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Environmental Protection Technology Series

Industrial Water Softener Waste Brine Reclamation

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February 1974

INDUSTRIAL WATER SOFTENER WASTE BRINE RECLAMATION

By

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Project No. 12120 GLE
Program Element No. 1BB037

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ABSTRACT

Where discharge of brine wastes from water softener regeneration to sewers or receiving streams is undesirable because of possible pollution, there are two alternatives:

1. Hauling the total brine waste.
2. Partial hauling with reclamation and reuse of the brine.

Brine reclamation and reuse has been studied for one year at a central regeneration plant for portable ion exchange water softeners. The process is modified lime-soda softening and is operated in daily batches.

This process produces a 95% sodium chloride brine at 60° Salometer. This is perfectly acceptable for reuse as a regenerant brine. The lime-soda softening sludge is the only waste. The volume of the waste is 11% of the waste brine from which it came. The solids of the sludge are insoluble and can be disposed of in many environmentally acceptable ways.

This process is feasible technically, but is marginal economically. Costs of reclamation are higher for this specific plant, than costs of hauling. The economics will differ for each plant, depending primarily on trucking and disposal fees. Each plant must be given a separate cost study. However, the reduction of salt discharge by 89% clearly indicates the ecologic value of reclamation and reuse.

Though capital expenditures were modest and reclamation operating costs are low, the present space has been found to be larger than is necessary and it is indicated that future study, under the new budget, could reduce capital and operating costs. Further studies into the de-watering of the sludge could make this minimal waste disposal even more environmentally acceptable.

This report was submitted in fulfillment of Project Number 12120 GLE, under the partial sponsorship of the Office of Research and Development, Environmental Protection Agency.

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SECTION 1

CONCLUSIONS

The regeneration of ion exchange water softeners produces a waste brine consisting of the mixed chlorides of calcium, magnesium and sodium. This study demonstrates that a modified lime-soda softening process will remove the contaminating calcium and magnesium and produce a purified brine suitable for immediate reuse.

1. This study has conclusively demonstrated that discharge of soluble wastes from water softener regeneration can be virtually eliminated, thus reducing potential pollution of streams and ground water resources. Discharges of soluble salts to receiving waters are reduced by 89%.

2. This is an almost classic example of immediate recycling of waste material. Within 24 hours the waste brines have been treated and are back in use. Acceptably high levels of purity and concentration are readily maintained.

3. The volume of the untreated waste is shown to be reduced by about 87% by this process. The present waste, a sludge, is hauled by tank truck to a site where the included solubles cannot enter the streams or ground water aquifers of the area. Present knowledge indicates that the sludge could be further concentrated to form a filter cake. It is believed that this could be disposed of as a solid waste.

4. High percentages of salt recovery have been achieved by direct reuse of the brine.

5. All operations, including chemical dosages, have been developed for operation by non-professional people.

6. Recirculation of the reacting chemicals was found to be necessary to assure complete solution and reaction. At the same time sludge solidification was prevented at the bottom of the reactor cone and in the discharge lines.

7. It was found that the addition of both soda ash and lime was

desirable, even though lime was not needed to produce the desired quality in the reclaimed brine. Soda ash alone reduced the concentrations of calcium and magnesium to acceptable levels. Lime did reduce the magnesium concentration, but more importantly, the lime improved sludge settlability, and reduced the acid requirement for subsequent pH adjustment.

8. For this specific plant, current study shows that costs of brine reclamation are significantly higher than are costs for the alternate procedure of hauling wastes to an improved dumping site. However, capital charges are high for this particular plant. Further study could reduce capital charges, labor needs and perhaps chemical usage.

   Considering the costs for regenerating the water softeners (salt, water, waste disposal), the following conclusions apply.

   A. Chemical costs are about 10% less when the wastes are reclaimed than when the wastes are hauled. That is, the added costs for lime and soda ash are less than is the value of salt and water reclaim by their use.

   B. Depreciation costs for building and equipment at <u>this</u> location with <u>this</u> equipment are about 55% less than the separate chemical costs for regeneration and waste disposal.

   C. Hauling costs for sludge disposal are about 32% of similar costs for hauling waste brine in the alternate procedure.

   D. The additional operating, non-technical, labor costs are about 69% as large as the separate chemical costs for regeneration and waste disposal.

   E. The comparable <u>partial</u> costs for regenerating each water softener are as follows:

\$0.165	discharge all waste to sewers
\$0.137	discharge 70% of waste to sewers, reuse 30%
\$0.243	haul 70% of waste, reuse 30%
\$0.305	reclaim 90% of waste, haul 10%

9. The reduction in waste volume and in the amount of waste soluble salts makes this process more environmentally acceptable than total haulage of brine.

10. For this specific plantthere is no marked daily variation in

chemical dosage requirements.

SECTION 2

RECOMMENDATIONS

The information obtained from this project should be disseminated. The technical and economic conclusions should be considered where disposal of untreated water softener waste brines can adversely affect the environment.

The present plant has been most successful. With no changes, it can continue in operation at its present location. Dealer personnel have been trained and can operate the plant. After all projects are completed, the present plant should be turned over to the Riverside Dealership, on terms acceptable to the Dealership and to the Government.

Although the present study shows that brine reclamation is technically feasible, further study is indicated in the following areas:

AREA 1: The present waste is a watery sludge. It must be transported to an acceptable discharge point. Truck operating costs and dumping fees are major items in the costs of brine reclamation.

If the sludge could be de-watered to form a cake, it could be handled as a solid waste.

It is recommended that development of a method for complete de-watering be carried out at the present site by present personnel.

AREA 2: Dosages of soda ash were determined, for each batch, by chemical analysis. As an extension of this present project, dosages based on pH changes should be studied. If dosages based on pH changes produce results equal to those based on analysis, the process would be simplified from the present manual type of operation and would be preliminary to the development of a continuous process.

It is recommended that this study be carried on at the present site and with present personnel.

AREA 3: The present batch process requires three tanks of 3000 gallons capacity each. This large volume of storage increases costs of building and equipment.

Continuous operation would reduce the space requirement and by reducing labor could reduce operating costs.

To operate continuously, two conditions must be met. The first is that lime and soda ash feeds must be matched to the flow rate of the brine and to the concentrations of calcium and magnesium in the waste brine.

The second condition is to remove, continuously, the precipitated calcium carbonate and magnesium hydroxide.

There are strong indications that chemical dosage can be adjusted by a pH controller. Rapid separation of the solids from the liquid brine is another matter. However, Laminar flow separation, centrifugal separation, and a sludge blanket modification merit preliminary investigation.

Continuous operation can be studied at the present site by present personnel. An extended project will be necessary with some added equipment needed. It is recommended that this study be undertaken with full governmental cooperation.

AREA 4: The present study showed little daily variation in soda ash dosage. Lime dosage was constant from day to day. It is expected that in some areas the daily variation will be marked.

This daily variation in dosage rates could be studied as a possible alternative to chemical analysis and/or pH changes for control of chemical dosages.

However, another location is suggested as a site for this study.

AREA 5: Since the present study showed little variation in chemical dosage per gallon, it is quite possible that a simple feeder (for mixed lime and soda ash) actuated and controlled by a pacing meter could produce satisfactory results.

This could be studied at the present site by present personnel. Some modification of present equipment would be required. Additional equipment would need to be purchased.

It is recommended that this dosage control method be studied.

AREA 6: The present study shows that brine reclamation does reduce discharge of salt to the environment; it also shows that it is expensive. No effort was made during the study to develop more efficient chemical handling or other techniques for labor reduction. Approximately 45% of the costs for reclamation are labor costs.

Therefore, it is recommended that study be continued to reduce labor costs.

SECTION 3

INTRODUCTION

Ion exchange water softeners are regenerated with sodium chloride brine, usually at a strength of 40 to 60 degrees salometer (^{o}S) which corresponds to 10-16% sodium chloride by weight.

A sufficient excess (180 to 220%) of sodium chloride above the stoichiometric equivalent is required to produce an equilibrium favorable to hardness ion elution. The effluent from this recharge will be a solution of mixed sodium, calcium and magnesium chlorides.

Normal regeneration techniques are such that the effluent can be conveniently separated into three fractions:

1. Rinse waters low enough in salt to be discharged in the most convenient manner without risk of damage to the environment.

2. Brines high enough in concentration to produce risk of damage to the environment if discharged without treatment. These brines are usually mixed chlorides of calcium, magnesium and sodium.

3. Final rinse water, low in hardness but containing salt. This need not be discharged. After reconstitution with fresh salt, it can be used for regeneration. This reduces salt discharged and effects a small salt saving.

For this study, only fraction number 2 is under consideration. It cannot be reused for regeneration, even though it contains a large excess of sodium chloride, because the high concentrations of hardness ions make it ineffective.

This fraction contains the largest portion (about 90%) of the soluble salts and because of this is sometimes thought to be a hazard to the environment if it is discharged without modification or control.

Fraction number 2 can be disposed of by hauling to approved dumping sites. However, this is expensive. Removal of calcium and magnesium from the waste regenerant permits its reuse. Lime-soda softening was used in this study to selectively remove calcium and magnesium ions from this waste brine.

Hydrated lime (calcium hydroxide or $Ca(OH)_2$) and soda ash (sodium carbonate or Na_2CO_3) are normally used as chemicals for the precipitation of hardness (magnesium and calcium) ions. These chemicals do not react with the sodium chloride.

Magnesium chloride will react with the lime to precipitate insoluble magnesium hydroxide to form an equivalent amount of calcium chloride as illustrated in the equation:

$$MgCl_2 + Ca(OH)_2 \longrightarrow \underline{Mg(OH)_2} + CaCl_2 \qquad (1)$$

The calcium chloride formed in this reaction reacts with soda ash as does the calcium chloride in waste brine. This forms an insoluble precipitate of calcium carbonate. The reaction forms an equivalent amount of sodium chloride as is illustrated in the equation:

$$CaCl_2 + Na_2CO_3 \longrightarrow \underline{CaCO_3} + 2\ NaCl \qquad (2)$$

Equations (1) and (2) can be written together to illustrate two reactions which take place simultaneously, equation (3):

$$MgCl_2 + CaCl_2 + Ca(OH)_2 + 2\ Na_2CO_3$$

$$\longrightarrow 4NaCl + \underline{2CaCO_3} + \underline{Mg(OH)_2} \qquad (3)$$

Shown here is the net effect, which is to convert calcium and magnesium chlorides to an equivalent amount of sodium chloride plus insoluble precipitates. Removal of the insoluble precipitates allows the sodium chloride to be reused for the regeneration of softeners.

The use of solutions for chemical feed would add excessive amounts of water, which would dilute the reclaimed brine below the desired concentrations. Subsequent reconstitution to the desired strength would result in more brine than was needed for regeneration. Therefore, chemicals must be fed in the dry state.

This application of lime-soda softening was not studied in depth prior to this project.

Theoretical studies and small scale practical studies indicated that the process was technically feasible and economically interesting. Factual data were lacking. Therefore, the project was undertaken to establish full scale feasibility and cost data.

SECTION 4

OBJECTIVES

The objectives of the present study were as follows:

1. Establish a plant to apply the lime-soda softening process to the waste brine from the regeneration of ion exchange water softeners.

2. Optimize the process by actual operation, and to determine the detailed performance of the process.

3. Demonstrate the process over an extended period to determine its economic feasibility and to determine its usefulness in reducing waste discharges to the environment.

SECTION 5

METHOD

BUILDING AND EQUIPMENT

For this project, the facility for regenerating portable ion exchange softeners at Riverside, California was chosen.

As part of the project, a building addition 30' x 25' x 17'-4" (LWH) was planned and built. A part of this construction was a permanent reclaimed brine storage tank. This was below floor level and built to contain 4000 gallons (11' x 8' x 6').

The equipment included a waste brine recovery tank, and a reaction tank with a conical bottom. Auxiliary equipment included piping, chemical conveying, and feeding equipment. All controls were manually operated for full flexibility. Figure 1 is a flow diagram showing the dimensions of the various tanks, the pipe sizes and the capacities. Figures 2 through 9 are pertinent photographs of the plant, showing components and analytical facilities. Chemical analyses were important for process control and evaluation.

An obsolete oil tank truck was used to carry the waste sludge to the disposal pond maintained by the City of Riverside.

Chemicals were stored within the building addition.

Two major changes were made to the equipment during optimization. The first was to rearrange the piping so that the sludge transfer pump could be used for mixing by recirculation. The second was to install a single large pipe for decanting the clear, reclaimed brine. These changes will be discussed later in this section.

Only minor modification of the existing equipment of the regeneration plant was required to deliver the regenerant waste brine to the waste brine storage tank.

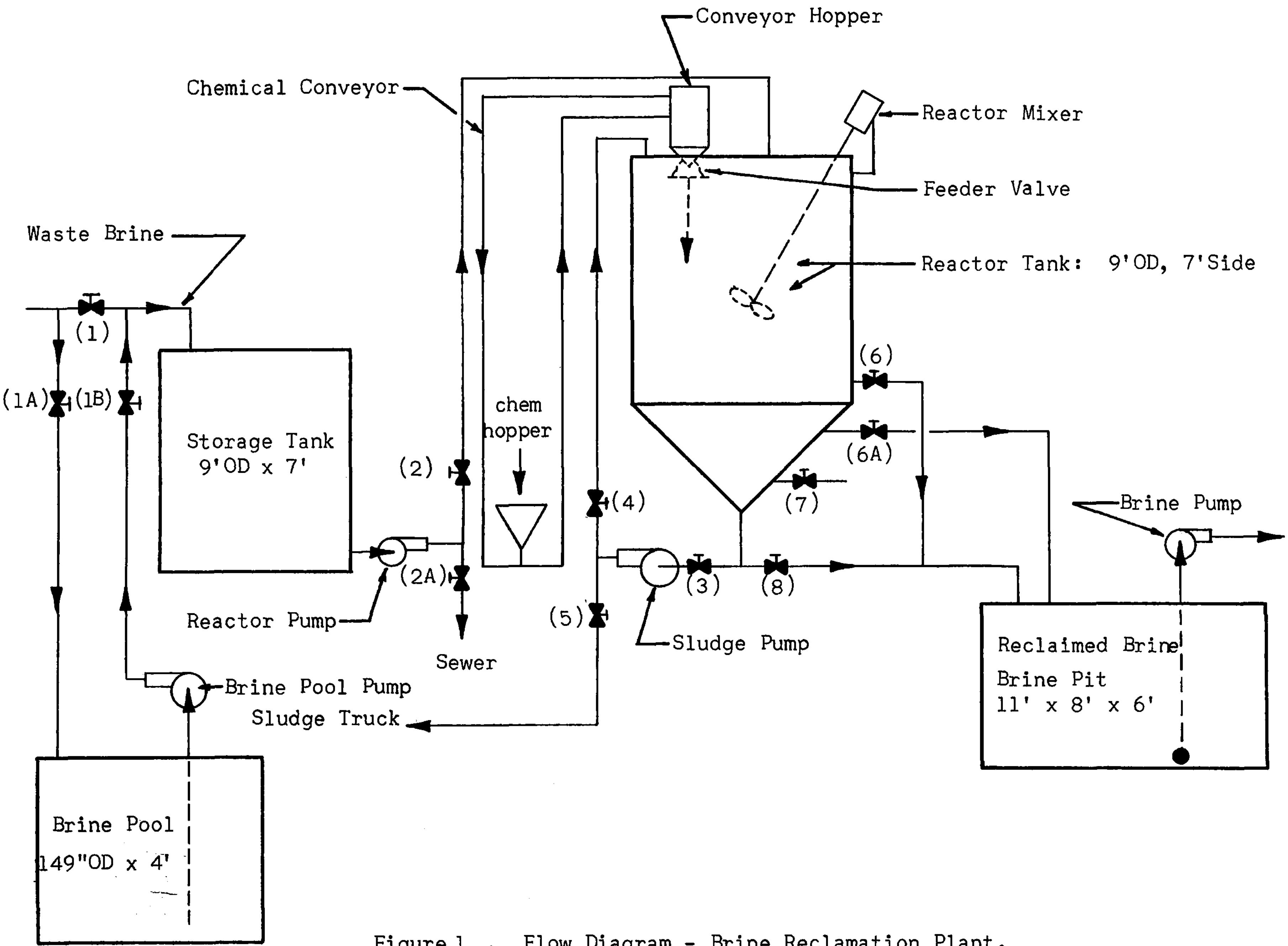

Figure 1 . Flow Diagram - Brine Reclamation Plant.

