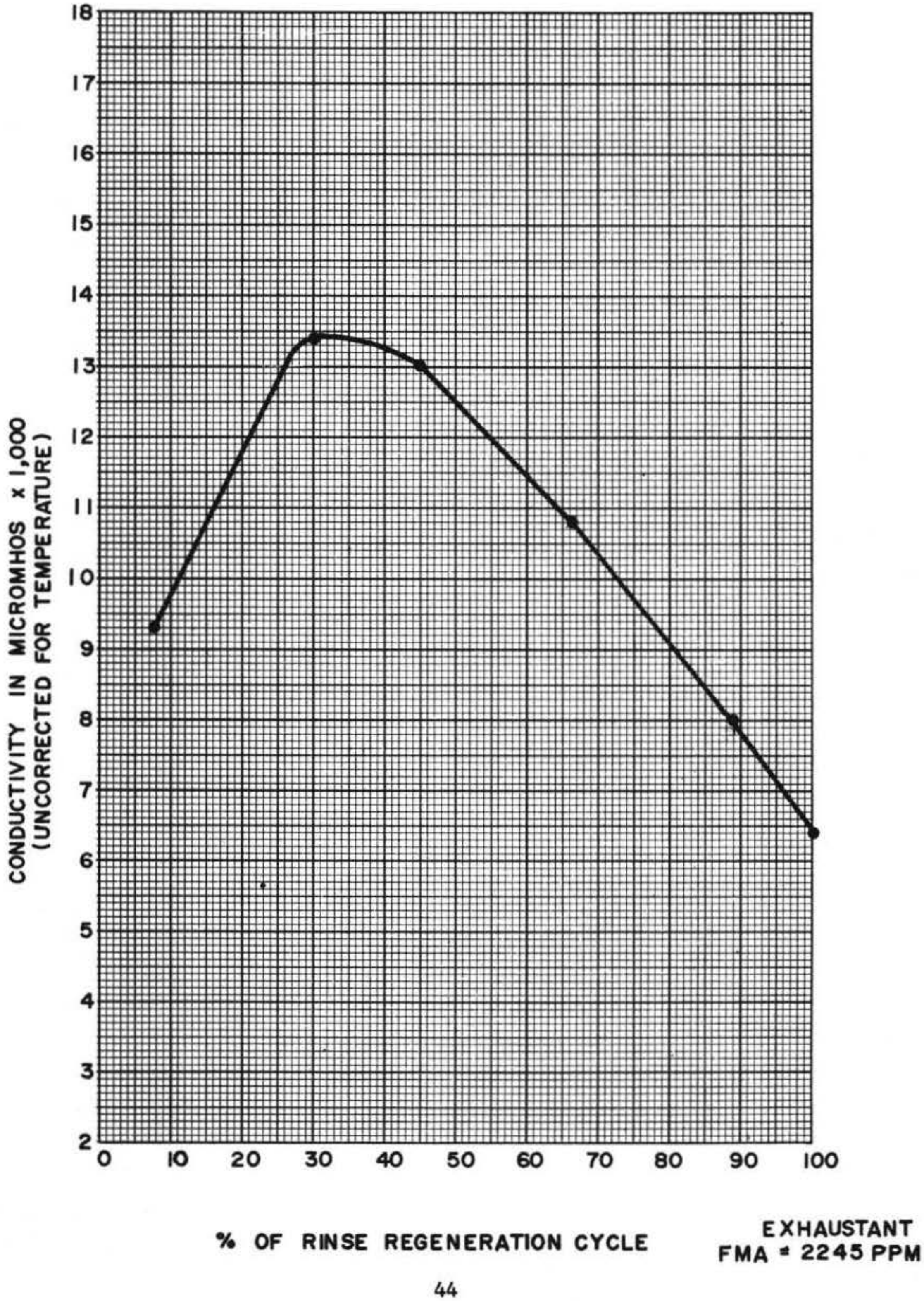


FIG. 13

AVERAGE EFFLUENT CONDUCTIVITY CHARACTERISTICS
DURING ANION RINSE REGENERATION

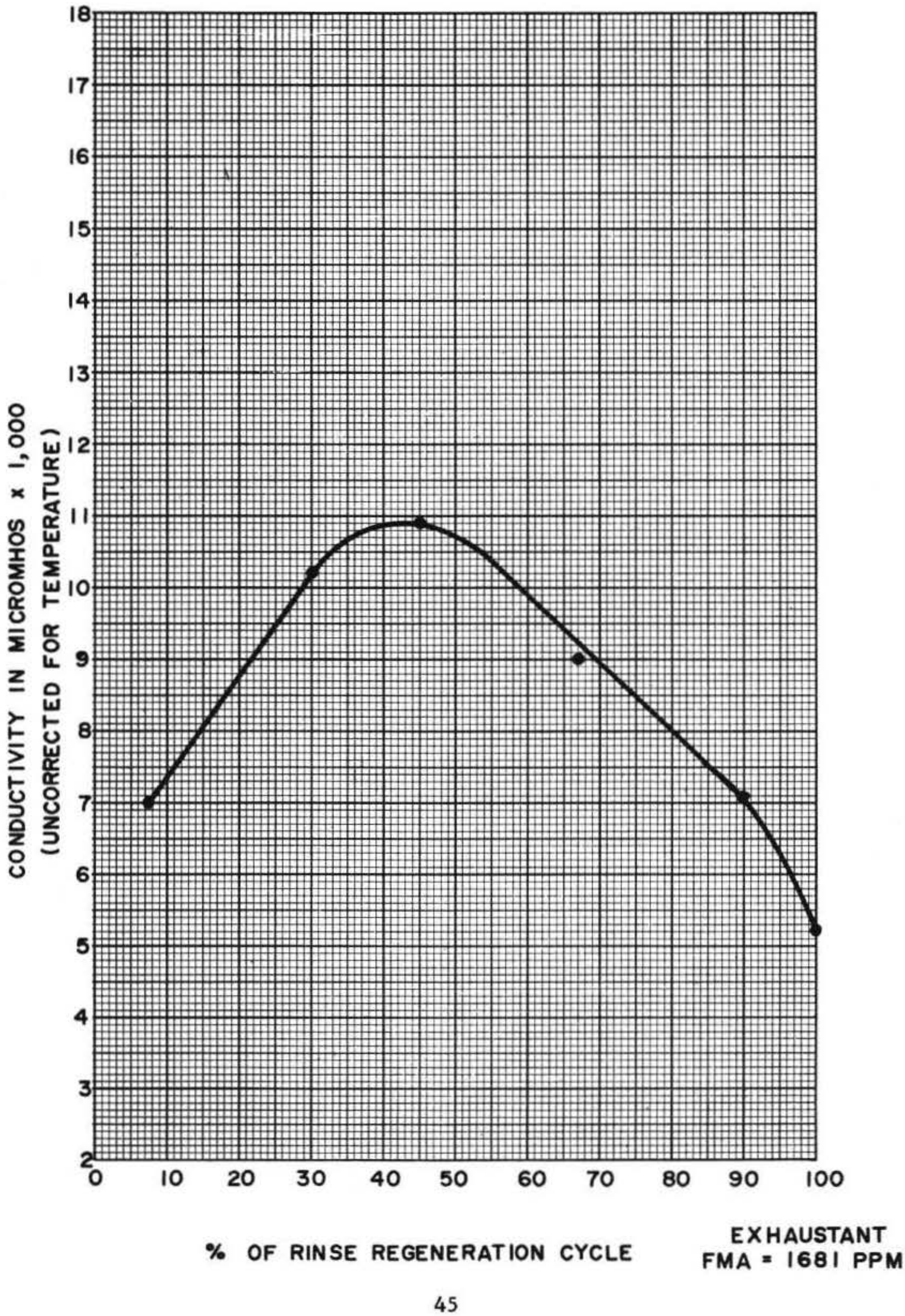


FIG. 14

AVERAGE EFFLUENT CONDUCTIVITY CHARACTERISTICS
DURING ANION RINSE REGENERATION

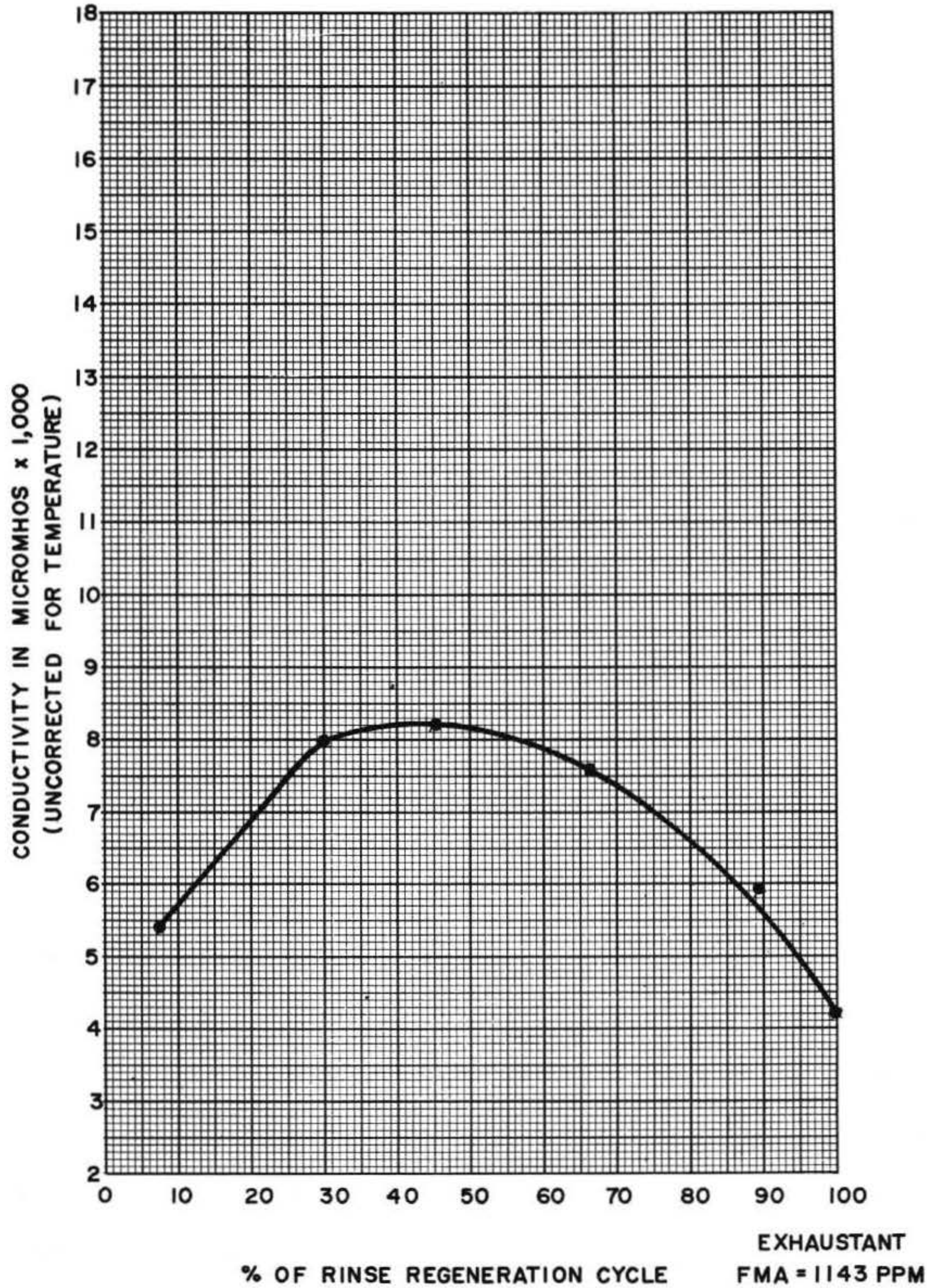


FIG. 15

AVERAGE EFFLUENT CONDUCTIVITY CHARACTERISTICS DURING ANION RINSE REGENERATION

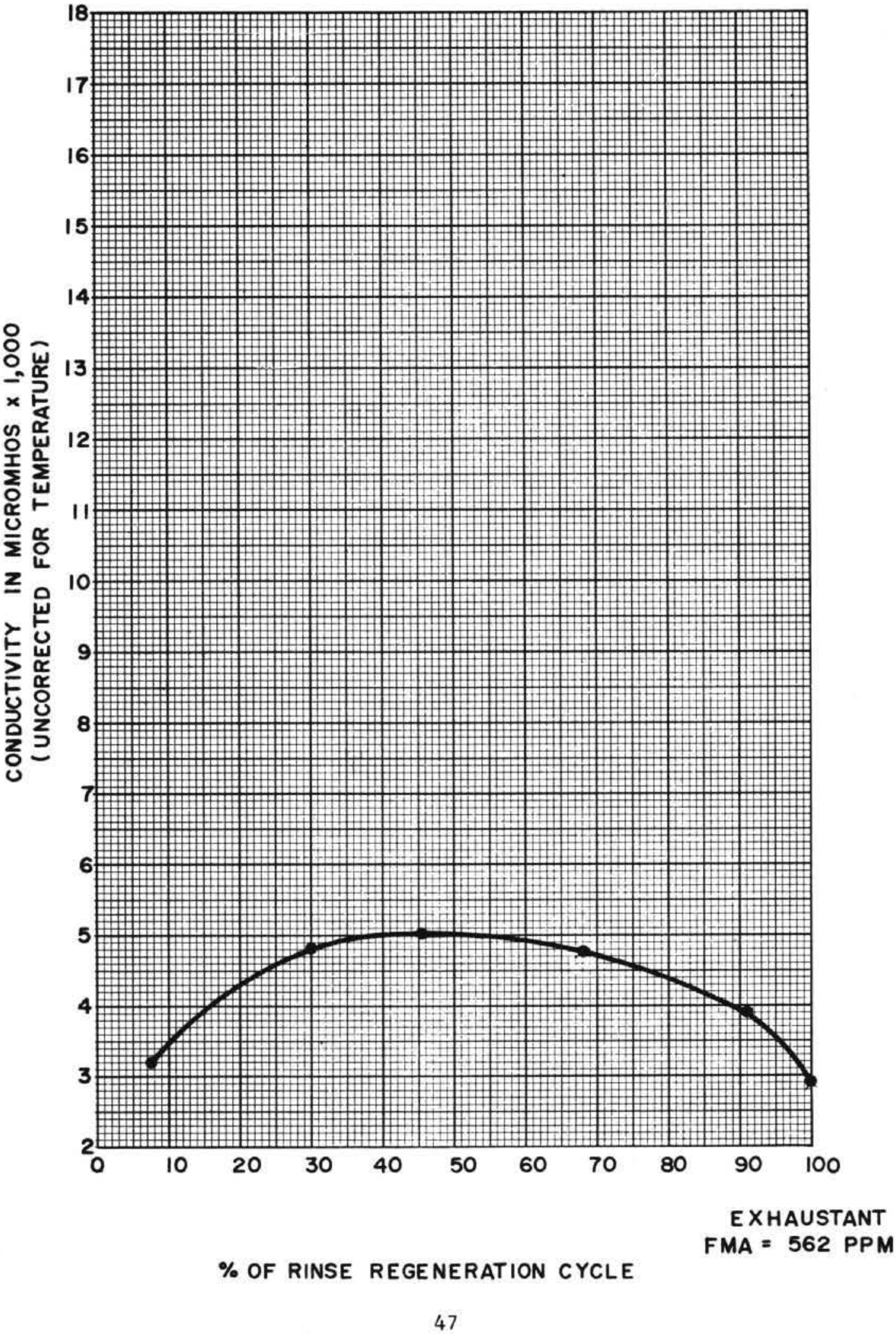


FIG. 16

EFFLUENT TDS AND FMA CHARACTERISTICS
OF WEAK ACID CATION EXCHANGE UNIT

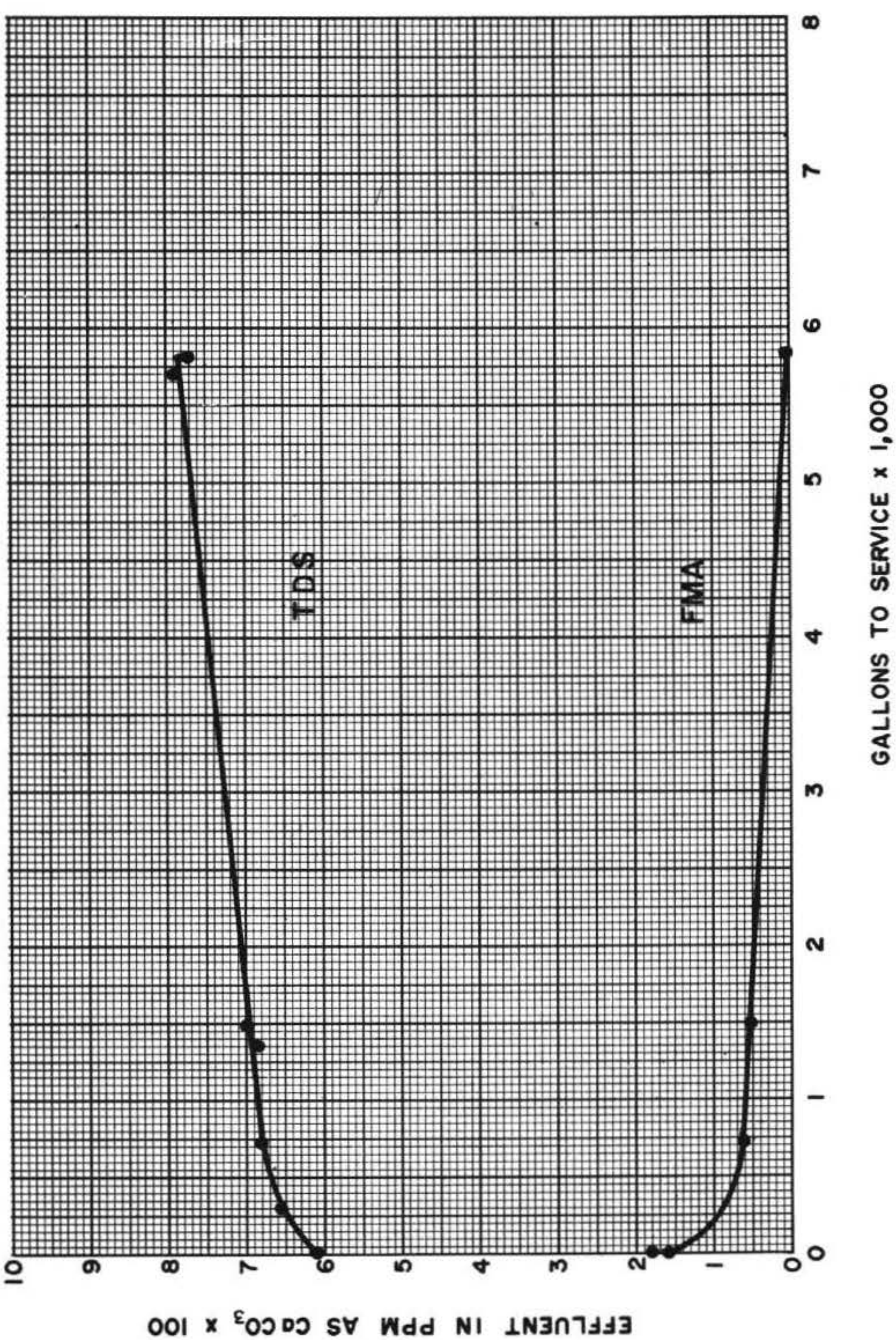
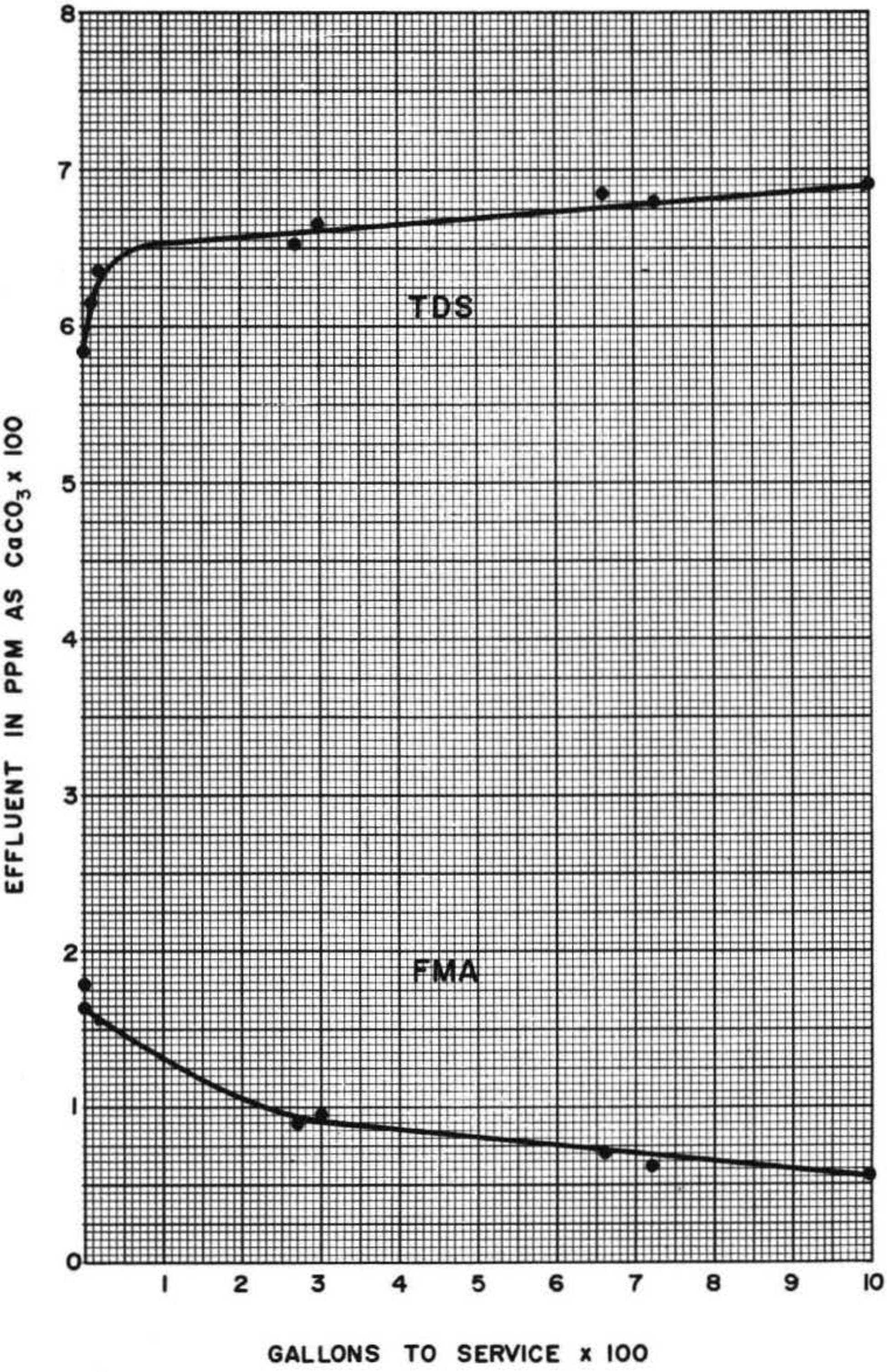


FIG. 17

EFFLUENT TDS AND FMA CHARACTERISTICS OF FIRST 1,000 GALLONS FROM WEAK ACID CATION EXCHANGE UNIT



## WATER ANALYSIS SHEET

Name Office of Saline Water

Address for Webster, South Dakota

1,000,000 gpd Three-Bed SUL-biSUL® Desalting Plant

Identification of Analyses Tabulated Below:
- A - Brackish Water Analysis No. 124342
- B - Pilot Plant Test Results No. 124735
- C - Blended 65.5% Product Water with 34.5% Raw Brackish Water

| | CONSTITUENT | | Analysis in PPM as | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| CATIONS | Calcium | $(Ca^{++})$ | $CaCO_3$ | 660 | 12 | 236 | | | |
| | Magnesium | $(Mg^{++})$ | $CaCO_3$ | 220 | 6 | 80 | | | |
| | Sodium | $(Na^+)$ | $CaCO_3$ | 202 | 20 | 85 | | | |
| | Hydrogen = FMA | $(H^+)$ | $CaCO_3$ | | | | | | |
| | Potassium | | $CaCO_3$ | | 4 | | | | |
| TOTAL CATIONS | | | $CaCO_3$ | 1082 | 42 | 401 | | | |
| ANIONS | Bicarbonate | $(HCO_3^-)$ | $CaCO_3$ | 372 | | 128 | | | |
| | Carbonate | $(CO_3^{--})$ | $CaCO_3$ | 0 | | 0 | | | |
| | Hydroxide | $(OH^-)$ | $CaCO_3$ | 0 | | 0 | | | |
| | Sulfate | $(SO_4^{--})$ | $CaCO_3$ | 700 | 28 | 260 | | | |
| | Chloride | $(Cl^-)$ | $CaCO_3$ | 10 | 14 | 13 | | | |
| | | | $CaCO_3$ | | | | | | |
| TOTAL ANIONS | | | $CaCO_3$ | 1082 | 42 | 401 | | | |
| Total Hardness | | | $CaCO_3$ | 880 | 18 | 316 | | | |
| Methyl Orange Alkalinity | | (MO) | $CaCO_3$ | 372 | | 128 | | | |
| Phenophthalein Alkalinity | | (P) | $CaCO_3$ | 0 | | 0 | | | |
| Carbon Dioxide, Free | | | $CO_2$ | 80 | 5-10 | 5-10 | | | |
| Silica | | | $SiO_2$ | 27 | 27 | 27 | | | |
| Turbidity | | | | 27 | 0 | 0 | | | |
| Total Dissolved Solids | | (TDS) | | | | | | | |
| pH | | | | 7.0 | | | | | |
| Iron, Total | | | Fe | 2.9 | 0.20 | | | | |
| Manganese | | | Mn | 0.45 | 0.02 | | | | |
| O.M. Index | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| CHEMICALS REQUIRED | PPM | POUNDS PER 1000 GALLONS |
|---|---|---|
| | | |

Carboxylic

# HYDROGEN CATION EXCHANGERS
(WEAKLY ACIDIC TYPE)

## PERFORMANCE:

### Total System

| | |
|---|---|
| Total influent cations, gpg as $CaCO_3$ - exchangeable ions | 21.8 |
| Design flow rate, gpm | 750 |
| Operating water pressure, psig | 40, min. |
| Number of units | Two |

### Per Unit

| | |
|---|---|
| Design flow rate, gpm | 750 |
| Peak flow rate, gpm | 750 |
| Backwash rate, gpm | 313 |
| Cation exchange material, type | IRC-84 |
| quantity, cu ft | 304 |
| capacity, Kgr per cu ft | 41.0 |
| Gallons treated per regeneration (includes ~~anion~~ quality rinse regeneration water) | 571,740 |
| Gallons treated to service (net) | 500,400 |
| Regenerant, type | Waste acid |
| quantity per regeneration | See comments on next page. |

## SPECIFICATIONS:

### Tanks

| | |
|---|---|
| Tank diameter | 120" |
| Straight side of tank | 96" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |

### Internals

| | |
|---|---|
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |

### Piping

| | |
|---|---|
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

# HYDROGEN CATION EXCHANGERS (cont'd.)
## (WEAKLY ACIDIC TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Reset meter |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type | 4" Crest full flow |
| Meter register | Auto. reset head |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| **Regeneration Equipment** | |
| Type of regenerant introduction | Pump |
| Regenerant introduction strength | Waste acid |

**ADDITIONAL SPECIFICATIONS:**

Regenerant acid waste from regular cation and anion units will be collected for 12 hours. This acid resistant collecting reservoir must have a minimum useable volume of 600,000 gallons. This dilute acid is pumped through the carboxylic exchanger at a high velocity (1,000 gpm) and regenerates the resin, achieving highly efficient useage of total acid applied to the entire system.