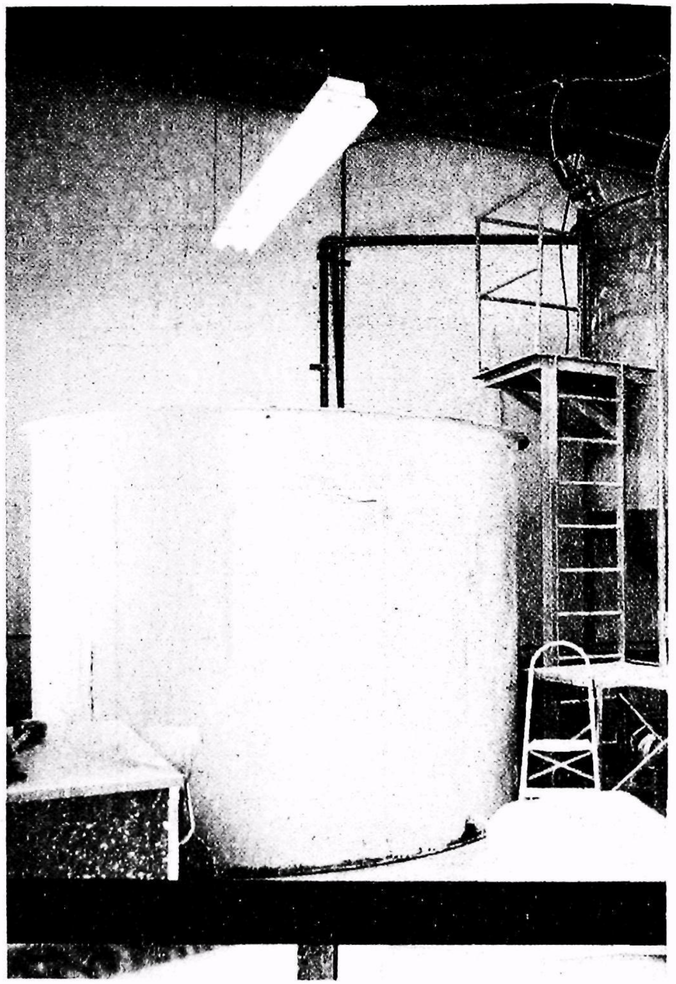

Figure 2. Storage Vessel

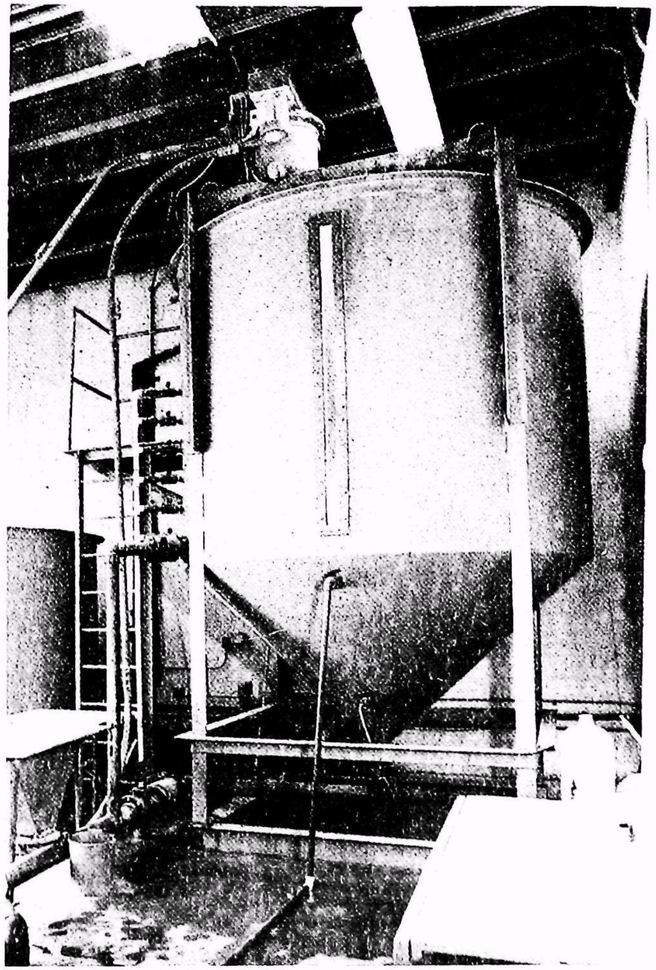

Figure 3. Reactor Tank

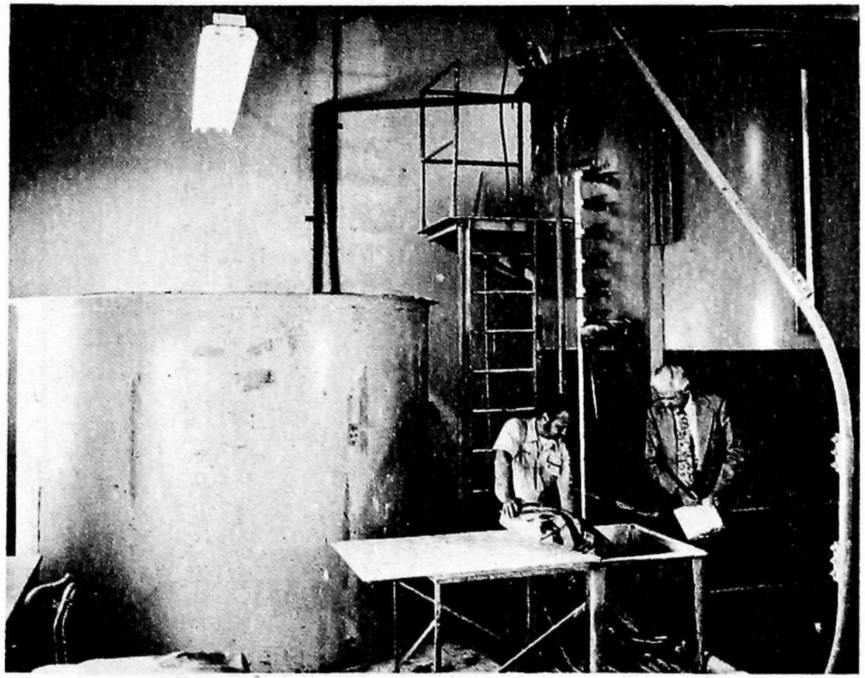

Figure 4. Addition of Chemicals to Conveyor Hopper

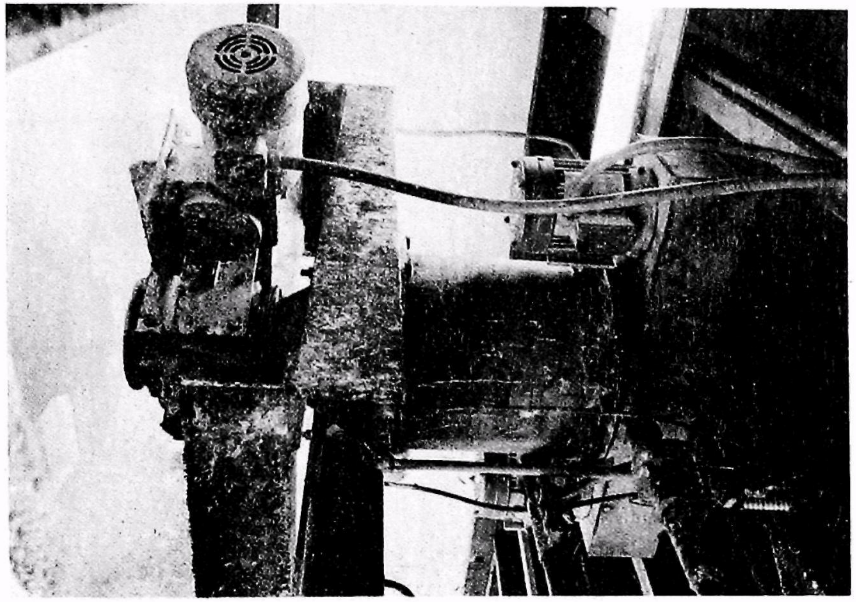

Figure 5. Chemical Feeder on Top of Reactor

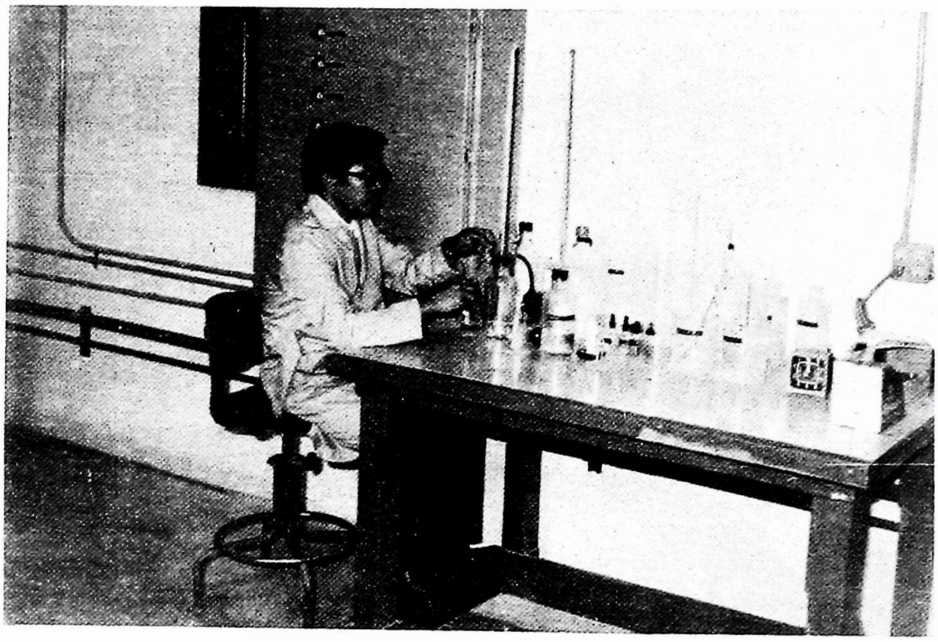

Figure 6. Chemical Analysis Section

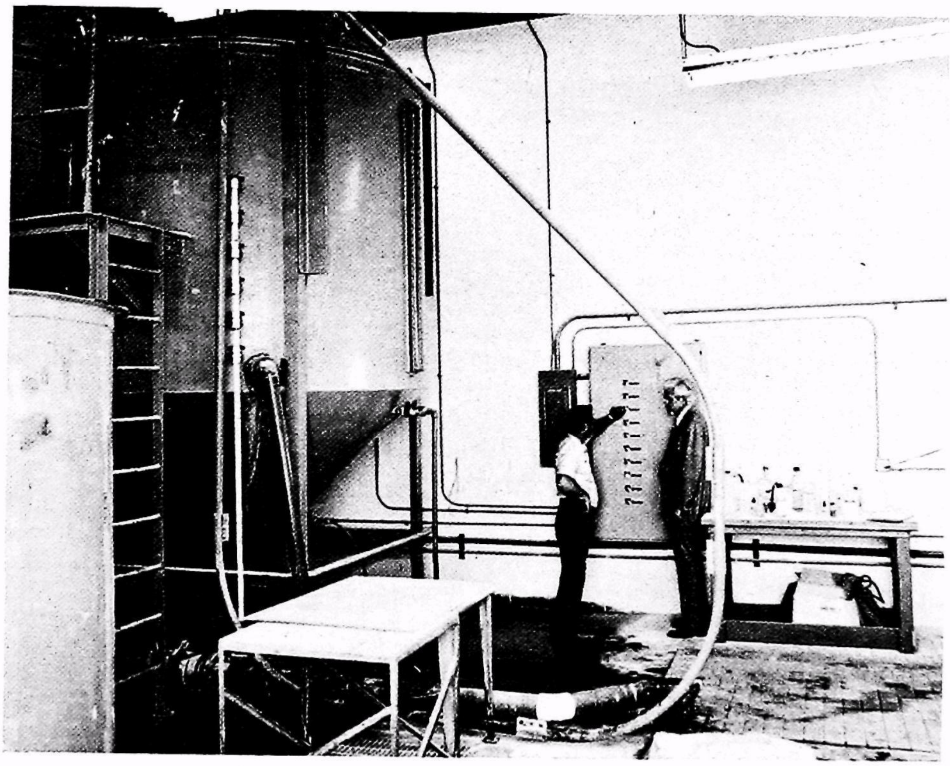

Figure 7. Electrical Control Panel

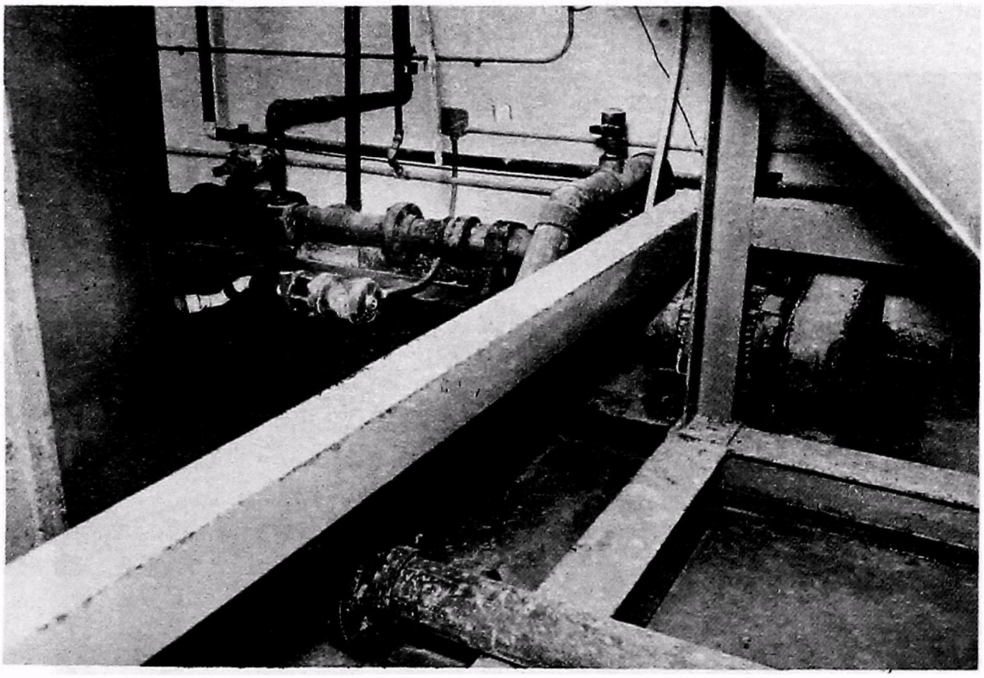

Figure 8. Sludge and Brine Transfer Equipment

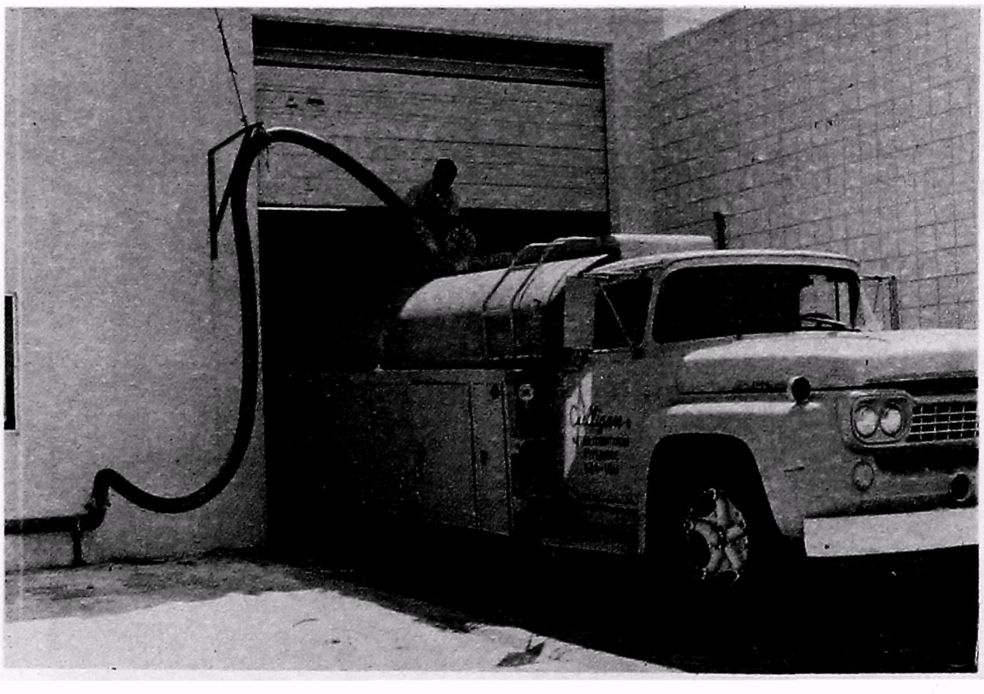

Figure 9. Sludge Discharge to Tank Truck

PROCESS OUTLINE

Large quantities of salt are used for the regeneration of portable ion exchange water softeners. The regeneration effluent is usually discharged to the city sewerage system or other convenient receiver. It is thought by some that this salt has a deleterious effect on the environment. In order to fully discuss the utility of the present study, an outline of the ion exchange softener process is in order.

Hard water is water which contains calcium and magnesium ions. Some other metallic ions can cause water to be hard, but their presence in natural waters is rare.

The ions of calcium and magnesium react with soap to form insoluble salts. These insolubles are inherently undesirable. In addition, the hardness in water wastes soap uselessly, because all of the hardness must be removed by reaction with soap before cleaning can proceed. This is an inefficient way to soften water (to remove the hardness).

There are several ways to remove hardness but for many reasons ion exchange is most convenient for home softening. Ion exchange is also used in many large municipal hardness reduction plants and for softening water for industry.

There are many substances which exhibit ion exchange properties. Only one or two have sufficient capacity for exchange along with other properties which make them suitable for use in softeners. One is inorganic zeolite and the term, "Zeolite" has become almost generic for ion exchange substances. The other is an organic resin. The hardness removal reactions of both materials are similar. In discussing these reactions, the letter "Z" will be used as a symbol for the ion exchange material.

Also for convenience, only the symbol for calcium (Ca) will be used because magnesium (Mg) will react similarly. Chloride ions are also present and will be represented by the chemical symbol for chlorine (Cl.)

Sodium ions do not react adversely with soap. "Na" is the symbol for sodium, while NaCl is the formula for sodium chloride used to regenerate the ion exchanger.

$$CaCl_2 + \underline{Na_2Z} \longrightarrow 2NaCl + \underline{CaZ} \qquad (4)$$

This can be read, "Calcium chloride in water reacts with sodium zeolite to form sodium chloride in water and calcium zeolite". The influent water containing calcium chloride is hard - due to the calcium - while the effluent water, containing an equivalent amount of sodium chloride, is soft.

Obviously, when the zeolite has given up all the sodium it contains, it can no longer soften water. It is then said to be exhausted. Practical considerations do not permit complete utilization of the capacity. The lesser usable capacity is obtained when the effluent water contains hardness in an amount equal to a small fraction of the influent hardness. The zeolite can be regenerated or recharged. The equation for recharge is as follows:

$$\underline{CaZ} + 2NaCl \longrightarrow \underline{Na_2Z} + CaCl_2 \tag{5}$$

It will be noted that equation (5) is exactly the reverse of equation (4). The reaction represented by equation (4) occurs in very dilute solution where the zeolite "prefers" calcium to sodium.

At high concentrations, the calcium/sodium preference is reversed. This "forces" the sodium onto the zeolite and "forces" the calcium from the zeolite. To further force the regeneration, excess salt is applied. In portable softeners, high capacities are desired to reduce the regeneration frequency. Thus, 15 pounds of salt are used for each cubic foot of ion exchanger. Only 5 pounds are theoretically needed. The unused 10 pounds are no longer useful because of the calcium and magnesium contaminants.

Since the contaminants in the waste brine are hardness, their removal requires a softening process. Lime-soda softening is probably the oldest method of softening. Prior to this project, preliminary bench tests were made using lime-soda softening. The process was found to be technically possible, however, simple arithmetic showed it to be economically impractical. Later, interest revived because of the possible need for environment protection. Pilot plant tests were made using 10 portable exchange units per day. Again it was found that the process worked, but was expensive.

Pressures by various public agencies to reduce salt wastes discharged to the environment resulted in the present study. The process uses these steps:

1. Waste brine storage.
2. Volume measurement, chemical analysis and transfer of waste to reactor.
3. Determination of chemical dosage.
4. Feed of lime and soda ash to brine in the reactor.
5. Agitation.
6. Sedimentation.
7. Decantation of clear brine.

8. Sludge draw-off.

9. pH and concentration adjustment of the purified brine.

10. Storage of purified brine.

11. Reuse of purified brine.

Each of these steps will be discussed.

Waste Brine Storage was in a steel open top tank of approximately 3000 gallon capacity. This volume was chosen since it readily accommodated the waste produced in one day. The tank was lined with an epoxy coating to reduce the corrosion which would otherwise result from contact with the brine.

Volume Measurement was accomplished by means of calibrating the waste brine-storage tank. Transfer was with a motor driven centrifugal pump. Waste brine analysis, along with its volume, determined the chemical dosage. The calcium and magnesium concentrations were determined by an EDTA (versenate) titration. Density expressed in degrees salometer was a part of this analysis. pH was determined by a pH meter.

Chemical dosages, originally projected to be 100% of theoretical, were determined by stoichiometric methods based on this equation:

$$CaCl_2 + MgCl_2 + Ca(OH)_2 + 2Na_2CO_3 \longrightarrow 4NaCl + \underline{2CaCO_3} + \underline{Mg(OH)_2} \qquad (6)$$

During optimization it was found that satisfactory results could be obtained by dosages of soda ash at 83-89% of theoretical and of lime at 63-72% of theoretical.

Lime and soda ash were fed in the dry state. The additions were made with a pneumatic conveyer and a vane type feeder. The chemicals were added gradually to the brine in the reaction tank to prevent caking. The contents were agitated constantly by means of a propeller type stirrer. During optimization, it was found that recirculation was also required.

The reaction between the chemicals was very rapid but solution of lime and soda ash was slow. This slow solution rate required slow feed of chemicals and rapid agitation. As the reaction proceeded, the contents of the reactor became noticeably thicker and much whiter due to precipitates that formed. The suspension closely resembled whitewash in appearance and in chemical composition.

After one hour of stirring, the reactor and its contents were allowed to remain static overnight. Good settling occurred with the supernatant brine clear enough (20 Jackson Turbidity Units--20 JTU) to draw off and neutralize. Neutralization was needed because the product brine from the reactor had a pH of about 9. Brine for softener regeneration must be below pH 8.3. The neutralization was accomplished by adding a measured quantity of hydrochloric acid (HCl) to the reclaimed brine during decantation.

The decanted brine was slightly below the desired strength of 60°S. Reconstitution was easily accomplished by adding a small quantity of 100°S brine which was available from the brine saturator of the regeneration plant. Use of data from the Brine Table of Appendix F permitted calculation of the adjustment. This is explained in Appendix D, Section VI.

The sludge was allowed to accumulate for three days. This produced a denser more grainy particle. It was pumped at three day intervals into a tank truck and removed to a dump pond provided by the City of Riverside.

PROCESS OPTIMIZATION

There were two basic objectives for optimization. First, determine the most effective use of chemicals to provide brine of acceptable purity. Second, determine methods for producing a dense sludge which would readily separate.

It has been accepted by the industry that chloride brines, which contain a minimum of 95% sodium (based on total cations) will be suitable for regeneration purposes.

Further, experience has shown that the pH must be below 8.3. This assures the absence of carbonate which would precipitate calcium and foul the exchange material. For this study, the range of 6.5-8.0 was arbitrarily set.

Material balances dictate that water should not be added during the reclamation process. Therefore, lime and soda ash were handled and fed as a dry powder.

In order to produce a brine of acceptable purity which would require minimal amounts of acid for pH adjustment, it was important that the precipitate separate readily from the supernatant brine. Efficient settling also eliminated the need for filtration.

Appendix A provides a record of the 48 test runs made during optimization. Variations were made in chemical dosage, agitation and sludge retention. The chemical and physical characteristics of the brine and sludge were entered for each run.

The remarks on each test data sheet show the variations of conditions for the runs and often provide qualitative comment on the success or failure of the procedure and the effect of change.

The first variations were with chemical dosages with the effort directed toward determining minimum dosages to produce maximum, at least acceptable, brine purity.

The time and nature of agitation was studied concurrently with varying dosages. It was observed during the first five or six test runs that sludge recirculation, during chemical addition, was necessary to prevent unreacted chemicals from caking and accumulating in the sludge drain pipe at the bottom of the reactor vessel. Piping was modified to recirculate the reactor contents along with the sludge, through the sludge discharge pump, back to the top of the reactor. Unreacted chemicals and sludge caking were thereby avoided.

The reactor was designed for brine decantation at several points on the side sheet. These were 1" outlets individually valved into a 4" line. This allowed decantation of the treated brine at several levels. This flexibility was found unnecessary. Also, the small outlets resulted in slow decantation. To reduce this time, a single 3" decanting outlet was installed at the bottom of the side sheet. This allowed ample room above the settled sludge. Decanting time was 20 minutes with the 3" outlet as compared to 90 minutes with the multiple openings.

The original plan was to decant the brine, and drain the sludge after each cycle. However, it was found that sludge accumulation was desirable. Test Runs 15 and 16 were the first effort to accumulate sludge. The total volume of sludge discharged for both runs was 900 gallons. All previous runs had discharged 700-900 gallons of sludge each.

Accumulation for three cycles and for four cycles was also tried. Three cycles accumulation was chosen as optimum because the 900 gallons which accumulated was easily hauled and there was ample room in the conical bottom of the reactor tank for the sludge. More cycles tended to overfill the cone, while fewer resulted in excess hauling.

The reduced sludge volume with three cycle accumulation was partly due to loss of water from the highly hydrated precipitates and partly due to nucleation. It is postulated that the already precipitated materials provided sites for new precipitation, resulting in larger sludge particles.

The discharged sludge was transferred to a tank truck for transportation to the approved dumping site. Discharge of sludge from the truck at the site was slow and incomplete. Therefore, the tank truck was modified to allow faster discharge. The discharge gate valve was changed from 4" to 8", while the bottom holes of the internal baffles were enlarged. These changes were made after optimization and during the demonstration portion of the project.

The program for determining optimum chemical dosage was executed in two stages: empirical plant tests, and laboratory bench tests. In the plant, the first nine runs applied dosages of soda ash in varying proportions ranging from 100% to 75% of theoretical. The dosage of lime remained constant at 150 pounds (83-99% of theoretical). Higher soda ash dosages tended to produce higher brine purities. However, since 95% brine purity was acceptable, 83-89% of theoretical was empirically established. Soda ash dosages of less than 85% left too much hardness in the brine: dosages greater than 89% were unnecessary.

Use of soda ash alone was tried during Runs 10-14. Even with 100% of the theoretical application of soda ash, the brine purity was only 94%. This comment was made on the data sheets, "The sludge was observed to be bulky and somewhat gummy in texture". With these results in mind, use of soda ash alone was abandoned until later.

Because of the convenience of using soda ash only, test Runs 32-36 utilized no lime. Low purities again resulted: the sludge was bulky and gummy: larger than normal acid amounts were required for pH control. Once again, it was shown that hydrated lime was desirable.

Theoretically, soda ash alone should reduce the magnesium concentration to acceptable (for this process) levels, but it did not seem practical for this project. Analyses of the reclaimed brine showed nearly zero calcium content and high, slightly reduced, magnesium content, with a high pH. The high pH being due to soluble magnesium carbonate ($MgCO_3$). The OH ion of the lime is required to precipitate the magnesium, and reduce the pH according to the following reaction.

$$MgCO_3 + Ca(OH)_2 \longrightarrow \underline{Mg(OH)_2} + \underline{CaCO_3} \qquad (7)$$

Figures 10, 11 and 12 show relationships of pH and chemical use to acid quantities needed to adjust the reclaimed brine to pH 8.0 or lower. The importance of low pH reclaimed brine is graphically illustrated in Figure 10. All test runs were applied to develop this curve. Obviously, lower pH before adjustment requires less acid for pH adjustment.

Figure 11 shows the acid requirement when soda ash alone was used. Notice again that the acid is measured in gallons. None of the adjusted brines had a pH below 10.1 so that all required 2-3 gallons of 30% hydrochloric acid.

Figure 12 shows acid requirement when soda ash and lime are added in the amounts chosen as optimum.

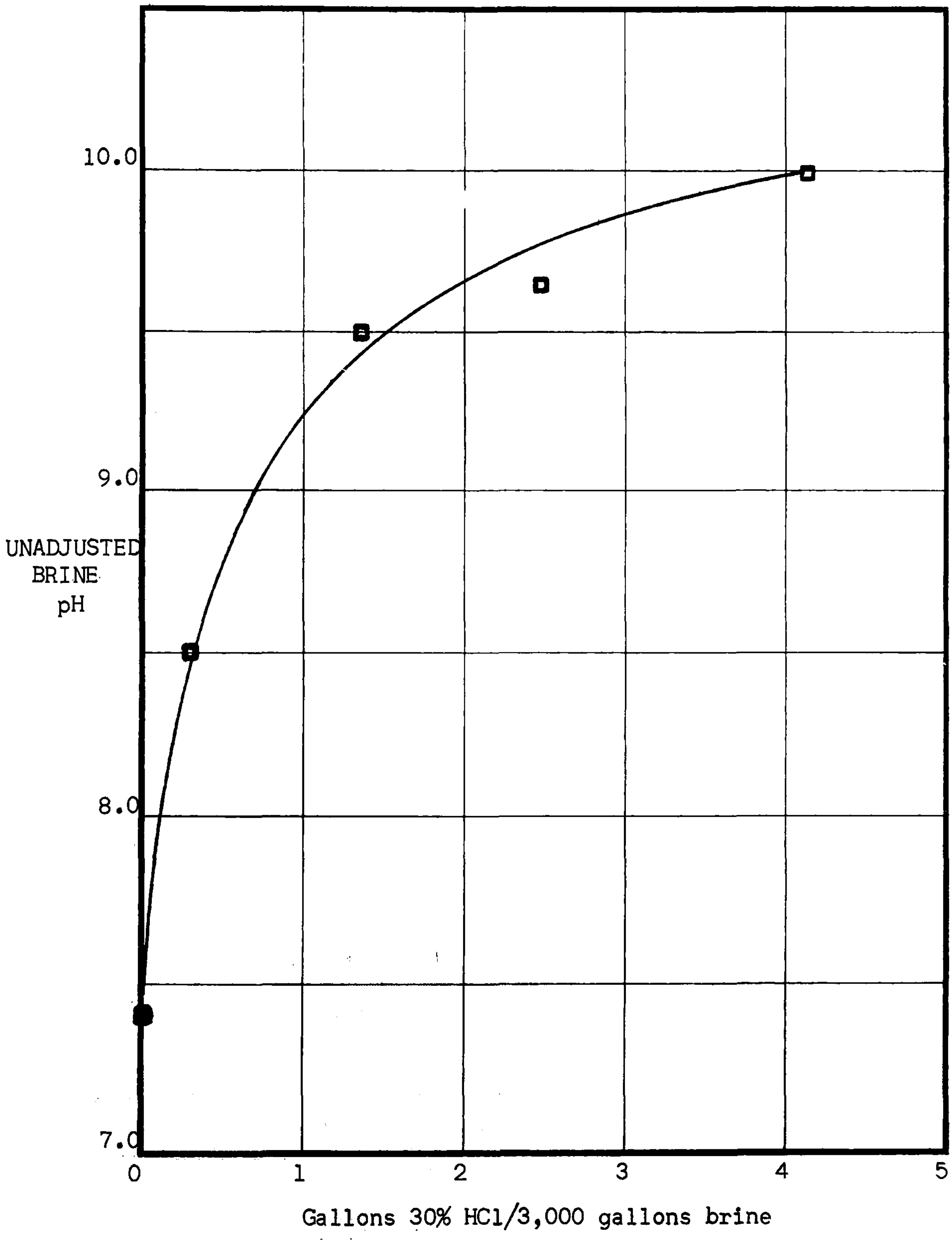

Figure 10. Amount of Hydrochloric Acid to Adjust Brine pH to 6.5-8.0. Various dosages of lime and soda ash used for treatment.

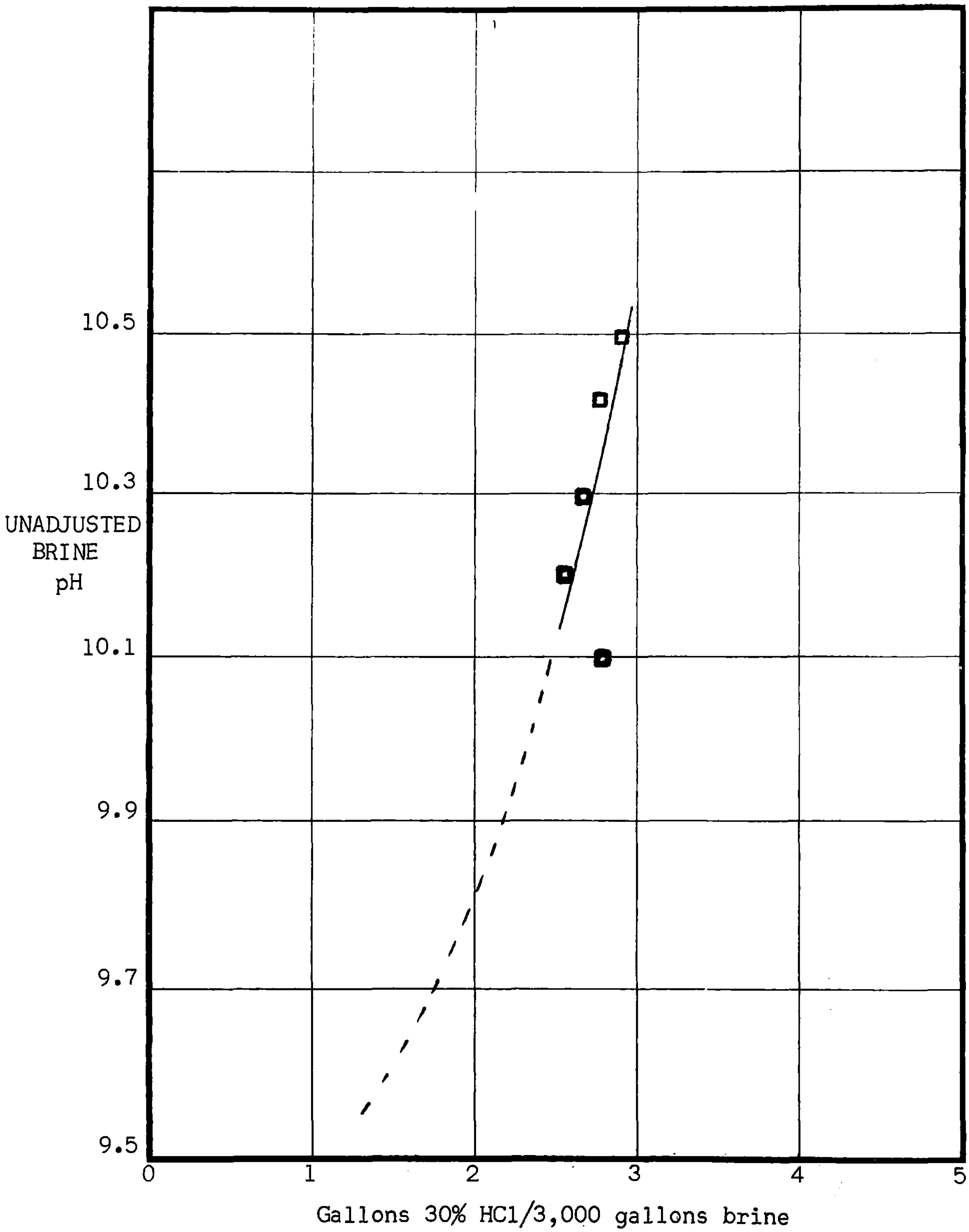

Figure 11. Amount of Hydrochloric Acid to Adjust Brine pH to 6.5-8.0. Soda ash only used for treatment.

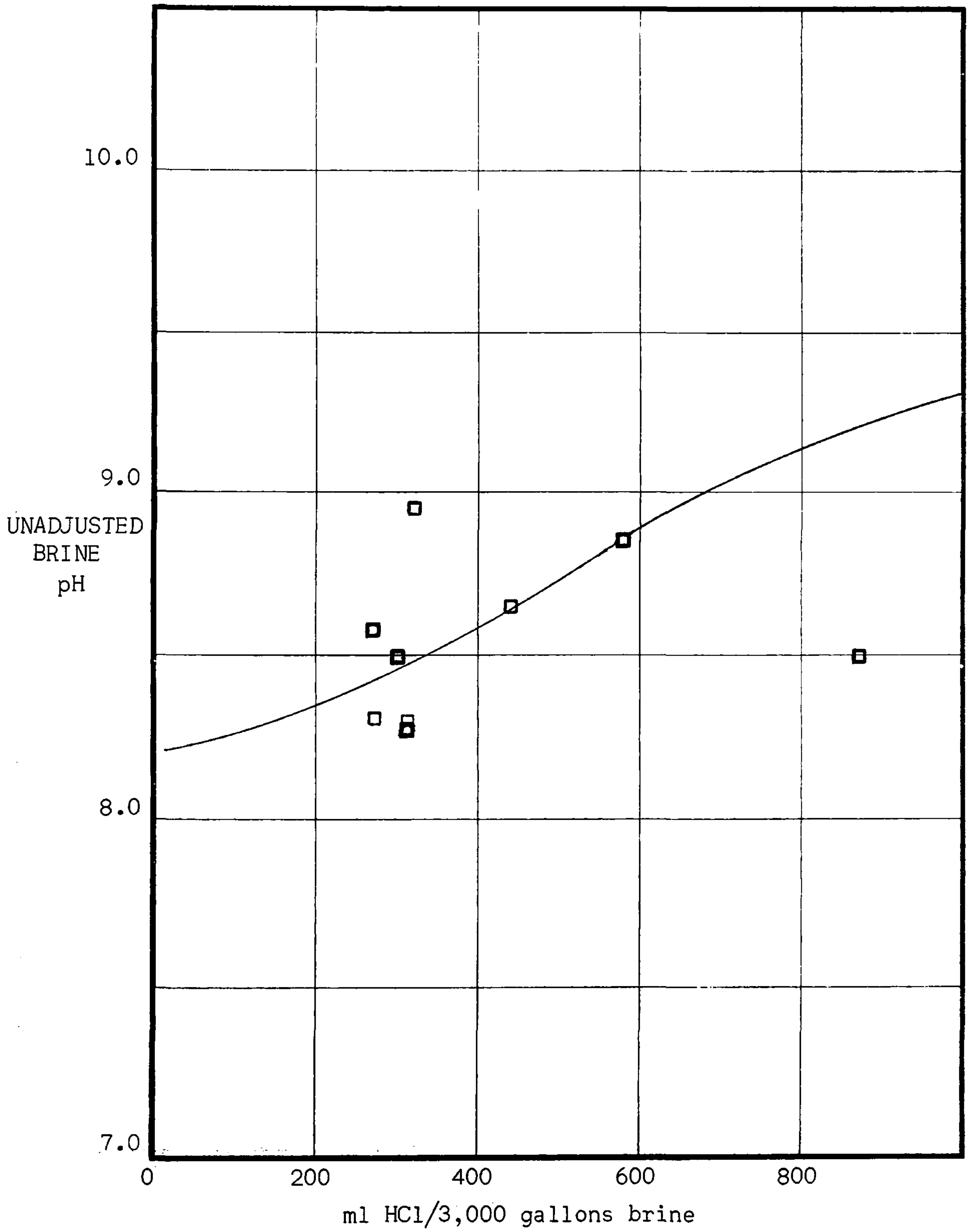

Figure 12. Amount of Hydrochloric Acid to Adjust Brine pH to 6.5-8.0. Optimum dosages of lime and soda ash used for treatment.

The unadjusted pH is quite low and the acid requirement is also low. Considering acid requirements, the need of soda ash and lime and the importance of proper dosage is illustrated in the following tabulation:

Table 1. ACID REQUIREMENT BASED ON CHEMICAL TYPES USED.

Chemicals used	Average acid requirement, per 1,000 gal. brine
Soda ash only	0.71 gal.
Soda ash and lime	0.18 gal.
Optimum dosage, soda ash and lime	0.04 gal.

Complete tabulation summary of unadjusted brine pH and acid usage is to be found in Appendix B.

Laboratory bench tests were run to verify empirically established "optimum" dosages. Since the reactions are equilibria, any of the reactions can be reversed with a change in conditions. The equilibria move in a given direction because of relative solubilities. These solubilities are recorded in Table 2.

Table 2. SOLUBILITY OF COMPOUNDS[1].
(In grams/100 grams of water at 20 degrees C.)

$CaCO_3$	0.0012
$Ca(OH)_2$	0.165
$Mg(CO_3)$	0.0106
$Mg(OH)_2$	0.0009
NaCl	36.0
Na_2CO_3	21.5
$MgCl_2$	54.5
$CaCl_2$	59.5

The table shows that, in this system, all chlorides are soluble. Also, because precipitation is preferential to less soluble salts, if hydrate alkalinity (OH) is present, $Mg(OH)_2$ will precipitate rather than $Ca(OH)_2$. Also, if carbonate alkalinity (CO_3) is present, $CaCO_3$ will precipitate rather than $Mg(CO)_3$. Therefore, an inadequate dosage of soda ash (supplying CO_3) will precipitate only calcium as $CaCO_3$; and, an inadequate dosage of lime -- $Ca(OH)_2$ will precipitate only magnesium as $Mg(OH)_2$.