This dilute acid, collected from both regular cation and anion regenerations, may contain precipitated chemicals and therefore require filtration prior to use.

Two (2) 500 gpm, 65' head, 15 HP, 3,600 rpm, Ampco metal pumps are included for transferring the dilute acid. Starters are included.

Double unit interlock included.

8" rate of flow meter included.

# PRESSURE FILTERS

For Waste Acid If Required

## PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Design flow rate, gpm | 1,000 |
| Operating water pressure, psig | 30, min. |
| Number of units | Three |
| Type of units | Vertical sand |
| **Per Unit** | |
| Design flow rate, gpm | 333 |
| Peak flow rate, gpm | 333 |
| Design rate, gpm/$ft^2$ of filter area | 4.25 |
| Backwash rate, gpm | 1,000 |
| Filter media, type | Quartz sand |
| quantity, cu ft | 156 |

## SPECIFICATIONS:

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 120" |
| Straight side of tank | 36" |
| Design working pressure of tank | 100 psi Non Code |
| Number of compartments (Multicel only) | --- |
| External surface | Prime painted |
| Internal surface | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x 16"manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 8" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. Saran lined valves |
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Time clock |
| Backwash control | Adj. rate set |

**Auxiliaries**

| | |
|---|---|
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |

**ADDITIONAL SPECIFICATIONS:**

This unit will backwash with raw well water or collected waste water.

# HYDROGEN CATION EXCHANGERS
## (STRONGLY ACIDIC TYPE)

### PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Total influent cations, gpg as $CaCO_3$ - exchangeable ions | 39.2 |
| Design flow rate, gpm | 750 |
| Operating water pressure, psig | 40, min. |
| Number of units | Four |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 200 |
| Cation exchange material, type | Rezex 5 or equal |
| quantity, cu ft | 168 |
| capacity, Kgr per cu ft | 8.35 |
| Gallons treated per regeneration (includes anion rinse ~~regeneration~~ water) | 35,650 |
| Gallons treated to service (net) | 31,280 |
| Regenerant, type | $H_2SO_4$ - 66° Be |
| quantity per regeneration | 336 lbs. |

### SPECIFICATIONS:

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 96" |
| Straight side of tank | 72" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12" x 16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Pure silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

**Control System**

| | |
|---|---|
| Control | Automatic |
| Initiation of regeneration | Signal from anion unit |
| Backwash control | Adj. rate set |

**Auxiliaries**

| | |
|---|---|
| Meter, size and type | None |
| Meter register | --- |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |

**Regeneration Equipment**

| | |
|---|---|
| Type of regenerant introduction | Pump |
| Regenerant introduction strength | 2% |

**ADDITIONAL SPECIFICATIONS:**

Four (4) Carpenter 20 stainless steel centrifugal acid pumps are included to transfer 66$^{O}$ Be' $H_2SO_4$ and inject it into the valve nests where proper dilution occurs automatically.

We recommend but have not included:

One (1) 15,000 gallon horizontal acid storage tank 8' x 40' to receive and store 66$^{O}$ Be' $H_2SO_4$. This tank is designed to contain 7 days acid supply when refilled with 10,000 gallon deliveries of acid. Weekly useage is estimated at 4,928 gallons. Tank is black steel, to be mounted on concrete saddles outside of and adjacent to one end of equipment building.

Included on each unit are rate of flow meters in the regenerating inlet line from the anion unit. These meters are equipped with alarm contacts connected to the acid pump to prevent pumping of acid until dilution water flows.

Solubridges are included to monitor diluted regenerating acid.

These four cations are part of two (2) double trains. One cation unit in each double train will be paired with one unit in the other double train so that the flow will be 750 gpm nearly 100% of the time by alternating trains.

All regenerant waste, including backwash and rinse will be collected in the waste acid regenerant collecting reservoir and used to regenerate the carboxylic cation units.

## ANION EXCHANGERS
(STRONGLY BASIC TYPE)

### PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Total influent exchangeable anions, gpg as $CaCO_3$ | 39.8 |
| Design flow rate, gpm | 750 |
| Operating water pressure, psig | 40, min. |
| Number of units | Four |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 120 |
| Anion exchange material, type | Rezex 71 or equal |
| quantity, cu ft | 448 |
| capacity, Kgr per cu ft | 2.90 |
| Gallons treated per regeneration | 31,280 |
| Regenerant, type | Well water |
| quantity per regeneration | 32,255 |

### SPECIFICATIONS:

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 120" |
| Straight side of tank | 120" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## ANION EXCHANGERS (cont'd.)
(STRONG BASE TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Signal from Solubridge |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type | 4" Crest full flow |
| Meter register | Totalizing only |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| Conductivity instrument, type | Solubridge |
| manufacturer | Beckman |
| model number | R13 or R14 |
| **Regeneration Equipment** | |
| Type of regenerant introduction | None |
| Regenerant introduction strength | Use raw water only |

**ADDITIONAL SPECIFICATIONS:**

The discharge from the raw water regeneration step is acidic. This flow will be divided, part going to supply all water used for cation regeneration and the surplus diverted to the waste acid collecting reservoir. This procedure conserves the total water pumped.

Additional Model RE Solubridges are included, 2 for each unit, to: (1) determine end of raw water anion rinse regeneration step and (2) monitor the finished product independently and to shut it off in case of any malfunction.

One rate of flow meter for each 2 units is included in the raw water lines to the anion units for setting regeneration flow rates.

One turbine type effluent totalizing meter on each unit.

## FORCED DRAFT DEGASIFIERS OR AERATOR

### PERFORMANCE:

**Total System**

| | |
|---|---|
| Function | Remove $CO_2$ |
| Influent $CO_2$ content, ppm | 244 |
| Influent MO alkalinity, ppm as $CaCO_3$ | |
| Influent temperature, °F | Ambient |
| Design flow rate, gpm | 750 |
| Water pressure at inlet | 15 psig, min. |
| Number of units | One |

**Per Unit**

| | |
|---|---|
| Design flow rate, gpm | 750 |
| Peak flow rate, gpm | 750 |

### SPECIFICATIONS:

**Tower**

| | |
|---|---|
| Size of tower | 96" |
| Height of tower | 144" |
| Materials of construction | Douglas Fir |

**Internals**

| | |
|---|---|
| Material of packing | Redwood trays |
| Depth of packing | 9' |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Support, design and materials | Redwood |

**Auxiliaries**

| | |
|---|---|
| Blower, type | Centrifugal |
| capacity, cfm | 3,000 |
| static head, inches $H_2O$ | 2" |
| Motor, type | O.D.P. |
| horsepower | 2 |
| voltage, current, phases | 220V-60cy-3ph |
| Level control, type | Float switches |
| Inlet valve, type | Diaphragm type, auto. |
| material of construction | Saran lined cast iron |
| size | 6" |

**Storage**

This degasifier should be mounted above or piped to the receiving tank and clear-well. This should have a minimum capacity of three hours continuous run and when added to total plant storage should equal one day's maximum plant output.

Included is one (1) air compressor, complete with storage tank, controls and filters to provide air for operating the automatic valves and controls.

Each carboxylic cation unit will produce water for 12 hours, but each cation-anion train will deliver only 31,280 gallons per regeneration. Each train will have a total cycle time of three hours, including regeneration and service. Thus each train can recycle continually throughout the 24 hour day for 8 cycles total or 32 cycles for two double trains. This will produce 1,000,900 gallons of desalted water per day. Since 24 hours are required to produce the 1,000,000 gallons daily requirement, it is recommended that the receiving and storage tank have at least one full day's capacity.

This equipment is designed to produce 1,000,900 gpd of desalted water having the quality as shown in column B of the water analysis on page 50. This quality is far better than U.S. Public Health Service Drinking Water Standards for acceptable water supplies. These standards permit as much as 260 ppm sulfate (as $CaCO_3$ equivalents). Therefore, if brackish water is blended with treated water until the sulfate content is 260 ppm, the analysis will be as shown in column C and all other aspects of the chemical analysis also meet U.S. Public Health Standards. Blending 65.5% treated water with 34.5% raw water will accomplish this and increase the potable water supply from 1,000,900 gpd to 1,528,000 gpd.

# WATER ANALYSIS SHEET

Name Office of Saline Water

Address for Webster, South Dakota

500,000 gpd Three-Bed SUL-biSUL® Desalting Plant

Identification of Analyses Tabulated Below:
A - Brackish Water Analysis No. 124342
B - Pilot Plant Test Results No. 124735
C - Blended 65.5% Product Water with 34.5% Raw Brackish Water

| | CONSTITUENT | | Analysis in PPM as | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| CATIONS | Calcium | ($Ca^{++}$) | $CaCO_3$ | 660 | 12 | 236 | | | |
| | Magnesium | ($Mg^{++}$) | $CaCO_3$ | 220 | 6 | 80 | | | |
| | Sodium | ($Na^+$) | $CaCO_3$ | 202 | 20 | 85 | | | |
| | Hydrogen = FMA | ($H^+$) | $CaCO_3$ | | | | | | |
| | Potassium | | $CaCO_3$ | | 4 | | | | |
| TOTAL CATIONS | | | $CaCO_3$ | 1082 | 42 | 401 | | | |
| ANIONS | Bicarbonate | ($HCO_3^-$) | $CaCO_3$ | 372 | | 128 | | | |
| | Carbonate | ($CO_3^{--}$) | $CaCO_3$ | 0 | | 0 | | | |
| | Hydroxide | ($OH^-$) | $CaCO_3$ | 0 | | 0 | | | |
| | Sulfate | ($SO_4^{--}$) | $CaCO_3$ | 700 | 28 | 260 | | | |
| | Chloride | ($Cl^-$) | $CaCO_3$ | 10 | 14 | 13 | | | |
| | | | $CaCO_3$ | | | | | | |
| TOTAL ANIONS | | | $CaCO_3$ | 1082 | 42 | 401 | | | |
| Total Hardness | | | $CaCO_3$ | 880 | 18 | 316 | | | |
| Methyl Orange Alkalinity | | (MO) | $CaCO_3$ | 372 | | 128 | | | |
| Phenolphthalein Alkalinity | | (P) | $CaCO_3$ | 0 | | 0 | | | |
| Carbon Dioxide, Free | | | $CO_2$ | 80 | 5-10 | 5-10 | | | |
| Silica | | | $SiO_2$ | 27 | 27 | 27 | | | |
| Turbidity | | | | 27 | 0 | 0 | | | |
| Total Dissolved Solids | | (TDS) | | 1300 | | 500 | | | |
| pH | | | | 7.0 | | | | | |
| Iron, Total | | | Fe | 2.9 | 0.20 | | | | |
| Manganese | | | Mn | 0.45 | 0.02 | | | | |
| O.M. Index | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| CHEMICALS REQUIRED | PPM | POUNDS PER 1000 GALLONS |
|---|---|---|
| | | |

Carboxylic

## HYDROGEN CATION EXCHANGERS
(WEAKLY ACIDIC TYPE)

**PERFORMANCE:**

| | |
|---|---|
| **Total System** | |
| Total influent cations, gpg as $CaCO_3$ - exchangeable ions | 21.8 |
| Design flow rate, gpm | 375 |
| Operating water pressure, psig | 40, min. |
| Number of units | Two |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 200 |
| Cation exchange material, type | IRC-84 |
| quantity, cu ft | 152 |
| capacity, Kgr per cu ft | 41.0 |
| Gallons treated per regeneration (includes ~~anion~~ quality rinse ~~regeneration~~ water) | 285,800 |
| Gallons treated to service (net) | 250,200 |
| Regenerant, type | Waste acid |
| quantity per regeneration | See comments on page. |

**SPECIFICATIONS:**

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 96" |
| Straight side of tank | 84" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## HYDROGEN CATION EXCHANGERS (cont'd.)
### (WEAKLY ACIDIC TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Reset meter |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type | 4" Crest full flow |
| Meter register | Auto. reset head |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| **Regeneration Equipment** | |
| Type of regenerant introduction | Pump |
| Regenerant introduction strength | Waste acid |

**ADDITIONAL SPECIFICATIONS:**

Regenerant acid waste from regular cation and anion units will be collected for 12 hours. This acid resistant collecting reservoir must have a minimum useable volume of 300,000 gallons. This dilute acid is pumped through the carboxylic exchanger at a high velocity and regenerates the resin, achieving highly efficient useage of total acid applied to the entire system.

This dilute acid, collected from both regular cation and anion regenerations may contain precipitated chemicals and therefore require filtration prior to use.

A 530 gpm, 65' head, 15 HP, 3,600 rpm, Ampco metal pump is included for transferring the dilute acid. Starter is included.

Double unit interlock included.

6" rate of flow meter included.

## PRESSURE FILTERS
For Waste Acid If Required

### PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Design flow rate, gpm | 530 |
| Operating water pressure, psig | 30, min. |
| Number of units | Three |
| Type of units | Vertical sand |
| **Per Unit** | |
| Design flow rate, gpm | 176 |
| Peak flow rate, gpm | 176 |
| Design rate, gpm/$ft^2$ of filter area | 4 |
| Backwash rate, gpm | 530 |
| Filter media, type | Quartz sand |
| quantity, cu ft | 88 |

### SPECIFICATIONS:

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 90" |
| Straight side of tank | 36" |
| Design working pressure of tank | 100 psi Non Code |
| Number of compartments (Multicel only) | --- |
| External surface | Prime painted |
| Internal surface | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. Saran lined valves |
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Time clock |
| Backwash control | Adj. rate set |

**Auxiliaries**

| | |
|---|---|
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |

**ADDITIONAL SPECIFICATIONS:**

This unit will backwash with raw well water or collected waste water.

# HYDROGEN CATION EXCHANGERS

## (STRONGLY ACIDIC TYPE)

## PERFORMANCE:

### Total System

| | |
|---|---|
| Total influent cations, gpg as $CaCO_3$ - exchangeable ions | 39.2 |
| Design flow rate, gpm | 375 |
| Operating water pressure, psig | 40, min. |
| Number of units | Two |

### Per Unit

| | |
|---|---|
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 200 |
| Cation exchange material, type | Rezex 5 or equal |
| quantity, cu ft | 168 |
| capacity, Kgr per cu ft | 8.35 |
| Gallons treated per regeneration (includes anion rinse ~~[illegible]~~ water) | 35,650 |
| Gallons treated to service (net) | 31,280 |
| Regenerant, type | $H_2SO_4$ - 66° Be' |
| quantity per regeneration | 336 lbs. |

## SPECIFICATIONS:

### Tanks

| | |
|---|---|
| Tank diameter | 96" |
| Straight side of tank | 72" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12" x 16" manhole |

### Internals

| | |
|---|---|
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Pure silica gravel |

### Piping

| | |
|---|---|
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## HYDROGEN CATION EXCHANGERS (cont'd.)
### (STRONGLY ACIDIC TYPE)

**Control System**

| | |
|---|---|
| Control | Automatic |
| Initiation of regeneration | Signal from anion unit |
| Backwash control | Adj. rate set |

**Auxiliaries**

| | |
|---|---|
| Meter, size and type | None |
| Meter register | --- |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |

**Regeneration Equipment**

| | |
|---|---|
| Type of regenerant introduction | Pump |
| Regenerant introduction strength | 2% |

**ADDITIONAL SPECIFICATIONS:**

Two (2) Carpenter 20 stainless steel centrifugal acid pumps are included to transfer 66$^{o}$ Be' $H_2SO_4$ and inject it into the valve nests where proper dilution occurs automatically.

We recommend but have not included:

One (1) 12,500 gallon horizontal acid storage tank 8' x 36' to receive and store 66$^{o}$ Be' $H_2SO_4$. This tank is designed to contain 7 days acid supply when refilled with 10,000 gallon deliveries of acid. Weekly useage is estimated at 2,464 gallons. Tank is black steel, to be mounted on concrete saddles outside and adjacent to one end of equipment building.

Included on each unit are rate of flow meters in the regenerating inlet line from the anion unit. These meters are equipped with alarm contacts connected to the acid pump to prevent pumping of acid until dilution water flows.

Solubridges are included to monitor diluted regenerating acid.

All regenerant waste, including backwash and rinse, will be collected in the waste acid regenerant collecting reservoir and used to regenerate the carboxylic units.

## ANION EXCHANGERS
(STRONGLY BASIC TYPE)

**PERFORMANCE:**

| | |
|---|---|
| **Total System** | |
| Total influent exchangeable anions, gpg as $CaCO_3$ | 39.8 |
| Design flow rate, gpm | 375 |
| Operating water pressure, psig | 40, min. |
| Number of units | Two |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 120 |
| Anion exchange material, type | Rezex 71 or equal |
| quantity, cu ft | 448 |
| capacity, Kgr per cu ft | 2.90 |
| Gallons treated per regeneration | 31,280 |
| Regenerant, type | Well water |
| quantity per regeneration | 32,255 |

**SPECIFICATIONS:**

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 120" |
| Straight side of tank | 120" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## ANION EXCHANGERS (cont'd.)
## (STRONGLY BASIC TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Signal from Solubridge |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type | 4" Crest full flow |
| Meter register | Totalizing only |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| Conductivity instrument, type | Solubridge |
| manufacturer | Beckman |
| model number | R13 or R14 |
| **Regeneration Equipment** | |
| Type of regenerant introduction | None |
| Regenerant introduction strength | Use raw water only |

**ADDITIONAL SPECIFICATIONS:**

The discharge from the raw water regeneration step is acidic. This flow will be divided, part going to supply all water used for cation regeneration and the surplus diverted to the waste acid collecting reservoir. This procedure conserves the total water pumped.

Additional Model RE Solubridges are included, 2 for each unit, to: (1) determine end of raw water anion rinse regeneration step and (2) monitor the finished product independently and to shut it off in case of any malfunction.

One rate of flow meter is included in raw water line to anion units for setting regeneration flow rates.

One turbine type effluent totalizing meter on each unit.

# FORCED DRAFT DEGASIFIERS OR AERATOR

## PERFORMANCE:

**Total System**

| | |
|---|---|
| Function | Remove $CO_2$ |
| Influent $CO_2$ content, ppm | 244 |
| Influent MO alkalinity, ppm as $CaCO_3$ | |
| Influent temperature, °F | Ambient |
| Design flow rate, gpm | 375 |
| Water pressure at inlet | 15 psig,min. |
| Number of units | One |

**Per Unit**

| | |
|---|---|
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |

## SPECIFICATIONS:

**Tower**

| | |
|---|---|
| Size of tower | 72" |
| Height of tower | 144" |
| Materials of construction | Douglas Fir |

**Internals**

| | |
|---|---|
| Material of packing | Redwood trays |
| Depth of packing | 9' |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Support, design and materials | Redwood |

**Auxiliaries**

| | |
|---|---|
| Blower, type | Centrifugal |
| capacity, cfm | 1,500 |
| static head, inches $H_2O$ | 2" |
| Motor, type | O.D.P. |
| horsepower | 1.0 |
| voltage, current, phases | 220V-60cy-3ph |
| Level control, type | Float switches |
| Inlet valve, type | Diaphragm type, auto. |
| material of construction | Saran lined cast iron |
| size | 6" |

**Storage**

This degasifier should be mounted above or piped to the receiving tank and clear-well. This should have a minimum capacity of three hours continuous run and when added to total plant storage should equal one day's maximum plant output.

Included is one (1) air compressor, complete with storage tank, controls and filters to provide air for operating the automatic valves and controls.

Each carboxylic cation unit will produce water for 12 hours, but each cation-anion train will deliver only 31,280 gallons per regeneration. Each train will have a total cycle time of three hours, including regeneration and service. Thus each train can recycle continually throughout the 24 hour day for 8 cycles total or 16 cycles for two trains. This will produce 500,400 gallons of desalted water per day. Since 24 hours are required to produce the 500,000 gallons daily requirement, it is recommended that the receiving and storage tank have at least one full day's capacity.

This equipment is designed to produce 500,400 gpd of desalted water having the quality as shown in column B of the water analysis on page 61. This quality is far better than U.S. Public Health Service Drinking Water Standards for acceptable water supplies. These standards permit as much as 260 ppm sulfate (as $CaCO_3$ equivalents). Therefore, if brackish water is blended with treated water until the sulfate content is 260 ppm, the analysis will be as shown in column C and all other aspects of the chemical analysis will also meet U.S. Public Health Standards. Blending 65.5% treated water with 34.5% raw water will accomplish this and increase the potable water supply from 500,400 gpd to 763,900 gpd.

# WATER ANALYSIS SHEET

Name Office of Saline Water

Address for Webster, South Dakota

1,000,000 gpd Two-Bed SUL-biSUL® Desalting Plant

Identification of Analyses Tabulated Below:

A - Brackish Water No. 124342
B - Pilot Plant Test Results No. 124483
C - Blended 68.2% Product Water with 31.8% Raw Brackish Water

| | CONSTITUENT | | Analysis in PPM as | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| CATIONS | Calcium | $(Ca^{++})$ | $CaCO_3$ | 660 | 30 | 230 | | | |
| CATIONS | Magnesium | $(Mg^{++})$ | $CaCO_3$ | 220 | 18 | 82 | | | |
| CATIONS | Sodium | $(Na^{+})$ | $CaCO_3$ | 202 | 31 | 86 | | | |
| CATIONS | Hydrogen = FMA | $(H^{+})$ | $CaCO_3$ | | | | | | |
| CATIONS | | | $CaCO_3$ | | | | | | |
| TOTAL CATIONS | | | $CaCO_3$ | 1082 | 79 | 398 | | | |
| ANIONS | Bicarbonate | $(HCO_3^-)$ | $CaCO_3$ | 372 | 20 | 132 | | | |
| ANIONS | Carbonate | $(CO_3^{--})$ | $CaCO_3$ | 0 | 0 | 0 | | | |
| ANIONS | Hydroxide | $(OH^-)$ | $CaCO_3$ | 0 | 0 | 0 | | | |
| ANIONS | Sulfate | $(SO_4^{--})$ | $CaCO_3$ | 700 | 55 | 260 | | | |
| ANIONS | Chloride | $(Cl^-)$ | $CaCO_3$ | 10 | 4 | 6 | | | |
| ANIONS | | | $CaCO_3$ | | | | | | |
| TOTAL ANIONS | | | $CaCO_3$ | 1082 | 79 | 398 | | | |
| Total Hardness | | | $CaCO_3$ | 880 | 48 | 312 | | | |
| Methyl Orange Alkalinity | | (MO) | $CaCO_3$ | 372 | 20 | 132 | | | |
| Phenophthalein Alkalinity | | (P) | $CaCO_3$ | 0 | 0 | 0 | | | |
| Carbon Dioxide, Free | | | $CO_2$ | 80 | 5-10 | 5-10 | | | |
| Silica | | | $SiO_2$ | 27 | 27 | 27 | | | |
| Turbidity | | | | 27 | 0 | 0 | | | |
| Total Dissolved Solids | | (TDS) | | | | | | | |
| pH | | | | 7.0 | 6.9 | | | | |
| Iron, Total | | | Fe | 2.9 | 0.15 | | | | |
| Manganese | | | Mn | 0.45 | 0.03 | | | | |
| O.M. Index | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| CHEMICALS REQUIRED | PPM | POUNDS PER 1000 GALLONS |
|---|---|---|
| | | |

## HYDROGEN CATION EXCHANGERS
### (STRONGLY ACIDIC TYPE)

**PERFORMANCE:**

| | |
|---|---|
| **Total System** | |
| Total influent cations, gpg as $CaCO_3$ | 63.3 |
| Design flow rate, gpm | 750 |
| Operating water pressure, psig | 40, min |
| Number of units | Four |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 200 |
| Cation exchange material, type | Rezex 5 or equal |
| quantity, cu ft | 300 |
| capacity, Kgr per cu ft | 7.55 |
| Gallons treated per regeneration (includes ~~anion~~ quality rinse regeneration water) | 35,725 |
| Gallons treated to service (net) | 31,275 |
| Regenerant, type | $H_2SO_4$ - 66° Be' |
| quantity per regeneration | 600 lbs. |

**SPECIFICATIONS:**

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 96" |
| Straight side of tank | 120" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime Painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Pure silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## HYDROGEN CATION EXCHANGERS (cont'd.)
## (STRONGLY ACIDIC TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Signal from anion unit |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type | 3" Crest full flow |
| Meter register | Totalizing dial only |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| **Regeneration Equipment** | |
| Type of regenerant introduction | Pump |
| Regenerant introduction strength | 2% |

**ADDITIONAL SPECIFICATIONS:**

Four (4) Carpenter 20 stainless steel centrifugal acid pumps are included to transfer 66° Be' $H_2SO_4$ and inject it into the valve nests where proper dilution occurs automatically.

We recommend but have not included:

One (1) 19,000 gallon horizontal acid storage tank, 9' x 40' to receive and store 66° Be' $H_2SO_4$. This tank is designed to contain 7 days acid supply when refilled with 10,000 gallon deliveries of acid. Weekly useage is estimated at 8,735 gallons. Tank is black steel, to be mounted on concrete saddles outside of and adjacent to one end of equipment building.

Included on each unit are rate of flow meters in the regenerating inlet line from the anion unit. These meters are equipped with alarm contacts connected to the acid pump to prevent pumping of acid until dilution water flows.

Solubridges are included to monitor diluted regenerating acid.

These four cations are part of two (2) double trains. One cation unit in each double train will be paired with one unit in the other double train so that the flow will be 750 gpm nearly 100% of the time by alternating trains.

## ANION EXCHANGERS

(STRONGLY BASIC TYPE)

### PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Total influent exchangeable anions, gpg as $CaCO_3$ | 39.2 |
| Design flow rate, gpm | 375 |
| Operating water pressure, psig | 40, min. |
| Number of units | Four |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 120 |
| Anion exchange material, type | Rezex 71 or equal |
| quantity, cu ft | 441 |
| capacity, Kgr per cu ft | 2.78 |
| Gallons treated per regeneration | 31,275 |
| Regenerant, type | Well water |
| quantity per regeneration | 31,750 |

### SPECIFICATIONS:

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 120" |
| Straight side of tank | 120" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## ANION EXCHANGERS (cont'd.)
(STRONGLY BASIC TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Signal from Solubridge |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type on raw water regenerating inlet | 4" Crest full flow |
| Meter register | Totalizing only |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| Conductivity instrument, type | Solubridge |
| manufacturer | Beckman |
| model number | RI3 or RI4 |
| **Regeneration Equipment** | |
| Type of regenerant introduction | None |
| Regenerant introduction strength | Use Raw water only |

**ADDITIONAL SPECIFICATIONS:**

The discharge from the raw water regeneration step is acidic. This flow will be divided, part going to supply all water used for cation regeneration and the surplus sent to waste. This procedure conserves water.

Additional Model RE Solubridges are included, 2 for each unit, to: (1) determine end of raw water anion rinse regeneration step and (2) monitor the finished product independently and to shut it off in case of any malfunction.

One rate of flow meter for each double train is included in the raw water lines to the anion units for setting regeneration flow rates.

## FORCED DRAFT DEGASIFIERS OR AERATOR

### PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Function | Remove $CO_2$ |
| Influent $CO_2$ content, ppm | 244 |
| Influent MO alkalinity, ppm as $CaCO_3$ | 20 |
| Influent temperature, °F | Ambient |
| Design flow rate, gpm | 375 |
| Water pressure at inlet | 15 psig, min. |
| Number of units | One |
| **Per Unit** | |
| Design flow rate, gpm | 750 |
| Peak flow rate, gpm | 750 |

### SPECIFICATIONS:

| | |
|---|---|
| **Tower** | |
| Size of tower | 96" |
| Height of tower | 144" |
| Materials of construction | Douglas Fir |
| **Internals** | |
| Material of packing | Redwood trays |
| Depth of packing | 9' |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Support, design and materials | Redwood |
| **Auxiliaries** | |
| Blower, type | Centrifugal |
| capacity, cfm | 3,000 |
| static head, inches $H_2O$ | 2" |
| Motor, type | O.D.P. |
| horsepower | 2 |
| voltage, current, phases | 220V-60cy-3ph |
| Level control, type | Float switches |
| Inlet valve, type | Diaphragm type, auto. |
| material of construction | Saran lined cast iron |
| size | 6" |

**Storage**

This degasifier should be mounted above or piped to the receiving tank and clear-well. This should have a minimum capacity for three hours continuous run and when added to total plant storage should equal one day's maximum plant output.

Included is one (1) air compressor, complete with storage tank, controls and filter to provide air for operating the automatic controls and valves.

The equipment thus far described covers two double trains. Each train consists of one cation unit followed by one anion unit. Two of these cation-anion combinations make up one double train. By alternating the flow from two trains, 375 gpm can be maintained nearly all the time. By adding a second set of double trains the flow can be increased to 750 gpm. This is the system described herein.

Each single train can deliver 31,275 gallons per regeneration. Each train can be run through a complete regeneration and service cycle 8 times per day. Thus each train can produce 250,200 gallons per day. By using 4 trains (two double trains) 1,000,800 gallons of desalted water per day can be produced. Since 24 hours are required to produce this amount of water, it is recommended that the receiving and storage tank have at least one full day's capacity.

This equipment is designed to produce 1,000,800 gpd of desalted water having the quality as shown in column B of the water analysis on page 72. This quality is far better than U.S. Public Health Service Drinking Water Standards for acceptable water supplies. These standards permit as much as 260 ppm sulfate (as $CaCO_3$ equivalents). Therefore, if brackish water is blended with treated water until the sulfate content is 260 ppm, the analysis will be as shown in column C and all other aspects of the chemical analysis also meet U.S. Public Health Standards. Blending 68.2% treated water with 31.8% raw water will accomplish this and increase potable water supply from 1,000,900 gpd to 1,467,400 gpd.

# WATER ANALYSIS SHEET

Name: Office of Saline Water

Address: for Webster, South Dakota

500,000 gpd Two-Bed SUL-biSUL® Desalting Plant

Identification of Analyses Tabulated Below:

A - Brackish water No. 124342
B - Pilot Plant Test Results No. 124483
C - Blended 68.2% Product Water with 31.8% Raw Brackish Water

| | CONSTITUENT | | Analysis in PPM as | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| CATIONS | Calcium | ($Ca^{++}$) | $CaCO_3$ | 660 | 30 | 230 | | | |
| | Magnesium | ($Mg^{++}$) | $CaCO_3$ | 220 | 18 | 82 | | | |
| | Sodium | ($Na^{+}$) | $CaCO_3$ | 202 | 31 | 86 | | | |
| | Hydrogen = FMA | ($H^{+}$) | $CaCO_3$ | | | | | | |
| | | | $CaCO_3$ | | | | | | |
| TOTAL CATIONS | | | $CaCO_3$ | 1082 | 79 | 398 | | | |
| ANIONS | Bicarbonate | ($HCO_3^-$) | $CaCO_3$ | 372 | 20 | 132 | | | |
| | Carbonate | ($CO_3^{--}$) | $CaCO_3$ | 0 | 0 | 0 | | | |
| | Hydroxide | ($OH^-$) | $CaCO_3$ | 0 | 0 | 0 | | | |
| | Sulfate | ($SO_4^{--}$) | $CaCO_3$ | 700 | 55 | 260 | | | |
| | Chloride | ($Cl^-$) | $CaCO_3$ | 10 | 4 | 6 | | | |
| | | | $CaCO_3$ | | | | | | |
| TOTAL ANIONS | | | $CaCO_3$ | 1082 | 79 | 398 | | | |
| Total Hardness | | | $CaCO_3$ | 880 | 48 | 312 | | | |
| Methyl Orange Alkalinity | | (MO) | $CaCO_3$ | 372 | 20 | 132 | | | |
| Phenophthalein Alkalinity | | (P) | $CaCO_3$ | 0 | 0 | 0 | | | |
| Carbon Dioxide, Free | | | $CO_2$ | 80 | 5-10 | 5-10 | | | |
| Silica | | | $SiO_2$ | 27 | 27 | 27 | | | |
| Turbidity | | | | 27 | 0 | 0 | | | |
| Total Dissolved Solids | | (TDS) | | | | | | | |
| pH | | | | 7.0 | 6.9 | | | | |
| Iron, Total | | | Fe | 2.9 | 0.15 | | | | |
| Manganese | | | Mn | 0.45 | 0.03 | | | | |
| O.M. Index | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| CHEMICALS REQUIRED | PPM | POUNDS PER 1000 GALLONS |
|---|---|---|
| | | |

# HYDROGEN CATION EXCHANGERS
## (STRONGLY ACIDIC TYPE)

**PERFORMANCE:**

| | |
|---|---|
| **Total System** | |
| Total influent cations, gpg as $CaCO_3$ | 63.3 |
| Design flow rate, gpm | 375 |
| Operating water pressure, psig | 40, min. |
| Number of units | Two |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 200 |
| Cation exchange material, type | Rezex 5 or equal |
| quantity, cu ft | 300 |
| capacity, Kgr per cu ft | 7.55 |
| Gallons treated per regeneration (includes ~~anion~~ quality rinse ~~regeneration~~ water) | 35,725 |
| Gallons treated to service (net) | 31,275 |
| Regenerant, type | $H_2SO_4$ - 66° Be' |
| quantity per regeneration | 600 lbs. |

**SPECIFICATIONS:**

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 96" |
| Straight side of tank | 120" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime Painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Pure silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## HYDROGEN CATION EXCHANGERS (cont'd.)
### (STRONGLY ACIDIC TYPE)

**Control System**

| | |
|---|---|
| Control | Automatic |
| Initiation of regeneration | Signal from anion unit |
| Backwash control | Adj. rate set |

**Auxiliaries**

| | |
|---|---|
| Meter, size and type | 3" Crest full flow |
| Meter register | Totalizing dial only |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |

**Regeneration Equipment**

| | |
|---|---|
| Type of regenerant introduction | Pump |
| Regenerant introduction strength | 2% |

**ADDITIONAL SPECIFICATIONS:**

Two (2) Carpenter 20 stainless steel centrifugal acid pumps are included to transfer 66$^{o}$ Be' $H_2SO_4$ and inject it into the valve nest where proper dilution occurs automatically.

We recommend but have not included:
One (1) 15,000 gallon horizontal acid storage tank, 8' x 40' to receive and store 66$^{o}$ Be' $H_2SO_4$. This tank is designed to contain 7 days acid supply when refilled with 10,000 gallon deliveries of acid. Weekly useage is estimated at 4,370 gallons. Tank is black steel, to be mounted on concrete saddles outside of and adjacent to one end of equipment building.

Included on each unit are rate of flow meters in the regenerating inlet lime from the anion unit. These meters are equipped with alarm contacts connected to the acid pump to prevent pumping of acid until dilution water flows.

Solubridges are included to monitor diluted regenerating acid.

## ANION EXCHANGERS
(STRONGLY BASIC TYPE)

**PERFORMANCE:**

| | |
|---|---|
| **Total System** | |
| Total influent exchangeable anions, gpg as $CaCO_3$ | 39.2 |
| Design flow rate, gpm | 375 |
| Operating water pressure, psig | 40, min. |
| Number of units | Two |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |
| Backwash rate, gpm | 120 |
| Anion exchange material, type | Rezex 71 or equal |
| quantity, cu ft | 441 |
| capacity, Kgr per cu ft | 2.78 |
| Gallons treated per regeneration | 31,275 |
| Regenerant, type | Well water |
| quantity per regeneration | 31,750 |

**SPECIFICATIONS:**

| | |
|---|---|
| **Tanks** | |
| Tank diameter | 120" |
| Straight side of tank | 120" |
| Design working pressure of tank | 100 psi Non Code |
| External surface | Prime painted |
| Tank lining, material and thickness | 90 mil Plastisol |
| Tank supports | Adj. jacks |
| Access opening(s) | 12"x16" manhole |
| **Internals** | |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Underdrain system, design and materials | PVC Header-Lateral |
| Supporting bed | Silica gravel |
| **Piping** | |
| Main piping size | 6" |
| Main piping material | Saran lined steel |
| Main valving arrangement | Nest of auto. valves |
| Main valving material | Saran lined cast iron |

## ANION EXCHANGERS (cont'd.)
(STRONGLY BASIC TYPE)

| | |
|---|---|
| **Control System** | |
| Control | Automatic |
| Initiation of regeneration | Signal from Solubridge |
| Backwash control | Adj. rate set |
| **Auxiliaries** | |
| Meter, size and type | 4" Crest full flow |
| Meter register | Totalizing only |
| Interconnecting piping between multiple units | Included |
| Pressure gauges | Included |
| Sample cocks | Included |
| Test set | --- |
| Conductivity instrument, type | Solubridge |
| manufacturer | Beckman |
| model number | R13 or R14 |
| **Regeneration Equipment** | |
| Type of regenerant introduction | None |
| Regenerant introduction strength | Use raw water only |

**ADDITIONAL SPECIFICATIONS:**

The discharge from the raw water regeneration step is acidic. This flow will be divided, part going to supply all water used for cation regeneration and the surplus sent to waste. This procedure conserves water.

Additional Model RE Solubridges are included, 2 for each unit, to: (1) determine end of raw water anion rinse regeneration step and (2) monitor the finished product independently and to shut it off in case of any malfunction.

One rate of flow meter is included in raw water lines to the anion units for setting regeneration flow rates.

## FORCED DRAFT DEGASIFIERS OR AERATOR

### PERFORMANCE:

| | |
|---|---|
| **Total System** | |
| Function | Remove $CO_2$ |
| Influent $CO_2$ content, ppm | 244 |
| Influent MO alkalinity, ppm as $CaCO_3$ | 20 |
| Influent temperature, °F | Ambient |
| Design flow rate, gpm | 375 |
| Water pressure at inlet | 15 psig, min. |
| Number of units | One |
| **Per Unit** | |
| Design flow rate, gpm | 375 |
| Peak flow rate, gpm | 375 |

### SPECIFICATIONS:

| | |
|---|---|
| **Tower** | |
| Size of tower | 72" |
| Height of tower | 144" |
| Materials of construction | Douglas Fir |
| **Internals** | |
| Material of packing | Redwood trays |
| Depth of packing | 9' |
| Inlet distributor, design and materials | PVC Header-Lateral |
| Support, design and materials | Redwood |
| **Auxiliaries** | |
| Blower, type | Centrifugal |
| capacity, cfm | 1,500 |
| static head, inches $H_2O$ | 2" |
| Motor, type | O.D.P. |
| horsepower | 1.0 |
| voltage, current, phases | 220V-60cy-3ph |
| Level control, type | Float switches |
| Inlet valve, type | Diaphragm type, auto. |
| material of construction | Saran lined cast iron |
| size | 6" |

**Storage**

This degasifier should be mounted above or piped to the receiving tank and clear-well. This should have a minimum capacity for three hours continuous run and when added to total plant storage should equal one day's maximum plant output.

Included is one (1) air compressor, complete with storage tank, controls and filter to provide air for operating the automatic valves and controls.

Each train will deliver 31,275 gallons per regeneration. Each total cycle including regeneration and service run will consume 3 hours. Thus each train can recycle continually throughout the 24 hour day for 8 cycles total or 16 cycles for two trains. This will produce 500,400 gallons of desalted water per day. Since 24 hours are required to produce the 500,000 gallons daily requirement, it is recommended that the receiving and storage tank have at least one full day's capacity.

This equipment is designed to produce 500,400 gpd of desalted water having the quality as shown in column B of the water analysis on page 79. This quality is far better than U.S. Public Health Service Drinking Water Standards for acceptable water supplies. These standards permit as much as 260 ppm sulfate (as $CaCO_3$ equivalents). Therefore, if brackish water is blended with treated water until the sulfate content is 260 ppm, the analysis will be as shown in column C and all other aspects of the chemical analysis also meet U.S. Public Health Standards. Blending 68.2% treated water with 31.8% raw water will accomplish this and increase potable water supply from 500,400 gpd to 733,700 gpd.

## WATER ANALYSIS SHEET

Name Office Of Saline Water

Address for Webster, South Dakota

Three Bed SUL-biSUL® Desalting Plant

Identification of Analyses Tabulated Below:

A - Hypothetical Raw Water Analysis

B - Estimated Product Water Quality

C - Blended 76.3% Product Water with 23.7% Raw Brackish Water

| | CONSTITUENT | Analysis in PPM as | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|
| CATIONS | Calcium ($Ca^{++}$) | $CaCO_3$ | 915 | 17 | 230 | | | |
| | Magnesium ($Mg^{++}$) | $CaCO_3$ | 305 | 8 | 78 | | | |
| | Sodium ($Na^{+}$) | $CaCO_3$ | 280 | 23 | 92 | | | |
| | Hydrogen = FMA ($H^{+}$) | $CaCO_3$ | | | | | | |
| | | $CaCO_3$ | | | | | | |
| TOTAL CATIONS | | $CaCO_3$ | 1500 | 58 | 400 | | | |
| ANIONS | Bicarbonate ($HCO_3^-$) | $CaCO_3$ | 516 | | 122 | | | |
| | Carbonate ($CO_3^{--}$) | $CaCO_3$ | | | | | | |
| | Hydroxide ($OH^-$) | $CaCO_3$ | | | | | | |
| | Sulfate ($SO_4^{--}$) | $CaCO_3$ | 970 | 39 | 260 | | | |
| | Chloride ($Cl^-$) | $CaCO_3$ | 14 | 19 | 18 | | | |
| | | $CaCO_3$ | | | | | | |
| TOTAL ANIONS | | $CaCO_3$ | 1500 | 58 | 400 | | | |
| Total Hardness | | $CaCO_3$ | 1220 | 25 | 308 | | | |
| Methyl Orange Alkalinity (MO) | | $CaCO_3$ | 516 | | 122 | | | |
| Phenophthalein Alkalinity (P) | | $CaCO_3$ | 0 | 0 | 0 | | | |
| Carbon Dioxide, Free | | $CO_2$ | | 5-10 | 5-10 | | | |
| Silica | | $SiO_2$ | 27 | 27 | 27 | | | |
| Turbidity | | | 27 | 0 | 0 | | | |
| Total Dissolved Solids (TDS) | | | | | | | | |
| pH | | | 7.0 | 6.5-7.2 | | | | |
| Iron, Total | | Fe | 2.9 | 0.20 | | | | |
| Manganese | | Mn | 0.45 | 0.02 | | | | |
| O.M. Index | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| CHEMICALS REQUIRED | PPM | POUNDS PER 1000 GALLONS |
|---|---|---|
| | | |

## WATER ANALYSIS SHEET

Name Office Of Saline Water

Address for Webster, South Dakota

Three Bed SUL-biSUL® Desalting Plant

Identification of Analyses Tabulated Below:
A - Hypothetical Raw Water Analysis
B - Estimated Product Water Quality
C - Blended 83.25% Produce Water with 16.75% Raw Brackish Water

| | CONSTITUENT | | Analysis in PPM as | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| CATIONS | Calcium | $(Ca^{++})$ | $CaCO_3$ | 1220 | 22 | 223 | | | |
| | Magnesium | $(Mg^{++})$ | $CaCO_3$ | 407 | 11 | 77 | | | |
| | Sodium | $(Na^{+})$ | $CaCO_3$ | 373 | 45 | 100 | | | |
| | Hydrogen = FMA | $(H^{+})$ | $CaCO_3$ | | | | | | |
| | | | $CaCO_3$ | | | | | | |
| TOTAL CATIONS | | | $CaCO_3$ | 2000 | 78 | 400 | | | |
| ANIONS | Bicarbonate | $(HCO_3^{-})$ | $CaCO_3$ | 688 | | 115 | | | |
| | Carbonate | $(CO_3^{--})$ | $CaCO_3$ | | | | | | |
| | Hydroxide | $(OH^{-})$ | $CaCO_3$ | | | | | | |
| | Sulfate | $(SO_4^{--})$ | $CaCO_3$ | 1294 | 52 | 260 | | | |
| | Chloride | $(Cl^{-})$ | $CaCO_3$ | 18 | 26 | 25 | | | |
| | | | $CaCO_3$ | | | | | | |
| TOTAL ANIONS | | | $CaCO_3$ | 2000 | 78 | 400 | | | |
| Total Hardness | | | $CaCO_3$ | 1627 | 33 | 300 | | | |
| Methyl Orange Alkalinity | | (MO) | $CaCO_3$ | 688 | 0 | 115 | | | |
| Phenophthalein Alkalinity | | (P) | $CaCO_3$ | 0 | 0 | 0 | | | |
| Carbon Dioxide, Free | | | $CO_2$ | | 5-10 | 5-10 | | | |
| Silica | | | $SiO_2$ | 27 | 27 | 27 | | | |
| Turbidity | | | | 27 | 0 | 0 | | | |
| Total Dissolved Solids | | (TDS) | | | | | | | |
| pH | | | | 7.0 | 6.5-7.2 | | | | |
| Iron, Total | | | Fe | 2.9 | 0.20 | | | | |
| Manganese | | | Mn | 0.45 | 0.02 | | | | |
| O.M. Index | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| CHEMICALS REQUIRED | PPM | POUNDS PER 1000 GALLONS |
|---|---|---|
| | | |

TABLE XIV

PRODUCT WATER YIELDS

Three Bed SUL-biSUL® System

| Influent TDS as $CaCO_3$ | Unblended | | Blended | |
|---|---|---|---|---|
| | % Product | % Waste | % Product | % Waste |
| 1082 ppm | 45.2 | 54.8 | 55.7 | 44.3 |
| 1500 ppm | 40.7 | 59.3 | 47.2 | 52.8 |
| 2000 ppm | 41.0 | 59.0 | 45.5 | 54.5 |

Two Bed SUL-biSUL® System

| | | | | |
|---|---|---|---|---|
| 1082 ppm | 46.0 | 54.0 | 55.5 | 44.5 |

## VII INSTRUMENTATION REQUIREMENTS

A central control panel or cubicle will contain the necessary timers, interlocks, and controls for operating this plant. In addition, there will be pacing controller assemblies on each individual tank. These individual controllers will actually pace their respective units through the procedures for regeneration and service cycles, but will be initiated and controlled primarily from the central control panel.

In general, instrumentation will consist of water meters, rate of flow meters, and Solubridges. The instrumentation presented herein is considered minimal, and basically essential for the efficient operation of the plant. Additional instrumentation, such as recorders, can be added as desired but are not considered part of the minimum essential instruments.

The carboxylic cation exchangers each have an ordinary water meter on the inlet to measure total throughput volume for each tank. These meters will totalize the water pumped and be equipped with automatic reset heads to initiate regeneration when the preset number of gallons of water has been treated.

An orifice type rate of flow indicator is placed in the waste acid pump discharge line. This meter will measure the rate of flow at which the waste acid is pumped through the carboxylic cation exchangers for their regeneration. This same meter can also be used to adjust flow rates in the filters, if they are needed. These filters can be backwashed and rinsed with waste acid water since there is a surplus of it.

The cation exchanger will receive water only from the carboxylic unit or the anion unit. Since these have already been metered, no additional water meters are required on these cation exchangers. However, a rate of flow indicator is placed on the regenerant water inlet of each cation exchanger. This permits the accurate setting of flow rates during each phase of regeneration.

Solubridges (RA5 type) will be placed in the diluted acid lines downstream from the mixing tee. This meter will be calibrated in per cent of sulfuric acid. It will continuously monitor the strength of the acid used to regenerate the cation exchanger and be used for the initial setting of acid pumping rates. If desired, alarm contacts on this meter can be connected to indicate whether the acid strength exceeds maximum or minimum limits.

Each anion exchanger has a raw saline water inlet meter. They are used only to totalize the raw water pumped through the anion unit for regeneration.

A totalizing meter is also placed on the outlet of each anion unit to record and measure the total amount of treated water passing through that train.

One orifice type rate of flow meter is included for each of two trains (cation-anion units) so that regeneration and backwash flow rates can be easily adjusted.

An RE type Solubridge type controller is used to monitor the anion regeneration and determine when this regeneration has been completed.

An RI3 Solubridge is used to provide continuous monitoring of the rinse water and desalted water going to service. Alarm switches on this instrument are also used to indicate the end of the service cycle by detecting when the quality reaches a peak and begins to drop off. When the quality begins to drop off, a signal is sent to the control panel initiating regeneration of the cation-anion train.

A third Solubridge, a model RE controller type, is also used as a safety monitoring device. It is in no way connected with the other controls and functions independently. Thus, if through some malfunction of the plant saline or acid water should be present at the final discharge point, this Solubridge would detect the non-quality effluent, sound an alarm, and close the shut-off valve automatically.