Because magnesium carbonate is sparingly soluble, dosage with sufficient soda would also precipitate $MgCO_3$, and it would be possible to meet the 95% sodium requirement.

The chemical reactions are illustrated in equations (8) and (9), where the chloride ions associated with the cations are not shown.

$$\underset{24.3}{Mg^{++}} + \underset{74.1}{Ca(OH)_2} \longrightarrow \underline{Mg(OH)_2} + Ca^{++} \quad \text{(Reaction weights)} \tag{8}$$

$$\underset{24.3}{Mg^{++}} + \underset{106.0}{Na_2CO_3} \longrightarrow \underline{MgCO_3} + 2Na^{+} \quad \text{(Reaction weights)} \tag{9}$$

These equations show that 24.3 pounds of magnesium require either 74.1 pounds of $Ca(OH)_2$ or 106.0 pounds of Na_2CO_3 for reaction. The 74.1 pounds of $CA(OH)_2$, at $0.0235 per pound, costs $1.74. The 106.0 pounds of Na_2CO_3, at $0.0372 per pound costs $3.94. Obviously, it is cheaper to use $Ca(OH)_2$ to precipitate the magnesium.

The sequence of adding chemicals is of interest. In the original planned procedure it was arbitrarily decided to add the soda ash first. This sequence remained unchanged in this study.

For this study and considering the quantities of chemicals used, the following equation can describe the reaction with soda ash only.

$$MgCl_2 + CaCl_2 + Na_2CO_3 \longrightarrow \underline{CaCO_3} + MgCl_2 + 2NaCl \tag{10}$$

Since the established soda ash dosage was about 85% of theoretical for reaction with the calcium hardness, it is likely that very little, if any, magnesium is precipitated as the carbonate in this stage.

After the soda ash was added, separate feed of lime was made. The reaction of lime is as follows:

$$MgCl_2 + Ca(OH)_2 \longrightarrow \underline{Mg(OH)_2} + CaCl_2 \tag{11}$$

The formula NaCl is not shown in the reaction because it remains soluble throughout. These reactions are considered equilibria. The degree of movement in a given direction can be checked by separating the reactants and analyzing the results. This was done in the laboratory bench tests. The procedure used for these tests is in Appendix C, "Riverside Procedure - Optimum Dosage Determination".

The procedure was to treat brine for reclamation with dosages of soda ash equal to 50, 75, 85, 100 and 110 percent of the stoichiometric requirement of soda ash. The reacting solutions were analyzed at 15 minute intervals for the concentration of calcium, magnesium, and the pH value. These results appear in Table 17 in Appendix C, and were plotted so that the optimum dosages and mixing times could be selected considering maximum calcium removal.

Figure 13, "Treated Brine Magnesium Hardness, Etc." shows the remaining magnesium hardness as a function of the soda ash dosages and reaction time. This graph indicates that with soda ash dosages which are less than the stoichiometric amount, the effect on the magnesium hardness is small. The graph shows that with 100 or 110% dosages, the reaction time should be about 60 minutes with little difference between the two dosages.

Figure 14, "Treated Brine Calcium Hardness, Etc." shows the remaining calcium hardness as a function of soda ash dosages and reaction time. The graph shows that the 85% dosage will reduce the calcium hardness with 60 minutes of contact time. Increasing the dosage to 100 or 110% decreases the concentration at a slightly faster rate.

Figure 15, "Treated Brine pH, Etc." plots the treated brine pH as a function of soda ash dosages and reaction time. The graph illustrates the higher pH values caused by higher dosages of soda ash.

Reviewing Figures 13, 14 and 15 illustrates that the optimum dosage of soda ash should be about 85% with a reaction time of about 60 minutes.

A similar procedure was used with four new separate samples of untreated brine being treated only with hydrated lime. Similar data was obtained with similar resulting graphs. The data is in Table 18 in Appendix C, and is plotted in the attached Figures 16 and 17. Figure 16 shows the remaining magnesium hardness in the treated brine as a function of the hydrated lime addition and reaction time. The figure shows the increasing reduction of the magnesium hardness concentration with increasing dosage and reaction time. Complete reduction of the magnesium requires a dosage of 100 or 110% with a reaction time of 60 minutes. However, such complete reduction is unnecessary to meet our "95% purity" specification for the reclaimed brine.

The calcium hardness data has not been plotted into graphs because the addition of only lime does not materially affect the calcium hardness. A slight increase results because of the solubility of calcium hydroxide.

Figure 17 plots the treated brine pH as a function of lime dosage and

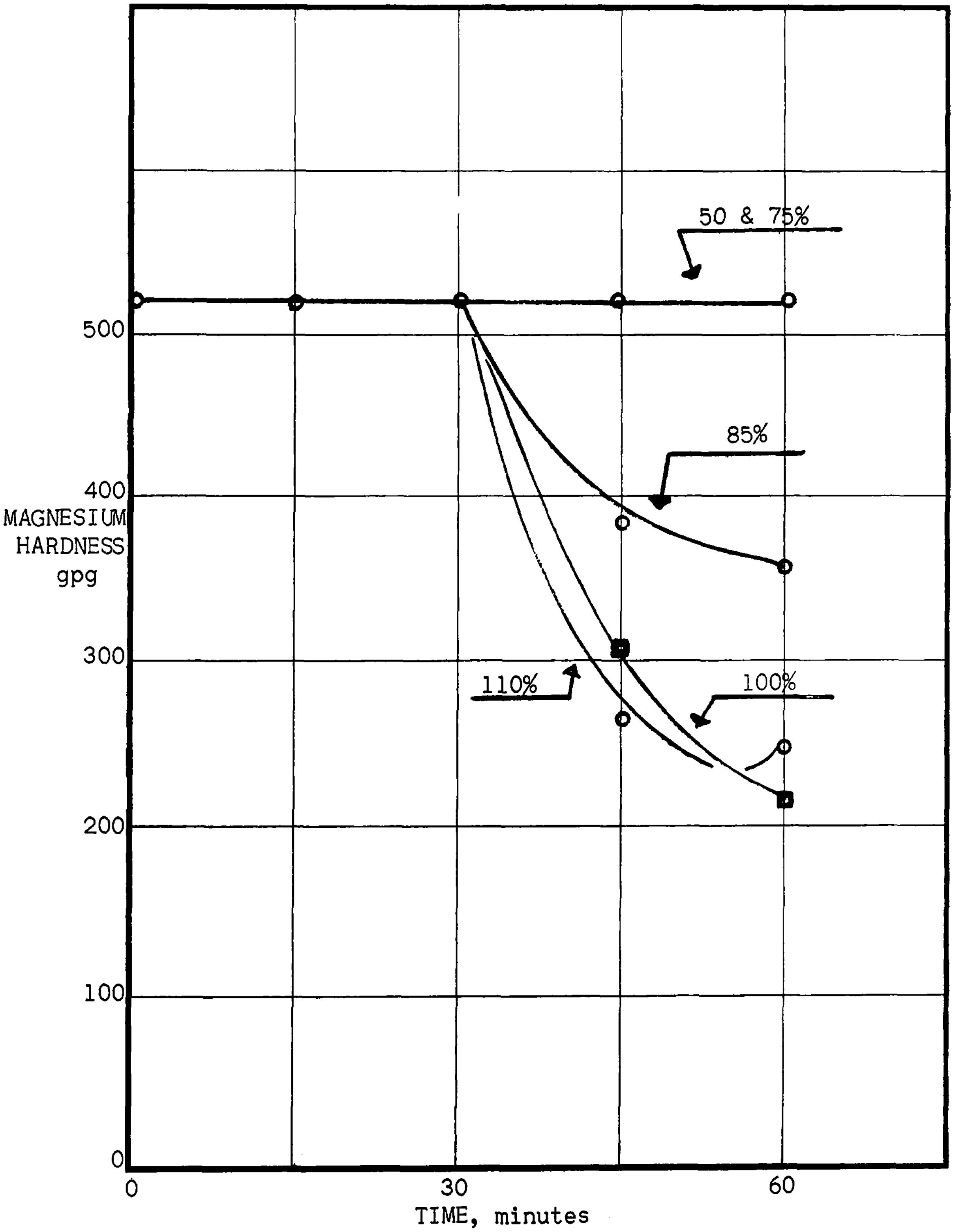

Figure 13. Treated Brine Magnesium Hardness, as Functions of Soda Ash Dosage and Reaction Time.

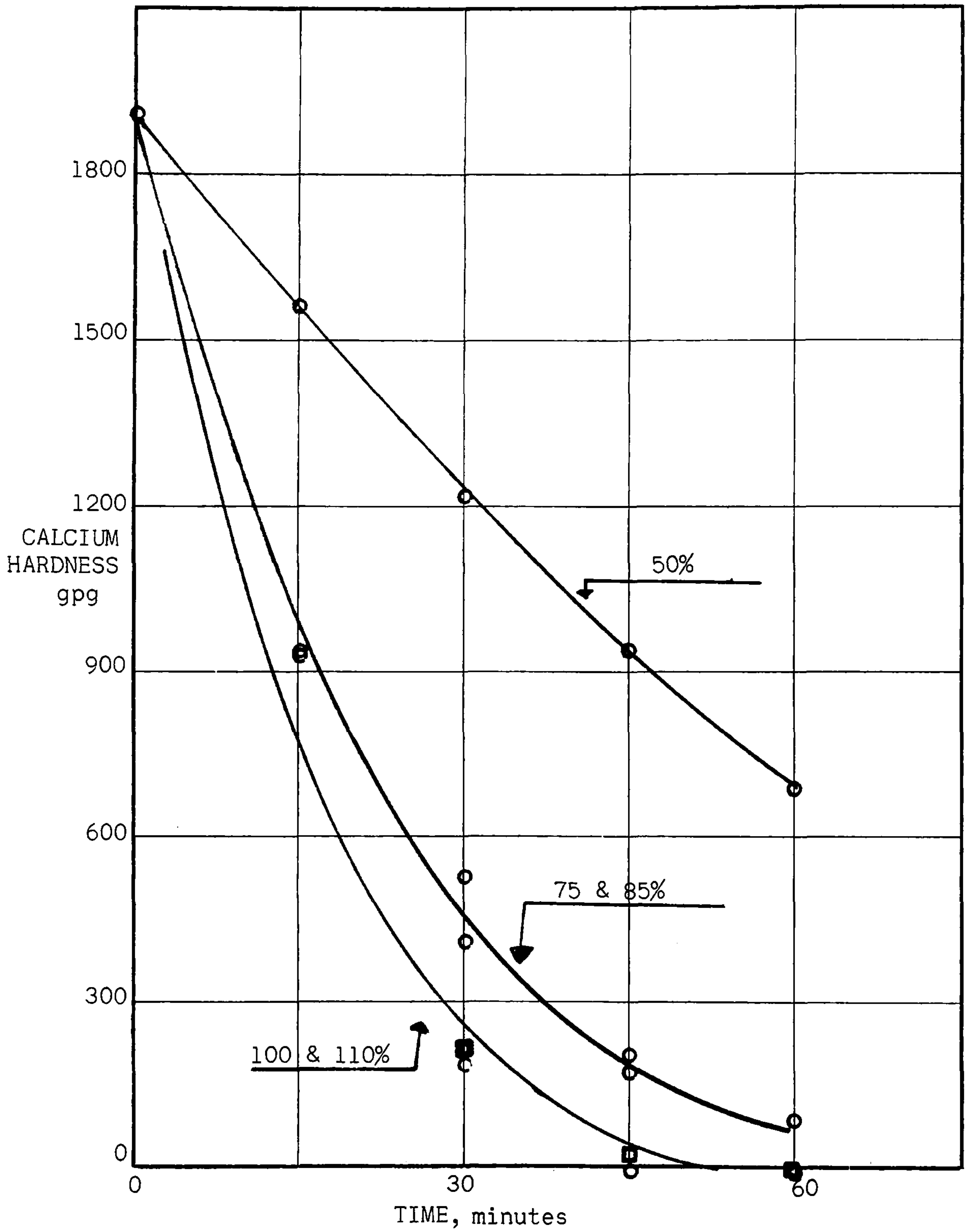

Figure 14. Treated Brine Calcium Hardness, as Functions of Soda Ash Dosage and Reaction Time.

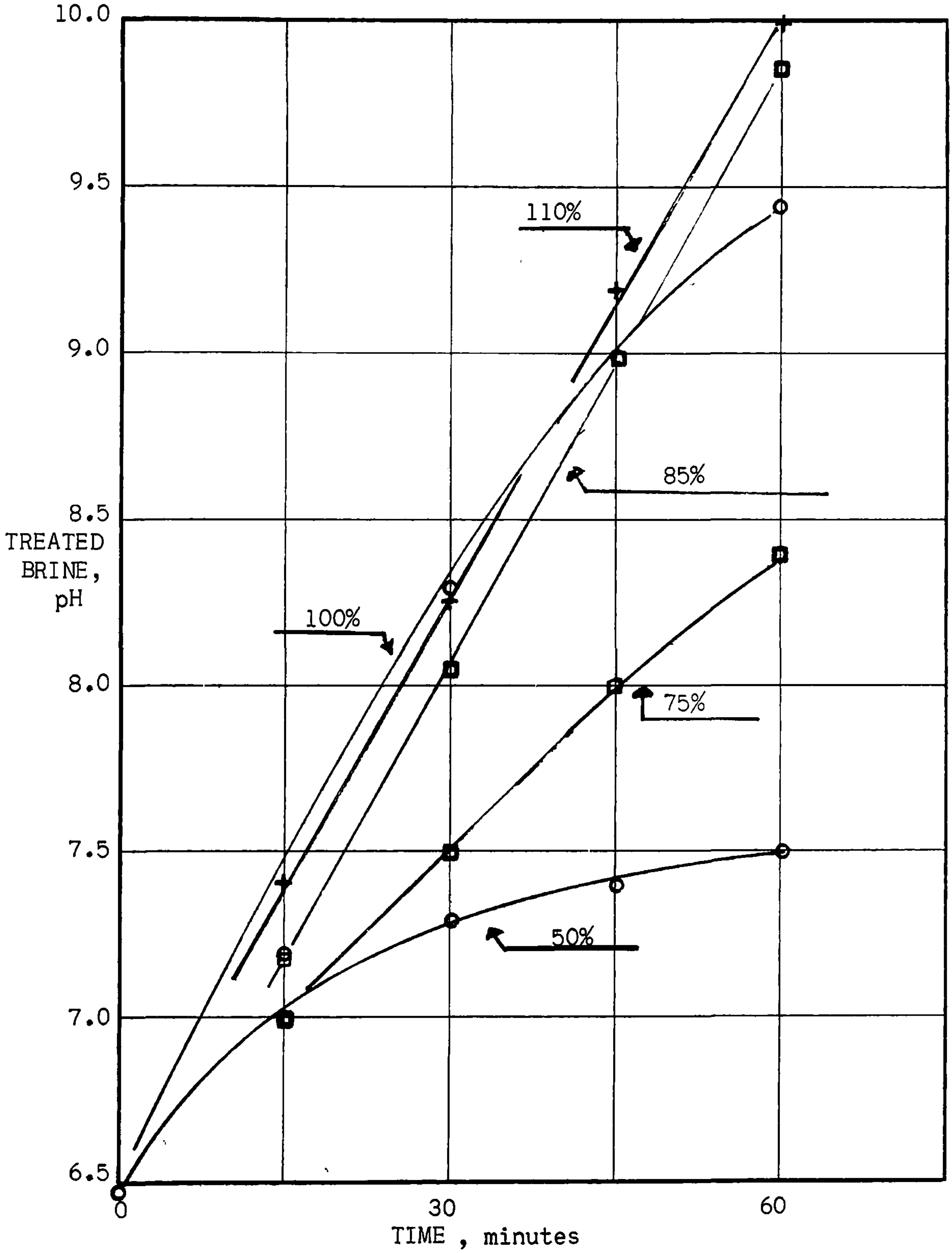

Figure 15. Treated Brine pH, as Functions of Soda Ash Dosage and Reaction Time.

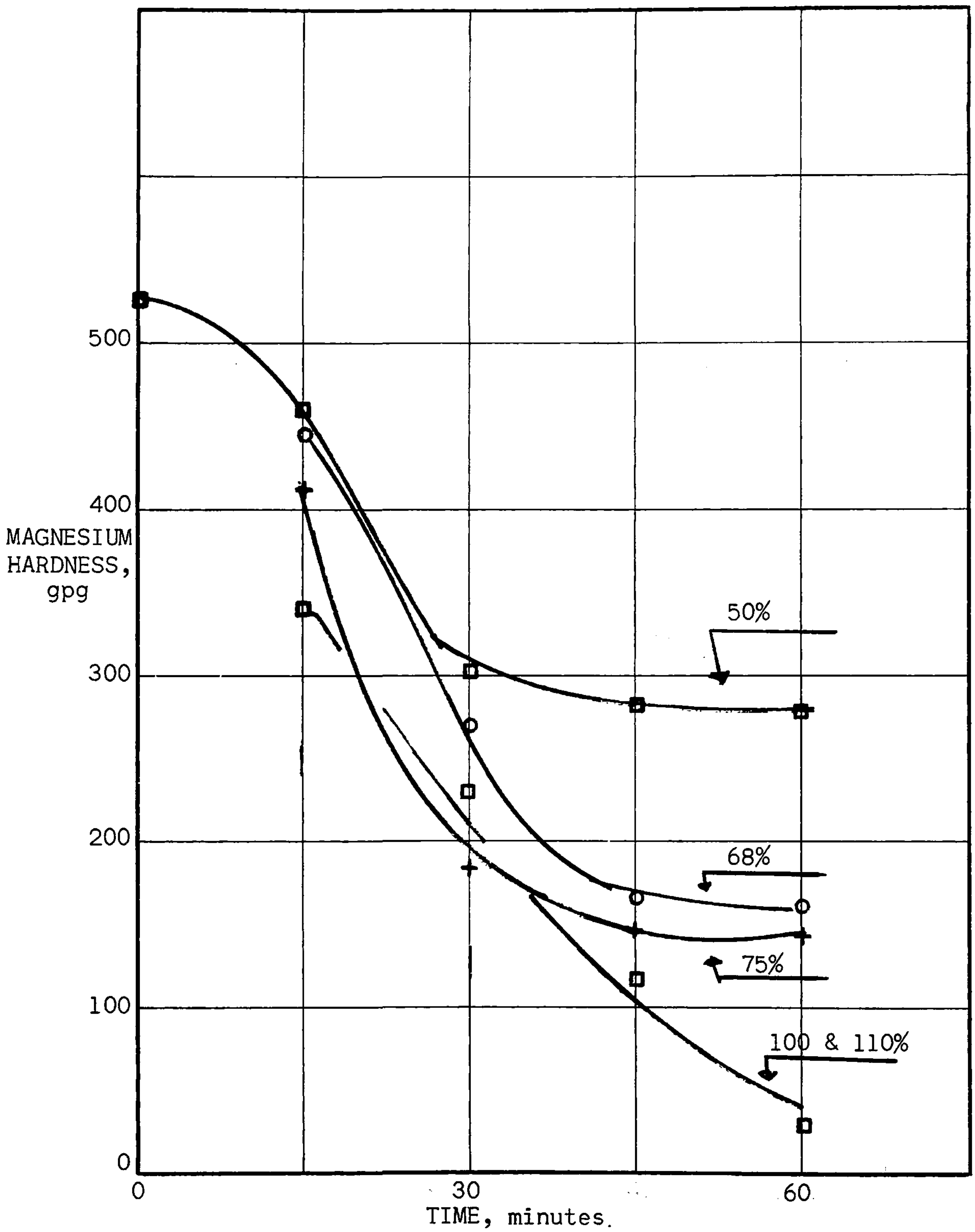

Figure 16. Treated Brine Magnesium Hardness, as Functions of Hydrated Lime Dosage and Reaction Time.

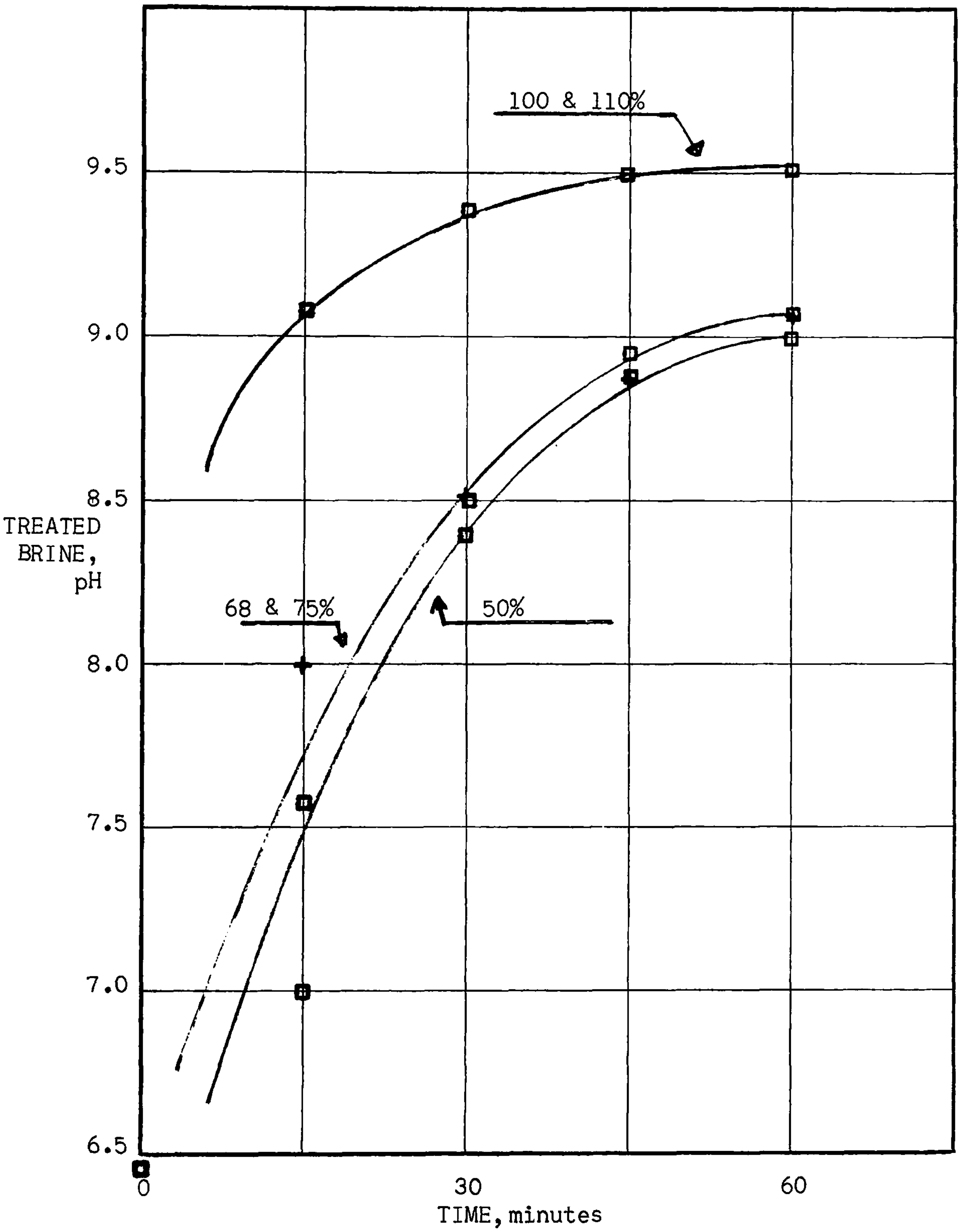

Figure 17. Treated Brine pH, as Functions of Hydrated Lime Dosage and Reaction Time.

reaction time. The graphs clearly show the increased pH values due to the solubility of calcium hydroxide.

The laboratory data were reviewed with the determination that the optimum dosages should be less than stoichiometric: 85% for soda ash and 68% for hydrated lime. With these dosages, then, a third series of laboratory tests were made with waste brine to be reclaimed. The waste brine was treated with soda ash (85% of stoichiometric), stirred 45 minutes, then treated with hydrated lime (68% stoichiometric) and stirred an additional 45 minutes. The reactants were sampled periodically and analyzed for calcium, magnesium and pH. Triplicate tests were performed: the values were averaged for preparation of Table 19 in Appendix C. The tabular data was then used to prepare the graphs of Figures 18, 19 and 20.

Figure 18 shows the remaining calcium hardness as a function of time. The figure shows that the soda ash addition was sufficient to reduce the calcium hardness to zero but that the subsequent hydrated lime addition increased the calcium hardness.

Figure 19 plots the remaining magnesium hardness and clearly shows that the magnesium hardness was unaffected by the soda ash addition and that the hydrated lime significantly reduced the magnesium.

Figure 20 shows the treated brine pH value. It clearly indicates that the pH increases with soda ash addition, but that subsequent addition of hydrated lime reduces the pH. A review of this data indicates that the optimum dosages will yield a reclaimed brine of suitable quality except that the pH of about 9 must be reduced with subsequent addition of acid.

With the established dosages and with the addition of soda ash first and lime second, minimal amounts of acid were required for pH adjustment of the effluent. This adjustment was made by adding a predetermined amount (usually 100-150 ml) of hydrochloric acid (20° Bé) as the decantation was occurring. This provided sufficient agitation for mixing.

The brine as originally drawn off had a turbidity of 20 JTU, due to unsettled small particles of precipitate. The acid added for pH adjustment dissolved the precipitate to produce a product brine of about 1.0 JTU. The slight increase in hardness that resulted was not sufficient to cause failure to meet specifications.

The established procedure is outlined in detail in Appendix D, which includes plant operation, lab testing, etc. This procedure was used throughout the subsequent demonstration runs.

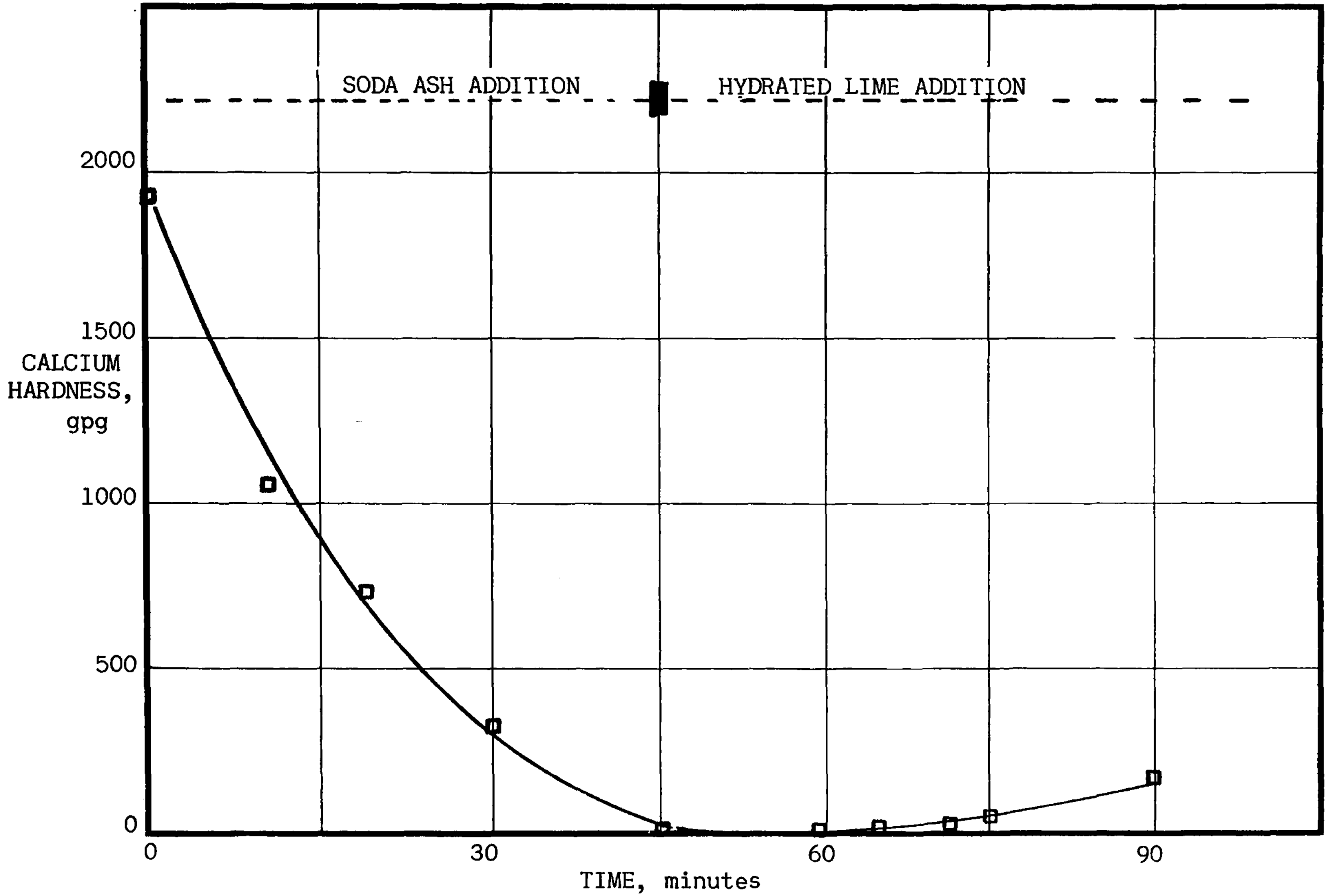

Figure 18. Effect of Chemical Addition on Remaining Calcium Hardness. Soda ash 85%, hydrated lime 68% of stoichiometric.