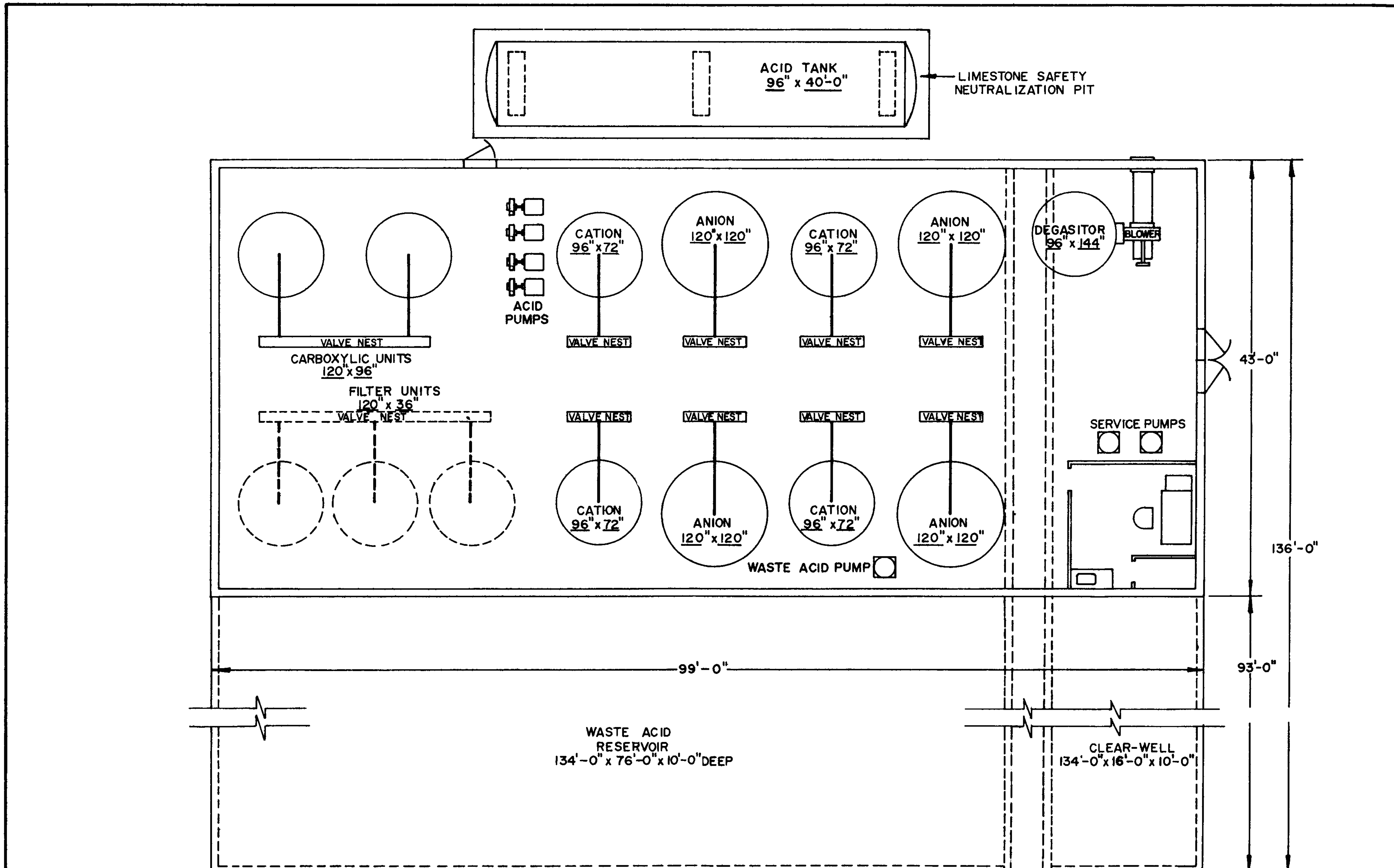
A final totalizing meter is placed in the plant effluent line to measure the total output of the plant and keep an accumulative total. It is quite possible that recording instruments would be desired for this meter, but none have been included since they are not absolutely essential for the plant's operation.

No other instrumentation is required with the exception of timers, which are an integral part of the control panel.