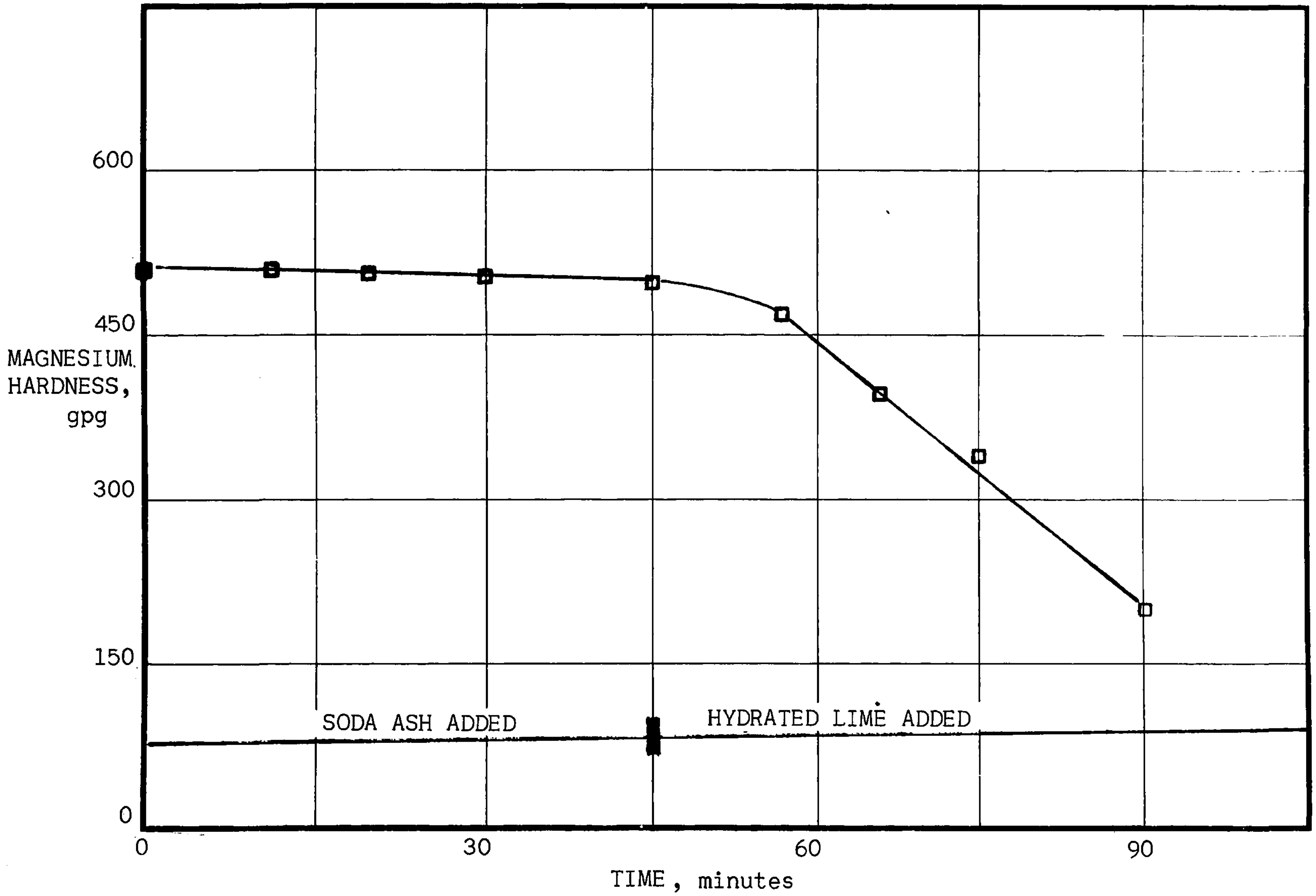

Figure 19. Effect of Chemical Addition on Remaining Magnesium Hardness. Soda ash 85%, hydrated lime 68% of stoichiometric.

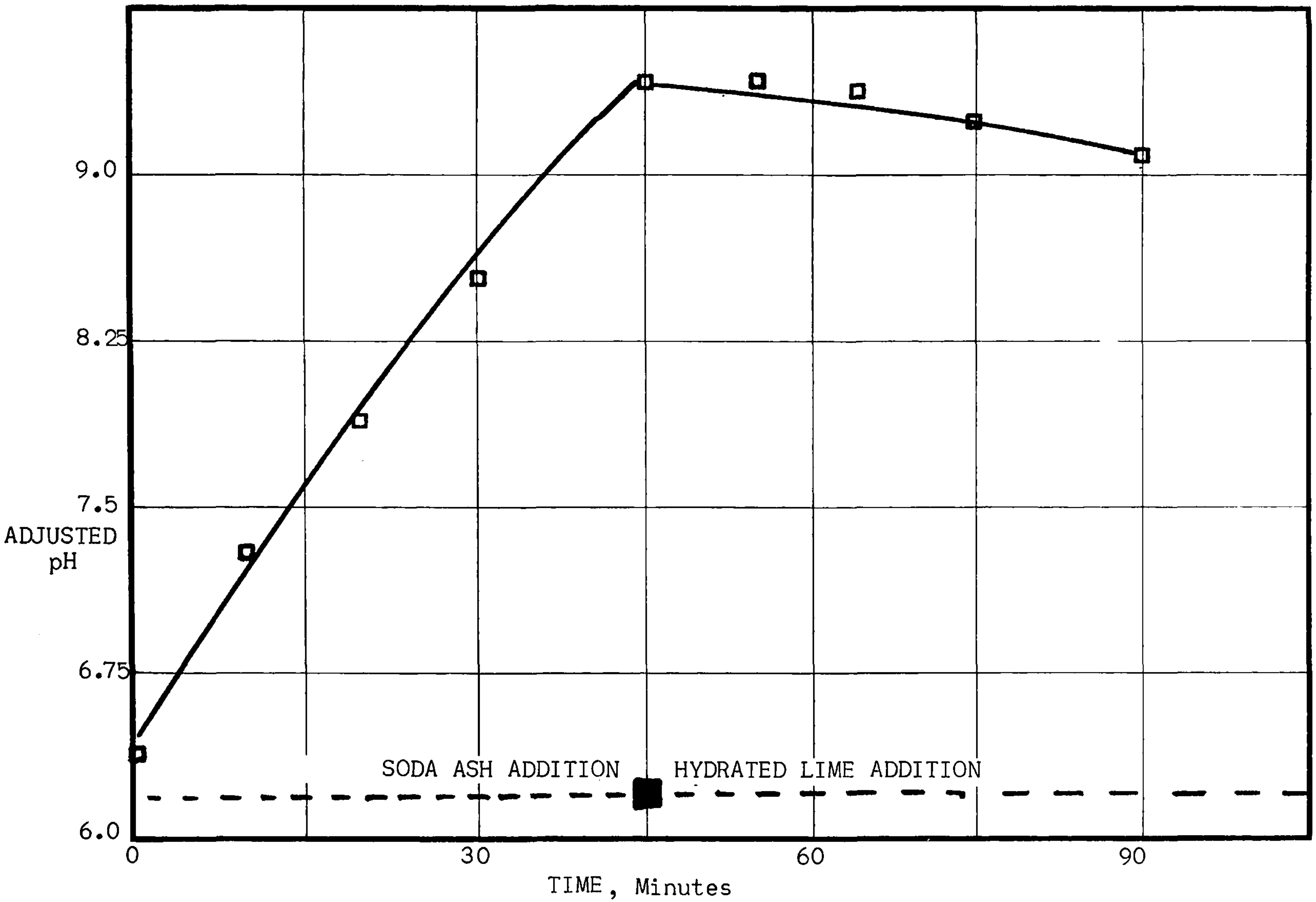

Figure 20. Effect of Chemical Addition on Adjusted pH. Soda ash 85%, hydrated lime 68% of stoichiometric.

PROCESS DEMONSTRATION

Without basic change, the optimum procedure (Appendix D) was used for 174 demonstration runs. The process was actually carried out over a period of ten months. The wastes of the regeneration plant were processed routinely with the optimum procedure. Brine was processed, a product was returned for use, and salts were prevented from entering the environment.

During the last month of the project, the equipment was in use under the control of non-professional personnel of the regeneration plant. There were no reports of difficulty with their operation. It would seem that the process lends itself to operation by non-technical personnel.

Appendix G is a record of the operation throughout the demonstration. Complete data for each run is recorded: data sheets for each run are included in Appendix G. These runs provide data which show the following:

1. The process can be sustained productively.

2. The process can be carried out routinely by non-technical personnel.

3. The measurements and calculations were of sufficient accuracy to produce material balances.

4. The process could materially reduce salts discharged, thus reducing potential pollution.

5. The process was not economically favorable at this location. Possibly, cost values at other locations would be more favorable.

It had been empirically determined during Process Optimization (and verified with laboratory bench tests) that the optimum range of chemical dosages was 83-89% of theoretical for soda ash, and 63-72% for hydrated lime.

The soda ash dosage was determined as follows. Soda ash was used to reduce the calcium concentration according to the following typical reaction:

$$CaCl_2 + Na_2CO_3 \longrightarrow \underline{CaCO_3} + 2NaCl \qquad (12)$$

From the above it is seen that each equivalent of calcium hardness requires one equivalent of soda ash. Our analyses express the calcium hardness in terms of grains per gallon (gpg), as $CaCO_3$. <u>In terms of $CaCO_3$</u>, then, each gpg of calcium requires one gpg of soda ash.

Conversion from "as $CaCO_3$" to "as substance" requires multiplication by the ratio of the equivalent weights, as follows:

$$\text{Ca, as } CaCO_3 \times \frac{\text{eq wt } Na_2CO_3}{\text{eq wt } CaCO_3} = \text{Ca, as } Na_2CO_3$$

$$\frac{\text{eq wt } Na_2CO_3}{\text{eq wt } CaCO_3} = \frac{53}{50.1} = 1.057$$

The soda ash was needed to react with the calcium chloride produced in the hydrated lime reaction (equation 11) as well as with the calcium originally present. Therefore, the total hardness (rather than only calcium) of the untreated brine was used in this calculation. The soda ash dosage in pounds per hundred gallons then is:

Soda ash dosage = gpg total hardness x 1.057 x 1 lb/7000 gr x 100

Soda ash dosage = gpg total hardness x 0.0151

Since much of the data is repetitive, three typical runs (76A, 77A and 78A) were chosen to provide data for discussion. Three runs cover a complete cycle: three waste brine collections, three chemical dosages, three reclaimed brine decantations, and one sludge withdrawal. Pertinent data from these three runs is included here as Table 4, "TEST DATA SUMMARY".

Soda ash dosage calculations, using the factor 0.0151 developed immediately above, are shown in Table 3.

Table 3. CALCULATION OF SODA ASH DOSAGE.

Test run	76A	77A	78A
Total hardness, gpg	2220	2330	2300
Factor	0.0151	0.0151	0.0151
Volume, 100 gal.	29	27	27
Dosage, lb soda ash:			
Theoretical	970	950	940
Added	800	800	800
% of Theoretical	83	84	85

Table 4 . TEST DATA SUMMARY

Run	76A	77A	78A	Total or (Average)
Untreated Brine:				
Volume, gal.	2900	2700	2700	8300
Strength, ^{o}S	56	57	56	(56)
Solubles, lb	3960	3760	3700	11,420
Magnesium, $CaCO_3$, gpg	480	555	530	(522)
Calcium, $CaCO_3$, gpg	1740	1775	1770	(1762)
Chemicals Added:				
Hydrated Lime:				
lb	100	100	100	300
% theoretical	68	64	66	(66)
Soda Ash:				
lb	800	800	800	2400
% theoretical	83	84	85	(84)
Reclaimed Brine:				
Volume, gal.	2700	2700	2500	7900
Strength, ^{o}S	55	56	55	(55)
Solubles, lb	3620	3700	3340	10,660
Total Hardness, gpg	405	465	405	(425)
Purity, %	95	95	95	(95)
Waste:				
Volume, gal.	----	----	----	900
Insoluble, lb:				
leach calc	----	----	----	2810
analysis calc	----	----	----	2985
Solubles, lb:				
leach calc	----	----	----	970
analysis calc	----	----	----	795
Waste Reduction, %:				
Volume	----	----	----	89
Solubles, lb:				
leach calc	----	----	----	92
analysis calc	----	----	----	93

The hydrated lime dosage was determined as follows: lime was used to reduce the magnesium concentration according to the following typical reaction:

$$MgCl_2 + Ca(OH)_2 \longrightarrow \underline{Mg(OH)_2} + CaCl_2 \qquad (13)$$

Again, in terms of $CaCO_3$, each gpg of magnesium hardness requires one gpg of lime. Also, conversion from "as $CaCO_3$" to "as substance" requires multiplication by the ratio of the equivalent weights; thusly,

$$\text{Mg, as } CaCO_3 \times \frac{\text{eq wt } Ca(OH)_2}{\text{eq wt } CaCO_3} = \text{Mg, as } Ca(OH)_2$$

$$\frac{\text{eq wt } Ca(OH)_2}{\text{eq wt } CaCO_3} = \frac{37.1}{50.1} = 0.74$$

For each gpg of magnesium, the lime dosage in <u>pounds</u> per <u>hundred</u> gallons is calculated thusly:

Lime dosage = gpg magnesium x 0.74 x 1 lb/7000 gr x 100

Lime dosage = gpg magnesium x 0.0105

Lime dosage calculations, using the factor 0.0105 just developed, are shown in Table 5.

Table 5. CALCULATION OF HYDRATED LIME DOSAGE.

Test run	76A	77A	78A
Magnesium hardness, gpg	480	555	530
Factor	0.0105	0.0105	0.0105
Volume, 100 gal.	29	27	27
Dosage, lb hydrated lime:			
Theoretical	146	157	150
Added	100	100	100
% of Theoretical	68	64	66

These dosages, with soda ash applied first, consistently resulted in the production of brine containing 95% sodium chloride.

Bench tests applied to waste brine using soda ash in the 83-89% range, and lime in the 63-72% range produced the following results:

Table 6. BENCH TEST RESULTS.

Sample	Total hardness	Calcium	Magnesium
Waste brine, gpg	2450	1925	525
Treated brine, gpg	380	175	205
Remaining, %	15.5	9.1	39

Since the dosage of soda ash is calculated on the total hardness, and since 83-89% of theoretical was applied, then 85% reduction of total hardness seems within the range of expectation, and is a sufficient reduction to produce a brine which is quite useful for regeneration of softeners.

MATERIAL BALANCES

The difficulty in achieving material balances in this study is indicated at other points in this report. Specific reference is made to the later section on Economic Evaluation where credit was given for the return of $54 worth of water, when $49 entered the system. Obviously, dilution waters may contribute to this imbalance.

Scale up from laboratory analyses to applied dosages presents another source of error. Determinations made, even with good accuracy, do have inherent errors and these errors become appreciable when the results are calculated from a 100 ml sample and extrapolated to a 3,000 gallon batch.

Representative samples are difficult to collect where non-homogeneous materials, such as sludge, must be examined. The material balances were calculated for typical runs rather than for the larger time interval represented in the later Economic Study. Balances will cover waste brine and chemicals into the reclamation plant vs products out.

Two methods were available to determine the weight of solubles in the sludge. One used the loss in weight by leaching the solubles from the dry solids. The range of pounds per reaction batch (from three runs) ranged from 390-1100 pounds per batch. Only about 13% of the 174 runs were under 700 pounds of solubles in the sludge.

The other system of solubles determination was based on the analysis

Table 7. SALT BALANCE BASED ON SALOMETER READINGS

<u>Input to Reclaim Plant</u>		
Brine, gal	8,300	
Strength, ^{o}S	56.3	
Solubles, lb NaCl		11,420
<u>Output from Reclaim Plant</u>		
Brine, gal	7,900	
Strength, ^{o}S	55.3	
Solubles, lb NaCl	10,660	
Sludge Solubles, Table 4	970	
Solubles, lb NaCl		11,630
Average, lb		11,525
Deviation, lb		105
Deviation, %		0.9

Table 8. WATER BALANCE

<u>Input to Reclaim Plant</u>			
Brine:			
Volume, gal.	8,300		
Strength, °S	56.3		
Water, gal./gal. brine	0.9457		
Water, gal.		7,850	
Total Water In, gal.			7,850
<u>Output from Reclaim Plant</u>			
Brine:			
Volume, gal.	7,900		
Strength, °S	55.3		
Water, gal/gal. brine	0.9467		
Water, gal.		7,480	
Sludge:			
Volume, gal.	900		
Density, lb/gal.	10.8		
Total Solids, lb/gal.	4.2		
Water, lb/gal.	6.6		
Water, lb	5,940		
Water, gal. (8.33 lb/gal.)		713	
Total Water Out, gal.			8,193
Average, gal.			8,022
Deviation, gal.			171
Deviation, %			2.2

of the supernatant brine. This calculation had a range of 215-885 pounds per batch of sludge, with 16 runs containing less than 550 pounds of solubles. Either calculation is acceptable.

Test Runs No. 76A, 77A and 78A were chosen as being in the range where data from the majority of the runs fell. Table 4, "TEST DATA SUMMARY", is a representation of the daily test run data, with the waste determinations taken from the sludge discharge. Averages and totals were calculated and are entered in the last column of the table.

A material balance can be based on soluble salts, by simply using the brine table (Appendix F) and assuming all solubles are sodium chloride. The balance is shown in Table 7, "SALT BALANCE BASED ON SALOMETER READINGS". The deviation is 0.9%, which is excellent.

Water balance is also of interest. Table 8, "WATER BALANCE", illustrates the water balance. The deviation for materials balance for water is 2.2% which is reasonable and shows "greater output than input" which is indicated and explained elsewhere.

Following is a balance for all solids, equating them equivalent to $CaCO_3$. Any equivalent could be used; however, calcium carbonate is chosen for its convenience in calculating water analysis, etc. Factors are provided in the literature[2] for conversion of common mineral constituents to $CaCO_3$ equivalents. The following tabulation shows the factors needed for the material balance.

Table 9. CONVERSION FACTORS

To change:

$NaCl$ to $CaCO_3$ multiply by 0.856

Na_2CO_3 to $CaCO_3$ multiply by 0.944

$Ca(OH)_2$ to $CaCO_3$ multiply by 1.35

The soda ash and lime dosages were considered separately in the "input". (Table 10) Since the preponderance of the sludge is calcium carbonate, and since there is no convenient way to separate the magnesium hydroxide present, the weight of the sludge was considered to be all calcium carbonate. Table 10, "SALT AND CHEMICAL BALANCE", shows the chemical balance. The input is 12,446 pounds compared with the output of 12,940 pounds, both as calcium carbonate. A reasonable balance is indicated.

It should be noted from Table 10, "SALT AND CHEMICAL BALANCE", that

Table 10. SALT AND CHEMICAL BALANCE.
(Basis as $CaCO_3$)

Input			
Brine:			
Volume, gal.	8,300		
Solubles:			
NaCl (Table 7), lb	11,420		
$CaCO_3$ (11420 x 0.856), lb		9,775	
Magnesium, $CaCO_3$:			
gpg	522		
lb/1000 gal. (522/7)	74.5		
lb/batch (74.5 x 8.3)		618	
Calcium, $CaCO_3$:			
gpg	1,762		
lb/1000 gal. (1762/7)	251		
lb/batch (251 x 8.3)		2,083	
Total Hardness, $CaCO_3$, lb			2,701
Total NaCl as $CaCO_3$, lb		7,074	7,074
Chemicals Added:			
Soda Ash:			
lb as is	2,400		
lb as $CaCO_3$ (2400 x 0.944)			2,266
Hydrated Lime:			
lb as is	300		
lb as $CaCO_3$ (300 x 1.35)			405
Total Input, $CaCO_3$, lb			12,446
Output			
Brine:			
Volume, gal.	7,900		
Solubles:			
NaCl (Table 7), lb	10,660		
$CaCO_3$ (10660 x 0.856), lb		9,125	
Total Hardness $CaCO_3$:			
gpg	425		
lb/1000 gal (425/7)	61		
lb/batch (61 x 7.9)		482	482
NaCl as $CaCO_3$, lb		8,643	8,643
Sludge:			
Volume, gal.	900		
Solubles:			
NaCl, lb	970		
as $CaCO_3$ (970 x 0.856), lb			830
Insolubles from Analysis $CaCO_3$, lb			2,985
Total Output, $CaCO_3$, lb			12,940
Average, lb			12,693
Deviation, lb			247
Deviation, %			1.9

about 11,420 pounds of salts (as NaCl) were received into the process and that 10,660 pounds of NaCl (as NaCl) were returned to use, plus 970 pounds in the sludge. Therefore, a significant return of salt was realized. It is of much greater importance, however, that the 11,420 pounds of salts did not reenter the environment as potential pollution.

The materials balance for the insolubles produced is presented in Table 11, "SLUDGE BALANCE". The input considers only the chemicals (soda ash and lime) which were added to cause precipitation. Their addition has been calculated to a total input of 2671 pounds as $CaCO_3$. The output is in the insolubles of the sludge. Chemical analysis of the sludge indicated that the 900 gallons of sludge contained 2985 pounds of solids. Although the insolubles are a mixture of calcium carbonate and magnesium hydroxide, the amount of the latter precipitate is small and will not appreciably affect the balance. The deviation is shown as 5.5%, which is reasonable.

Table 11. SLUDGE BALANCE

Input:			
Soda ash, lb:			
as is	2400		
as $CaCO_3$		2266	
Hydrated lime, lb:			
as is	300		
as $CaCO_3$		405	
Total input			2671
Output:			
Sludge:			
volume, gal.	900		
insolubles, lb	2985		
Total output			2985
Average, lb			2828
Deviation, lb			157
Deviation, %			5.5

ECONOMIC EVALUATION

Indirect costs are not considered in this evaluation; only direct costs. During the process demonstration, a convenient accounting period was chosen to compare the cost of various methods of waste brine handling. During this period, 5,612 portable exchange softeners were regenerated. This required 92,500 pounds of salt contained in about 59,000 gallons of water, resulting in about 62,700 gallons of brine of 60°S strength. As a base for cost comparison, the usual practice of simple discharge to the sewer was considered.

At the present site, salt was delivered at $19.00 per ton ($0.0095/lb) and water at $6.25 per 1,000 cubic feet, which is equal to $0.836 per 1,000 gallons. Since no special equipment was required beyond that used in all regeneration processes considered, and since no special labor was required for open discharge, the basic costs are for salt and water. Therefore, rounding off to the nearest dollar, the costs were:

92,500 lbs of salt x $0.0095/lb =	$879	salt
59,000 gallons / 1,000 x $0.836 =	$ 49	water
	$928	total

Thus the cost -- $928 -- is the basic cost for regenerating 5,612 portable exchange softeners. There is no attempt to protect the environment and no effort to be efficient in salt use beyond reasonable business practice.

As a step in reducing this cost, a portion of the rinse water which contained some salt, but very little hardness, was diverted to the salt dissolver to be reconstituted and then reused for regeneration. During the accounting period, this was approximately 21,000 gallons with an average salometer of 30°. The salt recovered was 7.4 tons; water 20,600 gallons.

Basic cost for salt and water	$ 928
Less salt saved (7.4 x $19.00)	-141
Less water saved (20.6 x $0.836)	-17
Net cost with brine recovery	$ 770

City regulations at Riverside allow the discharge of 30% of the purchased salt to the sewer. This is permitted by the regulation in the form of a waiver for central softener regeneration plants. The waiver is subject to withdrawal.

For a time, the Riverside regeneration plant operated by hauling a portion of the brine which contained about 70% of the salt to an acceptable dumpsite. The remainder was recovered as above, while some was discharged as very dilute solutions to the city sewer system. The volume of brine hauled was 43,900 gallons.

During the accounting period, the costs for hauling were as follows:

Dumping fee	$ 260
Gasoline	35
Labor	210
Truck expense (depreciation, license, etc)	91
Total hauling cost	$ 596
Basic costs for salt and water	928
Total cost with hauling brine waste	$ 1524

Since brine was recovered as before, the net cost of hauling brine is:

Total cost hauling brine waste	$ 1524
Less salt and water saved	-158
Net cost hauling brine	$1366

The present study is concerned with the lime-soda softening process for the brine waste reclamation. The following analysis will show the costs using this system.

Table 12 shows the depreciation costs for the accounting period.

Table 12. DEPRECIATION COSTS

Building - contracted price $19,085.00	
Depreciation for accounting period (20 yrs)	$ 79.54
Equipment - purchase price $14,530.00	
Depreciation for accounting period (5 yrs)	242.17
Total depreciation	$ 321.71
Rounded off to	$ 322.00

It was difficult to properly assign capital costs fairly in this study. A special building addition was required and the equipment was designed for flexibility rather than durability and economy.

In the Southern California climate, most of the equipment could be outdoors with minimal protection. The full costs were used here with the understanding that with present knowledge, capital investment could be smaller for plants at other locations.

With recovery plus reclamation of brine, the cost of chemicals used during the accounting period totaled $563.00. These were:

Soda ash 14,550 lbs @ 0.035	=	$ 510
Lime - 1600 lbs @ 0.0325	=	52
Hydrochloric acid - 17.5 lbs @ 0.054	=	1
Total chemicals		$ 563

During the accounting period, 30.9 tons of salt in the form of reclaimed brine was returned to the system. The value of this salt was:

30.9 tons x $19.00 = $ 587 salt value

This salt was contained in 43,700 gallons of water. The value of this water was:

$$\frac{43{,}700 \text{ gal.}}{1000} \times \$0.836 = \$\ 37 \text{ water value}$$

The reclamation system costs are summarized in Table 13.

Table 13. RECLAMATION SYSTEM COSTS
(Direct costs only.)

Salt	$ 879	
Water	49	
Dumping fee	30	
Gasoline	8	
Hauling labor	48	
Operating labor	489	
Truck expense	91	
Utilities	14	
Chemicals	563	
Depreciation	322	
Total cost		$ 2,493
Less water recovered	17	
Less water reclaimed	37	
Water saving	$ 54	-54
Cost less water saving		$ 2,439
Less salt recovered	141	
Less salt reclaimed	587	
Salt savings	$ 728	-728
Net cost with recovery and reclamation		$ 1,711

Table 14, "COST COMPARISON STUDY" is a summary of the cost for the four waste brine handling processes.

It appears that brine reclamation is unfavorable from an economic standpoint at this location. However, different values for cost

Table 14. COST COMPARISON
(Direct costs only.)

Variable	Open Discharge	Open Discharge & Recovery	Hauling and Recovery	Reclaim and Recovery
Chemicals:				
Salt, basic	$ 879	$ 879	$ 879	$ 879
Water, basic	49	49	49	49
Lime & Soda ash	---	---	---	563
Less salt returned	---	-141	-141	728
Less water returned	---	- 17	- 17	- 54
Total Chemical Cost	$ 928	$ 770	$ 770	$ 709
Building, equip. depr.	---	---	---	322
Operating Costs:				
Dumping fee	---	---	260	30
Gasoline	---	---	35	8
Labor:				
Hauling	---	---	210	48
Plant	---	---	---	489
Truck depr, ins,etc	---	---	91	91
Utilities	---	---	---	14
Total Costs	$ 928	$ 770	$1,366	$1,711
Cost per softener regenerated, $	.165	.137	.243	.305

factors at other locations may reverse this indication. Additionally, the environmental impact study will show that the process has environmental protective values.

One item stands out in the table. A credit for $54 water returned is applied, but only $49 worth of water is charged. Both values are determined by volume measurement of brines. Salt table factors are applied and the amount of water present is calculated. The values are recorded and utilized in the study. The fact that more water is returned than was used is due to the return of dilution waters as well as errors introduced by analysis.

The study reported here has shown that the reclamation process is technically successful. Discharges were reduced by about 90%. Effects on the environment were minimized. However, the expense is significantly greater than other disposal methods for this location. Some of the costs could be reduced by continued study and the application of improved management techniques.

Chemical costs are probably irreducible, but depreciation and operating labor can be reduced. Such reduction should be established by procedures outlined in the Section, "RECOMMENDATIONS".

The present plant is overdesigned in some respects, and the building could be smaller. Reduction of capital expenditures would reduce depreciation costs, which is one of the large cost items.

Changes in the plant design can be made which can make the operating labor less expensive. At the same time, plants can be designed to be less expensive.

At other locations where dumping fees are higher, or where hauling distances are greater, the differences between hauling and reclamation may be reduced. With these reductions, it is probable that cost of reclamation can be brought equal to hauling and recovery costs.

ENVIRONMENTAL IMPACT

Probably the most important aspect of the present study is the change in environmental effect by the use of the process. Environmental effects might (for this discussion) be:

1. Alteration of types and quantities of resources used.

2. Alteration of types and quantities of wastes discharged.

3. Alteration of energy uses.

Since this process is not a great user of energy (utilities and sludge transport), the subject of direct energy usage can be disposed of quickly. Direct energy use is minimal, being in the order of $25-30 per month. However, the energy used to manufacture lime and soda ash is of a much higher order than the energy used to manufacture comparable quantities of sodium chloride. Comparison of energy usage is beyond the scope of this report but comparisons should be made during the planning of all long-range ecological projects.

From the standpoint of resources used, the process is quite encouraging. Table 15, "COMPARISON OF MATERIALS USED" compares the materials used during a convenient accounting period for regenerations made with four methods of waste discharge. The figures are derived from measured volumes of brine used and by calculations from brine tables. The pounds of chemicals are actual purchased amounts.

Open discharge simply means all salt purchased was discharged after use as a softener regenerant. The 92,500 pounds is that amount required to regenerate 5,612 portable exchange softeners. This is the base amount. Other methods used the same 92,500 pounds of salt for regeneration, but the net usage is less because of salt recovered or reclaimed.

Table 15. COMPARISON OF MATERIALS USED

	Open Discharge	Open Discharge & Recovery	Hauling and Recovery	Reclaim and Recovery
Chemicals:				
Salt, lb	92,500	77,700	77,700	15,900
Soda ash, lb				14,550
Lime, lb				1,600
Total, lb	92,500	77,700	77,700	32,050
Water, gal.	59,000	38,400	38,400	(5,300)[a]

[a] Portion of rinse water collected, resulting in a "negative" use of water.

Partial recovery of salt is achieved by returning some of the dilute rinse water to the brine saturator. This results in a saving of both water and salt. This is shown in Table 14.

Both open discharge plus recovery; and hauling plus recovery result in the discharge of 77,700 pounds of salt to the environment. In the first case to the sewer, in the second to an acceptable but perhaps distant place.

Reclamation plus recovery reduces chemical purchases from 92,500 pounds to 32,050 pounds. Thus reducing (even if there were no other consideration) the effect on the local environment to about one-third the previous effect.

Water usage is also decreased--by reuse--thus decreasing the deplation of this resource.

It is shown that the gross quantity of resources used and therefore discharged is greatly reduced. The effect of the consumption of soda ash and lime and the processing of these chemicals on the total environment is unknown. It will be different than with the use of sodium chloride.

It is probably in the matter of types of quantities and wastes that this process is valuable in protecting the environment. The major constituent of the waste is an insoluble solid consisting of calcium carbonate and magnesium hydroxide. The remainder is sodium chloride brine which constitutes the liquid part of the sludge.

A discharge comparison is shown in Table 16. There is obviously a similarity to Table 15. The difference is in the insolubles reported in the present table. These are based on complete utilization of the added chemicals. It is logical to expect 100% utilization because theoretically low dosages were applied. Ample time for solution and reaction was given, and agitation was vigorous.

Table 16. COMPARISON OF MATERIALS DISCHARGED

	Open Discharge	Open Discharge & Recovery	Hauling and Recovery	Reclaim and Recovery
Solubles, lb	92,500	77,700	77,700	15,900
Insolubles:				
$CaCO_3$, lb				13,750
$Mg(OH)_2$, lb				1,250
Total lbs	92,500	77,700	77,700	30,900
Water, gal.	59,000	38,400	38,400	(5,300)[a]

[a] Rinse water returned, resulting in a "negative" discharge.

The important difference between Tables 15 and 16 is the protection of the environment in that a total of 15,000 pounds of waste is in the form of an insoluble solid.

As can be seen, chemical usage and actual discharge are reduced to about one-third compared to the open discharge of regenerant brines. Discharge of soluble waste which could potentially pollute a water resource is reduced to about one-sixth. Water usage is reduced to a "negative" value because of partial reuse of rinse water.

It is obvious that the reclamation process has less adverse impact on the environment than does the uncontrolled discharge of regenerant brines.

SECTION 6

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The personnel and plant facilities of the central regeneration facility for portable exchange water softeners located in Riverside, California and known as, "Culligan Water Conditioning of the Inland Empire", were a basic necessity for the successful completion of the project. The facility provided a convenient source of raw materials in the form of a waste brine for our tests. This availability eliminated the need for making a synthetic regenerant waste. The cooperation, services and tolerance of the personnel at this facility provided a friendly atmosphere.

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SECTION 7

GLOSSARY OF TERMS AND ABBREVIATIONS

Alkalinity - In water or brine solution is usually due to the presence of bicarbonate, carbonate and hydrate ions.

Acid - Any compound of hydrogen and at least one other element that produces hydrogen ions when dissolved in water or certain other solvents. The resulting solutions are sour and turn Litmus paper red.

Base - A substance capable of changing Litmus paper blue, and of neutralizing acids to form salts. Base is a more general term than alkali.

Brine - A solution of sodium chloride (common salt) used to regenerate or recharge water softeners.

Calcium & Magnesium - Two of the elements making up the earth's crust, the compounds of which when dissolved in water make the water hard. The presence of calcium and magnesium in water is a factor contributing to the formation of scale, and insoluble soap curds which are means of clearly identifying hard water.

Calcium carbonate equivalent - Is commonly used for expressing all forms of hardness and other salts in the same terms.

Cullex - A synthetic cation exchange resin chemically described as a sulfonated co-polymer of styrene and divinyl-benzene. Cullex is one of the most durable and highest capacity water softening resins available.

Effluent - The water or solution which emerges from a water softener during any phase of the operating cycle.

Grain per gallon (GPG) - A common basis (unit) of reporting water analysis in the United States. One grain per US gallon equals 17.1 parts per million (ppm).

Hardness - Dissolved calcium and magnesium salts in water. Compounds of these two elements are responsible for most scaling in pipes and cause numerous problems in laundry, kitchen and bath.

Hydrated lime - Is the commercial name for calcium hydroxide. Empirical formula - $Ca(OH)_2$.

Ion exchange - A process whereby ions in solution are interchanged for others from a reactive material.

Jackson Turbidity Units (JTU) - A comparative unit used to quantify the amount of turbidity present.

pH value - A number denoting alkalinity or acidity. The pH scale runs from 0 to 14, 7.0 being the neutral point. Numbers below 7.0 indicate acidity, which increases as the number becomes smaller. Numbers above 7.0 indicate alkalinity which increases as the numbers become larger.

Purity, brine - An expression to quantify presence of non-sodium salts in brine. Is calculated in percent by dividing the sodium concentration by the concentration of the total cations.

Regeneration - In general includes the backwash, brine and fresh water rinse steps necessary to prepare the exchanger bed for service after exhaustion. Specifically, the term may be applied to the "brine" step in which a sodium chloride solution is passed through the exchanger bed. The sodium ions displace the hardness ions which are rinsed to waste.

Rinse - That part of the recharge cycle of a water softener where fresh water is introduced to remove spent regenerant and excess salt prior to placing the softener into service.

Salometer - A hydrometer used to measure the specified gravity of brine for measuring brine concentrations. The scale of measurement ranges from 0-100, with the latter value associated with saturated (100%) salt solutions. The brine concentrations are then reported in "degrees salometer"; or, "^{o}S". These "^{o}S" readings are equal to "percent of saturation", not "percent solution."

Salt - Sodium chloride used for regenerating water softeners.

Soda ash - The commercial name for the chemical compound sodium carbonate -- empirical formula: Na_2CO_3.

Sludge - The waste product from the lime soda reaction. This thick suspension is a mixture of the insoluble precipitates of calcium carbonate and magnesium hydroxide with residual soluble salts.

Service exchange softener - A portable ion exchange water softener. This is the home service water softener tank that undergoes brine regeneration after the mineral has lost its ability to exchange sodium ions for hardness ions (calcium and magnesium).

Turbidity - Lack of clarity. In liquids, refers to suspended, undissolved solids.

Waste brine - A mixture of the chlorides of sodium, calcium and magnesium in water solution. This is an effluent from the regeneration of service exchange softeners.

SECTION 8

REFERENCES

1. "Handbook of Chemistry", edited by Norbert Lange, Handbook Publishers, Inc, Sandusky, Ohio.

2. Nordell, E., "Water Treatment for Industrial and Other Uses", New York, Reinhold Publishing Corporation, Second Edition, 1961.

APPENDICES

APPENDIX A

OPTIMIZATION TEST DATA SHEETS

RUNS 1-48

The following pages provide a summary for each of the Process Optimization test runs.

Items such as "Volume", "Strength", and "Magnesium Hardness" are actual measurements. Items such as, "Solubles, Total Lb", and "% Theoretical" are calculations for that run.

In the rows for waste data, two values are recorded, thus 3290/3395. Two methods of determining solubles and insolubles were used, sometimes with noticeable lack of agreement. Scale-up errors and sampling difficulties may account for this divergence.

Values to the left of the slash are determined from the loss in weight of the dried sludge by leaching with demineralized water.

Values to the right of the slash are determined from an analysis of the brine which is the liquid part of the sludge.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	1	2	3	4
DATE	11-23-71	11-30-71	12-2-71	12-3-71
UNTREATED WASTE BRINE				
Volume, Gallons	3000	3000	3000	3000
Strength, °Salometer	60°	62°	62°	58°
Solubles, Total lbs.	4400	4600	4600	4250
Magnesium Hardness, gpg	540	530	520	525
Calcium Hardness, gpg	2375	2390	2280	2325
CHEMICALS ADDED				
Hydrated Lime, lbs.	150	150	150	150
% Theoretical	95%	90%	92%	91%
Soda Ash, lbs.	1300	1000	1100	1200
% Theoretical	100%	75%	87%	93%
RECLAIMED BRINE				
Volume, Gallons	2400	2400	2400	2400
Strength, °Salometer	56%	61%	61%	57%
Solubles, Total lbs.	3260	3600	3600	3340
Total Hardness, gpg	50	450	290	100
Purity, % Na/Solubles	98%	95%	97%	98%
WASTE				
Cumulated for Test numbers	1	2	3	4
Volume, Gallons	700	700	700	700
Insolubles, lbs.		ANALYSIS PROCEDURE		
Solubles, lbs.		NOT ESTABLISHED		
REDUCTION OF WASTE %				
Volume	76.7	76.7	76.7	76.7
Solubles				

REMARKS: These first series of test runs were made with a constant dosage of hydrated lime and variable dosages of soda ash. The reclaimed brine has high pH level and difficulties encountered with the sludge discharge due to hard lumps of precipitated hardness.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	5	6	7	8
DATE	12-6-71	12-8-71	12-10-71	12-14-71
UNTREATED WASTE BRINE				
Volume, Gallons	3000	2500	3000	3000
Strength, °Salometer	58°	57°	55°	58°
Solubles, Total lbs.	4250	3500	4000	4250
Magnesium Hardness, gpg	760	580	580	580
Calcium Hardness, gpg	2220	2220	2200	2100
CHEMICALS ADDED				
Hydrated Lime, lbs.	200	150	150	150
% Theoretical	84%	99%	83%	83%
Soda Ash, lbs.	1200	1000	1000	1000
% Theoretical	89%	95%	80%	83%
RECLAIMED BRINE				
Volume, Gallons	2400	2400	2400	2400
Strength, °Salometer	57%	57%	54%	57%
Solubles, Total lbs.	3340	3340	3150	3340
Total Hardness, gpg	378	10	590	480
Purity, % Na/Solubles	95%	99%	92%	94%
WASTE				
Cumulated for Test numbers		5-6	7	8
Volume, Gallons		900	700	700
Insolubles, lbs.		ANALYSIS PROCEDURE		
Solubles, lbs.		NOT ESTABLISHED		
REDUCTION OF WASTE %				
Volume		83.7	76.7	76.7
Solubles				

REMARKS: Due to the accumulation of hard lumps of unreacted soda ash at the bottom of the reactor tank, the rate of agitation and chemical addition has been reduced by 50%. Still encountered problems with the sludge discharge.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	9	10	11	12
DATE	12-17-71	12-21-71	12-22-71	12-27-71
UNTREATED WASTE BRINE				
Volume, Gallons	3000	3000	3000	3000
Strength, °Salometer	59°	59°	60°	60°
Solubles, Total lbs.	4350	4350	4400	4400
Magnesium Hardness, gpg	580	640	520	550
Calcium Hardness, gpg	2280	2275	2260	2300
CHEMICALS ADDED				
Hydrated Lime, lbs.	150	none	none	none
% Theoretical	83%	0%	0%	0%
Soda Ash, lbs.	1100	1300	1200	1200
% Theoretical	85%	100%	95%	93%
RECLAIMED BRINE				
Volume, Gallons	2400	2400	2400	2400
Strength, °Salometer	57°	57°	59°	58°
Solubles, Total lbs.	3340	3340	3480	3400
Total Hardness, gpg	440	495	510	530
Purity, % Na/Solubles	94%	94%	94%	93%
WASTE				
Cumulated for Test numbers	9	10	11	12
Volume, Gallons	700	700	700	700
Insolubles, lbs.				
Solubles, lbs.	ANALYSIS	PROCEDURE NOT	ESTABLISHED	
REDUCTION OF WASTE %				
Volume	76.7	76.7	76.7	76.7
Solubles				

REMARKS: These tests were made for the possible elimination of hydrated lime for waste brine hardness reduction. The sludge was observed to be bulky and somewhat gummy in texture. The sludge is still hard to handle.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	13	14	15	16
DATE	12-29-71	1-7-72	1-10-72	1-12-72
UNTREATED WASTE BRINE				
Volume, Gallons	3000	3000	3000	2500
Strength, °Salometer	61°	60°	58°	57°
Solubles, Total lbs.	4500	4400	4300	3480
Magnesium Hardness, gpg	530	570	550	590
Calcium Hardness, gpg	2150	2250	2250	2120
CHEMICALS ADDED				
Hydrated Lime, lbs.	none	none	150	150
% Theoretical	0%	0%	87%	96%
Soda Ash, lbs.	1100	1200	1100	900
% Theoretical	90%	94%	97%	87%
RECLAIMED BRINE				
Volume, Gallons	2400	2200	2700	2300
Strength, °Salometer	59°	59°	57°	56°
Solubles, Total lbs.	3480	3200	3760	3150
Total Hardness, gpg	550	460	380	360
Purity, % Na/Solubles	93%	94%	95%	95%
WASTE				
Cumulated for Test numbers	13	14		15-16
Volume, Gallons	700	900		900
Insolubles, lbs.				
Solubles, lbs.	ANALYSIS	PROCEDURE NOT	ESTABLISHED	
REDUCTION OF WASTE %				
Volume	76.7	70.0		83.7
Solubles				

REMARKS: A comparison of test runs with hydrated lime and without hydrated were made to investigate the texture of the sludge form and quality of the reclaimed brine. Also, the addition of a recycle line of the reactor tank improved the system to sludge discharge

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	17	18	19	20
DATE	1-14-72	1-17-72	1-20-72	1-21-72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2600	2900	2600
Strength, °Salometer	57°	59°	60°	58°
Solubles, Total lbs.	4050	3760	4280	3700
Magnesium Hardness, gpg	580	650	575	580
Calcium Hardness, gpg	2100	2300	2425	2270
CHEMICALS ADDED				
Hydrated Lime, lbs.	150	150	150	150
% Theoretical	85%	84%	86%	94%
Soda Ash, lbs.	1000	1000	1100	900
% Theoretical	84%	87%	84%	88%
RECLAIMED BRINE				
Volume, Gallons	2700	2300	2700	2300
Strength, °Salometer	56°	58°	59°	57°
Solubles, Total lbs.	3700	3270	3920	3200
Total Hardness, gpg	405	365	420	470
Purity, % Na/Solubles	95%	96%	95%	95%
WASTE				
Cumulated for Test numbers				19-20
Volume, Gallons				900
Insolubles, lbs.				3910
Solubles, lbs.				1850
REDUCTION OF WASTE %				
Volume				83.7
Solubles				77.1

REMARKS: **These test runs were made to reduce the waste with respect ot the volume and quantity of soluble present with the sludge. This was accomplished by making a single discharge of sludge for two complete test runs. The quality of the reclaimed brine has improved with the use of both soda ash and hydrated lime.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	21	22	23	24
DATE	1-25-72	1-27-72	1-28-72	2-1-72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2600	2900	2600
Strength, °Salometer	57°	57°	59°	59°
Solubles, Total lbs.	4050	3620	4200	3760
Magnesium Hardness, gpg	580	540	580	580
Calcium Hardness, gpg	2160	1960	1980	2060
CHEMICALS ADDED				
Hydrated Lime, lbs.	150	100	100	100
% Theoretical	85%	68%	57%	63%
Soda Ash, lbs.	1000	800	900	800
% Theoretical	83%	81%	80%	77%
RECLAIMED BRINE				
Volume, Gallons	2700	2300	2700	2300
Strength, °Salometer	56°	57°	58°	58°
Solubles, Total lbs.	3700	3200	3840	3260
Total Hardness, gpg	410	380	465	525
Purity, % Na/Solubles	95%	95%	95%	94%
WASTE				
Cumulated for Test numbers		21&22		23&24
Volume, Gallons		900		900
Insolubles, lbs.		3045 / 4175		2520 / 2145
Solubles, lbs.		1635 / 505		770 / 645
REDUCTION OF WASTE %				
Volume		83.7		83.7
Solubles		78.7 / 93.4		90.4 / 92.0

REMARKS: These test runs were made to reduce the waste further by discharging the waste (sludge) after two test runs of process optimization. The quality of the reclaimed brine has been maintained above the minimum purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	25	26	27	28
DATE	2-2-72	2-4-72	2-7-72	2-8-72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2600	2300	2900
Strength, °Salometer	58°	56°	58°	58°
Solubles, Total lbs.	4120	3560	3270	4120
Magnesium Hardness, gpg	640	600	525	525
Calcium Hardness, gpg	2040	1880	2040	1925
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	50	100
% Theoretical	51%	61%	40%	62%
Soda Ash, lbs.	900	800	700	900
% Theoretical	77%	82%	78%	75%
RECLAIMED BRINE				
Volume, Gallons	2700	2300	2300	2700
Strength, °Salometer	56°	55°	57°	57°
Solubles, Total lbs.	3700	3082	3200	3760
Total Hardness, gpg	535	365	465	435
Purity, % Na/Solubles	94%	95%	95%	95%
WASTE				
Cumulated for Test numbers			25,26 & 27	
Volume, Gallons			900	
Insolubles, lbs.			4610 / 5440	
Solubles, lbs.			1540 / 710	
REDUCTION OF WASTE %				
Volume			88.5	
Solubles			86.0 / 93.5	

REMARKS: **These test runs were made to make a comparison of the quality of reclaimed brine with a reduction of dosages in hydrated lime and a further reduction of waste by discharging waste sludge after three (3) test runs of process optimization.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	29	30	31	32
DATE	2-9-72	2-10-72	2-14-72	2-15-72
UNTREATED WASTE BRINE				
Volume, Gallons	2600	2300	2900	2600
Strength, °Salometer	58°	56°	56°	57°
Solubles, Total lbs.	3700	3140	3970	3620
Magnesium Hardness, gpg	585	535	580	580
Calcium Hardness, gpg	1980	1915	1940	1870
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	none
% Theoretical	62%	77%	57%	0%
Soda Ash, lbs.	800	700	800	735
% Theoretical	80%	82%	72%	76%
RECLAIMED BRINE				
Volume, Gallons	2300	2300	2700	2600
Strength, °Salometer	57°	55°	55°	56°
Solubles, Total lbs.	3200	3080	3620	3550
Total Hardness, gpg	435	410	570	585
Purity, % Na/Solubles	95%	95%	93%	93%
WASTE				
Cumulated for Test numbers		28,29&30		
Volume, Gallons		900		
Insolubles, lbs.		~~3290~~ 3335		
Solubles, lbs.		~~590~~ 545		
REDUCTION OF WASTE %				
Volume		88.5		
Solubles		~~94.6~~ 95.0		

REMARKS: These test runs were observed on the nature and density of waste sludge that was discharged only after making three (3) process optimization test runs.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	33	34	35	36
DATE	2-16-72	2-18-72	2-21-72	2-22-72
UNTREATED WASTE BRINE				
Volume, Gallons	2600	2900	2600	2600
Strength, °Salometer	58°	58°	58°	58°
Solubles, Total lbs.	3700	4100	3700	3700
Magnesium Hardness, gpg	555	540	525	530
Calcium Hardness, gpg	1950	2050	2120	2070
CHEMICALS ADDED				
Hydrated Lime, lbs.	none	none	none	none
% Theoretical	0%	0%	0%	0%
Soda Ash, lbs.	765	900	900	800
% Theoretical	78%	80%	87%	79%
RECLAIMED BRINE				
Volume, Gallons	2300	2700	2600	2400
Strength, °Salometer	57°	57°	57°	57°
Solubles, Total lbs.	3200	3760	3630	3320
Total Hardness, gpg	595	605	465	640
Purity, % Na/Solubles	93%	93%	94%	93%
WASTE				
Cumulated for Test numbers	31,32&33			34,35&36
Volume, Gallons	900			1000
Insolubles, lbs.	5835 / 5980			2790 / 3180
Solubles, lbs.	715 / 570			2260 / 1870
REDUCTION OF WASTE %				
Volume	88.9			87.5
Solubles	93.7 / 95.0			80.4 / 83.7

REMARKS: These test runs were made to observe the effect of not using hydrated lime for chemical reaction with soda ash. The reclaimed brine quality is under consideration, so a capacity check was made on water softeners regenerated with this brine.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	37	38	39	40
DATE	2-23-72	2-24-72	2-29-72	3-2-72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2600	2600	2900
Strength, °Salometer	59°	58°	58°	58°
Solubles, Total lbs.	4200	3700	3700	4100
Magnesium Hardness, gpg	580	585	585	555
Calcium Hardness, gpg	2040	2065	2215	2095
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	57%	62%	62%	59%
Soda Ash, lbs.	900	800	900	900
% Theoretical	79%	77%	82%	78%
RECLAIMED BRINE				
Volume, Gallons	2600	2600	2600	2700
Strength, °Salometer	57°	56°	57°	57°
Solubles, Total lbs.	3620	3560	3620	3760
Total Hardness, gpg	510	585	395	485
Purity, % Na/Solubles	94%	93%	95%	94%
WASTE				
Cumulated for Test numbers			37,38 & 39	
Volume, Gallons			900	
Insolubles, lbs.			4930 / 5005	
Solubles, lbs.			500 / 425	
REDUCTION OF WASTE %				
Volume			88.9	
Solubles			95.3 / 96.0	

REMARKS: **These test runs were made to observe the nature of the sludge form with the use of soda ash along for reaction. The sludge was observed to be gummy and bulky. Acid requirement for pH adjustment is quite high.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	41	42	43	44
DATE	3-3-72	3-7-72	3-9-72	3-10-72
UNTREATED WASTE BRINE				
Volume, Gallons	2600	2500	2900	2500
Strength, °Salometer	57°	58°	57°	58°
Solubles, Total lbs.	3620	3520	4100	3550
Magnesium Hardness, gpg	525	1960	1875	1870
Calcium Hardness, gpg	2025	1960	1875	1870
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	none	100
% Theoretical	69%	67%	0%	72%
Soda Ash, lbs.	800	850	1050	750
% Theoretical	80%	89%	100%	83%
RECLAIMED BRINE				
Volume, Gallons	2500	2500	2500	2500
Strength, °Salometer	56°	57°	56°	57°
Solubles, Total lbs.	3420	3480	3400	3480
Total Hardness, gpg	410	390	390	490
Purity, % Na/Solubles	94%	95%	95%	94%
WASTE				
Cumulated for Test numbers		40,41 & 42		
Volume, Gallons		900		
Insolubles, lbs.		5390 / 5390		
Solubles, lbs.		580 / 580		
REDUCTION OF WASTE %				
Volume		88.9		
Solubles		94.9 / 94.9		

REMARKS: These test runs were made to establish the optimum dosages of soda ash and hydrated lime. The quality of the treated brine was also verified for putity level.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	45	46	47	48
DATE	3-13-72	3-14-72	3-15-72	3-16-72
UNTREATED WASTE BRINE				
Volume, Gallons	2500	2900	2700	2500
Strength, °Salometer	57°	58°	58°	57°
Solubles, Total lbs.	3480	4100	3820	3480
Magnesium Hardness, gpg	535	525	535	555
Calcium Hardness, gpg	1920	1925	1965	1925
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	71%	63%	66%	68%
Soda Ash, lbs.	800	900	850	800
% Theoretical	83%	84%	83%	86%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2500	2500
Strength, °Salometer	56°	57°	57°	56°
Solubles, Total lbs.	3420	3770	3480	3420
Total Hardness, gpg	485	445	425	440
Purity, % Na/Solubles	94%	95%	95%	95%
WASTE				
Cumulated for Test numbers	43,44&45			46,47 &48
Volume, Gallons	900			900
Insolubles, lbs.	5295 / 5780			5100 / 5385
Solubles, lbs.	955 / 470			900 / 615
REDUCTION OF WASTE %				
Volume	88.9			88.9
Solubles	91.4 / 95.8			92.1 / 94.6

REMARKS: **These test runs were made to investigate the best combination of soda ash and hydrated lime dosages that could be used as the standard optimum dosages in a soda lime hardness reduction process.**

APPENDIX B

SUMMARY OF HYDROCHLORIC ACID REQUIREMENTS

APPENDIX - B

Muriatic Acid Required for pH Adjustment - Process Optimization

Test Run #	Reclaimed Brine (Gallon)	pH Reading	HCR Used (ML)	Test Run #	Reclaimed Brine (Gallon)	pH Reading	HCl Used (ML)
1	2400	10.0	15,500	25	2700	8.9	285
2	2400	7.4	0.0	26	2300	9.4	1,830
3	2400	8.5	840	27	2300	9.7	2,420
4	2400	9.7	9,060	28	2700	8.5	350
5	2400	9.5	5,080	29	2300	8.5	250
6	2400	10.6	7,870	30	2300	8.6	250
7	2400	6.6	0.0	31	2700	8.8	315
8	2400	7.8	0.0	32	2600	9.8	3,400
9	2400	7.9	0.0	33	2300	8.8	350
10	2400	10.5	11,300	34	2700	9.6	6,600
11	2400	10.4	10,650	35	2600	10.8	9,700
12	2400	10.3	9,850	36	2400	9.8	4,700
13	2400	10.2	9,500	37	2600	8.8	545
14	2200	10.1	10,600	38	2600	7.9	0.0
15	2700	8.5	840	39	2600	8.9	305
16	2300	8.8	560	40	2700	8.7	635
17	2700	7.1	0.0	41	2500	8.8	940
18	2300	8.7	420	42	2500	8.9	2,340
19	2700	8.7	420	43	2500	10.8	14,600
20	2300	7.6	0.0	44	2500	8.9	440
21	2700	8.4	380	45	2500	8.9	350
22	2300	8.5	300	46	2700	9.0	410
23	2700	8.4	225	47	2500	8.9	320
24	2300	8.6	220	48	2500	8.8	265

APPENDIX C

RIVERSIDE LAB PROCEDURE

OPTIMUM DOSAGE DETERMINATION

RIVERSIDE LAB PROCEDURE - OPTIMUM DOSAGE DETERMINATION

I. PROCEDURE

1. Use waste brine from Riverside.

2. Analyze - pH, Mg, Ca, Salometer.

3. Using 200 ml samples, five separate tests:

   a. Add 50% stoichiometric of soda ash to beaker "A", stir.

   b. Add 75% stoichiometric of soda ash to beaker "B", stir.

   c. Add 85% stoichiometric of soda ash to beaker "C", stir.

   d. Add 100% stoichiometric of soda ash to beaker "D", stir.

   e. Add 110% stoichiometric of soda ash to beaker "E",. stir.

4. At 15 minute intervals, analyze and record the composition of the reacting brine for the following: (The analyses to be made on a filtered sample.)

   a. pH

   b. magnesium

   c. calcium

5. Tabulate results of analyses and graphically represent the values as a function of time of stirring.

   a. Final pH vs dosage.

   b. pH vs time at 50%, 75%, etc.

   c. Ca concentration vs time at 50%, 75%, etc.

   d. Mg concentration vs time at 50%, 75%, etc.

6. Choose optimum time and dosage from these by the point of maximum calcium removal. (Minimum calcium concentration.)

7. Use five new, separate, 200 ml samples of brine.

8. Without using soda ash, add hydrated lime at the following dosages, as a percent of stoichiometric.

Beaker	Lime Dosage, %
"F"	50
"G"	68
"H"	75
"I"	100
"J"	110

9. Repeat Steps 4 and 5.

10. Choose optimum lime dosage and mixing time based on producing 95% purity, rather than on obtaining maximum magnesium removal.