FIG. 18

PLANT PLAN - 1.0 M GPD THREE BED

SUL-bi SUL(T) SYSTEM FOR WEBSTER, SOUTH DAKOTA



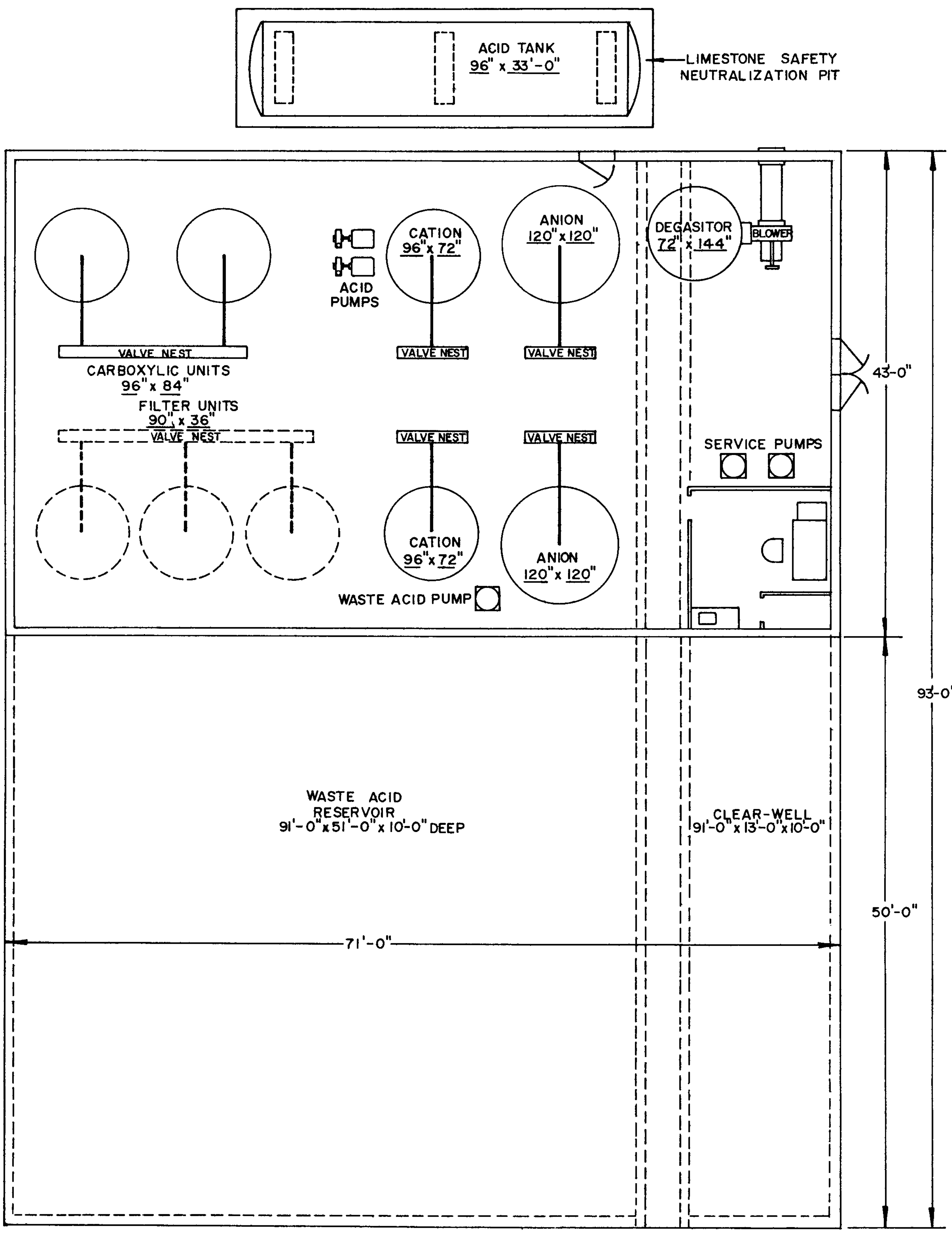



FIG. 19

PLANT PLAN - 0.5 M GPD THREE BED SUL-bi SUL® SYSTEM FOR WEBSTER, SOUTH DAKOTA

FIG. 20

PLANT PLAN- 1.0M GPD TWO BED

SUL-biSUL$^{Ⓣ}$ SYSTEM FOR WEBSTER, SOUTH DAKOTA

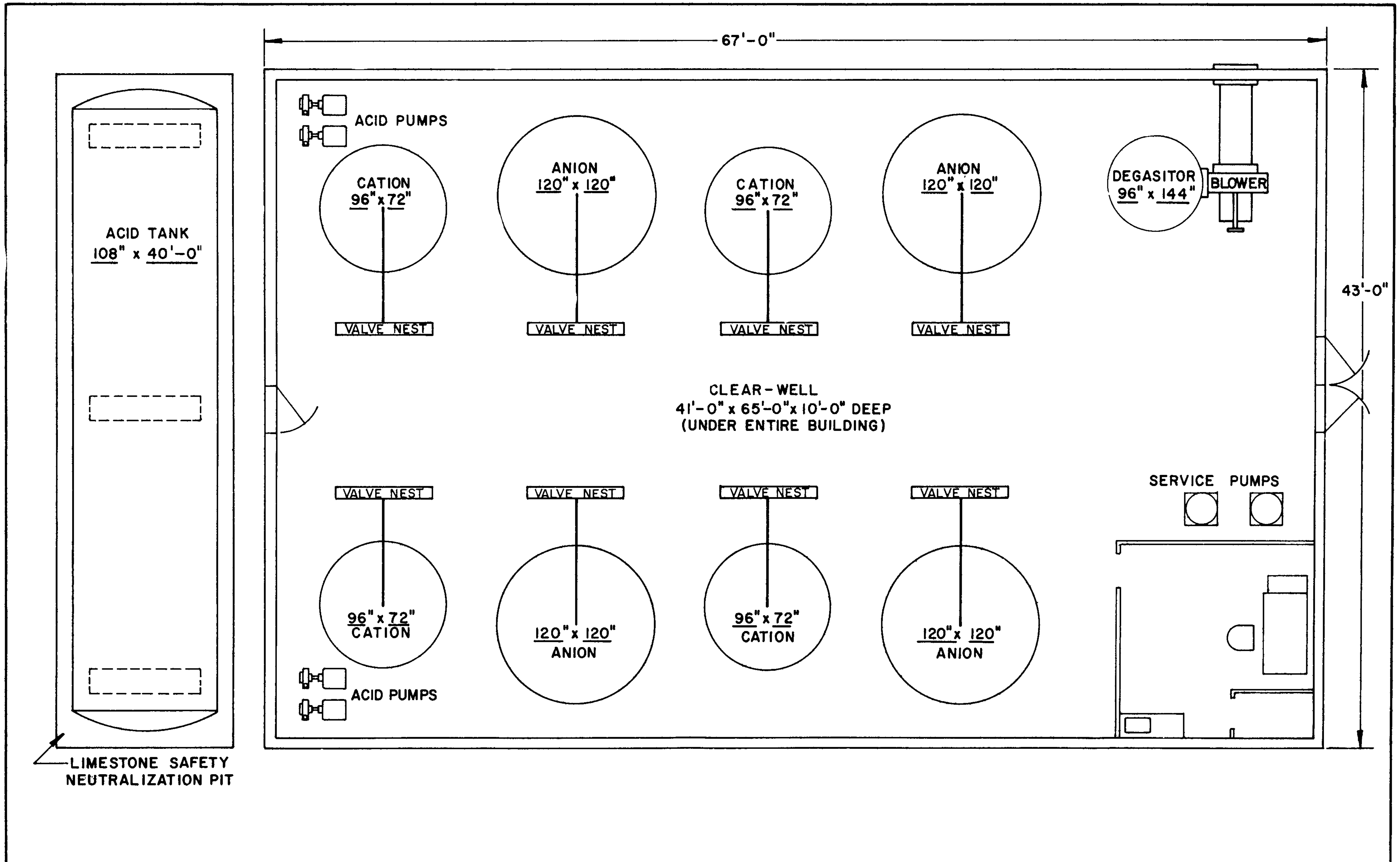


FIG. 21

PLANT PLAN - 0.5 M GPD TWO BED
SUL-bi SUL® SYSTEM FOR WEBSTER, SOUTH DAKOTA

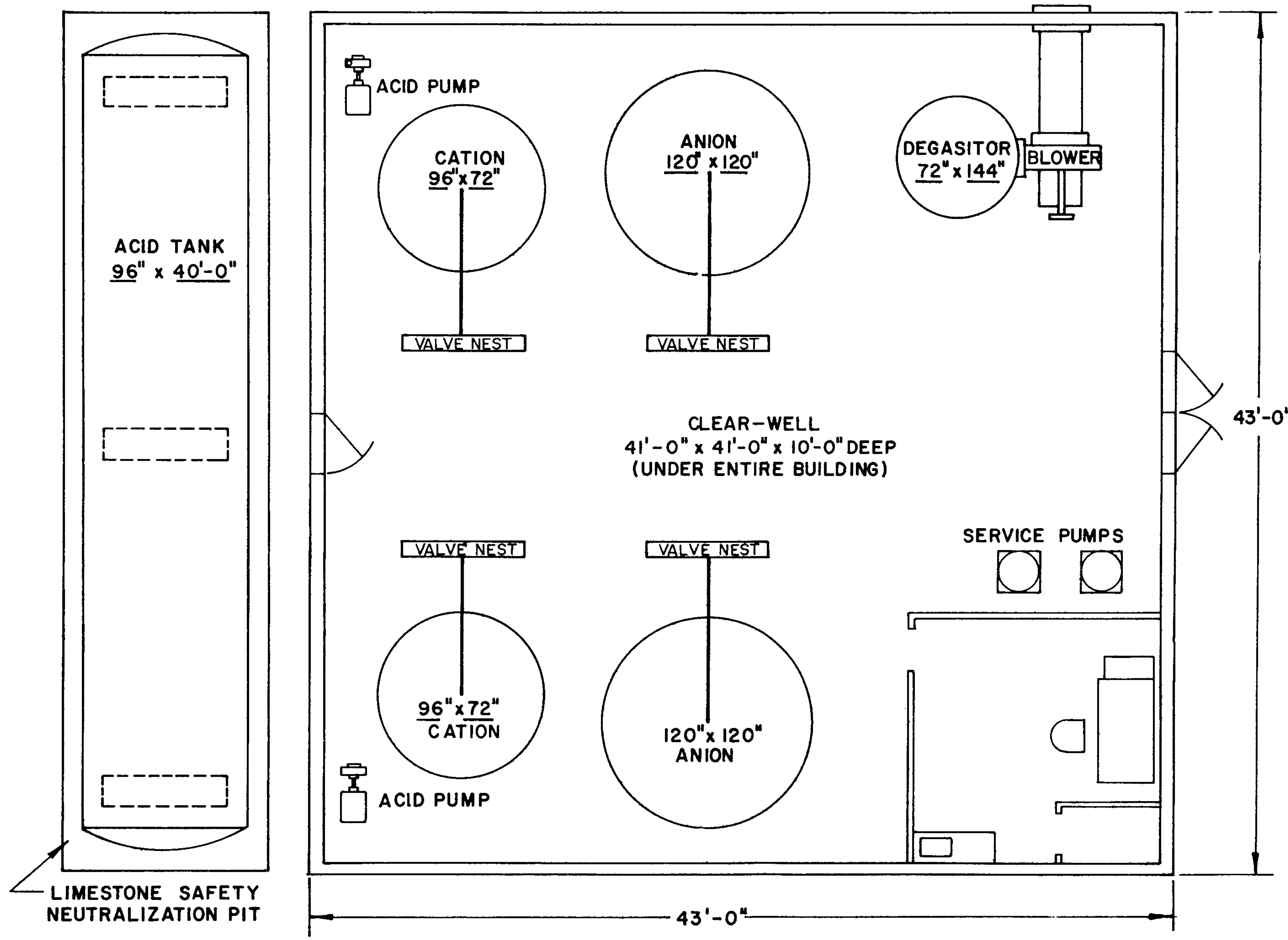


FIG. 22

FLOW DIAGRAM - 1.0 M GPD THREE BED

SUL - bi SUL(T) SYSTEM FOR WEBSTER, SOUTH DAKOTA

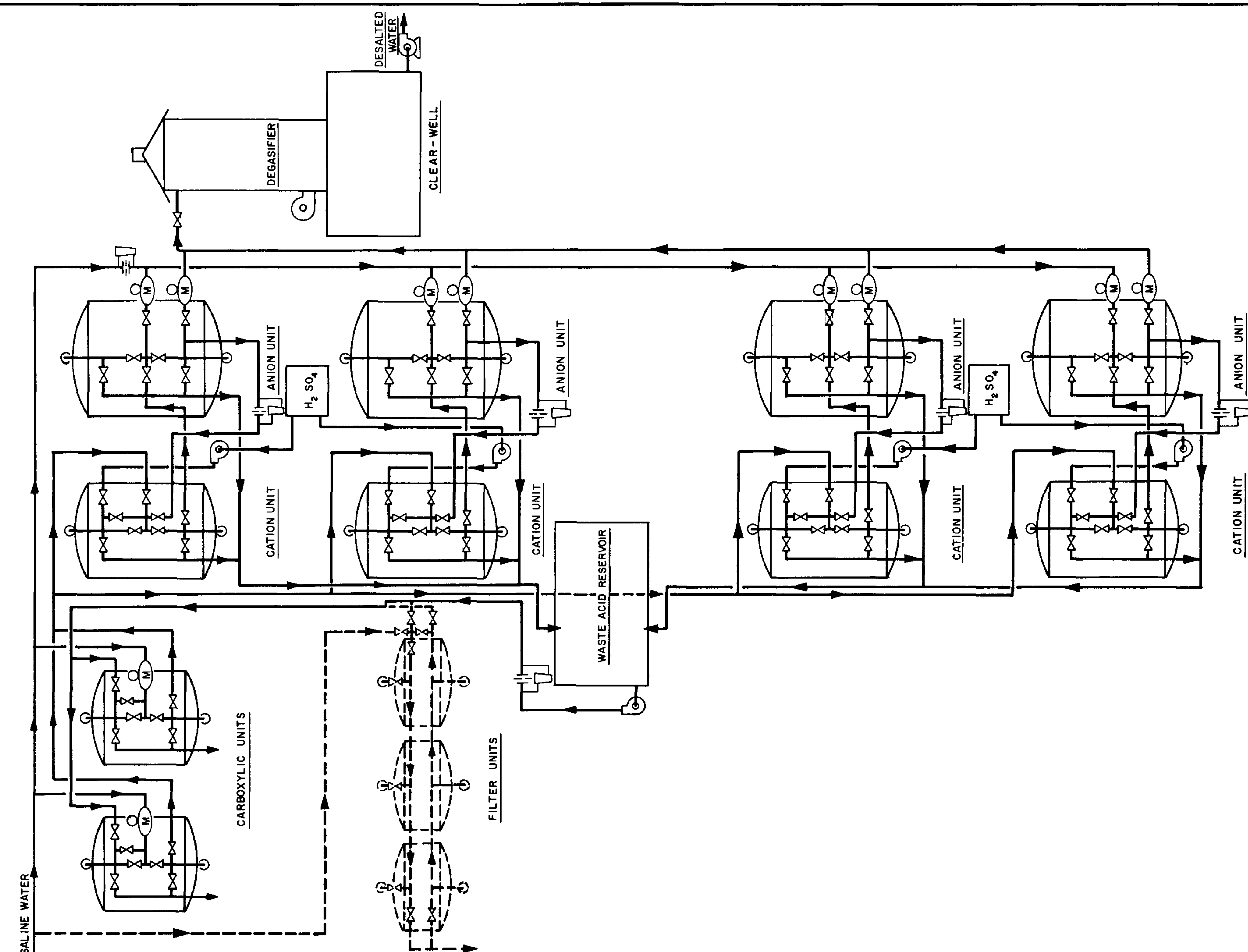


FIG. 23

FLOW DIAGRAM - 0.5 M GPD THREE BED SUL-bi SUL(T) SYSTEM FOR WEBSTER, SOUTH DAKOTA

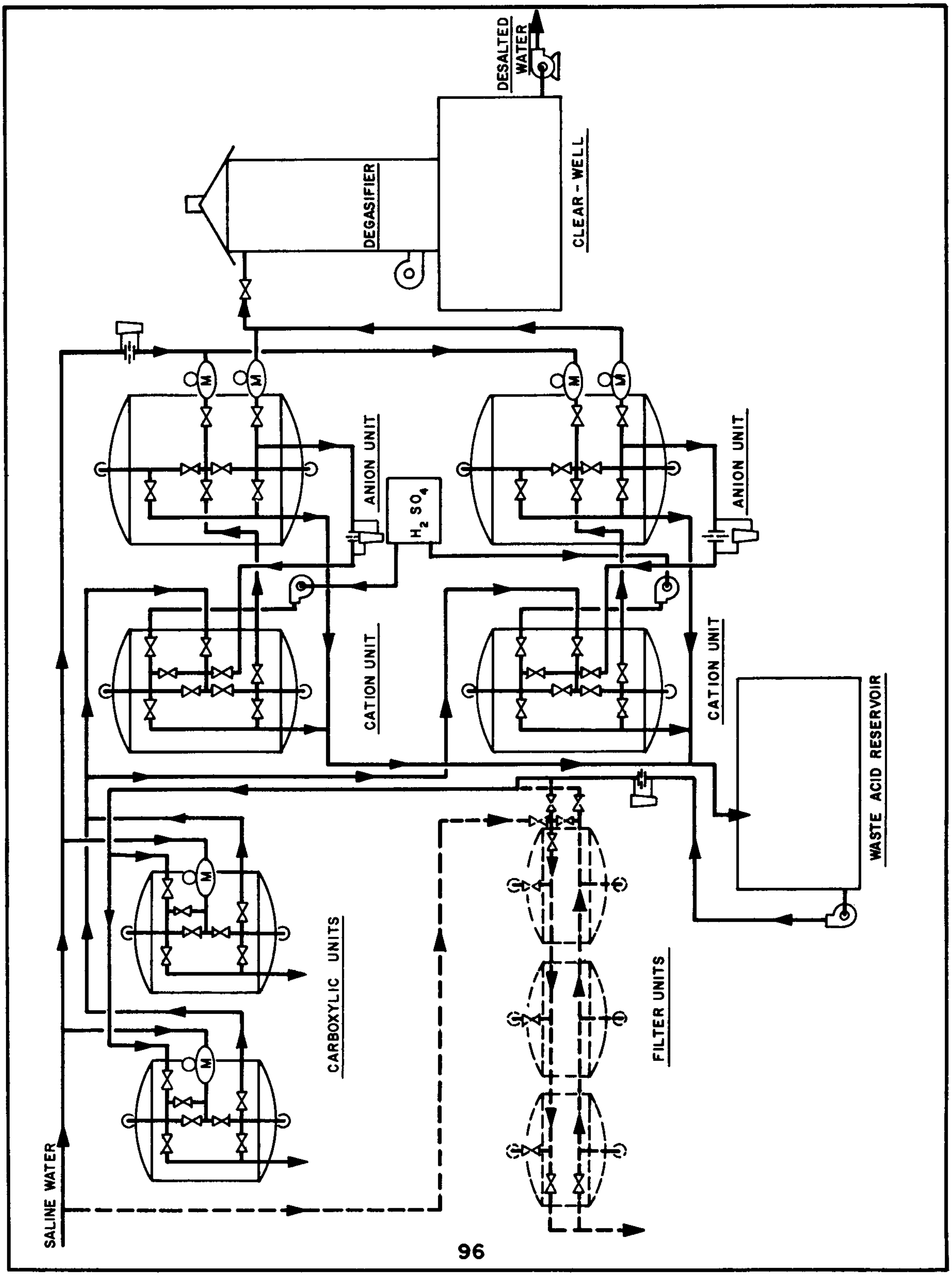


FIG. 24

FLOW DIAGRAM - 1.0 M GPD TWO BED
SUL-bi SUL(T) SYSTEM FOR WEBSTER, SOUTH DAKOTA

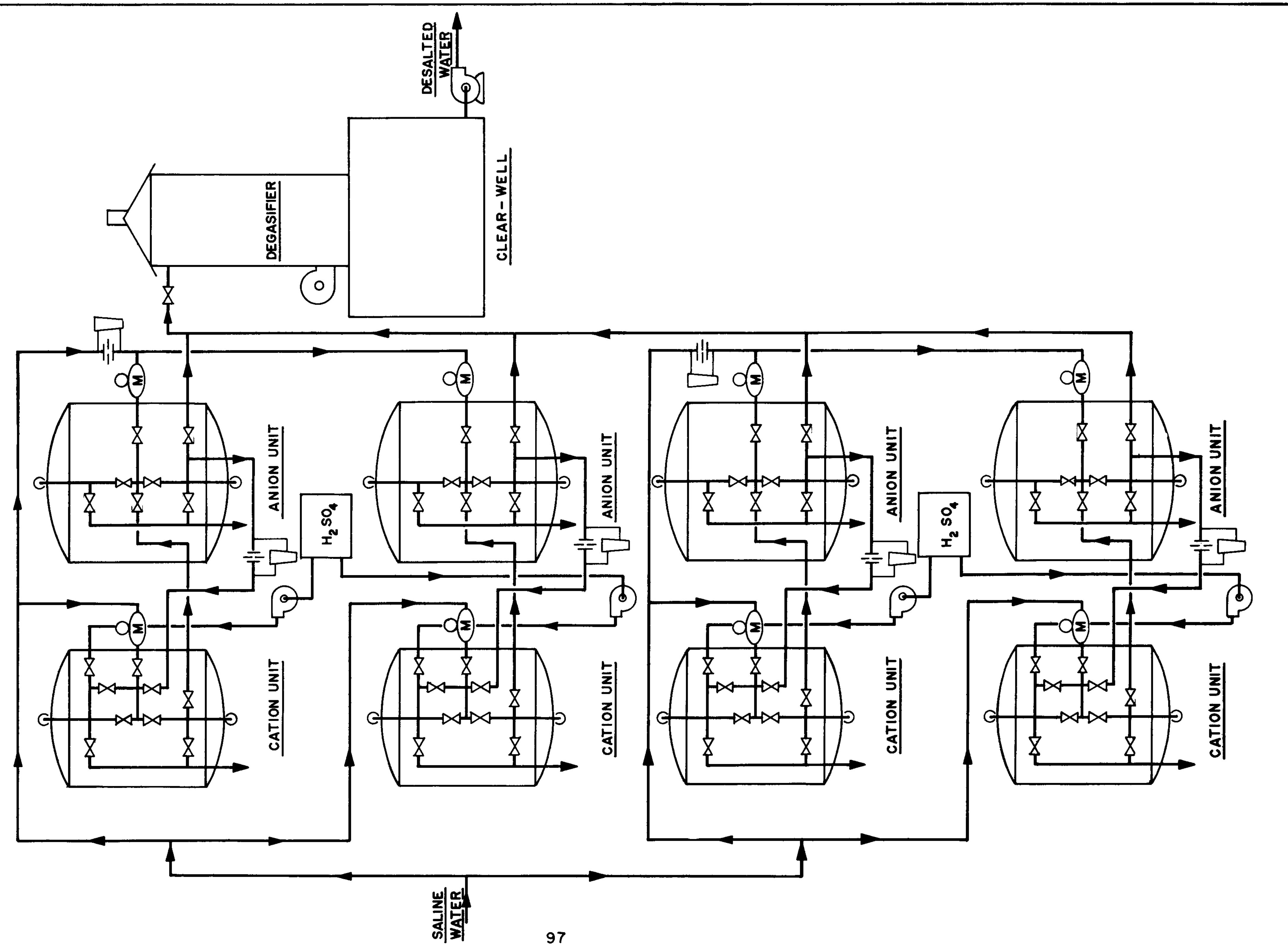
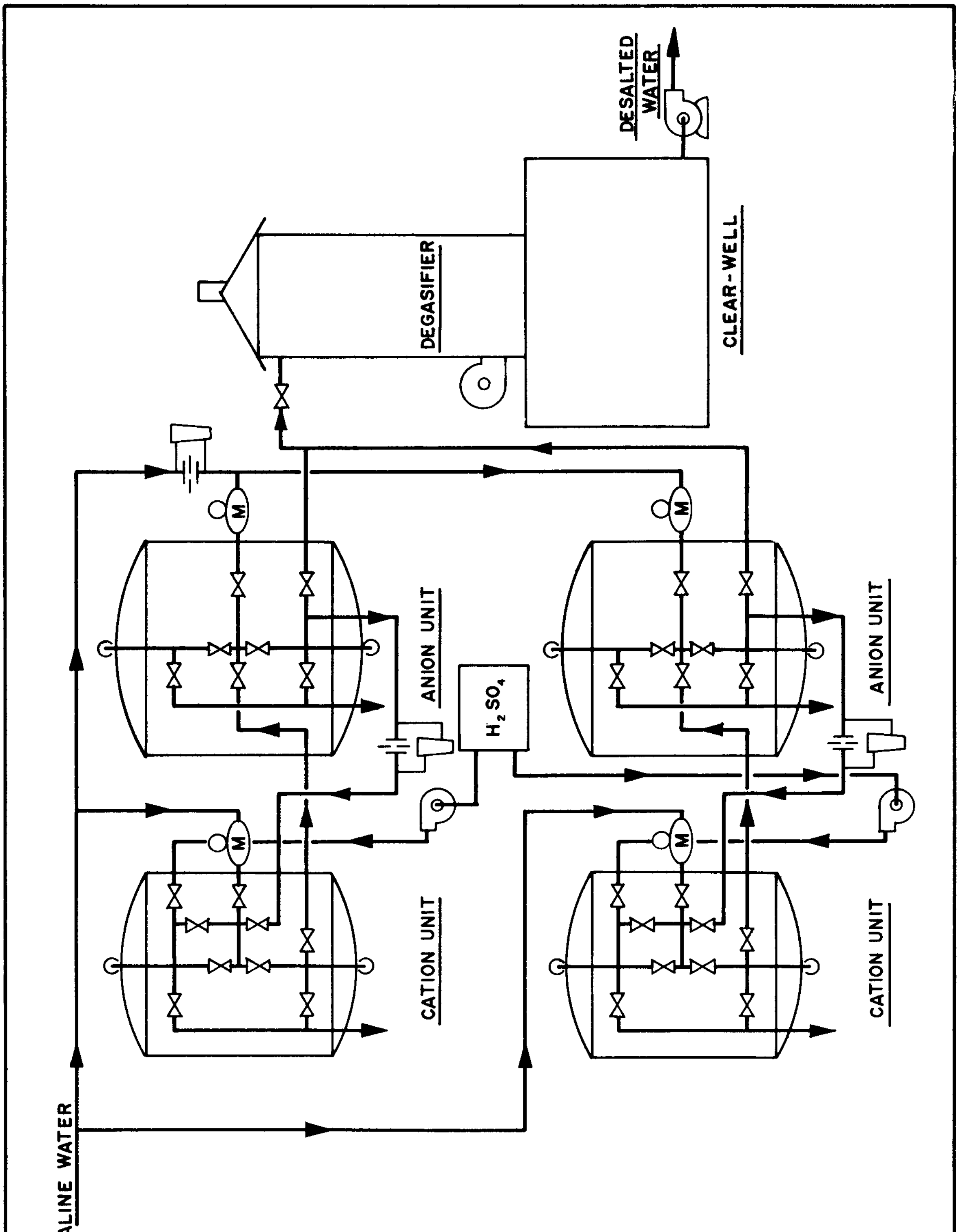


FIG. 25

FLOW DIAGRAM - 0.5 M GPD TWO BED SUL-bi SUL(T) SYSTEM FOR WEBSTER, SOUTH DAKOTA



OPERATING INSTRUCTIONS
3-BED SUL-biSUL® DESALTING SYSTEM
1.0 M GPD TREATED WATER
WEBSTER, SOUTH DAKOTA

## INTRODUCTION

The Elgin SUL-biSUL® system is a fully automatic system designed to produce potable water from brackish water. The SUL-biSUL® process employs partial deionization which removes mineral salts from water to a level that is very acceptable as a potable water supply.

The exchanger units are set up as double units for partial treatment followed by four trains for final treatment to provide 1,000,000 gallons of desalted water per day. It consists of two weakly acidic cation exchangers, four strongly acidic cation exchangers, four strong base anion exchangers, and a degasifier. (See flow diagram on page 95).

The saline water first passes through one of the weakly acidic carboxylic type cation exchangers. Only one of these two units will be in service at a time. Following this unit the water will flow through two trains while the other two are being regenerated. Each train consists of one strongly acidic cation unit followed by one anion unit. Following the cation-anion train, the water goes to the degasifier and then drops into the clear well from which it is pumped to the external storage reservoir.

In the weakly acidic carboxylic cation unit, calcium and magnesium are removed in an amount equivalent to the alkalinity content. The alkalinity in the water is simultaneously converted to carbon dioxide. This water is partially desalted but still contains an excessive amount of mineral salts. Therefore it next passes through the strongly acidic cation unit where most of the remaining calcium, magnesium and sodium are removed. When they are removed, hydrogen takes their place in the water forming mineral acids with the negative ions still present.

The water next enters the anion exchanger which absorbs and removes the sulfuric and hydrochloric acid formed in the cation unit. Carbon dioxide remains in the water in the form of carbonic acid. Thus the water is still corrosive at this point.

The water next passes through the degasifier where the carbon dioxide is blown off to the atmosphere, leaving a water essentially free of carbon dioxide and containing only 42 ppm of mineral salts.

Each of the ion exchange units has a specified capacity limit for removal of dissolved mineral salts. When this limit is reached, the material is said to be exhausted and requires regenerating so it can repeat its performance. When one train of strong cation-anion units is exhausted, the alternate train goes into service producing potable water while the exhausted train is regenerating. The anion unit can be regenerated with raw saline water. By passing a large amount of saline water through the anion unit at a high velocity, the resin is regenerated to its original form. The waste water from this procedure contains sulfuric acid and is collected in the waste acid reservoir. To conserve water, part of the waste water from the anion regeneration is reused as the supply water for regenerating the strongly acidic cation unit. The balance of the anion regenerating water is waste and collected in the waste acid reservoir.

Concentrated sulfuric acid is pumped into the strongly acidic cation unit and diluted with part of the waste water from the anion unit. This is constantly monitored by an instrument to measure the acid strength. When the proper amount of acid has been pumped into the strong cation unit, it is rinsed free of the strong acid using the same waste water from the anion unit. All of the waste regenerant from the cation unit is also collected in the waste acid reservoir.

The simultaneous regeneration of one anion and one cation unit requires approximately 90 minutes. The service run of the other train also requires approximately 90 minutes. Thus when regeneration is completed, the train is ready to go back on stream. By alternating constantly between two double trains 24 hours a day, 1,000,000 gallons of potable water can be produced.

After these two double trains have alternately been in service for 12 hours or a total of 16 cycles, approximately 600,000 gallons of water will have collected in the waste acid reservoir. During this same 12 hours, the one weakly acidic carboxylic cation exchanger will have become exhausted and require regeneration. The second unit is placed on stream. The waste acid in the reservoir is pumped through the exhausted weakly acidic cation exchanger unit to regenerate it. Ten hours are required to pump this waste acid. The weakly acidic cation unit is then rinsed with raw saline water and placed in a stand-by condition until needed for service.

The final item of equipment is the degasifier wherein water and air flow counter currently. The water is broken up into a thin film and tiny droplets so the carbon dioxide can be "stripped" from it by the forced draft from the blower. The "degasified" water drops into the clear well where it remains until pumped to storage.

At this point the water quality is excellent, far better than APHA specifications. If desired it can be blended with saline water in the ratio of 34.5% saline water with 65.5% desalted water to produce a supply containing only 250 ppm sulfates and less than 500 ppm total solids. This is in strict compliance with APHA standards. If this blending is employed, the yield of potable water will increase from 1,000,800 gpd to 1,527,800 gpd.

## OPERATING INSTRUCTIONS

This system is fully automatic in operation. Once it is started, the operator should check all functions periodically and employ normal supervisory maintenance to keep the equipment in peak operating efficiency. Once the system is in operation, the automatic controls will pace each unit through its programed functions, time the various operations as required, and maintain supervision of the entire system. During start up, the following adjustments, settings, etc., should be made.

## CARBOXYLIC CATION EXCHANGER

### Automatic Reset Meter

The saline water will enter each weakly acidic carboxylic cation exchanger through an automatic reset water meter. This meter should be adjusted to recycle the exchanger after 571,000 gallons have passed through. The exhausted unit will then begin regeneration and the stand-by unit will go on stream. This procedure will be repeated each day, initiated by the automatic reset meter.

### Backwash Adjustment

The first step in regeneration is backwash. The limit stop on the backwash valve should be adjusted to produce a flow rate of 313 gpm. Initially, backwash time should be adjusted for 10 minutes. If at the end of this time the backwash water is not clear, the backwash time should be increased until the water does run clear.

### Regenerant Flow Rate

The controls will next open the acid regeneration valves and pump waste acid through the unit. The flow rate of waste acid should be regulated for 1000 gpm by adjusting the limit stop on the valve. It will require 9.9 hours to pump 595,600 gallons of waste acid through this unit.

### Rinse Flow Rate

Following the addition of this waste acid, the controls will step the unit to the rinse operation using raw saline water. The flow rate should be adjusted to 375 gpm by means of the limit stop on the control valve. Rinsing should continue until the acidity has dropped to 175 ppm as determined by test. It is estimated rinsing will require about 35 minutes. Following completion of rinse, the automatic controls will place this unit in a stand-by position until required to go on stream when unit number 2 becomes exhausted.

When unit number 2 becomes exhausted and requires regeneration, the procedure just described will be repeated for unit number 2.

## CATION-ANION TRAINS

The weakly acidic carboxylic cation units will supply only the cation-anion trains in service. Only two of these trains will be in service at a time. No water from these weakly acidic units will go to these trains for their regeneration except during final rinse to quality. All other regenerating water for the separate trains will be raw water.

### Regeneration Of Anion Unit

Trains number 1 and 3 will be in service while trains number 2 and 4 are being regenerated. Both cation and anion units of trains number 2 and 4 will be regenerated simultaneously. The anion units use no chemicals whatsoever for regeneration; only raw saline water. Contrary to most ion exchange regeneration procedures, actual regeneration of the anion unit is the first step instead of backwashing. The raw water enters the unit through the influent totalizing meter and flows downward through the resin bed at a flow rate of 450 gpm. This flow rate should be regulated by means of the limit stop on the inlet valve using the rate of flow meter to observe correct adjustment. Each anion unit regeneration requires 32,255 gallons of raw saline water in a period of 72 minutes.

The waste water from the anion unit will contain sulfuric acid as a by-product of the regenerating procedure. The regenerating water will flow from the unit through two outlets. Part of this water will be used by the strongly acidic cation exchanger to provide its water supply for regeneration. The balance of the flow will go to the waste acid reservoir through the waste outlet valve.

### Backwash Adjustment Of Anion Unit

When all the regenerating water has passed through the anion exchangers, the automatic controls will place the units into backwash position. The backwash valve limit stop should be adjusted to produce a flow rate of 120 gpm. Backwashing should normally require approximately 5 minutes but should continue longer if the backwash water is not clear.

### Backwash Adjustment Of Cation Unit

While the anion units are proceeding through their lengthy regenerating procedure, the automatic controls will simultaneously regenerate the strongly acidic cation exchangers. Waste water from the anion regeneration will be used for the entire regeneration of the cation unit. The first step is backwash. The limit stop on the backwash control valve should be adjusted for a flow rate of 200 gpm as observed on the rate of flow meter. This backwash operation should continue for approximately 5 minutes or longer if the backwash water is not clear.

## Regeneration Of Cation Unit

The controls will next place the units in regeneration. The flows of dilution water should be set at 168 gpm by means of limit stops on the control valves. The rate of flow meters on the inlets from the anion units will show when the proper setting has been obtained. The alarm switches on these rate of flow meters will prevent the concentrated acid pump from starting until this diluting flow rate has been obtained. This is a safety feature to prevent either concentrated or improperly diluted acid from entering the cation exchangers.

The concentrated acid and the diluting water will be mixed together in mixing tees in the valve nests. Down stream from these tees there will be Solubridge instruments calibrated in percent of sulfuric acid. The flow rate on the concentrated acid pumps should be adjusted by means of a rate set valve so that the Solubridge monitor reads exactly two percent sulfuric acid. Each regeneration of each cation exchanger requires 336 pounds of $66^{o}$ Be' sulfuric acid. This is equivalent to 22 gallons per regeneration and will require 11 minutes at a flow rate of 2 gpm. Dilution water flowing at the same time will be 1,876 gallons. Acid volume will be controlled by timers that will stop the acid pumps and let the diluting water continue to flow at the same flow rate. This will then become the rinse water. Rinse will continue for approximately 21 minutes and require 3,530 gallons. At the end of the rinse operation, acidity in the water should be about 730 ppm as $CaCO_3$.

All waste water from the cation units, that is backwash, acid injection, and rinse will go to the waste acid reservoir. Total regeneration time for each unit will be about 38 to 40 minutes. The regeneration of the anion units will not have been completed at this time. Consequently from this time on the total regeneration water flow from the anion units will go directly to the waste acid reservoir. In the meantime, the cation units will be on stand-by until the anion unit has completed its regeneration.

## Rinse To Quality

When anion backwash is complete, the controls will place both trains two and four in a final rinse to quality position. At this point, the trains will take water from the carboxylic unit which will pass through the cation exchanger first and then into and through the anion unit to the waste acid reservoir. The flow rate on the cation inlet valve should be adjusted to 375 gpm by means of the limit stop. This quality rinse operation will continue for approximately 12 minutes and consume 4,370 gallons for each train. Upon initial start up, this operation can be timed exactly by means of specific resistance measurements. The specific resistance will continually increase until a point where it begins to level off. This point should be selected by experience and is the point at which each train should be placed into service and the automatic control timers adjusted accordingly.

## Water Quality Controls

Trains number 1 and 3 will now have become exhausted and returned to regenerating status by the control panel. Trains number 2 and 4 will now provide water to service while trains number 1 and 3 are regenerated as described herein. The Solubridge monitors will have two alarm switches which should be set so that when the specific resistance rises to its topmost peak and then begins to drop, it will have passed both alarm points which will then signal the end of the service cycle and place trains number 2 and 4 into regeneration.

A totalizing water meter is placed in the service line from each train to aid in the keeping of detailed production records. In the treated water line from each train there is also another Solubridge which should be set at the minimum specific resistance value as determined by experience. Thus if there is some malfunction of the equipment, and desalted water is not obtained, this Solubridge will sound an alarm and shut the system down preventing saline water from going through the degasifier and clear well into the distribution system.

Each train is capable of producing 31,280 gallons of desalted water per regeneration. It will require approximately 90 minutes to produce this amount of water per train. Thus with two trains operating simultaneously, 62,560 gallons are produced in 90 minutes. During this time the opposite two trains will have gone through their entire regeneration and be ready to go back on stream in the service position. Thus each pair of trains will require 90 minutes for regeneration and 90 minutes for service or a total of 3 hours for one complete cycle. Therefore each train can recycle a maximum of 8 times per 24 hours. Since there are four trains there is a potential 32 cycles per day or a maximum production of 1,000,900 gallons of water each 24 hour period.

## Degasifier

Water from these trains will go to the degasifier so there will be a continuous flow in the degasifier of 750 gpm. The degasifier consists of a wood stave tower in which there are nine feet of wooden trays to break up the downward flow of water into a thin film and tiny droplets. The counter current of air through this tower scrubs the gases from the water, stripping it of the dissolved carbon dioxide formed in the cation exchangers. Carbon dioxide when dissolved in water is present in the form of carbonic acid and produces a corrosive water with a low, acidic type pH. Therefore the degasified water will have a pH above 7 and be non-corrosive.

## Water Quality

The desalted water at this point will have the following analysis:

| | | | |
|---|---|---|---|
| Calcium | 12 ppm | Bicarbonate | 0 ppm |
| Magnesium | 6 ppm | Sulfate | 28 ppm |
| Sodium | 20 ppm | Chloride | 14 ppm |
| Potassium | 4 ppm | Total | 42 ppm (as $CaCO_3$) |
| Total | 42 ppm (as $CaCO_3$) | | |

| | |
|---|---|
| Total Hardness (as $CaCO_3$) | 18 |
| Carbon Dioxide (as $CO_2$) | 5 to 10 |
| Silica (as $SiO_2$) | 27 |
| Turbidity | 0 |

The quality of this water is far better than the minimum APHA standard. Much greater yields of potable water can be obtained by blending this high quality water with raw saline water. Water blended in the ratio of 65.5% desalted water with 34.5% saline water will produce a potable supply acceptable to the minimum APHA standard. Such blending equipment has not been shown on any of the drawings. This equipment is of very nominal cost and will be included if desired. It would increase the yield of potable water from 1,000,900 gpd to 1,528,000 gpd. An analysis of the water produced by such a blend is as follows:

| | | | |
|---|---|---|---|
| Calcium | 236 ppm | Bicarbonate | 128 ppm |
| Magnesium | 80 ppm | Sulfate | 260 ppm |
| Sodium | 85 ppm | Chloride | 13 ppm |
| Total | 401 ppm (as $CaCO_3$) | Total | 401 ppm (as $CaCO_3$) |

| | |
|---|---|
| Total Hardness (as $CaCO_3$) | 316 |
| Carbon Dioxide (as $CO_2$) | 5 to 10 |
| Silica (as $SiO_2$) | 27 |
| Turbidity | 0 |

## DESIGN AND OPERATING DATA FOR
## 3-BED SUL-biSUL® DESALTING SYSTEM
## 1.0 M GPD TREATED WATER
## WEBSTER, SOUTH DAKOTA

### Weakly Acidic Carboxylic Cation Exchanger

| | |
|---|---|
| Number of Units | Two |
| Exchanger tank size | 120" x 96" |
| Cation resin, type | IRC-84 |
| Cation resin, cu. ft. each | 304 |
| Backwash rate, gpm | 313 |
| Backwash time, estimated minutes | 10 |
| Regenerant used, type | Waste Acid |
| Regenerant used, quantity | 595,600 gal. |
| Regenerant flow rate, gpm | 1,000 |
| Regenerant time | 9.9 hours |
| Rinse rate, gpm | 375 |
| Rinse time, estimated minutes | 35 |
| Cations removed, gpg | 21.8 |
| Capacity, gallons per regeneration | 571,700 |

### Strongly Acidic Cation Exchangers

| | |
|---|---|
| Number of Units | Four |
| Exchanger tank size | 96" x 72" |
| Cation resin, type | Rezex 5 or equal |
| Cation resin, cu. ft. each | 168 |
| Backwash rate, gpm | 200 |
| Backwash time, estimated minutes | 5 |
| Regenerant used, type | $H_2SO_4$ - 66° Be' |
| Regenerant used, lbs. | 336 |
| gallons | 22 |
| Conc. acid flow rate, gpm | 2 |
| Conc. acid dilution rate, gpm | 168 |
| Conc. acid pumping time, minutes | 11 |
| Rinse rate, gpm | 168 |
| Rinse time, estimated minutes | 21 |
| Cations removed, gpg | 39.2 |
| Capacity, total gallons per regeneration | 35,650 |

### Anion Exchanger

| | |
|---|---|
| Number of Units | Four |
| Exchanger tank size | 120" x 120" |
| Anion resin, type | Rezex 71 or equal |
| Anion resin, cu. ft. each | 448 |

| | |
|---|---|
| Backwash rate, gpm | 120 |
| Backwash time, estimated minutes | 5 |
| Regenerant type | Raw Saline Water |
| Regenerant used, gal. | 32,255 |
| Regenerant flow rate, gpm | 450 |
| Regenerant time, minutes | 72 |
| Rinse to quality rate, gpm | 375 |
| Rinse to quality time, estimated minutes | 12 |
| Anions removed, gpg | 39.8 |
| Capacity, gallons per regeneration | 31,280 |

OPERATING INSTRUCTIONS
3-BED SUL-biSUL® DESALTING SYSTEM
0.5 M GPD TREATED WATER
WEBSTER, SOUTH DAKOTA

## INTRODUCTION

The Elgin SUL-biSUL® system is a fully automatic system designed to produce potable water from brackish water. The SUL-biSUL® process employs partial deionization which removes mineral salts from water to a level that is very acceptable as a potable water supply.

The exchanger units are set up as double units for partial treatment followed by two trains for final treatment to provide 500,000 gallons of desalted water per day. It consists of two weakly acidic cation exchangers, two strongly acidic cation exchangers, two strong base anion exchangers, and a degasifier. (See flow diagram on page 96).

The saline water first passes through one of the weakly acidic carboxylic type cation exchangers. Only one of these two units will be in service at a time. Following this unit the water will flow through either one of two trains while the other is being regenerated. Each train consists of one strongly acidic cation unit followed by one anion unit. Following the cation-anion train, the water goes to the degasifier and then drops into the clear well from which it is pumped to the external storage reservoir.

In the weakly acidic carboxylic cation unit, calcium and magnesium are removed in an amount equivalent to the alkalinity content. The alkalinity in the water is simultaneously converted to carbon dioxide. This water is partially desalted but still contains an excessive amount of mineral salts. Therefore it next passes through the strongly acidic cation unit where most of the remaining calcium, magnesium and sodium are removed. When they are removed, hydrogen takes their place in the water forming mineral acids with the negative ions still present.

The water next enters the anion exchanger which absorbs and removes the sulfuric and hydrochloric acid formed in the cation unit. Carbon dioxide remains in the water in the form of carbonic acid. Thus the water is still corrosive at this point.

The water next passes through the degasifier where the carbon dioxide is blown off to the atmosphere, leaving a water essentially free of carbon dioxide and containing only 42 ppm of mineral salts.

Each of the ion exchange units has a specified capacity limit for removal of dissolved mineral salts. When this limit is reached, the material is said to be exhausted and requires regenerating so it can repeat its performance. When one train of strong cation-anion units is exhausted, the alternate train goes into service producing potable water while the exhausted train is regenerating. The anion unit can be regenerated with raw saline water. By passing a large amount of saline water through the anion unit at a high velocity, the resin is regenerated to its original form. The waste water from this procedure contains sulfuric acid and is collected in the waste acid reservoir. To conserve water, part of the waste water from the anion regeneration is reused as the supply water for regenerating the strongly acidic cation unit. The balance of the anion regenerating water is waste and collected in the waste acid reservoir.

Concentrated sulfuric acid is pumped into the strongly acidic cation unit and diluted with part of the waste water from the anion unit. This is constantly monitored by an instrument to measure the acid strength. When the proper amount of acid has been pumped into the strong cation unit, it is rinsed free of the strong acid using the same waste water from the anion unit. All of the waste regenerant from the cation unit is also collected in the waste acid reservoir.

The simultaneous regeneration of one anion and one cation unit requires approximately 90 minutes. The service run of the other train also requires approximately 90 minutes. Thus when regeneration is completed, the train is ready to go back on stream. By alternating constantly in this manner 24 hours a day, 500,000 gallons of potable water can be produced.

After these two trains have alternately been in service for 12 hours or a total of 8 cycles, approximately 300,000 gallons of water will have collected in the waste acid reservoir. During this same 12 hours, the one weakly acidic carboxylic cation exchanger will have become exhausted and require regeneration. The second unit is placed on stream. The waste acid in the reservoir is pumped through the exhausted weakly acidic cation exchanger unit to regenerate it. Ten hours are required to pump this waste acid. The weakly acidic cation unit is then rinsed with raw saline water and placed in a stand-by condition until needed for service.