II. INITIAL ANALYSES AND DOSAGE CALCULATION

1. Experimental Determinations

   a. Volume of waste brine sample - 500 ml.

   b. Reaction time for lime soda process 90 minutes.

   c. Time intervals for determination - 10 and 15 minutes.

   d. Determinations - calcium, magnesium and pH.

2. Waste Brine Chemical Analysis

   a. Total volume - 500 ml.

   b. Concentration - 57^{o} salometer.

   c. Total hardness - 2450 grains per gallon.

   d. Calcium hardness - 1925 gpg.

   e. Magnesium hardness - 525 gpg.

   f. pH reading - 6.4.

3. Chemical Dosages

a. Soda ash (85% of stoichiometric)

$$= \text{total hardness} \times (0.0151) \times \text{ml} \times \frac{\text{gal.}}{\text{ml}} \times \frac{1}{\text{gal.}} \times \frac{\text{gram}}{\text{lb}}$$

$$= 2450 \times 0.0151 \times 500 \times \frac{1}{3785} \times \frac{1}{100} \times 454$$

$$= 22 \text{ grams} \times 0.85 = \underline{\underline{18.70 \text{ grams}}}$$

b. Hydrated lime (68% of stoichiometric)

$$= \text{magnesium hardness} \times (0.0105) \times \text{ml} \times \frac{\text{gal.}}{\text{ml}} \times \frac{1}{\text{gal.}} \times \frac{\text{gram}}{\text{lb}}$$

$$= 525 \times 0.0105 \times 500 \times \frac{1}{3785} \times \frac{1}{100} \times 454$$

$$= 3.3 \text{ grams} \times 0.68 = \underline{\underline{2.22 \text{ grams}}}$$

III. REACTIONS DATA - SODA ASH ONLY

Table 17. ANALYSES OF LABORATORY REACTIONS SOLUTIONS. (Analyses expressed in grains per gallon, as $CaCO_3$; except that pH is in units.)

Variables	0 Minutes	15 Min.	30 Min.	45 Min.	60 Min.
50% Dosage					
TH	2450	2045	1750	1460	1225
Ca	1925	1520	1225	935	700
Mg	525	525	525	525	525
pH	6.4	7.0	7.3	7.4	7.5
75% Dosage					
TH	2450	1460	1050	700	610
Ca	1925	935	525	175	85
Mg	525	525	525	525	525
pH	6.4	7.0	7.5	8.0	8.4
85% Dosage					
TH	2450	1520	935	700	465
Ca	1925	935	410	210	0
Mg	525	525	525	490	465
pH	6.4	7.2	8.3	9.0	9.4
100% Dosage					
TH	2450	1810	815	410	350
Ca	1925	1285	290	30	0
Mg	525	525	525	380	350
pH	6.4	7.2	8.1	9.0	9.8
110% Dosage					
TH	2450	1750	760	410	320
Ca	1925	1225	235	0	0
Mg	525	525	525	410	320
pH	6.4	7.4	8.3	9.2	10.0

IV. REACTION DATA - LIME ONLY

Table 18. ANALYSES OF LABORATORY REACTIONS SOLUTIONS. (Analysis expressed in grains per gallon, as $CaCO_3$; except that pH is in units.)

Variables	0 Minutes	15 Min.	30 Min.	45 Min.	60 Min.
50% Dosage					
TH	2450	2400	2295	2360	2450
Ca	1925	1940	1990	2075	2166
Mg	525	460	305	285	285
pH	6.4	7.0	8.4	8.8	9.0
68% Dosage					
TH	2450	2400	2260	2405	2450
Ca	1925	1950	1990	2230	2275
Mg	525	450	270	175	175
pH	6.4	7.6	8.5	8.9	9.1
75% Dosage					
TH	2450	2360	2180	2275	2450
Ca	1925	1950	1995	2130	2305
Mg	525	410	185	145	145
pH	6.4	8.0	8.5	8.8	9.1
100% Dosage					
TH	2450	2335	2275	2395	2450
Ca	1925	1985	2045	2280	2420
Mg	525	350	230	115	30
pH	6.4	9.1	9.4	9.5	9.5
110% Dosage					
TH	2450	2395	4330	2395	2450
Ca	1925	2045	2100	2280	2450
Mg	525	350	230	115	0
pH	6.4	9.1	9.4	9.5	9.5

V. REACTIONS DATA - SODA ASH AND LIME

Table 19. ANALYSES OF LABORATORY REACTIONS SOLUTIONS.[a] (Analysis expressed in grains per gallon, as $CaCO_3$; except that pH is in units.)

Time, min.	Calcium Hardness, gpg	Magnesium Hardness, gpg	pH, unit
0	1925	525	6.4
10	990	525	7.3
20	720	525	8.0
30	235	525	8.5
45	0	525	9.4
55	0	525	9.4
65	60	375	9.3
75	145	320	9.2
90	185	200	9.1

[a]Solutions treated with soda ash (85% stoichiometric), stirred 45 minutes, treated with hydrated lime (68% stoichiometric) and stirred 45 additional minutes. Average values from triplicate tests.

APPENDIX D

PLANT DESCRIPTION, OPERATION AND ANALYTICAL PROCEDURES

PLANT DESCRIPTION, OPERATION AND ANALYTICAL PROCEDURES

I. EQUIPMENT DESCRIPTION - See Figure 21, "Flow Diagram."

A. Valves

Valve No.	Identification	Location
1	Waste brine valve to storage tank	Waste brine line
1A	Waste brine valve to brine pool	Waste brine line
1B	Waste brine valve from brine pool to storage tank	Waste brine line
2	Waste brine transfer valve	Storage tank transfer line
2A	Waste brine drain valve	Storage tank transfer line
3	Reactor tank discharge valve	Reactor tank bottom discharge
4	Recycle line valve	Recycle line to reactor tank
5	Sludge disposal valve	Sludge disposal line
6	Decanting valve	Reactor tank decanting outlet
6A	Lower decanting valve	Reactor tank upper drain outlet
7	Drain valve	Reactor tank lower drain outlet
8	Sludge and brine cut-off valve	Reactor tank bottom discharge

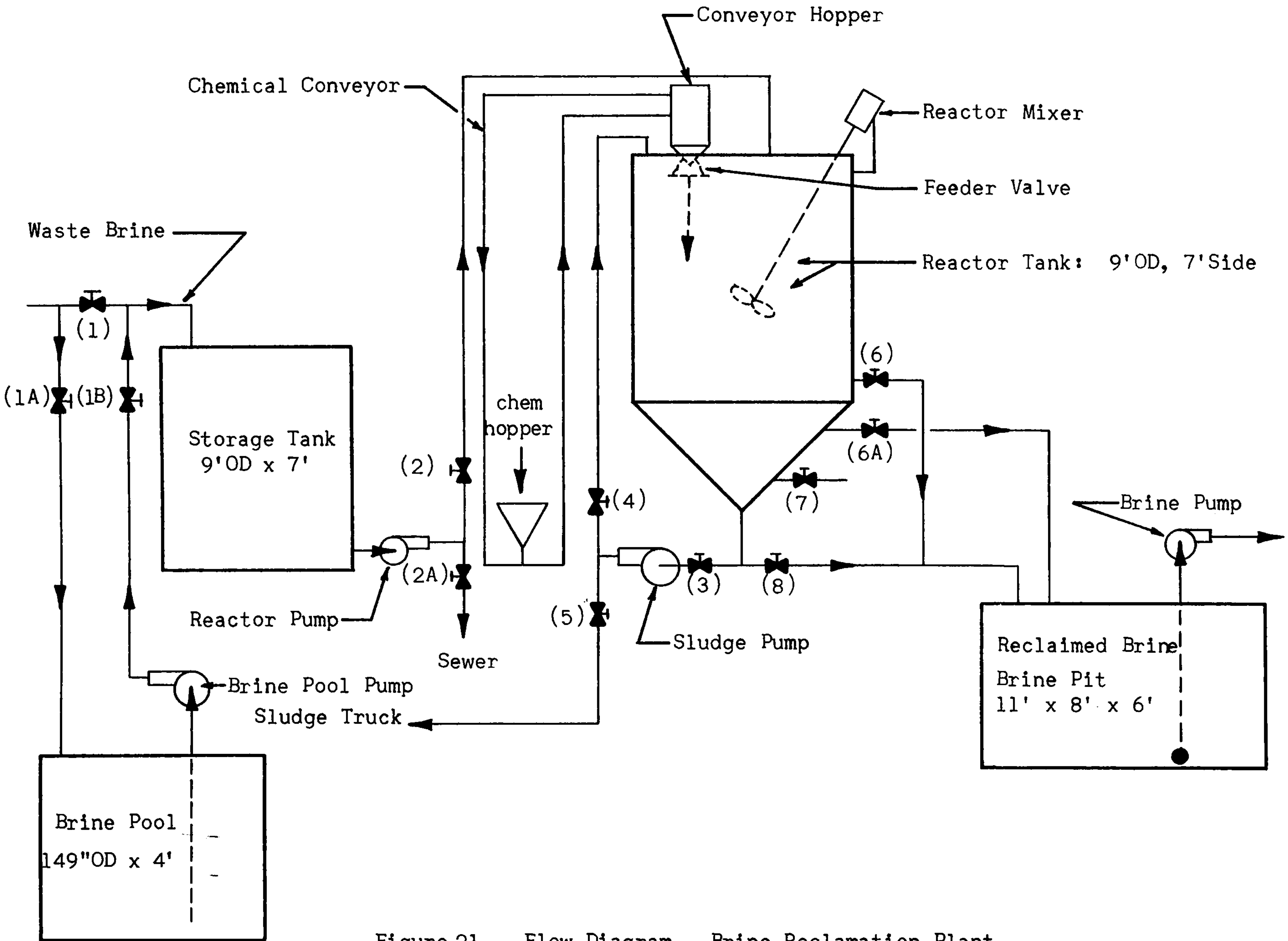

Figure 21. Flow Diagram - Brine Reclamation Plant.

B. Switches, located in the control panel

Switch identification

Panel main control. Energizes all electric controls.

Reactor mixer. Continuous operation of mixer, as desired.

Reactor sludge transfer pump. Continuous operation, as energized, for sludge transfer: either for discharge or recirculation.

Reactor pump. Continuous operation of pump to transfer brine into reactor, as energized.

Brine pump. Continuous operation of pump to transfer reclaimed brine to regeneration plant, as energized.

Chemical feeder valve. Cyclic operation of feeder discharge. Controlled by feeder timer.

Floor sump pump. Float controlled for automatic discharge.

Conveyer blower. Pneumatically transfers dry lime and soda ash continuously from lower hopper to upper hopper.

Master control of all switches.

Feeder heater. Thermostatically controlled at heater to reduce humidity, thereby avoiding agglomeration of chemicals.

Feeder timer. To control cyclic operation of feeder discharge valve.

C. Pumps and other equipment

Identification	Location	Function & Comments
Brine pool pump	Near brine pool	Transfer waste brine from brine pool to storage tank. Price E100-100B, 1 HP, bronze centrifugal. 40 gpm at 68 ft of head. Manually controlled.
Reactor pump	Near storage tank	Transfer waste brine from storage tank to reactor tank. Same style pump as brine pool pump.
Brine pump	Near brine pit	Transfer reclaimed brine to regeneration plant. Same style as brine pool pump.
Reactor sludge pump	Near reactor tank	Pump sludge for disposal or recycle reactants to the reactor tank. Moyno CDQ, frame 2LB, 3 HP, 900 RPM, 24 gpm.
Floor sump pump	Near drain trough	Pump floor wastes to sewer discharge.
Reactor mixer	Top of reactor	Mix reacting chemical and brine. Eastern RG8-NTR, 3 HP, 400 RPM, totally enclosed.
Chemical hopper	Floor level	Supply chemicals to conveyer.
Chemical conveyer	From floor to top of reactor tank	Convey soda ash and hydrated lime to reactor. Watubo 2000 energizer on 16" cyclone.

Identification	Location	Function & Comments
Chemical feeder valve	Discharge of the conveyer system	Discharge chemicals at uniform rate.
Electrical control panel	Back wall	Electric control of motors or other equipment
Sludge truck	Parking lot	Sludge collection and transfer to dump site. Obsolete oil tanker.

D. Pipes and Fittings

Identification	Color, size	Function
Water pipes	blue, 1" copper	Supply water for the project
Electric conduits	orange, conduit	All electrical lines
Waste brine pipes	gray PVC, 1-1/2"	Waste brine flow to brine pool or storage tank
Waste brine transfer pipe	gray PVC, 1-1/2"	Waste brine transfer to reactor tank
Decanting outlet pipe	gray PVC, 3"	Decant reclaimed brine from reactor
Drain outlet pipe	gray PVC, 1"	Further recovery of treated brine in drain outlets
Sludge discharge pipe	gray PVC, 4"	Bottom discharge of sludge and recycle of reactants
Recycle pipe	gray PVC, 2"	Recycle contents of reactor
Chemical conveying tubes	blue-green 2" aluminum	Convey soda ash and hydrated lime to reactor
Brine line	gray PVC, 1-1/2"	Transfer reclaimed brine to regeneration plant
Sump pipe	gray PVC, 1-1/2"	Transfer floor wastes to sewer discharge

II. SAMPLING PROCEDURES

A. Waste Brine

Fill a 1000 ml beaker with waste brine from the storage tank.

B. Regeneration Brine

Fill a 1000 ml beaker from the discharge line coming from the plant brine regeneration line. To be obtained for each three demonstration runs.

C. Reclaimed Brine

Fill a 1000 ml beaker with clear effluent in the reactor tank. This sample is to be taken after overnight settling before decantation.

D. Hard and Soft Water

Fill a 500 ml beaker from the hard water line in the regeneration plant. This will be the influent water for the water softener undergoing capacity check. Every hour during the capacity check, collect a sample of the softened water at the discharge of the water softener undergoing capacity check. This will be done until this water is 1 gpg hard.

E. Sludge

Fill a 1000 ml bottle with sludge during the time of sludge discharge to the sludge truck. This must be taken in increments of 200 ml at intervals of 5 minutes.

III. ANALYTICAL REQUIREMENTS

A. Regeneration Brine Samples

1. Total hardness

2. pH

3. Concentration

4. Purity

B. Reclaimed Brine Samples

1. Total hardness

2. Calcium hardness

3. Carbonate alkalinity

4. pH

5. Concentration

6. Purity

C. Water Samples

1. Total hardness

D. Sludge Samples (Analyzed at central laboratory)

1. Wet density, lb/gal.

2. Settled sludge volume, %

3. Dry (105^{o}C) density, lb/gal.

4. Solubles: Percent weight loss from the dry sample after a 250 ml wash with demineralized water.

IV. LABORATORY SUPPLIES AND EQUIPMENT

A. pH

1. Calibrated pH meter

2. 100 ml beaker for sample

3. Demineralized water in a wash bottle

B. Hardness Determination

1. 50 ml automatic buret

2. 250 ml erlenmeyer flask for sample

3. Demineralized water for sample dilution

4. 0.02N Versenate standard solution

5. Buffer solution for hardness

6. Indicators: Calcium, and total hardness

C. Carbonate Alkalinity

1. 50 ml automatic buret
2. 0.02N H_2SO_4 standard solution
3. Phenolphthalein indicator solution
4. 250 ml erlenmeyer flask for sample

D. Brine Concentration

1. Hydrometer cylinder
2. Salometer tube, calibrated in percent brine concentration (degrees Salometer)
3. Two 1000 ml beakers

E. Sludge Sample Containers

1. 1000 ml polyethylene bottles
2. 1000 ml graduated cylinder

F. Acid Adjustment

1. Graduated cylinder - 1000 ml
2. Gallon capacity acid bottles
3. 4000 ml polyethylene beaker
4. Concentrated hydrochloric acid
5. 6-inch diameter funnel

G. Miscellaneous

1. 1 ml pipets
2. Graduated cylinder, 58.3 ml standard water sample
3. Timer - alarm, 120 minute
4. 500 ml beakers

V. ANALYTICAL PROCEDURES

A. Brine Calcium (or Total) Hardness - two tests, two samples

1. Pipet a 1 ml sample and transfer it to a 250 ml erlenmeyer flask.
2. Dilute to about 100 ml with demineralized water.
3. Add 2 ml of hardness buffer solution.
4. Add a small quantity of calcium (or total) hardness indicator to the sample.
5. Titrate with 0.02N Versenate solution.
6. Multiply the buret reading by 58.3 to calculate calcium (or total) hardness concentration in grains per gallon (gpg) expressed as $CaCO_3$.

B. Water Calcium (or Total) Hardness - two tests, two samples

1. Transfer a 58.3 ml sample to a 250 ml flask for titration.
2. Add 2 ml of hardness buffer solution.
3. Add a small quantity of calcium (or total) hardness indicator.
4. Titrate with 0.02N Versenate solution.
5. Record the buret reading. This is numerically equal to the calcium (or total) hardness in gpg as $CaCO_3$.

C. pH

1. Fill a 100 ml beaker with waste brine.
2. Insert the pH meter probes in sample.
3. Record the pH reading.

D. Concentration of brine, in Degrees Salometer

1. Fill the hydrometer cylinder with the sample.
2. Insert, with a mild spinning action, the salometer tube in the sample.

3. Take the direct reading of the soluble salt concentration.

4. Using the Brine Table in Appendix F and the salometer reading, determine the pounds of soluble salts per gallon of brine.

E. Brine Purity

1. Refer to Appendix E, "Percent Purity".

2. On the left column find the row that lists the brine salometer.

3. Move to the right in this row to the column headed with the nearest hundred of grains per gallon total hardness.

4. The number in the square at this intersection is the "Brine Purity" in percent. This refers to the percent of sodium chloride present in the total salts.

F. Carbonate Alkalinity

1. Transfer a 58.3 ml sample to a 250 ml flask for titration.

2. Add three drops of phenolphthalein indicator.

3. Titrate with 0.02N H_2SO_4 to discharge the pink color.

4. Record the buret reading. This is numerically equal to the carbonate alkalinity, expressed in gpg as $CaCO_3$.

VI. CALCULATION OF CHEMICAL REQUIREMENTS

A. The calculations for the optimum dosages of soda ash and hydrated lime are made using the following techniques:

1. Stoichiometric requirement for hydrated lime -- 100% $Ca(OH)_2$:

$$(\text{Mg hardness}) \times (0.0105) \times \left(\frac{\text{total gal.}}{100 \text{ gal.}}\right) =$$

$$\left(\frac{\text{gr}}{\text{gal.}}\right) \times \left(\frac{\text{Eq wt } Ca(OH)_2}{\text{Eq wt } CaCO_3} \times \frac{1 \text{ lb}}{7000 \text{ gr}}\right) \times \left(\frac{\text{gal.}}{\text{gal.}}\right) =$$

pounds of hydrated lime per total batch.
Optimum dosage of hydrated lime is 63-72% of stoichiometric.

2. Stoichiometric requirement for soda ash -- 100% Na_2CO_3:

$$(\text{total hardness}) \times (0.0151) \times \left(\frac{\text{total gal.}}{100 \text{ gal.}}\right) =$$

$$\left(\frac{\text{gr}}{\text{gal.}}\right) \times \left(\frac{\text{Eq wt } Na_2CO_3}{\text{Eq wt } CaCO_3} \times \frac{1 \text{ lb}}{7000 \text{ gr}}\right) \times \left(\frac{\text{gal.}}{\text{gal.}}\right) =$$

pounds of soda ash per total batch. Optimum dosage is 83-87% of stoichiometric.

3. Acid requirement for 35% hydrochloric acid having a density of 9.7 pounds per gallon:

$$(\text{Carbonate alkalinity}) \times (0.03) \times \left(\frac{3785}{9.7}\right) \times \left(\frac{\text{total gal.}}{100 \text{ gal.}}\right) =$$

$$\left(\frac{\text{gr}}{\text{gal.}}\right) \times \left(\frac{\text{Eq wt HCl}}{\text{Eq wt } CaCO_3} \times \frac{1 \text{ lb}}{7000 \text{ gr}} \times \frac{1}{0.35}\right) \times \left(\frac{\text{ml/gal.}}{\text{lb/gal.}}\right) \times \left(\frac{\text{gal.}}{\text{gal.}}\right) =$$

ml of hydrochloric acid (HCl) per total batch.
The acid requirement is this stoichiometric amount.

4. Amount of $100^{\circ}S$ brine needed to adjust decanted brine to $60^{\circ}S$:

$$\frac{1.4744-C}{1.1725} \times V = V^1$$

where,

1.4744 is the pounds of salt per gallon of $60^{\circ}S$ brine. (Appendix F)

C	is the pounds of salt per gallon of brine decanted.
1.1725	is the "excess" pounds (over that in 60°S brine) of salt per gallon of 100°S brine.
V	is the gallons of brine decanted.
V^1	is the gallons of 100°S brine needed.

VII. COLLECTION AND STORAGE OF WASTE BRINE - See Figure 21

Waste brine is collected from the effluent of the water softener's regeneration and is stored as follows.

A. Waste Brine Collection in the Brine Pool

1. Open Valve No. 1A.

2. Close Valve No. 1 and 1B.

3. Transfer of waste brine is controlled during regeneration. Therefore, the only attention required is to avoid overfilling the brine pool.

B. Waste Brine Transfer from Brine Pool to Storage Tank

1. Open Valve No. 1B.

2. Close Valve No. 1 and 1A.

3. Transfer waste brine by pump. Connect electrically the transfer pump near the brine pool. Manual control is necessary--do not overfill storage tank.

C. Waste Brine Collection Directly in Storage Tank.

1. Open Valve No. 1.

2. Close Valve No. 1A and 1B.

Note: Watch waste brine level in the storage tank. Manual control is necessary--do not overfill the storage tank.

VIII. TRANSFER OF WASTE BRINE TO REACTOR - See Figure 21 and 22

A. Transfer waste brine to reactor tank (after measuring volume and analyzing brine).

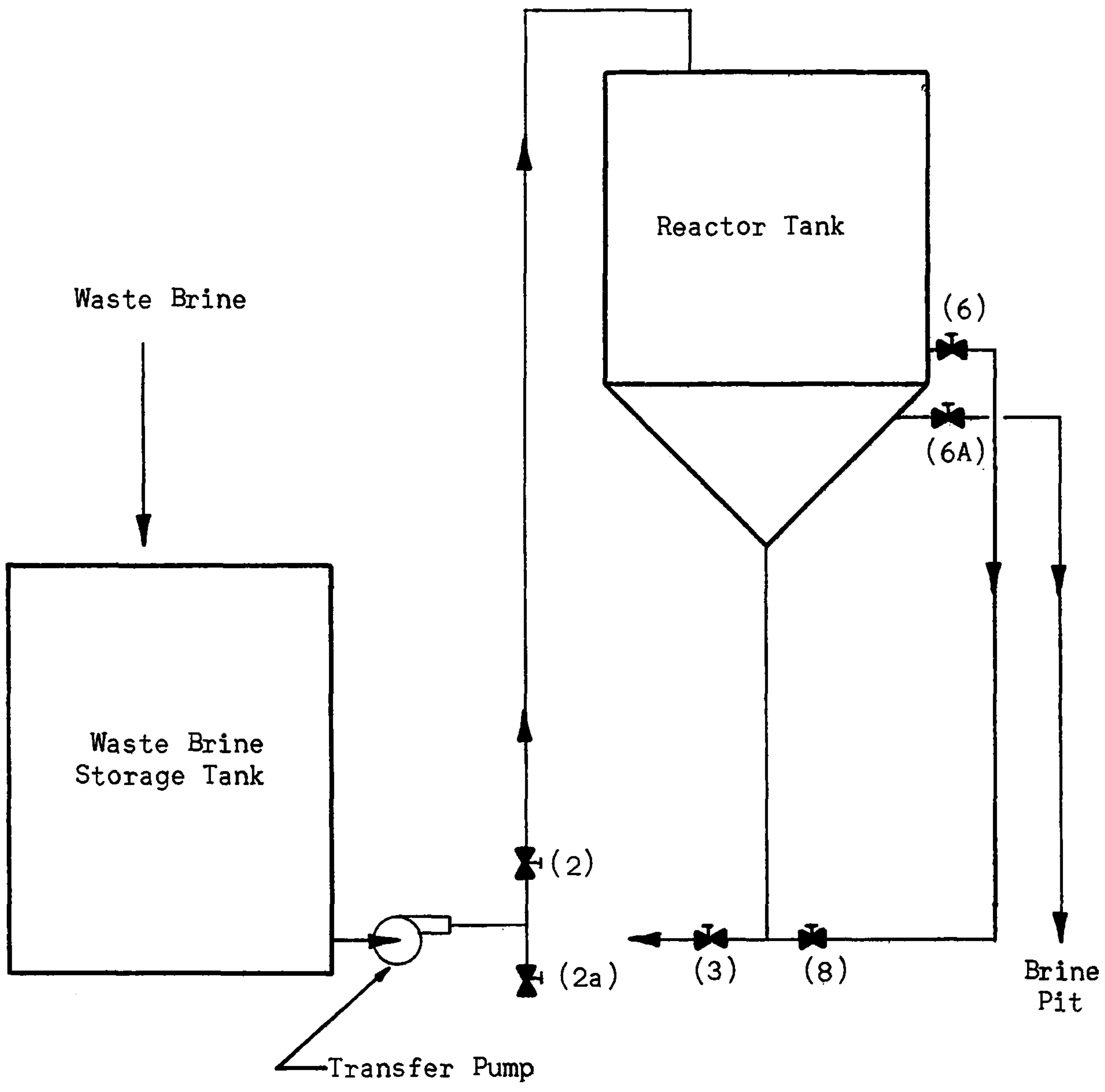

Figure 22. Flow Diagram - Transfer of Waste Brine to Reactor Tank.

1. Valve Control

   a. Open Valves No. 1A and 2.

   b. Close all other valves.

2. Switches Operating Sequence:

   a. Panel main control switch on.

   b. Master control switch on.

   c. Reactor pump switch on.

   d. The remaining switches off.

   e. Switch off all main switches when waste brine transfer to reactor tank is complete.

   f. Close Valve No. 2.

3. Pump

   a. Reactor pump transfers a known volume of waste brine to the reactor tank.

   b. Manual control is necessary.

   c. Switch off pump when brine transfer to the reactor tank is complete.

4. Pipe and Fitting Connections

   Verify that waste brine flows from the storage tank through the waste brine transfer line to the top of the reactor tank.

IX. CHEMICAL ADDITION TO REACTOR TANK - See Figure 23

With the dosages of chemicals known and ready for addition, the operation continues in this manner:

A. Valve Control

   1. Verify that Valves No. 3 and 4 are open.

B. Switches Operating Sequence

   1. Panel main control switch on.

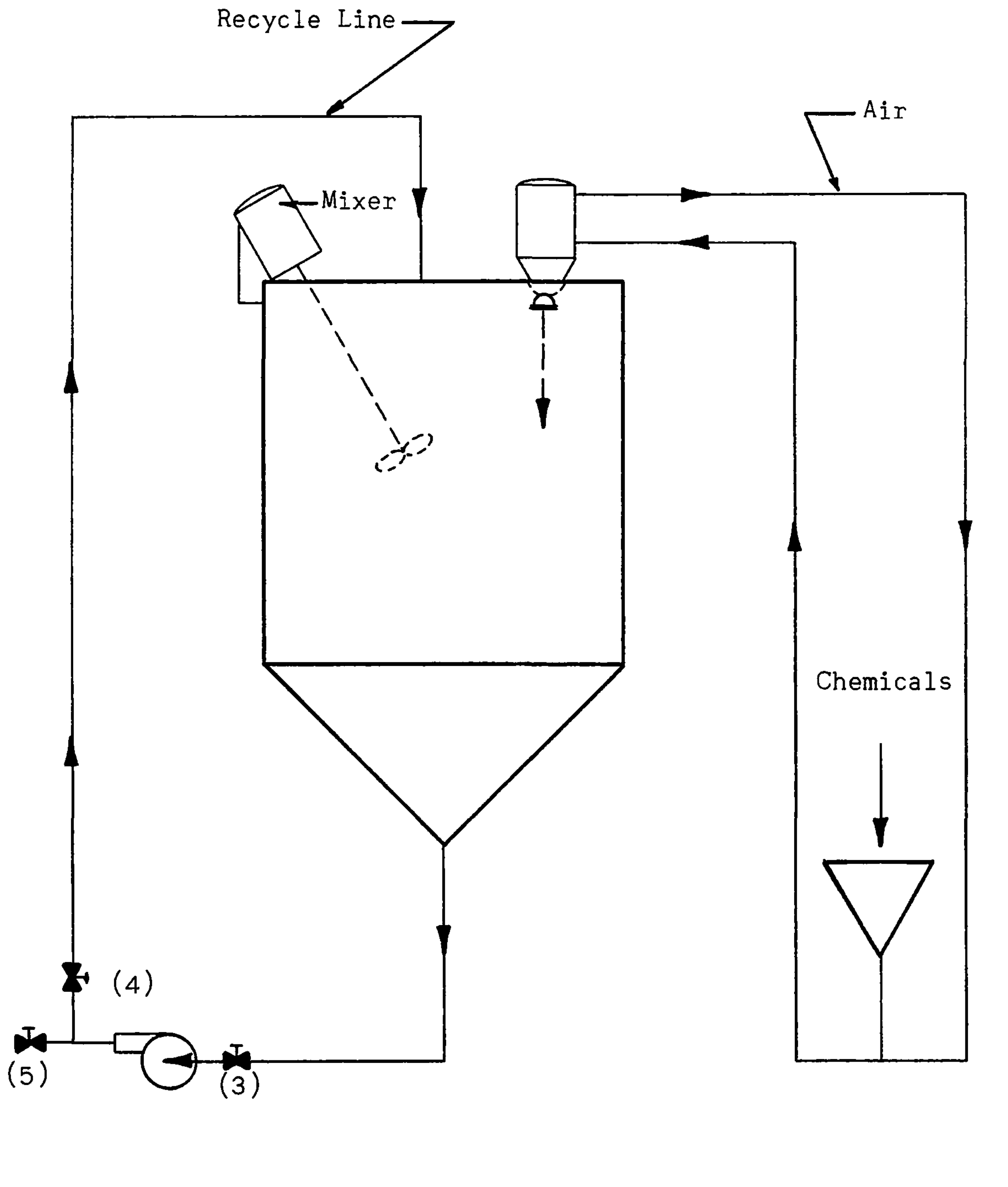

Figure 23. Flow Diagram - Chemical Addition and Recirculation of Reactants.