The final item of equipment is the degasifier wherein water and air flow counter currently. The water is broken up into a thin film and tiny droplets so the carbon dioxide can be "stripped" from it by the forced draft from the blower. The "degasified" water drops into the clear well where it remains until pumped to storage.

At this point the water quality is excellent, far better than APHA specifications. If desired it can be blended with saline water in the ratio of 34.5% saline water with 65.5% desalted water to produce a supply containing only 250 ppm sulfates and less than 500 ppm total solids. This is in strict compliance with APHA standards. If this blending is employed, the yield of potable water will increase from 500,400 gpd to 763,900 gpd.

## OPERATING INSTRUCTIONS

This system is fully automatic in operation. Once it is started, the operator should check all functions periodically and employ normal supervisory maintenance to keep the equipment in peak operating efficiency. Once the system is in operation, the automatic controls will pace each unit through its programed functions, time the various operations as required, and maintain supervision of the entire system. During start up, the following adjustments, settings, etc., should be made.

## CARBOXYLIC CATION EXCHANGER

### Automatic Reset Meter

The saline water will enter each weakly acidic carboxylic cation exchanger through an automatic reset water meter. This meter should be adjusted to recycle the exchanger after 285,200 gallons have passed through. The exhausted unit will then begin regeneration and the stand-by unit will go on stream. This procedure will be repeated each day, initiated by the automatic reset meter.

### Backwash Adjustment

The first step in regeneration is backwash. The limit stop on the backwash valve should be adjusted to produce a flow rate of 200 gpm. Initially, backwash time should be adjusted for 10 minutes. If at the end of this time the backwash water is not clear, the backwash time should be increased until the water does run clear.

### Regenerant Flow Rate

The controls will next open the acid regeneration valves and pump waste acid through the unit. The flow rate of waste acid should be regulated for 530 gpm by adjusting the limit stop on the valve. It will require 9.4 hours to pump 297,800 gallons of waste acid through this unit.

### Rinse Flow Rate

Following the addition of this waste acid, the controls will step the unit to the rinse operation using raw saline water. The flow rate should be adjusted to 175 gpm by means of the limit stop on the control valve. Rinsing should continue until the acidity has dropped to 175 ppm as determined by test. It is estimated rinsing will require about 35 minutes. Following completion of rinse, the automatic controls will place this unit in a stand-by position until required to go on stream when unit number 2 becomes exhausted.

When unit number 2 becomes exhausted and requires regeneration, the procedure just described will be repeated for unit number 2.

## CATION-ANION TRAINS

The weakly acidic carboxylic cation units will supply only the cation-anion trains in service. Only one of these trains will be in service at a time. No water from these weakly acidic units will go to these trains for their regeneration except during final rinse to quality. All other regenerating water for the separate trains will be raw water.

### Regeneration Of Anion Unit

Train number 1 will be in service while train number 2 is being regenerated. Both cation and anion units of train number 2 will be regenerated simultaneously. The anion unit uses no chemicals whatsoever for regeneration; only raw saline water. Contrary to most ion exchange regeneration procedures, actual regeneration of the anion unit is the first step instead of backwashing. The raw water enters the unit through the influent totalizing meter and flows downward through the resin bed at a flow rate of 450 gpm. This flow rate should be regulated by means of the limit stop on the inlet valve using the rate of flow meter to observe correct adjustment. Each anion unit regeneration requires 32,255 gallons of raw saline water in a period of 72 minutes.

The waste water from the anion unit will contain sulfuric acid as a by-product of the regenerating procedure. The regenerating water will flow from the unit through two outlets. Part of this water will be used by the strongly acidic cation exchanger to provide its water supply for regeneration. The balance of the flow will go to the waste acid reservoir through the waste outlet valve.

### Backwash Adjustment Of Anion Unit

When all the regenerating water has passed through the anion exchanger, the automatic controls will place the unit into backwash position. The backwash valve limit stop should be adjusted to produce a flow rate of 120 gpm. Backwashing should normally require approximately 5 minutes but should continue longer if the backwash water is not clear.

### Backwash Adjustment Of Cation Unit

While the anion unit is proceeding through its lengthy regenerating procedure, the automatic controls will simultaneously regenerate the strongly acidic cation exchanger. Waste water from the anion regeneration will be used for the entire regeneration of the cation unit. The first step is backwash. The limit stop on the backwash control valve should be adjusted for a flow rate of 200 gpm as observed on the rate of flow meter. This backwash operation should continue for approximately 5 minutes or longer if the backwash water is not clear.

Regeneration Of Cation Unit

The controls will next place the unit in regeneration. The flow of dilution water should be set at 168 gpm by means of limit stops on the control valve. The rate of flow meter on the inlet from the anion unit will show when the proper setting has been obtained. The alarm switches on this rate of flow meter will prevent the concentrated acid pump from starting until this diluting flow rate has been obtained. This is a safety feature to prevent either concentrated or improperly diluted acid from entering the cation exchanger.

The concentrated acid and the diluting water will be mixed together in a mixing tee in the valve nest. Down stream from this tee there will be a Solubridge instrument calibrated in percent of sulfuric acid. The flow rate on the concentrated acid pump should be adjusted by means of a rate set valve so that the Solubridge monitor reads exactly two percent sulfuric acid. Each regeneration of each cation exchanger requires 336 pounds of $66^{o}$ Be' sulfuric acid. This is equivalent to 22 gallons per regeneration and will require 11 minutes at a flow rate of 2 gpm. Dilution water flowing at the same time will be 1,876 gallons. Acid volume will be controlled by timers that will stop the acid pump and let the diluting water continue to flow at the same flow rate. This will then become the rinse water. Rinse will continue for approximately 21 minutes and require 3,530 gallons. At the end of the rinse operation, acidity in the water should be about 730 ppm as $CaCO_3$.

All waste water from the cation unit, that is backwash, acid injection, and rinse will go to the waste acid reservoir. Total regeneration time for this unit will be about 38 to 40 minutes. The regeneration of the anion unit will not have been completed at this time. Consequently from this time on the total regeneration water flow from the anion unit will go directly to the waste acid reservoir. In the meantime, the cation unit will be on stand-by until the anion unit has completed its regeneration.

Rinse To Quality

When anion backwash is complete, the controls will place the entire train in a final rinse to quality position. At this point, the train will take water from the carboxylic unit which will pass through the cation exchanger first and then into and through the anion unit to the waste acid reservoir. The flow rate on the cation inlet valve should be adjusted to 375 gpm by means of the limit stop. This quality rinse operation will continue for approximately 12 minutes and consume 4,370 gallons. Upon initial start up, this operation can be timed exactly by means of specific resistance measurements. The specific resistance will continually increase until a point where it begins to level off. This point should be selected by experience and is the point at which the train should be placed into service and the automatic control timers adjusted accordingly.

## Water Quality Controls

Train number 1 will now have become exhausted and returned to regenerating status by the control panel. Train number 2 will now provide water to service while train number 1 is regenerated as described herein. The Solubridge monitor will have two alarm switches which should be set so that when the specific resistance rises to its topmost peak and then begins to drop, it will have passed both alarm points which will then signal the end of the service cycle and place train number 2 into regeneration.

A totalizing water meter is placed in the service line from each train to aid in the keeping of detailed production records. In the treated water line from each train there is also another Solubridge which should be set at the minimum specific resistance value as determined by experience. Thus if there is some malfunction of the equipment, and desalted water is not obtained, this Solubridge will sound an alarm and shut the system down preventing saline water from going through the degasifier and clear well into the distribution system.

Each train is capable of producing 31,280 gallons of desalted water per regeneration. It will require approximately 90 minutes to produce this amount of water. During this time the opposite train will have gone through its entire regeneration and be ready to go back on stream in the service position. Thus each train will require 90 minutes for regeneration and 90 minutes for service or a total of 3 hours for one complete cycle. Therefore each train can recycle a maximum of 8 times per 24 hour day. With two trains, there is a potential of 16 cycles per day or a maximum production of 500,400 gallons of water each 24 hour period.

## Degasifier

Water from these two trains will alternately go to the degasifier so that there will be a continuous flow in the degasifier of 375 gpm. The degasifier consists of a wood stave tower in which there are 9 feet of wooden trays to break up the downward flow of water into a thin film and tiny droplets. The counter current of air through this tower scrubs the gases from the water, stripping it of the dissolved carbon dioxide formed in the cation exchangers. Carbon dioxide when dissolved in water is present in the form of carbonic acid and produces a corrosive water with a low, acidic type pH. Therefore the degasified water will have a pH above 7 and be non-corrosive.

## Water Quality

The desalted water at this point will have the following analysis:

| | | | |
|---|---|---|---|
| Calcium | 12 ppm | Bicarbonate | 0 ppm |
| Magnesium | 6 ppm | Sulfate | 28 ppm |
| Sodium | 20 ppm | Chloride | 14 ppm |
| Potassium | 4 ppm | Total | 42 ppm (as $CaCO_3$) |
| Total | 42 ppm (as $CaCO_3$) | | |

| | |
|---|---|
| Total Hardness (as $CaCO_3$) | 18 |
| Carbon Dioxide (as $CO_2$) | 5 to 10 |
| Silica (as $SiO_2$) | 27 |
| Turbidity | 0 |

The quality of this water is far better than the minimum APHA standard. Much greater yields of potable water can be obtained by blending this high quality water with raw saline water. Water blended in the ratio of 65.5% desalted water with 34.5% saline water will produce a potable supply acceptable to the minimum APHA standard. Such blending equipment has not been shown on any of the drawings. This equipment is of very nominal cost and will be included if desired. It would increase the yield of potable water from 500,400 gpd to 764,000 gpd. An analysis of the water produced by such a blend is as follows:

| | | | |
|---|---|---|---|
| Calcium | 236 ppm | Bicarbonate | 128 ppm |
| Magnesium | 80 ppm | Sulfate | 260 ppm |
| Sodium | 85 ppm | Chloride | 13 ppm |
| Total | 401 ppm (as $CaCO_3$) | Total | 401 ppm (as $CaCO_3$) |

| | |
|---|---|
| Total Hardness (as $CaCO_3$) | 316 |
| Carbon Dioxide (as $CO_2$) | 5 to 10 |
| Silica (as $SiO_2$) | 27 |
| Turbidity | 0 |

## DESIGN AND OPERATING DATA FOR
## 3-BED SUL-biSUL® DESALTING SYSTEM
## 0.5 M GPD TREATED WATER
## WEBSTER, SOUTH DAKOTA

### Weakly Acidic Carboxylic Cation Exchanger

| | |
|---|---|
| Number of Units | Two |
| Exchanger tank size | 96" x 84" |
| Cation resin, type | IRC-84 |
| Cation resin, cu. ft. each | 152 |
| Backwash rate, gpm | 200 |
| Backwash time, estimated minutes | 10 |
| Regenerant used, type | Waste acid |
| Regenerant used, quantity | 297,800 gal. |
| Regenerant flow rate, gpm | 530 |
| Regenerant time | 9.4 hours |
| Rinse rate, gpm | 175 |
| Rinse time, estimated minutes | 35 |
| Cations removed, gpg | 21.8 |
| Capacity, gallons per regeneration | 285,800 |

### Strongly Acidic Cation Exchangers

| | |
|---|---|
| Number of Units | Two |
| Exchanger tank size | 96" x 72" |
| Cation resin, type | Rezex 5 or equal |
| Cation resin, cu. ft. each | 168 |
| Backwash rate, gpm | 200 |
| Backwash time, estimated minutes | 5 |
| Regenerant used, type | $H_2SO_4$ - 66° Be' |
| Regenerant used, lbs. | 336 |
| gallons | 22 |
| Conc. acid flow rate, gpm | 2 |
| Conc. acid dilution rate, gpm | 168 |
| Conc. acid pumping time, minutes | 11 |
| Rinse rate, gpm | 168 |
| Rinse time, estimated minutes | 21 |
| Cations removed, gpg | 39.2 |
| Capacity, total gallons per regeneration | 35,650 |

### Anion Exchanger

| | |
|---|---|
| Number of Units | Two |
| Exchanger tank size | 120" x 120" |
| Anion resin, type | Rezex 71 or equal |
| Anion resin, cu. ft. each | 448 |

| | |
|---|---|
| Backwash rate, gpm | 120 |
| Backwash time, estimated minutes | 5 |
| Regenerant type | Raw saline water |
| Regenerant used, gal. | 32,255 |
| Regenerant flow rate, gpm | 450 |
| Regenerant time, minutes | 72 |
| Rinse to quality rate, gpm | 375 |
| Rinse to quality time, estimated minutes | 12 |
| Anions removed, gpg | 39.8 |
| Capacity, gallons per regeneration | 31,280 |

## 1.0 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 1082 PPM INFLUENT AS $CaCO_3$

### COST OF PRODUCT WATER

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 412 |
| 2) Cost per 1000 gals. product water of 42 ppm TDS as $CaCO_3$ Total M gallons per day | 1,000 | 0.412 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ Total M gallons per day | 1,528 | 0.270 |

### CARRYING CHARGES - (Annual Cost)

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 11,540 |
| 2) Interest on capital investment (5% bonds) | 37,834 |
| 3) Interest on working capital at 5% | 391 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 2,482 |
| 6) Operation and maintenance costs | 83,616 |
| Total yearly fixed costs | $ 135,888 |

### CAPITAL COSTS

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 439,002 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 93,500 | |
| Electrical | 50,000 | |
| Total | 143,500 | 143,500 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 3,813 | 49,569 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 13,464 | 134,640 |
| Total depreciable capital costs | | 766,711 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 7,815 |
| Total non-depreciable capital costs | | 8,315 |
| Total capital costs | | $ 775,026 |

### INSURANCE COST CENTER

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 766,711 | |
| Acid and limestone inventory | 2,150 | |
| Materials and supplies inventory | 3,818 | |
| Total | 772,679 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 1,932 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year Total M gals/year | 330 | 50 |
| Total cost per year | | $ 2,482 |

### OPERATING AND MAINTENANCE COST CENTERS

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 3,818 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 1,774 | 46,124 |
| Limestone at $7/ton Tons per year | 586 | 4,102 |
| Resin (15 year life) | | 11,222 |
| 6) Electric (estimated) | | 600 |
| 7) Heating fuel (estimated) | | 750 |
| 8) Laboratory standard test solutions | | 200 |
| Total operating and maintenance costs | | $ 83,616 |

### OPERATING CAPITAL

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 3,818 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 750 |
| 6) Electric (estimated) | 600 |
| 7) Laboratory standard test solutions | 200 |
| Total yearly operating capital | 22,168 |
| Monthly working capital requirements | $ 1,847 |

### WORKING CAPITAL

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 3,818 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 76.5 | 1,989 |
| Limestone at $7/ton Total tons | 23 | 161 |
| 3) Monthly working capital requirement | | 1,847 |
| Total working capital requirements | | $ 7,815 |

### RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)

| | |
|---|---|
| Weak Acid Cation Resin: Total cu. ft. x 6.67% = 41 $ft^3$ x $49.90/$ft^3$ = | $ 2,045 |
| Strong Acid Cation Resin: Total cu. ft. x 6.67% = 45 $ft^3$ x $23.00/$ft^3$ = | 1,035 |
| Strong Base Anion Resin: Total cu. ft. x 6.67% = 118 $ft^3$ x $69.00/$ft^3$ = | 8,142 |
| Total resin replacement costs/year | $ 11,222 |

## 0.50 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 1082 PPM INFLUENT AS $CaCO_3$

### COST OF PRODUCT WATER

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 253 |
| 2) Cost per 1000 gals. product water of 42 ppm TDS as $CaCO_3$ Total M gallons per day | 500 | 0.506 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ Total M gallons per day | 763 | 0.332 |

### CARRYING CHARGES - (Annual Cost)

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 7,181 |
| 2) Interest on capital investment (5% bonds) | 23,855 |
| 3) Interest on working capital at 5% | 292 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 1,728 |
| 6) Operation and maintenance costs | 50,508 |
| Total yearly fixed costs | $ 83,589 |

### CAPITAL COSTS

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 250,225 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 74,720 | |
| Electrical | 48,000 | |
| Total | 122,720 | 122,720 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 2996.2 | 38,951 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 6521.2 | 65,212 |
| Total depreciable capital costs | | 477,108 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 1,651 |
| Total non-depreciable capital costs | | 2,151 |
| Total capital costs | | $ 479,259 |

### INSURANCE COST CENTER

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 477,108 | |
| Acid and limestone inventory | 2,076 | |
| Materials and supplies inventory | 2,120 | |
| Total | 481,304 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 1,203 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year Total M gals/year | 165 | 25 |
| Total cost per year | | $ 1,728 |

### OPERATING AND MAINTENANCE COST CENTERS

| | | |
|---|---|---|
| 1) Operating and maintenance labor Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 2,120 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 887 | 23,062 |
| Limestone at $7/ton Tons per year | 293 | 2,051 |
| Resin (15 year life) | | 5,575 |
| 6) Electric (estimated) | | 300 |
| 7) Heating fuel (estimated) | | 500 |
| 8) Laboratory standard test solutions | | 100 |
| Total operating and maintenance costs | | $ 50,508 |

### OPERATING CAPITAL

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 2,120 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 500 |
| 6) Electric (estimated) | 300 |
| 7) Laboratory standard test solutions | 100 |
| Total yearly operating capital | 19,820 |
| Monthly working capital requirements | $ 1,651 |

### WORKING CAPITAL

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 2,120 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 76.5 | 1,989 |
| Limestone at $7/ton Total tons | 12.4 | 87 |
| 3) Monthly working capital requirement | | 1,651 |
| Total working capital requirements | | $ 5,847 |

### RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)

| | |
|---|---|
| **Weak Acid Cation Resin** | |
| Total cu. ft. x 6.67% = 20 $ft^3$ x $49.90/$ft^3$ = | $ 998 |
| **Strong Acid Cation Resin** | |
| Total cu. ft. x 6.67% = 22 $ft^3$ x $23.00/$ft^3$ = | 506 |
| **Strong Base Anion Resin** | |
| Total cu. ft. x 6.67% = 59 $ft^3$ x $69.00/$ft^3$ = | 4,071 |
| Total resin replacement costs/year | $ 5,575 |

## 0.25 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 1082 PPM INFLUENT AS $CaCO_3$

**COST OF PRODUCT WATER**

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 138 |
| 2) Cost per 1000 gals. product water of 42 ppm TDS as $CaCO_3$ Total M gallons per day | 250 | 0.552 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ Total M gallons per day | 381 | 0.362 |

**CARRYING CHARGES - (Annual Cost)**

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 4,002 |
| 2) Interest on capital investment (5% bonds) | 13,296 |
| 3) Interest on working capital at 5% | 153 |
| 4) Interest on land at 5% | 13 |
| 5) Insurance | 1,064 |
| 6) Operation and maintenance costs | 27,045 |
| Total yearly fixed costs | $ 45,573 |

**CAPITAL COSTS**

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 126,457 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 59,000 | |
| Electrical | 24,000 | |
| Total | 83,000 | 83,000 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 1,974 | 25,662 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 3,080 | 30,800 |
| Total depreciable capital costs | | 265,919 |
| 5) Land at $500. per acre | | 250 |
| 6) Working Capital | | 3,066 |
| Total non-depreciable capital costs | | 3,316 |
| Total capital costs | | $ 269,235 |

**INSURANCE COST CENTER**

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 265,919 | |
| Acid and limestone inventory | 1,038 | |
| Materials and supplies inventory | 1,265 | |
| Total | 268,222 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 671 |
| Workmen's Compensation at $2.00 per $1000 wages | | 180 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year Total M gals/year | 82.5 | 13 |
| Total cost per year | | $ 1,064 |

**OPERATING AND MAINTENANCE COST CENTERS**

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| Total | 9,000 | $ 9,000 |
| 2) Fringe benefits at 7% of wages | | 630 |
| 3) General and Administrative expenses at 5% of wages | | 450 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 1,054 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 444 | 11,544 |
| Limestone at $7/ton Tons per year | 147 | 1,029 |
| Resin (15 year life) | | 2,788 |
| 6) Electric (estimated) | | 150 |
| 7) Heating fuel (estimated) | | 300 |
| 8) Laboratory standard test solutions | | 100 |
| Total operating and maintenance costs | | $ 27,045 |

**OPERATING CAPITAL**

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 1,054 |
| 2) Labor | 9,000 |
| 3) Fringe benefits at 7% of wages | 630 |
| 4) General and Administration expenses at 5% of wages | 450 |
| 5) Heating fuel (estimated) | 300 |
| 6) Electric (estimated) | 150 |
| 7) Laboratory standard test solutions | 100 |
| Total yearly operating capital | 11,684 |
| Monthly working capital requirements | $ 974 |

**WORKING CAPITAL**

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 1,054 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 38.25 | 995 |
| Limestone at $7/ton Total tons | 6.2 | 43 |
| 3) Monthly working capital requirement | | 974 |
| Total working capital requirements | | $ 3,066 |

**RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)**

| | |
|---|---|
| Weak Acid Cation Resin | |
| Total cu. ft. x 6.67% = 10 $ft^3$ x $49.90/$ft^3$ = | $ 499 |
| Strong Acid Cation Resin | |
| Total cu. ft. x 6.67% = 11 $ft^3$ x $23.00/$ft^3$ = | 253 |
| Strong Base Anion Resin | |
| Total cu. ft. x 6.67% = 29.5 $ft^3$ x $69.00/$ft^3$ = | 2,036 |
| Total resin replacement costs/year | $ 2,788 |

## 1.0 M GPD 2-BED SUL-biSUL® DESALTING PLANT
## 1082 PPM INFLUENT AS $CaCO_3$

**COST OF PRODUCT WATER**

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 485 |
| 2) Cost per 1000 gals. product water of 79 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 1000 | 0.485 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 398 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 1467.4 | 0.330 |

**CARRYING CHARGES - (Annual Cost)**

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 8,291 |
| 2) Interest on capital investment (5% bonds) | 27,543 |
| 3) Interest on working capital at 5% | 364 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 1,941 |
| 6) Operation and maintenance costs | 121,886 |
| Total yearly fixed costs | $ 160,050 |

**CAPITAL COSTS**

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 364,475 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 70,125 | |
| Electrical | 50,000 | |
| Total | 120,125 | 120,125 |
| 3) Structures and improvements at $13. per square foot of building area. | | |
| Total square foot area | 2881 | 37,453 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. | | |
| Total square foot area | 2881 | 28,810 |
| Total depreciable capital costs | | 550,863 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 7,273 |
| Total non-depreciable capital costs | | 7,773 |
| Total capital costs | | 558,636 |

**INSURANCE COST CENTER**

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $550,863 | |
| Acid and limestone inventory | 2,331 | |
| Materials and supplies inventory | 3,150 | |
| Total | 556,344 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 1,391 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year | | |
| Total M gals/year | 330 | 50 |
| Total cost per year | | $ 1,941 |

**OPERATING AND MAINTENANCE COST CENTERS**

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 3,150 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Tons per year | 3,168 | 82,368 |
| Limestone at $7/ton | | |
| Tons per year | 1,148 | 8,036 |
| Resin (15 year life) | | 9,982 |
| 6) Electric (estimated) | | 600 |
| 7) Heating fuel (estimated) | | 750 |
| 8) Laboratory standard test solutions | | 200 |
| Total operating and maintenance costs | | $ 121,886 |

**OPERATING CAPITAL**

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 3,150 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 750 |
| 6) Electric (estimated) | 600 |
| 7) Laboratory standard test solutions | 200 |
| Total yearly operating capital | 21,500 |
| Monthly working capital requirements | $ 1,792 |

**WORKING CAPITAL**

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 3,150 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Total tons | 76.5 | 1,989 |
| Limestone at $7/ton | | |
| Total tons | 48.8 | 342 |
| 3) Monthly working capital requirement | | 1,792 |
| Total working capital requirements | | $ 7,273 |

**RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)**

| | | |
|---|---|---|
| Weak Acid Cation Resin | | |
| Total cu. ft. x 6.67% = ____ $ft^3$ x $49.90/$ft^3$ = | | $ |
| Strong Acid Cation Resin | | |
| Total cu. ft. x 6.67% = 80 $ft^3$ x $23.00/$ft^3$ = | | 1,840 |
| Strong Base Anion Resin | | |
| Total cu. ft. x 6.67% = 118 $ft^3$ x $69.00/$ft^3$ = | | 8,142 |
| Total resin replacement costs/year | | $ 9,982 |

## 0.50 M GPD 2-BED SUL-biSUL® DESALTING PLANT
## 1082 PPM INFLUENT AS $CaCO_3$

### COST OF PRODUCT WATER

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 284 |
| 2) Cost per 1000 gals. product water of 79 ppm TDS as $CaCO_3$ Total M gallons per day | 500 | 0.568 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 398 ppm TDS as $CaCO_3$ Total M gallons per day | 733.7 | 0.387 |

### CARRYING CHARGES - (Annual Cost)

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 5,193 |
| 2) Interest on capital investment (5% bonds) | 17,253 |
| 3) Interest on working capital at 5% | 272 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 1,397 |
| 6) Operation and maintenance costs | 69,561 |
| Total yearly fixed costs | $ 93,701 |

### CAPITAL COSTS

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 198,488 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 56,040 | |
| Electrical | 48,000 | |
| Total | 104,040 | 104,040 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 1,849 | 24,037 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 1,849 | 18,490 |
| Total depreciable capital costs | | 345,055 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 5,442 |
| Total non-depreciable capital costs | | 5,942 |
| Total capital costs | | $ 350,997 |

### INSURANCE COST CENTER

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 345,055 | |
| Acid and limestone inventory | 2,160 | |
| Materials and supplies inventory | 1,668 | |
| Total | 348,883 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 872 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year Total M gals/year | 165 | 25 |
| Total cost per year | | $ 1,397 |

### OPERATING AND MAINTENANCE COST CENTERS

| | | |
|---|---|---|
| 1) Operating and maintenance labor Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 1,668 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 1,584 | 41,184 |
| Limestone at $7/ton Tons per year | 574 | 4,018 |
| Resin (15 year life) | | 4,991 |
| 6) Electric (estimated) | | 300 |
| 7) Heating fuel (estimated) | | 500 |
| 8) Laboratory standard test solutions | | 100 |
| Total operating and maintenance costs | | $ 69,561 |

### OPERATING CAPITAL

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 1,668 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 500 |
| 6) Electric (estimated) | 300 |
| 7) Laboratory standard test solutions | 100 |
| Total yearly operating capital | 19,368 |
| Monthly working capital requirements | $ 1,614 |

### WORKING CAPITAL

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 1,668 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 76.5 | 1,989 |
| Limestone at $7/ton Total tons | 24.4 | 171 |
| 3) Monthly working capital requirement | | 1,614 |
| Total working capital requirements | | $ 5,442 |

### RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)

| | |
|---|---|
| Weak Acid Cation Resin Total cu. ft. x 6.67% = ____ $ft^3$ x $49.90/$ft^3$ = | $ |
| Strong Acid Cation Resin Total cu. ft. x 6.67% = 40 $ft^3$ x $23.00/$ft^3$ = | 920 |
| Strong Base Anion Resin Total cu. ft. x 6.67% = 59 $ft^3$ x $69.00/$ft^3$ = | 4,071 |
| Total resin replacement costs/year | $ 4,991 |

## 1.0 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 1500 PPM HYPOTHETICAL INFLUENT AS $CaCO_3$

**COST OF PRODUCT WATER**

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 467 |
| 2) Cost per 1000 gals. product water of 58 ppm TDS as $CaCO_3$ Total M gallons per day | 909.7 | 0.513 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ Total M gallons per day | 1,192 | 0.392 |

**CARRYING CHARGES - (Annual Cost)**

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 13,475 |
| 2) Interest on capital investment (5% bonds) | 38,772 |
| 3) Interest on working capital at 5% | 379 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 2,499 |
| 6) Operation and maintenance costs | 98,918 |
| Total yearly fixed costs | $ 154,068 |

**CAPITAL COSTS**

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 457,760 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 93,500 | |
| Electrical | 50,000 | |
| Total | 143,500 | 143,500 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 3,813 | 49,569 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 12,462 | 124,620 |
| Total depreciable capital costs | | 775,449 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 8,082 |
| Total non-depreciable capital costs | | 8,582 |
| Total capital costs | | $ 784,031 |

**INSURANCE COST CENTER**

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 775,449 | |
| Acid and limestone inventory | 2,231 | |
| Materials and supplies inventory | 3,989 | |
| Total | 781,669 | |
| Fire insurance cost at $0.25 per $1000 insured value | | 1,954 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year | | |
| Total M gals/year | 300 | 45 |
| Total cost per year | | $ 2,499 |

**OPERATING AND MAINTENANCE COST CENTERS**

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 3,989 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 22,572 | 58,687 |
| Limestone at $7/ton Tons per year | 812 | 5,684 |
| Resin (15 year life) | | 12,208 |
| 6) Electric (estimated) | | 600 |
| 7) Heating fuel (estimated) | | 750 |
| 8) Laboratory standard test solutions | | 200 |
| Total operating and maintenance costs | | $ 98,918 |

**OPERATING CAPITAL**

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 3,989 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 750 |
| 6) Electric (estimated) | 600 |
| 7) Laboratory standard test solutions | 200 |
| Total yearly operating capital | 22,339 |
| Monthly working capital requirements | $ 1,862 |

**WORKING CAPITAL**

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 3,989 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 76.5 | 1,989 |
| Limestone at $7/ton Total tons | 34.5 | 242 |
| 3) Monthly working capital requirement | | 1,862 |
| Total working capital requirements | | $ 8,082 |

**RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)**

| | |
|---|---|
| Weak Acid Cation Resin: Total cu. ft. x 6.67% = 52 $ft^3$ x $49.90/$ft^3$ = | $ 2,594 |
| Strong Acid Cation Resin: Total cu. ft. x 6.67% = 58 $ft^3$ x $23.00/$ft^3$ = | 1,334 |
| Strong Base Anion Resin: Total cu. ft. x 6.67% = 120 $ft^3$ x $69.00/$ft^3$ = | 8,280 |
| Total resin replacement costs/year | $ 12,208 |

## 0.5 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 1500 PPM HYPOTHETICAL INFLUENT AS $CaCO_3$

**COST OF PRODUCT WATER**

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 278 |
| 2) Cost per 1000 gals. product water of 58 ppm TDS as $CaCO_3$ Total M gallons per day | 454.88 | 0.611 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ Total M gallons per day | 596. | 0.466 |

**CARRYING CHARGES - (Annual Cost)**

| | | |
|---|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | | $ 7,315 |
| 2) Interest on capital investment (5% bonds) | | 24,300 |
| 3) Interest on working capital at 5% | | 298 |
| 4) Interest on land at 5% | | 25 |
| 5) Insurance | | 1,749 |
| 6) Operation and maintenance costs | | 58,191 |
| Total yearly fixed costs | | $ 91,878 |

**CAPITAL COSTS**

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 259,112 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 74,720 | |
| Electrical | 48,000 | |
| Total | 122,720 | 122,720 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 2996.2 | 38,951 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 6521.2 | 65,212 |
| Total depreciable capital costs | | 485,995 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 5,969 |
| Total non-depreciable capital costs | | 6,469 |
| Total capital costs | | $ 492,464 |

**INSURANCE COST CENTER**

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 485,995 | |
| Acid and limestone inventory | 2,110 | |
| Materials and supplies inventory | 2,201 | |
| Total | $ 490,306 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 1,226 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year Total M gals/year | 150 | 23 |
| Total cost per year | | $ 1,749 |

**OPERATING AND MAINTENANCE COST CENTERS**

| | | |
|---|---|---|
| 1) Operating and maintenance labor Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 2,201 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 11,286 | 29,344 |
| Limestone at $7/ton Tons per year | 406 | 2,842 |
| Resin (15 year life) | | 6,104 |
| 6) Electric (estimated) | | 300 |
| 7) Heating fuel (estimated) | | 500 |
| 8) Laboratory standard test solutions | | 100 |
| Total operating and maintenance costs | | $ 58,191 |

**OPERATING CAPITAL**

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 2,201 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 500 |
| 6) Electric (estimated) | 300 |
| 7) Laboratory standard test solutions | 100 |
| Total yearly operating capital | 19,901 |
| Monthly working capital requirements | $ 1,658 |

**WORKING CAPITAL**

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 2,201 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 76.5 | 1,989 |
| Limestone at $7/ton Total tons | 17.25 | 121 |
| 3) Monthly working capital requirement | | 1,658 |
| Total working capital requirements | | $ 5,969 |

**RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)**

| | |
|---|---|
| **Weak Acid Cation Resin** | |
| Total cu. ft. x 6.67% = 26 $ft^3$ x $49.90/$ft^3$ = | $ 1,297 |
| **Strong Acid Cation Resin** | |
| Total cu. ft. x 6.67% = 29 $ft^3$ x $23.00/$ft^3$ = | 667 |
| **Strong Base Anion Resin** | |
| Total cu. ft. x 6.67% = 60 $ft^3$ x $69.00/$ft^3$ = | 4,140 |
| Total resin replacement costs/year | $ 6,104 |

## 1.0 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 2000 PPM HYPOTHETICAL INFLUENT AS $CaCO_3$

### COST OF PRODUCT WATER

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 510 |
| 2) Cost per 1000 gals. product water of 78 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 821 | 0.621 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 985 | 0.518 |

### CARRYING CHARGES - (Annual Cost)

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 11,979 |
| 2) Interest on capital investment (5% bonds) | 39,794 |
| 3) Interest on working capital at 5% | 441 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 2,548 |
| 6) Operation and maintenance costs | 113,469 |
| Total yearly fixed costs | $ 168,256 |

### CAPITAL COSTS

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 524,697 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 111,200 | |
| Electrical | 50,000 | |
| Total | 161,200 | 161,200 |
| 3) Structures and improvements at $13. per square foot of building area. | | |
| Total square foot area | 3,813 | 49,569 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. | | |
| Total square foot area | 6,041 | 60,410 |
| Total depreciable capital costs | | 795,876 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 8,816 |
| Total non-depreciable capital costs | | 9,316 |
| Total capital costs | | $ 805,192 |

### INSURANCE COST CENTER

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 795,876 | |
| Acid and limestone inventory | 2,311 | |
| Materials and supplies inventory | 4,593 | |
| Total | 802,780 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 2,007 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year | | |
| Total M gals/year | 271 | 41 |
| Total cost per year | | $ 2,548 |

### OPERATING AND MAINTENANCE COST CENTERS

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 4,593 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Tons per year | 2,756 | 71,656 |
| Limestone at $7/ton | | |
| Tons per year | 1054.9 | 7,384 |
| Resin (15 year life) | | 11,486 |
| 6) Electric (estimated) | | 600 |
| 7) Heating fuel (estimated) | | 750 |
| 8) Laboratory standard test solutions | | 200 |
| Total operating and maintenance costs | | $ 113,469 |

### OPERATING CAPITAL

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 4,593 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 750 |
| 6) Electric (estimated) | 600 |
| 7) Laboratory standard test solutions | 200 |
| Total yearly operating capital | 22,943 |
| Monthly working capital requirements | $ 1,912 |

### WORKING CAPITAL

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 4,593 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Total tons | 76.5 | 1,989 |
| Limestone at $7/ton | | |
| Total tons | 46 | 322 |
| 3) Monthly working capital requirement | | 1,912 |
| Total working capital requirements | | $ 8,816 |

### RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)

| | |
|---|---|
| Weak Acid Cation Resin | |
| Total cu. ft. x 6.67% = 32 $ft^3$ x $49.90/$ft^3$ = | $ 1,596 |
| Strong Acid Cation Resin | |
| Total cu. ft. x 6.67% = 70 $ft^3$ x $23.00/$ft^3$ = | 1,610 |
| Strong Base Anion Resin | |
| Total cu. ft. x 6.67% = 120 $ft^3$ x $69.00/$ft^3$ = | 8,280 |
| Total resin replacement costs/year | $ 11,486 |

## 0.50 M GPD 3-BED SUL-biSUL® DESALTING PLANT
## 2000 PPM HYPOTHETICAL INFLUENT AS $CaCO_3$

**COST OF PRODUCT WATER**

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 298 |
| 2) Cost per 1000 gals. product water of 78 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 410.5 | 0.726 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of 400 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 492.8 | 0.605 |

**CARRYING CHARGES - (Annual Cost)**

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 7,472 |
| 2) Interest on capital investment (5% bonds) | 23,617 |
| 3) Interest on working capital at 5% | 307 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 1,772 |
| 6) Operation and maintenance costs | 65,281 |
| Total yearly fixed costs | $ 98,474 |

**CAPITAL COSTS**

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 271,976 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 74,720 | |
| Electrical | 48,000 | |
| Total | 122,720 | $ 122,720 |
| 3) Structures and improvements at $13. per square foot of building area. | | |
| Total square foot area | 2996.2 | 38,951 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. | | |
| Total square foot area | 6,281 | 62,810 |
| Total depreciable capital costs | | 496,457 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 6,132 |
| Total non-depreciable capital costs | | 6,632 |
| Total capital costs | | $ 503,089 |

**INSURANCE COST CENTER**

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 496,457 | |
| Acid and limestone inventory | 2,146 | |
| Materials and supplies inventory | 2,318 | |
| Total | $ 500,921 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 1,252 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year | | |
| Total M gals/year | 135.5 | 20 |
| Total cost per year | | $ 1,772 |

**OPERATING AND MAINTENANCE COST CENTERS**

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 2,318 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Tons per year | 1,378 | 35,828 |
| Limestone at $7/ton | | |
| Tons per year | 527.4 | 3,692 |
| Resin (15 year life) | | 5,743 |
| 6) Electric (estimated) | | 300 |
| 7) Heating fuel (estimated) | | 500 |
| 8) Laboratory standard test solutions | | 100 |
| Total operating and maintenance costs | | $ 65,281 |

**OPERATING CAPITAL**

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 2,318 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 500 |
| 6) Electric (estimated) | 300 |
| 7) Laboratory standard test solutions | 100 |
| Total yearly operating capital | 20,018 |
| Monthly working capital requirements | $ 1,668 |

**WORKING CAPITAL**

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 2,318 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Total tons | 76.5 | 1,989 |
| Limestone at $7/ton | | |
| Total tons | 22.4 | 157 |
| 3) Monthly working capital requirement | | 1,668 |
| Total working capital requirements | | $ 6,132 |

**RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)**

| | |
|---|---|
| Weak Acid Cation Resin | |
| Total cu. ft. x 6.67% = 16 $ft^3$ x $49.90/$ft^3$ = | 798 |
| Strong Acid Cation Resin | |
| Total cu. ft. x 6.67% = 35 $ft^3$ x $23.00/$ft^3$ = | 805 |
| Strong Base Anion Resin | |
| Total cu. ft. x 6.67% = 60 $ft^3$ x $69.00/$ft^3$ = | 4,140 |
| Total resin replacement costs/year | $ 5,743 |

# XIII SUMMARY AND DISCUSSION

## Experimental Results

The characteristics of the SUL-biSUL® process must be predictable before a water desalting plant can be designed and/or the cost of employing the process can be evaluated. Specifically, the performance characteristics of anion and cation resin exhaustion and regeneration must be known.

The experimental studies conducted under this contract have provided a relatively clear picture of anion resin performance. Of major concern, was the anion resin's capacity for free mineral acidity (of various chemical compositions) and the water requirements for anion rinse regeneration. This concern becomes obvious when reviewing the basic process, in that the anion portion of the system is the unique feature of the SUL-biSUL® process. Within an acceptable range of experimental error, the anion resin's capacity for free mineral acidity and raw water requirements for rinse regeneration are now predictable as shown in Figures 6, 8 and 9 (Pages 38, 40 and 41).

Cation resin performance characteristics on brackish water supplies are not yet totally predictable. In the authors opinion, it appears as though cation resin performance characteristics are more dependent on the total mineral content of the supply and less dependent on the actual chemical composition than in conventional systems. This does not imply that conventional ion exchange technology should be completely rejected - it should not. This does imply however, that modifications of existing ion exchange technology are necessary. To understand what these modifications are, further studies of cation resin performance characteristics employing brackish water influents are definitely required and strongly suggested. Once this information is gathered, the cost of building and operating a SUL-biSUL® desalting plant on any specified brackish water supply can be evaluated as a possible solution for producing a potable water meeting the suggested drinking water standards of the United States Department of Health.

## Equipment Operational Performance Characteristics

Several advantageous features of the Webster SUL-biSUL® desalting plant should be emphasized. They are:

1) All of the mechanical equipment employed in this plant is the same equipment that has been used for the past ten to fifteen years under essentially identical conditions of operation.

2) The automatic controls employed for this plant are the same reliable controls presently being employed in conventional ion exchange systems.

3) The ion exchange resins used in the SUL-biSUL® desalting system are the same resins currently being employed in conventional ion exchange systems. Only the chemistry of anion resin exhaustion and regeneration is new and unique; the cation exchange system is identical to that of the conventional system employing low levels of acid regeneration.

4) Anion rinse regeneration is extremely easy to control either manually or automatically. When the effluent conductivity of the anion exchange unit being rinse regenerated is equal to the influent conductivity, the resin is fully regenerated. Over rinse regenerating this unit will not be detrimental to the resin and will serve only as a safety factor insuring complete regeneration.

5) Water meters and conductivity instruments comprise the only instrumentation required for a fully automatic desalting plant save conventional ion exchange controls of proven reliability.

6) As will be noted after detail review of the equipment specifications and plant operating instructions, maintenance requirements for a SUL-biSUL® desalting plant are well within the acceptable talents of normal municipal water treatment plant operators.

Weak Acid Cation Resin Regeneration

In designing the Webster SUL-biSUL® desalting plant, we noted that the total amount of waste acid discharged from both the strong acid cation exchange unit and the acid discharged during anion rinse regeneration, if collected in a single storage vessel, would make available more acid than required for regeneration of the weak acid cation (WAC) exchange unit. If this waste acid could be utilized for WAC resin regeneration, three distinctive advantages would be realized. First, additional acid for WAC resin regeneration would not have to be purchased, lowering the overall cost of product water. Second, any waste acid utilized for regeneration of this unit would result in a reduction of the total acidic waste water requiring neutralization before discharge to a suitable area, reducing the cost of waste treatment. Finally, if acidic waste water could be used for this regeneration, raw water requirements (normally employed) could be drastically reduced resulting in a definite improvement in the overall product yield of the system.

If these two waste acid streams were collected in a single reservoir, the calculated average concentration of the acid would be approximately 600 ppm as calcium carbonate. Although WAC resins are normally regenerated with sulfuric acid concentrations of from 0.5 to 1 percent acid by weight, sound ion exchange technology indicates that efficient regeneration could be realized employing a 600 ppm acidic waste solution.

To firmly establish that this concentration of waste acid could be efficiently employed for WAC resin regeneration, a brief study was conducted at the Elgin, Illinois test site employing pilot equipment.

The pilot plant equipment used in these studies contained 1.28 cubic feet of weak acid cation exchange resin and the necessary valves and meters for a detailed study of the system in operation. The exhaustant test solution employed in these studies was a well water supply. The analysis is presented in Table XV (Page 131). Regeneration was conducted downflow using the well water supply adjusted to a free mineral acidity of 600 ppm as calcium carbonate with 66$^o$ Be' sulfuric acid. The regeneration cycle was terminated when the effluent mineral acidity from the unit reached 100 ppm as calcium carbonate. Exhaustion and regeneration cycles were repeated until several successive cycles showing essentially identical performance characteristics were observed, indicating the system was in cyclic equilibrium. The data presented in Table XVI (Page 131) summarizes the results of these studies.

As will be noted from the data presented in Table XVI, a very dilute solution of sulfuric acid can be efficiently employed for weak acid cation exchange regeneration. The average acid requirements for regeneration, with respect to the stoichiometric acid requirements of the resin, varied between 110 and 120 percent.

Economic Evaluation

The information presented in Section XII of this report is uninterpreted financial data concerning the cost of building and operating a SUL-biSUL® desalting plant under various specified conditions. Both the two bed and three bed systems, 500,000 and 1,000,000 gpd plants were designed and costed on the basis of observed experimental data. Additional plants were also presented utilizing the data developed under this contract and by assuming that cation resin (both types) capacities would remain constant when higher mineral content waters of the exact same chemical composition as Webster were treated. As will be noted, with higher mineralized water supplies, the volume of water that can be treated per dollar of equipment value is decreased; operating chemicals for regeneration and waste treatment are increased; a lower volume of product water is realized when expressed as a percentage of the total volume of water consumed by the process.

For comparative purposes, a brief evaluation of a two bed SUL-biSUL® system employed for treatment of the Dalpra Farms test water supply was made (Pages 133 and 134). As shown in Table XVII (Page 132), the raw water supply is high in sodium and has a total dissolved mineral content of over 2,000 ppm.

The overall cost of treating the Dalpra Farms water supply is double that of the same system employed for treatment of the Webster, South Dakota supply and the product water achieved is of a lesser quality. A comparison of the total mineral content of both water supplies and operating costs shows the desalting cost of the SUL-biSUL® process varies directly as the mineral content of the raw water.

In designing the desalting plants described in this report, it was decided that sand filtration of the acidic waste stream collected, prior to its use for weak acid cation resin regeneration, would not be required. This decision was made on the basis that no precipitation in the waste acid storage reservoir would occur. Because the calculations upon which this decision was made could possibly be in error or perhaps complicating circumstances not yet apparent to the authors might exist, space was provided in the plant design for a sand filtration system if this equipment was considered or found to be necessary.

Nowhere in the economical evaluation is the cost of pumping water considered. The additional charge for this expense must be added to the overall calculated cost of product water for each example sited when the exact source of raw water is defined - deep well, shallow well, surface supply, etc.

Figures 26, 27 and 28 (Pages 135, 136 and 137) are graphic interpretations of the cost figures presented in Section XII. Since interpretation of cost evaluation is highly subjective, the authors were reluctant to extensively interpret the financial data beyond a point that might be termed as almost indisputably objective. It was felt that additional economic interpretation of the data presented could be more objectively left to the discretion of the reader.

## Application Of The SUL-biSUL® Process

To date, ion exchange processes have not found extensive application for brackish water demineralization. The reason for this limitation can be specifically pinpointed to a single source, namely, the quantity and cost of regenerants required for cyclic operation.

The capital investment, labor and maintenance cost of ion exchange processes have always compared favorably with existing systems. Ease of operation and water qualities are also as good as, if not better than, that obtained from other systems. In general, an ion exchange system is usually easier to build and operate than other water treatment systems. However, ion exchange systems do require chemicals for operation and the cost of these chemicals has offset other advantages.

SUL-biSUL® is a new concept in ion exchange resin water treatment. The chemical principles of exhaustion and regeneration are completely different than those of the conventional resin system. The experimental results obtained under this contract clearly show that the SUL-biSUL® process can economically treat high mineral waters within the limitations of its operating range.

The operating range of the SUL-biSUL® process should not be misunderstood. In the authors opinion, a suitable water supply for SUL-biSUL® should have the following characteristics:

1) The total dissolved mineral content of the supply should not exceed approximately 2,000 ppm expressed in calcium carbonate equivalents.

2) The sulfate to chloride ion ratio should be approximately 9 sulfates to 1 chloride or more - a water supply containing substantial chloride ion content with respect to sulfate anions is not suitable for the process.

3) The alkalinity content of the water supply should represent at least 10% of the total anions present. Water supplies containing a very high percentage of alkaline anions are highly desirable.

4) Water supplies high in hardness and low (25% or less of the total cation content) in sodium ion concentration are suitable for SUL-biSUL® partial demineralization. A gypsum type water supply containing a substantial portion of bicarbonate alkalinity is most suitable for the process.

Although deviations from the above described water characteristics are possible, the characteristics of high alkalinity and sulfate are essential for SUL-biSUL® anion resin performance utilizing the rinse regeneration technique.