2. Master control switch on.

3. Reactor sludge pump and mixer; feeder heater and valve; and conveyer blower switches on.

4. The remaining switches are off.

5. Feeder heater and valve, and conveyer blower are to be switched off when addition of chemicals is complete.

6. Reactor sludge pump and mixer switches will be kept on for one hour additional reaction time, then switched off.

C. Pumps

Sludge pump will run continuously to recycle reacting solution during chemical addition and while reaction later continues in the reactor tank.

Note: Verify that brine flows through the reactor tank bottom discharge and the recycle line. During chemical feed, verify that chemicals flow through the conveyer tube to the discharge at the chemical feeder valve.

X. DECANTING TREATED BRINE FROM THE REACTOR TANK See Figure 24

After overnight settling, the clear reclaimable brine has been completely separated from the sludge. The clear brine will be analyzed, then decanted with this procedure.

A. Valve Control

1. Close all valves.

2. Open Valve No. 6.

3. Valve No. 6A may also be opened if clear brine is below that level.

4. Close Valves No. 6 and 6A when decantation is complete.

B. Switches and Pumps

Decantation is by gravity. No switches to be set, nor pumps to run.

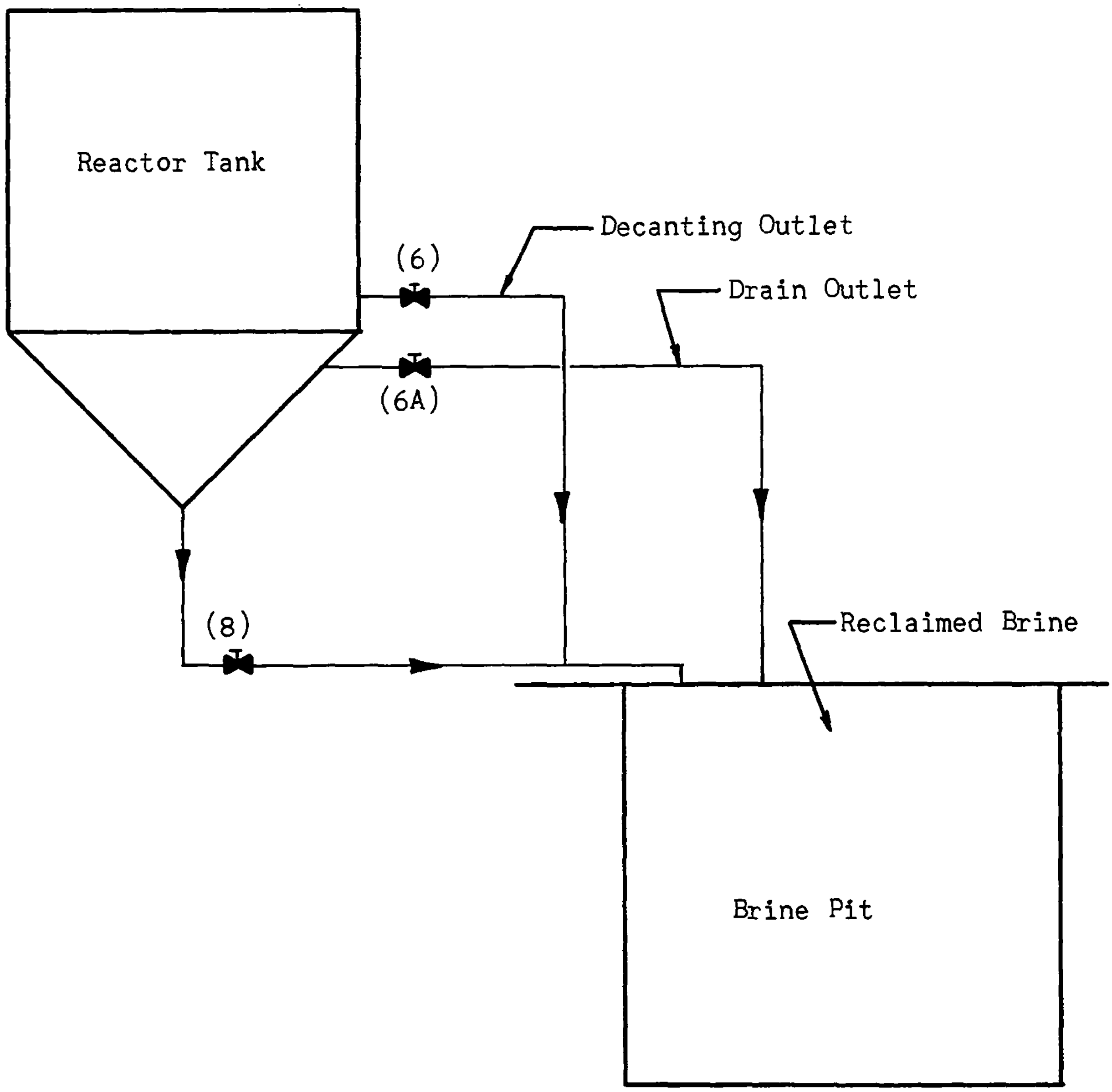

Figure 24. Flow Diagram - Decanting Brine to Brine Pit.

C. Pipes and Fitting Connections

Inspect the flow of treated brine through the decanting pipe to avoid a discharge that is very turbulent in the brine pit. It may be necessary to throttle Valve No. 6 and 6A.

D. Adjustment of pH

Gradually add the required hydrochloric acid to the brine pit at the place of mixing by the return brine.

XI. SLUDGE DISCHARGE - See Figure 25

After decantation of reclaimable brine, the sludge will be retained for three runs. The sludge will then be transferred to the sludge truck. The sequence of operation is as follows:

A. Park the sludge truck so its tank manhole will reach the sludge discharge flexible hose.

B. Valve Control

1. Open Valves No. 3 and 5.

2. Close all other valves.

C. Switch Operating Sequence

1. Panel main switch on.

2. Master control switch on.

3. Reactor sludge pump switch on.

4. The remaining switches are off.

5. Switch off all switches after the complete discharge of sludge.

D. Pump

The sludge pump must be kept running until all sludge is transferred to the sludge truck. It may be necessary to manually agitate the sludge in the reactor tank to facilitate the discharge of sludge through the 4" discharge pipe.

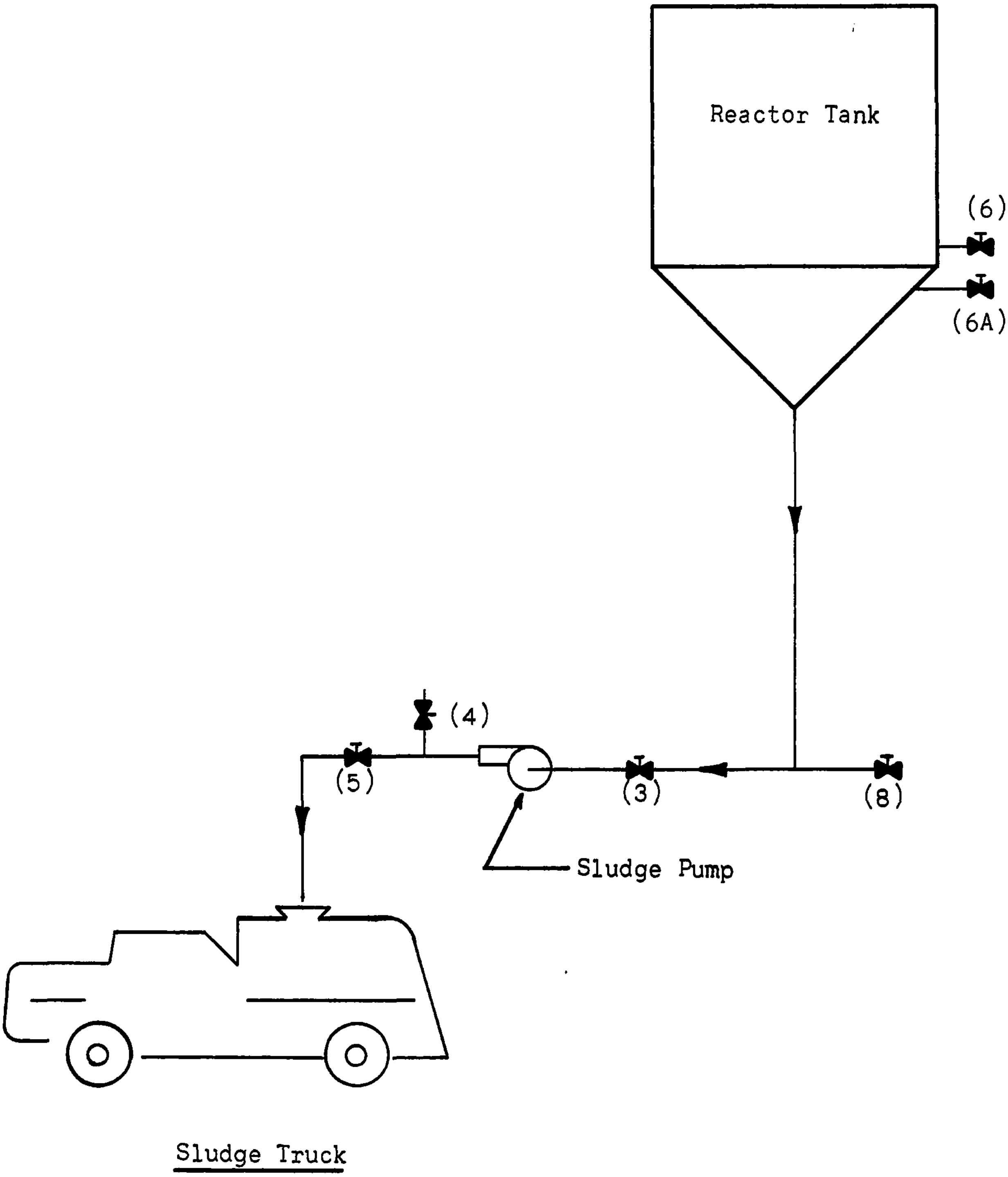

Figure 25 . Flow Diagram - Sludge Discharge.

E. Pipe and Fitting Connection

Inspect the flow of sludge from time to time to the sludge truck to verify transfer. At this inspection, collect the sludge samples at five minute intervals in increments of 200 ml until a liter capacity polyethylene bottle is filled.

XII. RECLAIMED BRINE TRANSFER FROM BRINE PIT TO REGENERATION PLANT

The reclaimed brine can be transferred to the regenerant plant as follows:

A. Valve Control

Open the 1.5" PVC valves located in the regeneration plant.

B. Switches Operating Sequence

1. Panel main switch on.
2. Master control switch on.
3. Brine pump switch on.
4. The remaining switches are off.
5. Switch off all switches after the complete transfer of reclaimed brine.

APPENDIX E

PERCENT PURITY

APPENDIX E

PERCENT PURITY

Salometer	2	4	6	8	10	12	14	16	18	20	22	24
36	96	92	88	84	80	76	72	68	64	60	56	52
38	96	93	89	85	81	77	74	70	66	62	59	55
40	96	93	89	86	82	79	75	71	68	64	61	57
42	97	93	90	87	83	80	77	73	70	67	63	60
44	97	94	91	87	84	81	78	75	71	68	65	62
46	97	94	91	88	85	82	79	76	73	70	67	64
48	97	94	91	88	86	83	80	77	74	71	68	65
50	97	95	92	89	86	83	81	78	75	72	69	67
52	97	95	92	89	87	84	81	79	76	73	71	68
54	98	95	92	90	87	85	82	80	77	75	72	70
56	98	95	93	90	88	85	83	80	78	76	73	71
58	98	95	93	91	88	86	84	81	79	76	74	72
60	98	96	93	91	89	86	84	82	80	77	75	73
62	98	96	93	91	89	87	85	82	80	78	76	74
64	98	96	94	92	90	87	85	83	81	79	77	75

Salometer	2	4	6	8	10	12	14	16	18	20	22	24
90	99	97	96	94	93	91	90	89	87	86	84	83
91	99	97	96	94	93	92	90	89	87	86	84	83
92	99	97	96	94	93	92	90	89	87	86	84	83
93	99	97	96	94	93	92	90	89	88	86	85	83
94	99	97	96	95	93	92	91	89	88	86	85	84
95	99	97	96	95	93	92	91	89	88	87	85	84
96	99	97	96	95	93	92	91	89	88	87	85	84
97	99	97	96	95	93	92	91	90	88	87	86	84
98	99	97	96	95	94	92	91	90	88	87	86	85
99	99	97	96	95	94	92	91	90	88	87	86	85
100	99	98	96	95	94	92	91	90	89	87	86	85

Calculation: Purity = (A-BC)A

where A = lb salt/gal. brine x 7000 $\frac{gr}{lb}$

= gpg salt

B = eq wt NaCl/eq wt $CaCO_3$

C = brine total hardness, gpg $CaCO_3$

1. Under "Salometer" column, find the brine strength in ^{o}S.

2. Move right in this row to the column headed (from 2-24) with the nearest hundred of gpg total hardness.

3. The number in this square is the Brine Purity in percent. This refers to the percent of sodium chloride present in the total salts.

APPENDIX F

BRINE TABLE AT 60°F

BRINE TABLE AT 60° F

STRENGTH OF BRINE					SALT				WATER						BRINE								FREEZING POINT §	
					Lb salt per				Lb water per			Gal water per			Lb brine per				Gal brine per					
Salometer deg.	Baumé deg.	Spec. grav.	% Salt by wt in brine	% Salt by wt in water	1 lb water	1 gal water	1 lb brine	1 gal brine	1 lb salt	1 lb brine	1 gal brine	1 lb salt	1 lb brine	1 gal brine	1 lb salt	1 lb water	1 gal water	1 gal brine	1 lb salt	1 lb water	1 gal water	1 lb brine	°F	°C
0	0.0	1.000	0.0000	0.0000	.0000	0.0000	.0000	.0000	∞	1.0000	8.32823	∞	.12007	1.0000	∞	1.0000	8.328	8.32823	∞	.12007	1.0000	.12007	+32.0	0.0
1	0.3	1.002	0.2640	0.2646	.0026	0.0221	.0026	.0220	378.358	.9974	8.322	45.3356	.11976	.9992	384.6154	1.0026	8.350	8.344	45.3696	.12016	1.0008	.11985	+31.8	−0.1
2	0.6	1.004	0.5279	0.5307	.0053	0.0442	.0053	.0441	189.072	.9947	8.316	22.6254	.11944	.9985	188.6793	1.0053	8.372	8.360	22.6594	.12025	1.0015	.11962	+31.5	−0.3
3	0.9	1.006	0.7919	0.7982	.0079	0.0665	.0079	.0663	125.945	.9921	8.309	15.0435	.11912	.9977	126.5823	1.0080	8.395	8.376	15.0777	.12035	1.0023	.11939	+31.3	−0.4
4	1.1	1.008	1.0558	1.0671	.0107	0.0889	.0106	.0886	93.231	.9894	8.303	11.2526	.11881	.9970	94.3396	1.0107	8.417	8.392	11.2870	.12044	1.0031	.11917	+31.1	−0.5
5	1.3	1.010	1.3198	1.3374	.0134	0.1114	.0132	.1110	74.683	.9868	8.296	8.9781	.11849	.9962	75.7576	1.0134	8.440	8.407	9.0126	.12053	1.0038	.11894	+30.8	−0.7
6	1.6	1.011	1.5837	1.6092	.0160	0.1340	.0158	.1334	62.305	.9842	8.290	7.4617	.11817	.9954	63.2911	1.0161	8.462	8.423	7.4964	.12063	1.0046	.11872	+30.5	−0.8
7	1.9	1.013	1.8477	1.8824	.0188	0.1568	.0185	.1559	53.079	.9815	8.283	6.3786	.11785	.9946	54.0541	1.0188	8.485	8.439	6.4134	.12073	1.0054	.11850	+30.2	−1.0
8	2.1	1.015	2.1116	2.1572	.0225	0.1797	.0211	.1785	44.425	.9789	8.276	5.5663	.11754	.9938	47.3934	1.0216	8.508	8.455	5.6011	.12082	1.0063	.11827	+30.0	−1.1
9	2.4	1.017	2.3756	2.4334	.0243	0.2027	.0238	.2012	41.135	.9762	8.270	4.9345	.11722	.9930	42.0168	1.0244	8.531	8.471	4.9694	.12092	1.0071	.11805	+29.6	−1.3
10	2.7	1.019	2.6395	2.7111	.0271	0.2258	.0264	.2240	36.887	.9736	8.263	4.4290	.11690	.9921	37.8788	1.0271	8.554	8.487	4.4641	.12102	1.0079	.11783	+29.3	−1.5
11	3.0	1.021	2.9035	2.9903	.0299	0.2490	.0290	.2469	33.422	.9710	8.256	4.0155	.11659	.9913	34.4828	1.0299	8.577	8.503	4.0507	.12113	1.0088	.11761	+29.1	−1.6
12	3.3	1.023	3.1674	3.2710	.0327	0.2724	.0317	.2698	30.553	.9683	8.249	3.6708	.11627	.9905	31.5457	1.0327	8.601	8.519	3.7062	.12123	1.0096	.11739	+28.8	−1.8
13	3.5	1.025	3.4314	3.5533	.0355	0.2959	.0343	.2928	28.129	.9657	8.242	3.3792	.11595	.9896	29.1545	1.0355	8.624	8.535	3.4147	.12133	1.0105	.11717	+28.5	−1.9
14	3.7	1.027	3.6953	3.8371	.0384	0.3196	.0370	.3160	26.042	.9630	8.234	3.1293	.11564	.9887	27.0270	1.0384	8.648	8.550	3.1649	.12144	1.0114	.11695	+28.2	−2.1
15	4.0	1.029	3.9593	4.1225	.0412	0.3433	.0396	.3392	24.254	.9604	8.227	2.9126	.11532	.9879	25.2525	1.0412	8.672	8.566	2.9484	.12155	1.0123	.11673	+27.9	−2.3
16	4.2	1.031	4.2232	4.4094	.0441	0.3672	.0422	.3625	22.696	.9578	8.220	2.7231	.11500	.9870	23.6967	1.0441	8.696	8.582	2.7590	.12166	1.0132	.11652	+27.6	−2.4
17	4.5	1.032	4.4872	4.6980	.0470	0.3913	.0449	.3858	21.263	.9551	8.213	2.5559	.11469	.9861	22.2717	1.0470	8.720	8.598	2.5918	.12176	1.0141	.11630	+27.3	−2.6
18	4.8	1.034	4.7511	4.9881	.0499	0.4154	.0475	.4093	20.052	.9525	8.205	2.4072	.11437	.9852	21.0526	1.0499	8.744	8.615	2.4433	.12187	1.0150	.11608	+27.0	−2.8
19	5.0	1.036	5.0151	5.2798	.0528	0.4397	.0502	.4328	18.925	.9498	8.198	2.2742	.11405	.9843	19.9203	1.0529	8.768	8.631	2.3104	.12198	1.0159	.11587	+26.7	−2.9
20	5.3	1.038	5.2790	5.5732	.0557	0.4642	.0528	.4565	17.957	.9472	8.190	2.1545	.11373	.9834	18.9394	1.0557	8.792	8.647	2.1908	.12210	1.0169	.11565	+26.4	−3.1
21	5.6	1.040	5.5430	5.8682	.0587	0.4887	.0554	.4802	17.044	.9446	8.183	2.0462	.11342	.9825	18.0505	1.0586	8.817	8.663	2.0826	.12221	1.0178	.11543	+26.1	−3.3
22	5.8	1.042	5.8069	6.1649	.0615	0.5134	.0581	.5040	16.252	.9419	8.175	1.9477	.11310	.9816	17.2117	1.0617	8.842	8.679	1.9842	.12232	1.0187	.11522	+25.7	−3.5
23	6.1	1.044	6.0709	6.4632	.0647	0.5383	.0607	.5279	15.466	.9393	8.167	1.8578	.11278	.9807	16.4745	1.0646	8.867	8.695	1.8944	.12244	1.0197	.11501	+25.4	−3.7
24	6.4	1.046	6.3348	6.7632	.0677	0.5633	.0633	.5519	14.780	.9367	8.160	1.7754	.11247	.9797	15.7978	1.0676	8.892	8.711	1.8121	.12256	1.0207	.11479	+25.1	−3.8
25	6.7	1.048	6.5988	7.0649	.0707	0.5884	.0660	.5759	14.152	.9340	8.152	1.6996	.11215	.9788	15.1515	1.0707	8.917	8.728	1.7364	.12267	1.0217	.11458	+24.7	−4.1
26	6.9	1.050	6.8627	7.3684	.0737	0.6137	.0683	.6001	13.574	.9314	8.144	1.6296	.11183	.9779	14.5773	1.0737	8.942	8.744	1.6665	.12279	1.0226	.11437	+24.4	−4.2
27	7.2	1.052	7.1267	7.6735	.0767	0.6391	.0713	.6243	13.040	.9287	8.136	1.5648	.11152	.9769	14.0253	1.0768	8.967	8.760	1.6018	.12291	1.0237	.11415	+24.0	−4.4
28	7.4	1.054	7.3906	7.9804	.0798	0.6646	.0739	.6448	12.525	.9261	8.128	1.5046	.11120	.9759	13.5318	1.0798	8.993	8.776	1.5508	.12304	1.0247	.11394	+23.7	−4.6
29	7.7	1.056	7.6546	8.2890	.0829	0.6903	.0765	.6730	12.067	.9235	8.120	1.4486	.11088	.9750	13.0719	1.0828	9.019	8.793	1.4858	.12316	1.0257	.11373	+23.3	−4.8
30	7.9	1.058	7.9185	8.5994	.0860	0.7162	.0792	.6975	11.624	.9208	8.111	1.3963	.11056	.9740	12.6263	1.0860	9.044	8.809	1.4336	.12328	1.0267	.11352	+23.0	−5.0
31	8.2	1.060	8.1825	8.9117	.0891	0.7422	.0818	.7221	11.227	.9182	8.103	1.3474	.11025	.9730	12.2249	1.0891	9.070	8.825	1.3848	.12341	1.0278	.11331	+22.6	−5.2
32	8.5	1.062	8.4464	9.2258	.0923	0.7683	.0845	.7468	10.839	.9155	8.095	1.3015	.10993	.9720	11.8384	1.0923	9.097	8.842	1.3390	.12353	1.0288	.11310	+22.3	−5.4
33	8.7	1.064	8.7104	9.5414	.0954	0.7946	.0871	.7716	10.478	.9129	8.087	1.2584	.10961	.9710	11.4811	1.0954	9.123	8.858	1.2960	.12366	1.0299	.11289	+22.0	−5.6
34	9.0	1.066	8.9743	9.8591	.0986	0.8211	.0897	.7964	10.139	.9103	8.078	1.2179	.10930	.9700	11.1483	1.0985	9.149	8.875	1.2556	.12379	1.0310	.11268	+21.6	−5.8
35	9.2	1.068	9.2383	10.1786	.1018	0.8477	.0924	.8214	9.820	.9076	8.070	1.1797	.10898	.9690	10.8225	1.1018	9.176	8.891	1.2175	.12392	1.0320	.11247	+21.3	−5.9
36	9.5	1.070	9.5022	10.4999	.1050	0.8745	.0950	.8464	9.521	.9050	8.061	1.1436	.10866	.9679	10.5263	1.1050	9.203	8.908	1.1814	.12405	1.0331	.11226	+20.9	−6.2
37	9.7	1.072	9.7662	10.8232	.1082	0.9014	.0977	.8715	9.239	.9023	8.053	1.1094	.10835	.9669	10.2354	1.1083	9.230	8.924	1.1474	.12418	1.0342	.11206	+20.5	−6.4
38	10.0	1.074	10.0301	11.1483	.1115	0.9285	.1003	.8968	8.971	.8997	8.044	1.0771	.10803	.9658	9.9701	1.1115	9.257	8.941	1.1151	.12432	1.0353	.11185	+20.2	−6.6
39	10.2	1.076	10.2941	11.4753	.1147	0.9557	.1029	.9220	8.719	.8971	8.035	1.0464	.10771	.9648	9.7182	1.1147	9.284	8.957	1.0845	.12445	1.0365	.11164	+19.8	−6.8
40	10.5	1.078	10.5580	11.8043	.1181	0.9831	.1056	.9474	8.470	.8944	8.026	1.0172	.10740	.9637	9.4697	1.1181	9.311	8.974	1.0555	.12459	1.0376	.11144	+19.4	−7.0
41	10.7	1.080	10.8220	12.1352	.1213	1.0107	.1082	.9729	8.243	.8918	8.017	.9895	.10708	.9627	9.2421	1.1213	9.339	8.990	1.0278	.12473	1.0388	.11123	+19.1	−7.2
42	11.0	1.082	11.0859	12.4681	.1247	1.0384	.1109	.9985	8.020	.8891	8.008	.9630	.10676	.9616	9.0171	1.1247	9.367	9.007	1.0015	.12487	1.0399	.11103	+18.7	−7.4
43	11.2	1.084	11.3499	12.8030	.1281	1.0663	.1135	1.0242	7.806	.8865	7.999	.9379	.10644	.9605	8.8106	1.1280	9.395	9.024	.9764	.12501	1.0411	.11082	+18.3	−7.6
44	11.5	1.086	11.6138	13.1398	.1313	1.0943	.1161	1.0499	7.616	.8839	7.990	.9138	.10613	.9594	8.6133	1.1314	9.423	9.040	.9525	.12515	1.0423	.11062	+17.9	−7.8
45	11.7	1.088	11.8778	13.4787	.1348	1.1225	.1188	1.0758	7.418	.8812	7.981	.8908	.10581	.9583	8.4175	1.1348	9.451	9.057	.9296	.12530	1.0435	.11041	+17.5	−8.1
46	12.0	1.090	12.1417	13.8196	.1382	1.1509	.1214	1.1017	7.236	.8786	7.972	.8689	.10549	.9572	8.2372	1.1382	9.479	9.074	.9077	.12544	1.0447	.11021	+17.1	−8.3
47	12.2	1.092	12.4057	14.1626	.1416	1.1795	.1241	1.1277	7.062	.8759	7.963	.8478	.10518	.9561	8.0580	1.1417	9.508	9.090	.8868	.12559	1.0459	.11001	+16.7	−8.5
48	12.5	1.094	12.6696	14.5077	.1450	1.2082	.1267	1.1538	6.896	.8733	7.953	.8277	.10486	.9550	7.8927	1.1451	9.537	9.107	.8667	.12574	1.0472	.10981	+16.2	−8.8
49	12.7	1.096	12.9336	14.8548	.1486	1.2371	.1293	1.1800	6.729	.8707	7.944	.8083	.10454	.9538	7.7340	1.1485	9.565	9.124	.8474	.12589	1.0484	.10960	+15.8	−9.0
50	12.9	1.098	13.1975	15.2041	.1521	1.2662	.1320	1.2063	6.575	.8680	7.934	.7897	.10422	.9527	7.5758	1.1521	9.595	9.141	.8290	.12604	1.0497	.10940	+15.4	−9.2
51	13.2	1.100	13.4615	15.5554	.1555	1.2955	.1346	1.2327	6.431	.8654	7.925	.7719	.10391	.9515	7.4294	1.1555	9.624	9.157	.8112	.12619	1.0509	.10920	+15.0	−9.4
52	13.4	1.102	13.7254	15.9090	.1591	1.3249	.1373	1.2592	6.285	.8627	7.915	.7547	.10359	.9504	7.2833	1.1592	9.653	9.174	.7942	.12634	1.0522	.10900	+14.5	−9.7
53	13.7	1.104	13.9894	16.2647	.1626	1.3546	.1399	1.2858	6.150	.8601	7.905	.7382	.10328	.9492	7.1480	1.1627	9.683	9.191	.7777	.12650	1.0535	.10880	+14.1	−9.9
54	13.9	1.106	14.2533	16.6226	.1662	1.3844	.1425	1.3124	6.017	.8575	7.895	.7223	.10296	.9480	7.0175	1.1662	9.713	9.208	.7619	.12666	1.0548	.10860	+13.7	−10.2
55	14.1	1.108	14.5173	16.9827	.1699	1.4144	.1452	1.3392	5.886	.8548	7.886	.7070	.10264	.9468	6.8871	1.1699	9.743	9.225	.7467	.12681	1.0561	.10840	+13.3	−10.4
56	14.4	1.110	14.7812	17.3450	.1734	1.4445	.1478	1.3660	5.767	.8522	7.876	.6923	.10232	.9457	6.7659	1.1734	9.773	9.242	.7320	.12697	1.0575	.10821	+12.8	−10.7
57	14.6	1.112	15.0452	17.7096	.1771	1.4749	.1505	1.3930	5.646	.8495	7.866	.6780	.10201	.9445	6.6445	1.1772	9.803	9.259	.7179	.12713	1.0588	.10801	+12.3	−10.9
58	14.8	1.114	15.3091	18.0764	.1807	1.5055	.1531	1.4200	5.534	.8469	7.856	.6643	.10169	.9433	6.5317	1.1808	9.834	9.276	.7007	.12730	1.0602	.10781	+11.8	−11.2
59	15.1	1.116	15.5731	18.4456	.1844	1.5362	.1557	1.4472	5.423	.8443	7.846	.6510	.10137	.9420	6.4226	1.1844	9.864	9.293	.6910	.12746	1.0615	.10761	+11.4	−11.4
60	15.3	1.118	15.8370	18.8171	.1882	1.5671	.1584	1.4744	5.313	.8416	7.835	.6381	.10106	.9408	6.3131	1.1882	9.895	9.310	.6782	.12762	1.0629	.10741	+10.9	−11.7
61	15.5	1.120	16.1010	19.1909	.1919	1.5983	.1610	1.5017	5.211	.8390	7.825	.6257	.10074	.9396	6.2112	1.1919	9.927	9.327	.6659	.12779	1.0643	.10722	+10.4	−12.0
62	15.8	1.122	16.3649	19.5670	.1956	1.6296	.1636	1.5292	5.112	.8364	7.815	.6136	.10042	.9384	6.1125	1.1956	9.958	9.344	.6540	.12796	1.0657	.10702	+9.9	−12.3
63	16.0	1.124	16.6289	19.9456	.1995	1.6611	.1663	1.5567	5.013	.8337	7.805	.6020	.10011	.9371	6.0132	1.1995	9.989	9.361	.6424	.12813	1.0671	.10682	+9.4	−12.5
64	16.2	1.126	16.8928	20.3265	.2032	1.6928	.1689	1.5843	4.921	.8311	7.794	.5907	.09979	.9359	5.9207	1.2032	10.021	9.379	.6312	.12830	1.0685	.10663	+8.9	−12.8
65	16.5	1.128	17.1538	20.7009	.2071	1.7248	.1716	1.6120	4.828	.8284	7.784	.5798	.09947	.9346	5.8275	1.2071	10.053	9.396	.6203	.12847	1.0699	.10643	+8.4	−13.1
66	16.7	1.130	17.4207	21.0957	.2109	1.7569	.1742	1.6399	4.742	.8258	7.773	.5692	.09916	.9334	5.7405	1.2109	10.085	9.413	.6098	.12864	1.0714	.10623	+7.9	−13.4
67	17.0	1.132	17.6847	21.4840	.2149	1.7892	.1768	1.6678	4.653	.8232	7.763	.5589	.09884	.9321	5.6561	1.2148	10.118	9.431	.5996	.12882	1.0728	.10604	+7.3	−13.7
68	17.2	1.134	17.9486	21.8748	.2188	1.8218	.1795	1.6958	4.570	.8205	7.752	.5489	.09852	.9308	5.5710	1.2188	10.150	9.448	.5897	.12899	1.0743	.10584	+6.8	−14.0
69	17.5	1.137	18.2126	22.2681	.2228	1.8546	.1821	1.7239	4.488	.8179	7.742	.5392	.09820	.9296	5.4915	1.2226	10.183	9.466	.5801	.12917	1.0758	.10565	+6.3	−14.3