## TABLE XV

## EXHAUSTANT WATER ANALYSIS

| Cations (ppm as $CaCO_3$) | | Anions (ppm as $CaCO_3$) | |
|---|---|---|---|
| Calcium | 68 | Bicarbonate | 340 |
| Magnesium | 56 | Sulfate | 60 |
| Sodium | 310 | Chloride | 34 |
| | 434 | | 434 |

pH = 8.3

## TABLE XVI

## UTILIZATION OF ACIDIC WASTE

| Run No. | Regenerant Flow Rate GPM/$ft^3$ of Resin | Regenerant Volume in Gal/$ft^3$ of Resin | Exhaustion Flow Rate in GPM/$ft^3$ of Resin | Exhaustion Volume in Gal/$ft^3$ of Resin | Waste Acid Utilization % Stoichiometric of Resin Requirements |
|---|---|---|---|---|---|
| 4 | 3 | 324 | 3 | 508 | 117.3 |
| 5 | 3 | 312 | 3 | 492 | 117.2 |
| 6 | 3 | 312 | 3 | 516 | 111.8 |
| 7 | 3 | 293 | 3 | 516 | 102.5 |

TABLE XVII

DALPRA FARMS RAW WATER ANALYSIS

| Cations (ppm as $CaCO_3$) | | Anions (ppm as $CaCO_3$) | |
|---|---|---|---|
| Calcium | 112 | Bicarbonate | 366 |
| Magnesium | 102 | Sulfate | 1568 |
| Sodium | 1882 | Chloride | 162 |
| Total | 2096 | Total | 2096 |

pH 7.5

3080 ppm TDS

1.0 M GPD 2-BED SUL-biSUL® DESALTING PLANT
2096 PPM INFLUENT AS $CaCO_3$ - DALPRA FARMS, COLORADO

**COST OF PRODUCT WATER**

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 645 |
| 2) Cost per 1000 gals. product water of 542 ppm TDS as $CaCO_3$ Total M gallons per day | 1,000 | 0.645 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of ____ ppm TDS as $CaCO_3$ Total M gallons per day | | |

**CARRYING CHARGES - (Annual Cost)**

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 8,522 |
| 2) Interest on capital investment (5% bonds) | 28,311 |
| 3) Interest on working capital at 5% | 399 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 1,981 |
| 6) Operation and maintenance costs | 173,589 |
| Total yearly fixed costs | $ 212,827 |

**CAPITAL COSTS**

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 379,829 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 70,125 | |
| Electrical | 50,000 | |
| Total | 120,125 | 120,125 |
| 3) Structures and improvements at $13. per square foot of building area. Total square foot area | 2,881 | 37,453 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. Total square foot area | 2,881 | 28,810 |
| Total depreciable capital costs | | 566,217 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 7,977 |
| Total non-depreciable capital costs | | 8,477 |
| Total capital costs | | $ 574,694 |

**INSURANCE COST CENTER**

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 566,217 | |
| Acid and limestone inventory | 2,885 | |
| Materials and supplies inventory | 3,289 | |
| Total | 572,391 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 1,431 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year Total M gals/year | 330 | 50 |
| Total cost per year | | $ 1,981 |

**OPERATING AND MAINTENANCE COST CENTERS**

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 3,289 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Tons per year | 5,570 | 144,820 |
| Limestone at $7/ton Tons per year | 3,336 | 23,352 |
| Resin (15 year life) | | 7,130 |
| 6) Electric (estimated) | | 600 |
| 7) Heating fuel (estimated) | | 750 |
| 8) Laboratory standard test solutions | | 200 |
| Total operating and maintenance costs | | $ 173,589 |

**OPERATING CAPITAL**

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 3,289 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 750 |
| 6) Electric (estimated) | 600 |
| 7) Laboratory standard test solutions | 200 |
| Total yearly operating capital | 21,639 |
| Monthly working capital requirements | $ 1,803 |

**WORKING CAPITAL**

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 3,289 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton Total tons | 76.5 | 1,989 |
| Limestone at $7/ton Total tons | 128 | 896 |
| 3) Monthly working capital requirement | | 1,803 |
| Total working capital requirements | | $ 7,977 |

**RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)**

| | |
|---|---|
| Weak Acid Cation Resin | |
| Total cu. ft. x 6.67% = ____ $ft^3$ x $49.90/$ft^3$ = | $ |
| Strong Acid Cation Resin | |
| Total cu. ft. x 6.67% = 142 $ft^3$ x $23.00/$ft^3$ = | 3,266 |
| Strong Base Anion Resin | |
| Total cu. ft. x 6.67% = 56 $ft^3$ x $69.00/$ft^3$ = | 3,864 |
| Total resin replacement costs/year | $ 7,130 |

## 0.5 M GPD 2-BED SUL-biSUL® DESALTING PLANT
## 2096 PPM INFLUENT AS $CaCO_3$ - DALPRA FARMS, COLORADO

### COST OF PRODUCT WATER

| | | |
|---|---|---|
| 1) Daily fixed cost based on 330 day year | | $ 399 |
| 2) Cost per 1000 gals. product water of 542 ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | 500 | 0.798 |
| 3) Cost per 1000 gals. product water blended to an effluent quality of ____ ppm TDS as $CaCO_3$ | | |
| Total M gallons per day | | |

### CARRYING CHARGES - (Annual Cost)

| | |
|---|---|
| 1) Total capital investment less land at 5% for 30 years. Sinking Fund Factor 66.43884750 | $ 5,268 |
| 2) Interest on capital investment (5% bonds) | 17,499 |
| 3) Interest on working capital at 5% | 288 |
| 4) Interest on land at 5% | 25 |
| 5) Insurance | 1,410 |
| 6) Operation and maintenance costs | 107,059 |
| Total yearly fixed costs | $ 131,549 |

### CAPITAL COSTS

| | | |
|---|---|---|
| 1) Cost of unerected desalting equipment | | $ 203,417 |
| 2) Cost of equipment erection | | |
| Mechanical | $ 56,040 | |
| Electrical | 48,000 | |
| Total | 104,040 | $ 104,040 |
| 3) Structures and improvements at $13. per square foot of building area. | | |
| Total square foot area | 1,849 | 24,037 |
| 4) Product water and acid waste water storage reservoir at $10. per square foot area. | | |
| Total square foot area | 1,849 | 18,490 |
| Total depreciable capital costs | | 349,984 |
| 5) Land at $500. per acre | | 500 |
| 6) Working Capital | | 6,789 |
| Total non-depreciable capital costs | | 7,289 |
| Total capital costs | | $ 357,273 |

### INSURANCE COST CENTER

| | | |
|---|---|---|
| FIRE: Total capital cost less land | $ 349,984 | |
| Acid and limestone inventory | 2,182 | |
| Materials and supplies inventory | 1,708 | |
| Total | 353,874 | |
| Fire insurance cost at $0.25 per $1000 insured value | | $ 885 |
| Workmen's Compensation at $2.00 per $1000 wages | | 300 |
| General liability (estimated) | | 200 |
| Product liability at $0.15 per M gals/year | | |
| Total M gals/year | 165 | 25 |
| Total cost per year | | $ 1,410 |

### OPERATING AND MAINTENANCE COST CENTERS

| | | |
|---|---|---|
| 1) Operating and maintenance labor | | |
| Salaries | $ 9,000 | |
| | 6,000 | |
| Total | 15,000 | $ 15,000 |
| 2) Fringe benefits at 7% of wages | | 1,050 |
| 3) General and Administrative expenses at 5% of wages | | 750 |
| 4) Supplies and maintenance inventory at 1% of unerected equipment | | 1,708 |
| 5) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Tons per year | 2,785 | 72,410 |
| Limestone at $7/ton | | |
| Tons per year | 1,668 | 11,676 |
| Resin (15 year life) | | 3,565 |
| 6) Electric (estimated) | | 300 |
| 7) Heating fuel (estimated) | | 500 |
| 8) Laboratory standard test solutions | | 100 |
| Total operating and maintenance costs | | $ 107,059 |

### OPERATING CAPITAL

| | |
|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected desalting equipment | $ 1,708 |
| 2) Labor | 15,000 |
| 3) Fringe benefits at 7% of wages | 1,050 |
| 4) General and Administration expenses at 5% of wages | 750 |
| 5) Heating fuel (estimated) | 500 |
| 6) Electric (estimated) | 300 |
| 7) Laboratory standard test solutions | 100 |
| Total yearly operating capital | 19,408 |
| Monthly working capital requirements | $ 1,617 |

### WORKING CAPITAL

| | | |
|---|---|---|
| 1) Supplies and maintenance inventory at 1% of unerected equipment | | $ 1,708 |
| 2) Chemicals: | | |
| 66° Be' sulfuric acid at $26/ton | | |
| Total tons | 76.5 | 1,989 |
| Limestone at $7/ton | | |
| Total tons | 64 | 448 |
| 3) Monthly working capital requirement | | 1,617 |
| Total working capital requirements | | $ 5,762 |

### RESIN REPLACEMENT REQUIREMENTS (15 YEAR LIFE BASIS)

| | |
|---|---|
| **Weak Acid Cation Resin** | |
| Total cu. ft. x 6.67% = ____ $ft^3$ x $49.90/$ft^3$ = | $ |
| **Strong Acid Cation Resin** | |
| Total cu. ft. x 6.67% = 71 $ft^3$ x $23.00/$ft^3$ = | 1,633 |
| **Strong Base Anion Resin** | |
| Total cu. ft. x 6.67% = 28 $ft^3$ x $69.00/$ft^3$ = | 1,932 |
| Total resin replacement costs/year | $ 3,565 |

FIG. 26
EFFECT OF PLANT SIZE ON POTABLE WATER COSTS

WEBSTER, SOUTH DAKOTA
1082 PPM AS $CaCO_3$ INFLUENT

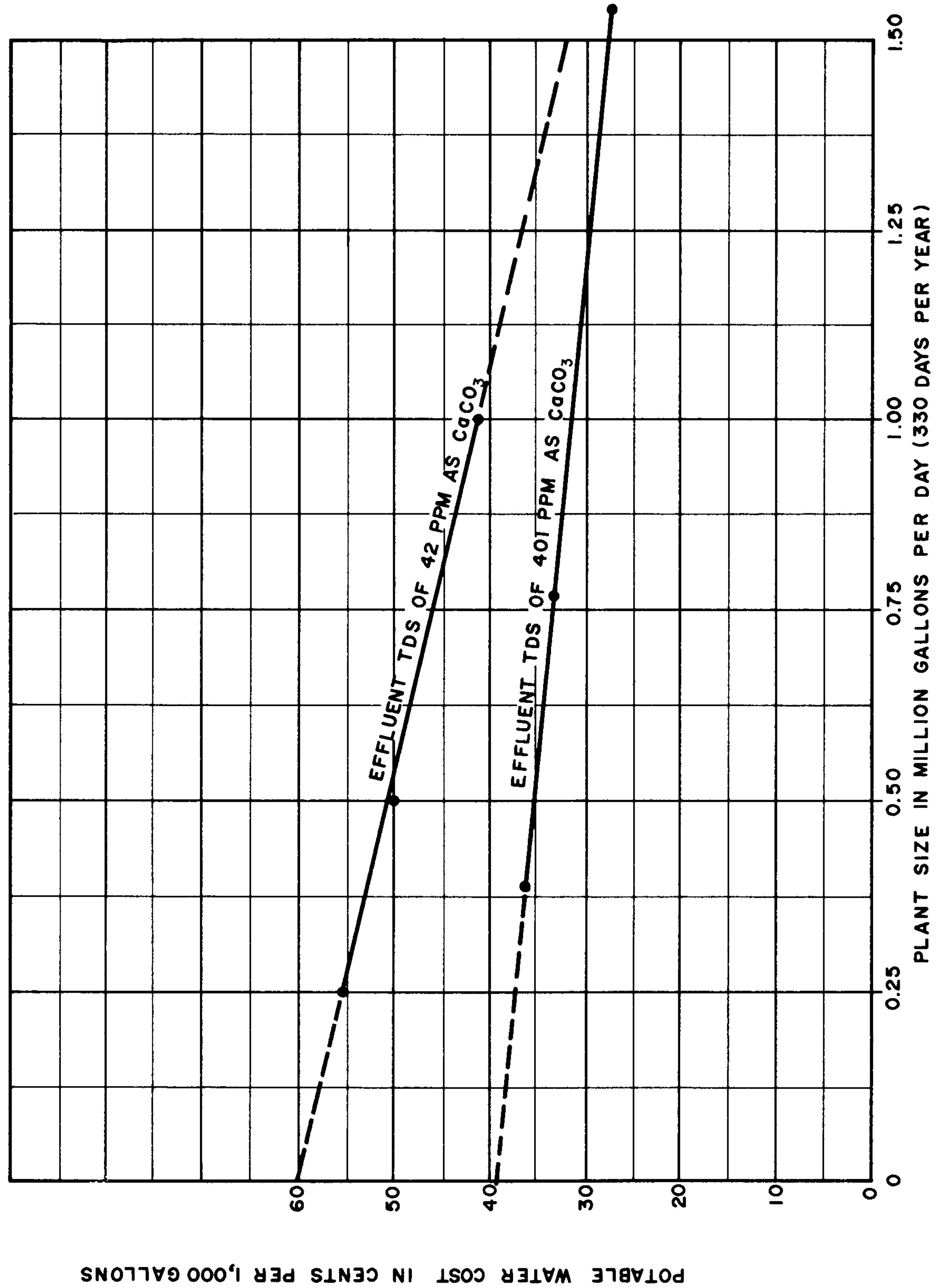


FIG. 27
EFFECT OF PLANT SIZE ON TOTAL DEPRECIABLE CAPITAL COST

WEBSTER, SOUTH DAKOTA
1082 PPM AS $CaCO_3$ INFLUENT

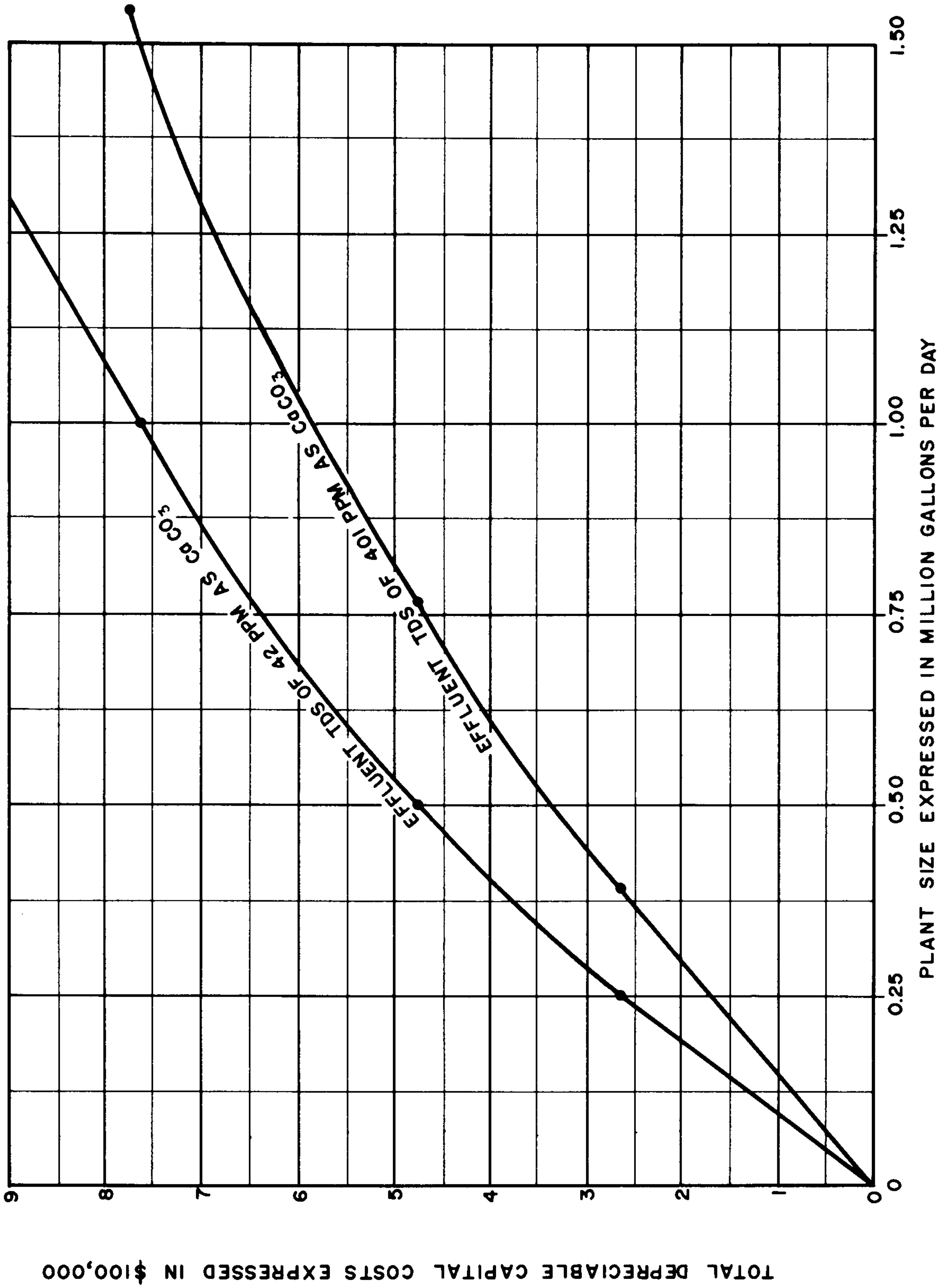
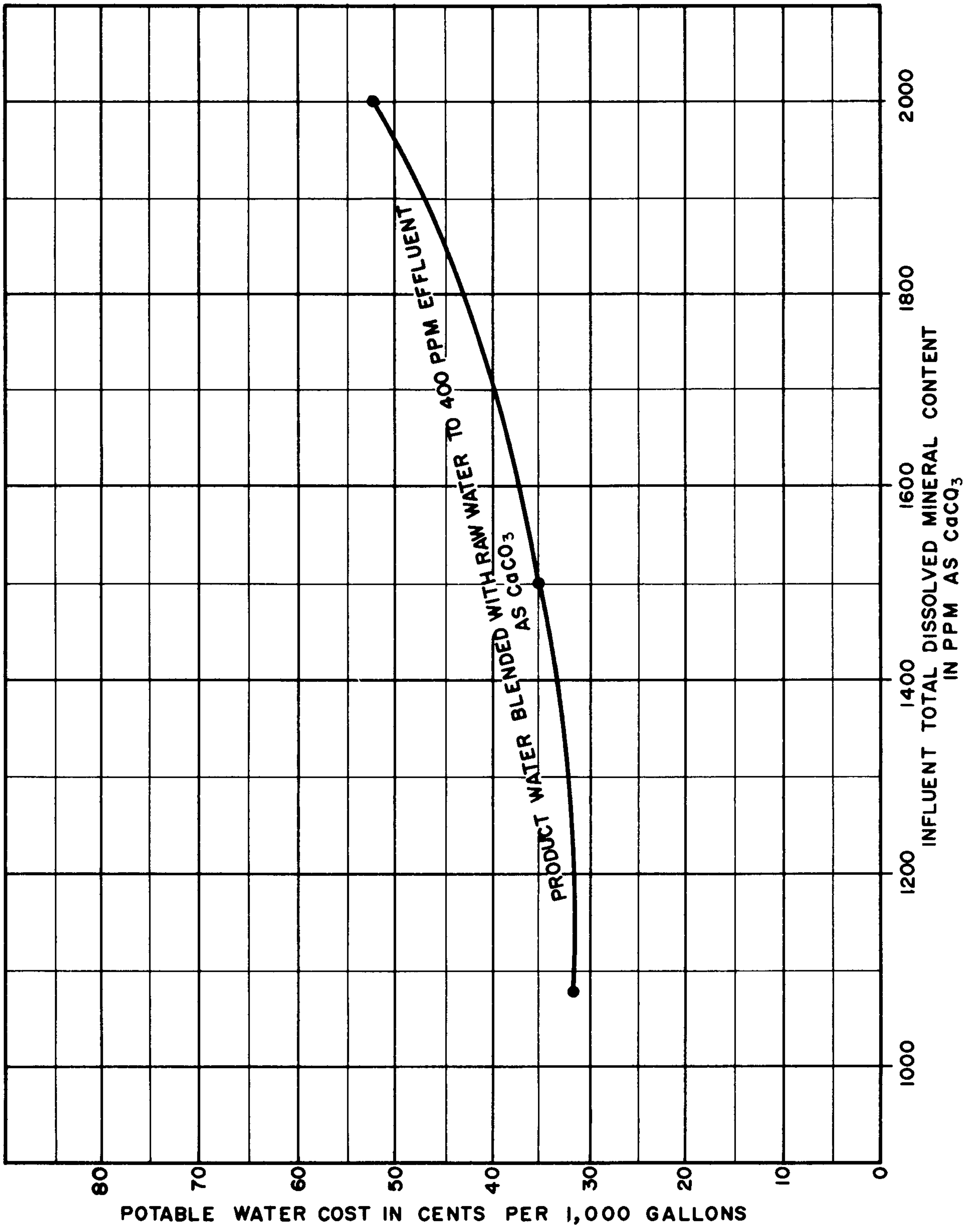
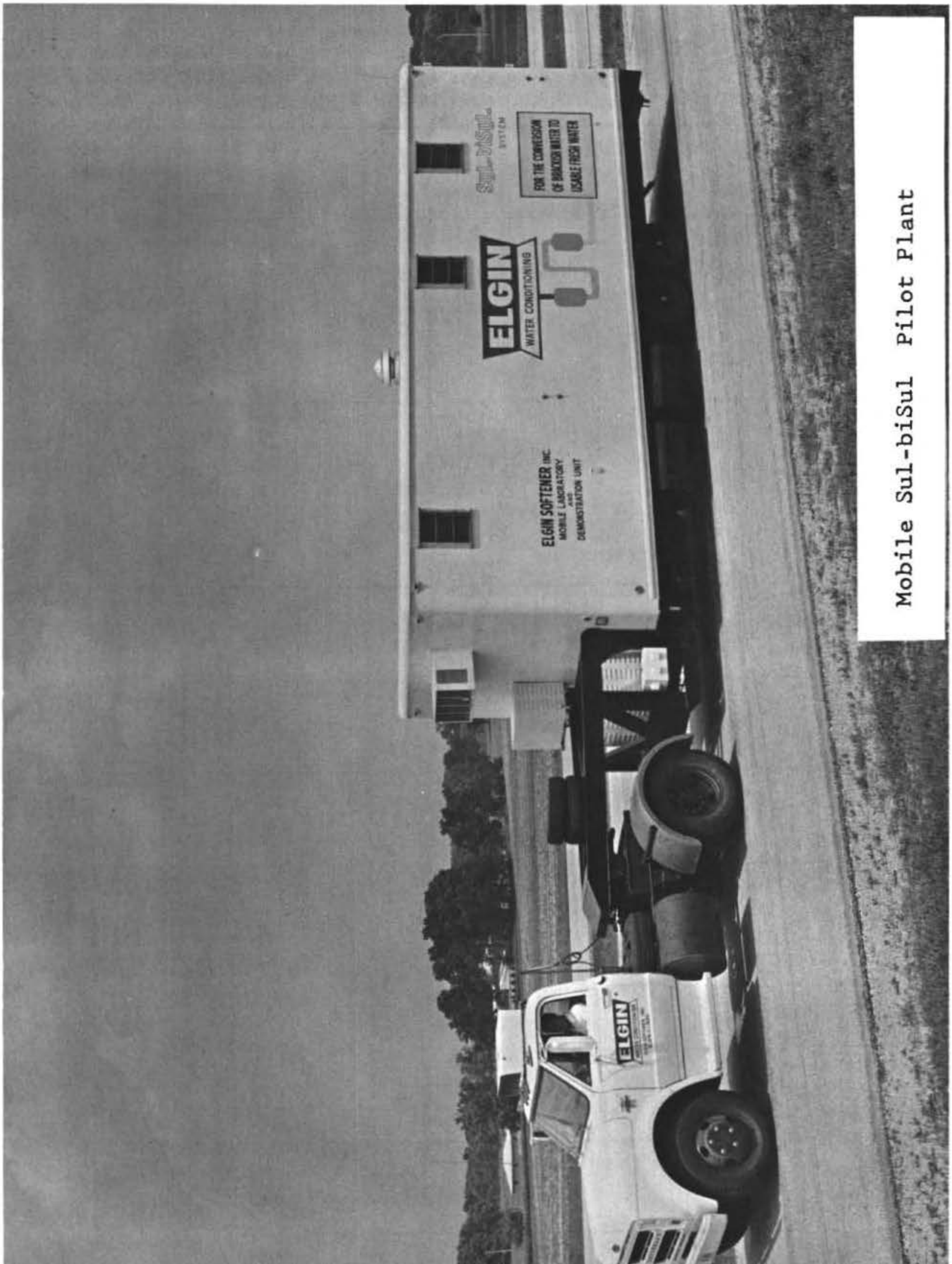


FIG. 28

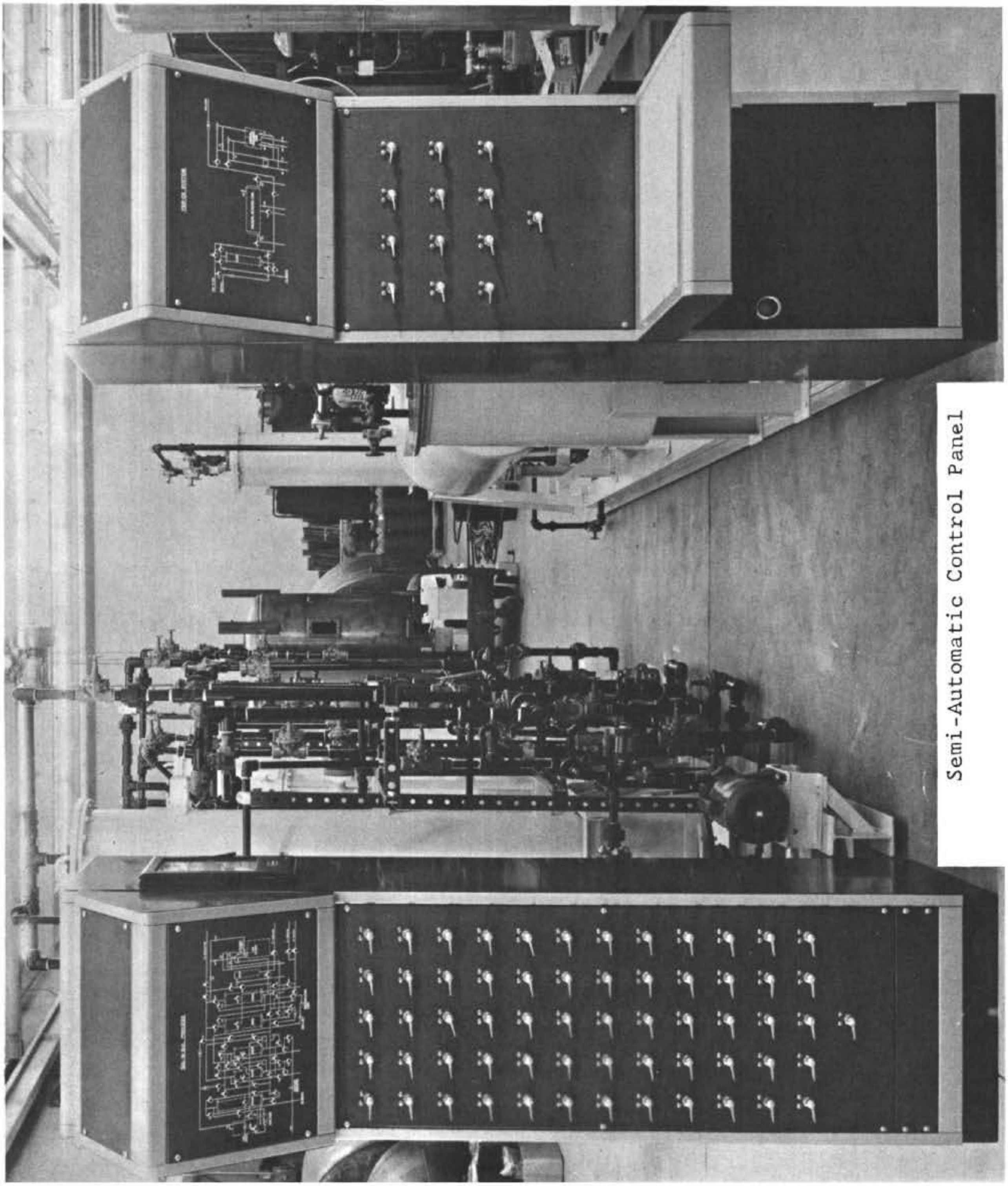
EFFECT OF INFLUENT TOTAL DISSOLVED MINERALS ON POTABLE WATER COSTS

WEBSTER, SOUTH DAKOTA
PLANT SIZE: 1.0 MILLION GALLONS PER DAY





Mobile Sul-biSul Pilot Plant



Semi-Automatic Control Panel



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