STRENGTH OF BRINE					SALT				WATER						BRINE								FREEZING POINT §	
					Lb salt per				Lb water per			Gal water per			Lb brine per				Gal brine per					
Salometer deg.	Baumé deg.	Spec. grav.	% Salt by wt in brine	% Salt by wt in water	1 lb water	1 gal water	1 lb brine	1 gal brine	1 lb salt	1 lb brine	1 gal brine	1 lb salt	1 lb brine	1 gal brine	1 lb salt	1 lb water	1 gal water	1 gal brine	1 lb salt	1 lb water	1 gal water	1 lb brine	°F	°C
70	17.7	1.139	18.4765	22.6640	.2267	1.8875	.1848	1.7521	4.411	.8152	7.731	.5298	.09789	.9283	5.4113	1.2267	10.216	9.483	.5707	.12935	1.0773	.10545	+5 7	−14.6
71	17.9	1.141	18.7405	23.0625	.2307	1.9207	.1874	1.7805	4.335	.8126	7.720	.5206	.09757	.9270	5.3362	1.2306	10.249	9.501	.5616	.12953	1.0788	.10526	+5 2	−14.9
72	18.1	1.143	19.0044	23.4635	.2346	1.9541	.1900	1.8089	4.263	.8100	7.709	.5117	.09725	.9257	5.2632	1.2346	10.282	9.518	.5528	.12971	1.0803	.10506	+4.6	−15.2
73	18.4	1.145	19.2684	23.8672	.2396	1.9877	.1927	1,8374	4.174	.8073	7.699	.5031	.09694	.9244	5.1894	1.2387	10.316	9.536	.5442	.12989	1.0818	.10487	+4.0	−15.5
74	18.6	1.147	19.5323	24.2735	.2428	2.0216	.1953	1.8661	4.119	.8047	7.688	.4947	.09662	.9231	5.1203	1.2427	10.350	9.554	.5359	.13008	1.0833	.10467	+3.4	−15.9
75	18.8	1.149	19.7963	24.6824	.2468	2.0556	.1980	1.8948	4.052	.8020	7.677	.4865	.09630	.9218	5.0505	1.2469	10.384	9.571	.5278	.13026	1.0850	.10448	+2.8	−16.2
76	19.1	1.151	20.0602	25.0941	.2510	2.0899	.2006	1.9236	3.984	.7994	7.666	.4785	.09599	.9204	4.9850	1.2509	10.418	9.589	.5199	.13045	1.0864	.10428	+2.2	−16.5
77	19.4	1.154	20.3242	25.5085	.2550	2.1244	.2032	1.9526	3.922	.7968	7.655	.4707	.09567	.9191	4.9213	1.2550	10.453	9.607	.5121	.13064	1.0880	.10409	+1.6	−16 9
78	19.6	1.156	20.5881	25.9257	.2593	2.1592	.2059	1.9816	3.857	.7941	7.643	.4631	.09535	.9178	4.8567	1.2593	10.487	9.625	.5046	.13083	1.0896	.10390	+1.0	−17.2
79	19.8	1.158	20.8520	26.3457	.2635	2.1941	.2085	2.0107	3.796	.7915	7.632	.4558	.09504	.9164	4.7962	1.2634	10.522	9.643	.4973	.13103	1.0912	.10370	+.4	−17.5
80	20.0	1.160	21.1160	26.7684	.2677	2.2293	.2112	2.0400	3.736	.7888	7.621	.4486	.09472	.9151	4.7348	1.2677	10.558	9.661	.4902	.13122	1.0928	.10351	−.4	−18.0
81	20.2	1.162	21.3800	27.1940	.2720	2.2648	.2138	2.0693	3.676	.7862	7.609	.4416	.09440	.9137	4.6773	1.2719	10.593	9.679	.4832	.13141	1.0945	.10332	−1.0	−18.3
82	20.4	1.164	21.6439	27.6225	.2762	2.3005	.2164	2.0988	3.621	.7836	7.598	.4347	.09408	.9123	4.6211	1.2761	10.629	9.697	.4765	.13161	1.0961	.10313	−1.6	−18.7
83	20.7	1.167	21.9079	28.0538	.2805	2.3364	.2191	2.1283	3.565	.7809	7.587	.4280	.09377	.9109	4.5641	1.2806	10.665	9.715	.4699	.13181	1.0978	.10293	−2.3	−19.0
84	21.0	1.169	22.1718	28.4881	.2848	2.3726	.2217	2.1580	3.511	.7783	7.575	.4215	.09345	.9096	4.5106	1.2849	10.701	9.733	.4634	.13201	1.0994	.10274	−3.0	−19.4
85	21.2	1.171	22.4358	28.9250	.2893	2.4090	.2244	2.1877	3.457	.7757	7.563	.4151	.09313	.9082	4.4563	1.2893	10.737	9.751	.4571	.13221	1.1011	.10255	−3.7	−19.8
86	21.4	1.173	22.6997	29.3656	.2937	2.4456	.2270	2.2176	3.405	.7730	7.552	.4089	.09282	.9067	4.4053	1.2937	10.774	9.769	.4509	.13242	1.1029	.10236	−4.4	−20.2
87	21.7	1.175	22.9637	29.8088	.2981	2.4826	.2296	2.2475	3.355	.7704	7.540	.4028	.09250	.9053	4.3554	1.2980	10.811	9.787	.4449	.13263	1.1046	.10217	−5.2	−20.7
88	21.9	1.177	23.2276	30.2551	.3026	2.5197	.2323	2.2776	3.305	.7677	7.528	.3969	.09218	.9039	4.3048	1.3026	10.848	9.805	.4391	.13284	1.1063	.10198	−5 8	−21 0
*88.3	22.0	1.178	23.3100	30.3951	.3039	2.5314	.2331	2.2870	3.291	.7669	7.524	.3950	.09208	.9034	4.2900	1.3040	10.860	9.811	.4373	.13290	1.1069	.10192	−6.0*	−21.1*
89	22.1	1.180	23.4916	30.7045	.3071	2.5572	.2349	2.3077	3.256	.7651	7.516	.3911	.09187	.9025	4.2571	1.3070	10.885	9.824	.4333	.13305	1.1081	.10180	−4.2	−20.1
90	22.3	1.182	23.7555	31.1570	.3115	2.5948	.2376	2.3380	3.210	.7624	7.504	.3854	.09155	.9010	4.2088	1.3116	10.923	9.842	.4277	.13327	1.1099	.10161	−1.1	−18 4
91	22.5	1.184	24.0195	31.6126	.3161	2.6328	.2402	2.3683	3.164	.7598	7.492	.3798	.09123	.8996	4.1632	1.3161	10.961	9.860	.4222	.13348	1.1117	.10142	+1.8	−16.8
92	22.8	1.186	24.2834	32.0714	.3206	2.6710	.2428	2.3988	3.119	.7572	7.479	.3744	.09092	.8981	4.1186	1.3207	10.999	9.878	.4169	.13370	1.1135	.10123	+4 8	−15.1
93	23.0	1.188	24.5474	32.5334	.3254	2.7095	.2455	2 4294	3.073	.7545	7.467	.3691	.09060	.8966	4.0733	1.3254	11.038	9.897	.4116	.13392	1.1153	.10104	+7.9	−13.4
94	23.2	1.190	24.811[illegible]	32.9987	.3296	2.7482	.2481	2.4600	3.034	.7519	7.455	.3639	.09028	.8951	4.0306	1.3300	11.076	9.915	.4065	.13414	1.1172	.10086	+11.1	−11.6
95	23.5	1.193	25.075[illegible]	33.4672	.3346	2.7872	.2508	2.4908	2.989	.7492	7.442	.3588	.08996	.8936	3.9872	1.3348	11.116	9.933	.4015	.13436	1.1190	.10067	+14.4	−9.8
96	23.7	1.195	25.3392	33.9391	.3394	2.8265	.2534	2.5217	2.946	.7466	7.430	.3538	.08965	.8921	3.9463	1.3394	11.155	9.952	.3966	.13459	1.1209	.10049	+18.0	−7.8
97	23.9	1.197	25.6032	34.4143	.3441	2.8661	.2560	2.5526	2.906	.7440	7.417	.3489	.08933	.8906	3.9063	1.3441	11.194	9.970	.3917	.13482	1.1228	.10030	+21 6	−5.8
98	24.2	1.199	25.8671	34.8929	.3489	2.9060	.2587	2.5837	2.866	.7413	7.405	.3441	.08901	.8891	3.8655	1.3490	11.234	9.988	.3870	.13505	1.1247	.10012	+25 5	−3.6
99	24.4	1.202	26.1311	35.3749	.3538	2.9462	.2613	2.6150	2.826	.7387	7.392	.3394	.08870	.8876	3.8270	1.3537	11.274	10.007	.3824	.13528	1.1267	.09993	+29.8	−1.2
99.6	24.5	1.203	26.2850	35.6576	.3566	2.9686	.2629	2.6323	2.804	.7372	7.385	.3369	.08851	.8867	3.8037	1.3567	11.298	10.018	.3799	.13541	1.1278	.09982	+32.3†	+0.2†
100	24.6	1.204	26.3950	35.8603	.3587	2.9865	.2640	2.6469	2.788	.7361	7.381	.3348	.08844	.8863	3.7879	1.3587	11.308	10.028	.3778	.13548	1.1283	.09978	+60.0‡	+15.56‡

*Eutectic point. For brines stronger than eutectic, the temperatures shown are the saturation temperatures for sodium chloride dihydrate. Brines stronger than eutectic deposit excess sodium chloride as dihydrate when cooled, and freeze at eutectic.

†Transition temperature from anhydrous salt to dihydrate.
‡Saturated brine at 60° F (15.56° C)
§Temperature at which freezing begins. Ice forms, brine concentrates, and freezing point lowers to eutectic

How to use the brine table

These data, as tabulated on this and the opposite page, apply only to brines tested at 60° F. Preferably, all Salometer readings should be made at 60° F. For other brine temperatures the observed Salometer readings must be converted before using them in the table.

For all practical purposes the correction amounts to approximately one degree Salometer less for each ten degrees below 60° F, and one degree Salometer more for each 10 degrees above 60° F.

For more accurate conversion, subtract from the observed Salometer reading the following correction for each degree of temperature below 60° F; add for temperature between 60° and 100° F.

The data in the Complete Sterling Brine Table at 60° F are based on properties of chemically pure sodium chloride. For all practical purposes they may be applied without modification to solutions of salt mined or manufactured by the International Salt Company, Incorporated, Scranton, Pa.

Observed Salometer reading	Approximate correction in Salometer degrees: Subtract per degree below 60° F	Add per degree above 60° F
0 to 10	0.049	0.060
11 to 20	0.064	0 082
21 to 30	0.077	0.094
31 to 40	0.087	0.103
41 to 50	0.095	0.112
51 to 60	0.102	0.118
61 to 70	0.107	0.123
71 to 80	0.112	0.128
81 to 90	0.116	0.131
91 to 100	0.120	0.134

The Research Department will at all times be ready to answer problems concerning the use of salt or salt brine. You are invited to submit any question or problem concerning salt or salt brine, wholly without obligation.

Freezing behavior of brines

It is sometimes mistakenly assumed that the stronger the brine, the lower the temperature at which freezing begins. This is true only for brine strengths to and including 88.3° Salometer.

Pure water freezes at 32° F and if salt is gradually added, ice first appears at successively lower temperatures. At a strength of 88.3° S, brine has its lowest freezing point, −6.0° F, the eutectic temperature.

At the opposite extreme from pure water is fully saturated brine of 100° S strength. Any drop in temperature will deposit out a few grains of salt, but the quantity will be very small, because salt solubility changes but little with temperature.

If a saturated brine is gradually diluted, salt will appear at successively lower temperatures; even at the slight dilution to 99.6° S, the salt does not appear until a temperature of 32.3° F is reached. Below this particular strength and temperature, salt does not appear; but instead, sodium chloride dihydrate, which looks and behaves much like ice, and is usually mistaken for ice.

The temperature at which the dihydrate first appears becomes successively lower as the brine is diluted, until at 88.3° S strength, the freezing temperature is −6.0° F. The solid material which appears in 88.3° S brine at −6.0° F is an intimate mixture of ice and dihydrate, although ice first forms in weaker brines, and dihydrate first forms in stronger brines.

Note that 1° S change in strength causes less than 1° F change in freezing point for brines slightly under 88.3° S strength, but approximately 3° F change for brines slightly over 88.3° S. Therefore, if freezing might cause trouble in refrigerating equipment, it is better to operate with brines somewhat under 88.3° S, rather than over, since slight variations in strength have less effect on the brine freezing point.

Courtesy of International Salt Company

APPENDIX G

DEMONSTRATION TEST DATA SHEETS

RUNS 1A-174A

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	1A	2A	3A	4A
DATE	3-20-72	3-21-72	3-23-72	3-24-72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2500	3000
Strength, °Salometer	58°	57°	57°	58°
Solubles, Total lbs.	4100	3760	3480	4250
Magnesium Hardness, gpg	525	530	555	525
Calcium Hardness, gpg	1895	1920	1825	1805
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	63%	66%	68%	61%
Soda Ash, lbs.	900	850	750	900
% Theoretical	85%	85%	83%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2500	2700
Strength, °Salometer	57°	56°	56°	57°
Solubles, Total lbs.	3760	3420	3420	3760
Total Hardness, gpg	455	450	455	410
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			1A, 2A, & 3A	
Volume, Gallons			900	
Insolubles, lbs.			3290 / 3395	
Solubles, lbs.			740	
REDUCTION OF WASTE %				
Volume			88.9 / 89.9	
Solubles			93.3 / 94.2	

REMARKS: The average dosages for runs #1A, 2A, 3A and 4A are: Soda ash 85%, hydrated lime 65% with the average total hardness in the reclaimed brine of 443 gpg and a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	5A	6A	7A	8A
DATE	3-27-72	3-28-72	3-30-72	3-31-72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	3000	2700
Strength, °Salometer	56°	57°	58°	58°
Solubles, Total lbs.	3700	3760	4250	3840
Magnesium Hardness, gpg	525	535	525	550
Calcium Hardness, gpg	1745	1935	1925	1790
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	68%	66%	63%	64%
Soda Ash, lbs.	800	850	950	800
% Theoretical	86%	85%	86%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2700	2700
Strength, °Salometer	56°	56°	58°	57°
Solubles, Total lbs.	3700	3700	3830	3760
Total Hardness, gpg	395	380	400	425
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		4A, 5A, & 6A		
Volume, Gallons		900		
Insolubles, lbs.		3590 / 3630		
Solubles, lbs.		550 / 510		
REDUCTION OF WASTE %				
Volume		89.3		
Solubles		93.3 / 94.2		

REMARKS: For these test runs the average dosages of soda ash is 86% and for hydrated lime is 65%. The average residual hardness of the reclaimed brine is 400 gpg with a corresponding purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	9A	10A	11A	12A
DATE	4-3-72	4-4-72	4-6-72	4-7-72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	3000	2700	2700
Strength, °Salometer	58°	57°	57°	57°
Solubles, Total lbs.	3840	4180	3760	3760
Magnesium Hardness, gpg	525	525	555	530
Calcium Hardness, gpg	2035	1815	1845	1830
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	67%	62%	64%	67%
Soda Ash, lbs.	900	900	850	800
% Theoretical	87%	85%	87%	83%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	57°	56°	56°	56°
Solubles, Total lbs.	3480	3700	3680	3420
Total Hardness, gpg	410	425	380	395
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	7A, 8A, & 9A			10A,11A,12A
Volume, Gallons	900			900
Insolubles, lbs.	3355 / 3450			3300 / 3280
Solubles, lbs.	515 / 420			390 / 410
REDUCTION OF WASTE %				
Volume	89.3			89.3
Solubles	95.7 / 96.5			96.7 / 96.5

REMARKS: The average dosages of soda ash and hydrated lime for these demonstration runs are 85.5% and 65% respectively. The average residual hardness in the reclaimed brine is 405 gpg with the corresponding purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	13A	14A	15A	16A
DATE	4-10-72	4-11-72	4-13-72	4-14-72
UNTREATED WASTE BRINE				
Volume, Gallons	3000	2700	2700	3000
Strength, °Salometer	56°	57°	56°	57°
Solubles, Total lbs.	4100	3760	3700	4150
Magnesium Hardness, gpg	520	545	535	520
Calcium Hardness, gpg	1800	1835	1825	1780
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	62%	65%	66%	62%
Soda Ash, lbs.	900	800	800	900
% Theoretical	86%	83%	84%	87%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	56°	56°	55°	56°
Solubles, Total lbs.	3700	3700	3350	3700
Total Hardness, gpg	405	435	395	435
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			13A,14A,15A	
Volume, Gallons			900	
Insolubles, lbs.			3440 / 3445	
Solubles, lbs.			610 / 605	
REDUCTION OF WASTE %				
Volume			89.3	
Solubles			94.7 / 94.5	

REMARKS: The average dosages of soda ash and hydrated lime for these demonstration runs are 85% and 64% respectively. The average residual hardness in the reclaimed brine is 423 gpg with the corresponding purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	17A	18A	19A	20A
DATE	4-17-72	4-18-72	4-18-72	4-20-72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	3000	2700
Strength, °Salometer	56°	57°	58°	58°
Solubles, Total lbs.	3700	3760	4250	3840
Magnesium Hardness, gpg	550	525	495	535
Calcium Hardness, gpg	1850	1835	1845	1915
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	67%	64%	66%
Soda Ash, lbs.	800	800	900	850
% Theoretical	83%	84%	85%	85%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	55°	56°	57°	57°
Solubles, Total lbs.	3620	3420	3760	3760
Total Hardness, gpg	445	400	405	385
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		16A, 17A, 18A		
Volume, Gallons		900		
Insolubles, lbs.		3655 / 3730		
Solubles, lbs.		755 / 680		
REDUCTION OF WASTE %				
Volume		89.3		
Solubles		93.5 / 94.2		

REMARKS: The average dosages of soda ash and hydrated lime for these demonstration runs are 84% and 65.5% respectively. The average residual hardness in the reclaimed brine is 409 gpg with the corresponding purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	21A	22A	23A	24A
DATE	4-24-72	4-26-72	4-27-72	4-28-72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	3000	2700	2700
Strength, °Salometer	59°	58°	57°	56°
Solubles, Total lbs.	3920	4250	3760	3700
Magnesium Hardness, gpg	525	535	555	540
Calcium Hardness, gpg	1865	1865	1865	1910
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	67%	60%	64%	65%
Soda Ash, lbs.	800	900	850	850
% Theoretical	83%	83%	86%	85%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	58°	57°	56°	55°
Solubles, Total lbs.	3550	3760	3700	3350
Total Hardness, gpg	435	445	400	385
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	19A,20A,21A			22A,23A,24A
Volume, Gallons	900			900
Insolubles, lbs.	1960 / 2030			3375
Solubles, lbs.	830 / 760			765 / 640
REDUCTION OF WASTE %				
Volume	89.3			89.3
Solubles	93.1 / 93.7			93.5 / 94.5

REMARKS: The average dosages of soda ash and hydrated lime for these demonstration runs are 84% and 64% respectively. The average residual hardness in the reclaimed brine is 416 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	25A	26A	27A	28A
DATE	5-1-72	5-2-72	5-3-72	5-4-72
UNTREATED WASTE BRINE				
Volume, Gallons	3000	2700	2700	3000
Strength, °Salometer	56°	57°	58°	57°
Solubles, Total lbs.	4100	3780	3840	4180
Magnesium Hardness, gpg	530	525	510	510
Calcium Hardness, gpg	1810	1875	1870	1845
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	61%	67%	68%	63%
Soda Ash, lbs.	900	850	800	900
% Theoretical	85%	87%	83%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	55°	56°	57°	56°
Solubles, Total lbs.	3620	3700	3480	3680
Total Hardness, gpg	410	380	405	415
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			25A,26A,27A	
Volume, Gallons			900	
Insolubles, lbs.			3070 / 3530	
Solubles, lbs.			810 / 350	
REDUCTION OF WASTE %				
Volume			89.3	
Solubles			93.1 / 97.0	

REMARKS:

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	29A	30A	31A	32A
DATE	5/8/72	5/9/72	5/10/72	5/11/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	3000	2700
Strength, $^{\circ}$Salometer	57°	56°	57°	56°
Solubles, Total lbs.	3760	3680	4180	3680
Magnesium Hardness, gpg	555	535	515	550
Calcium Hardness, gpg	1885	1965	1825	1870
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	66%	62%	64%
Soda Ash, lbs.	850	850	900	800
% Theoretical	85%	83%	85%	82%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, $^{\circ}$Salometer	56°	55°	56°	55°
Solubles, Total lbs.	3680	3350	3680	3620
Total Hardness, gpg	430	410	435	445
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		28A,29A,30A		
Volume, Gallons		900		
Insolubles, lbs.		3335 / 3825		
Solubles, lbs.		715 / 215		
REDUCTION OF WASTE %				
Volume		89.3		
Solubles		93.9 / 98.2		

REMARKS: **The average dosages of soda ash and hydrated lime for these demonstration runs are 84% and 64% respectively. The average residual hardness in the reclaimed brine is 430 gpg with a purity level of 95%.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	33A			
DATE	5/15/72			
UNTREATED WASTE BRINE				
Volume, Gallons	2700			
Strength, °Salometer	57°			
Solubles, Total lbs.	3760			
Magnesium Hardness, gpg	535			
Calcium Hardness, gpg	1855			
CHEMICALS ADDED				
Hydrated Lime, lbs.	100			
% Theoretical	66%			
Soda Ash, lbs.	800			
% Theoretical	83%			
RECLAIMED BRINE				
Volume, Gallons	2500			
Strength, °Salometer	56°			
Solubles, Total lbs.	3420			
Total Hardness, gpg	415			
Purity, % Na/Solubles	95%			
WASTE				
Cumulated for Test numbers	31A,32A,33A			
Volume, Gallons	900			
Insolubles, lbs.	3345 / 3590			
Solubles, lbs.	795 / 550			
REDUCTION OF WASTE %				
Volume	89.3			
Solubles	93.2 / 95.3			

REMARKS: ______________________________

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	34A	35A	36A	37A
DATE	5/16/72	5/17/72	5/18/72	5/22/72
UNTREATED WASTE BRINE				
Volume, Gallons	3000	2700	2700	2900
Strength, °Salometer	56°	56°	58°	57°
Solubles, Total lbs.	4100	3680	3830	4050
Magnesium Hardness, gpg	520	550	570	520
Calcium Hardness, gpg	1750	1750	1950	1780
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	62%	63%	62%	64%
Soda Ash, lbs.	900	800	900	900
% Theoretical	87%	86%	88%	89%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	55°	55°	57°	56°
Solubles, Total lbs.	3620	3620	3480	3660
Total Hardness, gpg	405	395	400	415
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			34A,35A,36A	
Volume, Gallons			900	
Insolubles, lbs.			~~3415~~ 3620	
Solubles, lbs.			~~815~~ 610	
REDUCTION OF WASTE %				
Volume			89.3	
Solubles			~~93.0~~ 94.8	

REMARKS: The average dosages of soda ash and hydrated lime are 87.5% and 63% respectively.

The average residual hardness in the reclaimed brine is 405 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	38A	39A	40A	41A
DATE	5/23/72	5/24/72	5/25/72	5/30/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	58°	57°	58°	57°
Solubles, Total lbs.	3840	3760	4120	3780
Magnesium Hardness, gpg	540	530	515	525
Calcium Hardness, gpg	1880	1800	1765	1835
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	66%	64%	68%
Soda Ash, lbs.	850	800	850	800
% Theoretical	86%	84%	85%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	57°	56°	57°	56°
Solubles, Total lbs.	3760	3420	3780	3680
Total Hardness, gpg	440	445	435	435
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		37A,38A,39A		
Volume, Gallons		900		
Insolubles, lbs.		3095 / 3530		
Solubles, lbs.		865 / 430		
REDUCTION OF WASTE %				
Volume		89.3		
Solubles		92.5 / 96.3		

REMARKS: The average dosages of soda ash and hydrated lime for these demonstration runs are 85% and 66% respectively. The average residual hardness in the reclaimed brine is 440 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	42A	43A	44A	45A
DATE	5/31/72	6/1/72	6/4/72	6/5/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	56°	57°	58°	57°
Solubles, Total lbs.	3700	4050	3840	3760
Magnesium Hardness, gpg	530	510	530	540
Calcium Hardness, gpg	1740	1820	1830	1780
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	67%	65%	67%	65%
Soda Ash, lbs.	800	900	800	800
% Theoretical	87%	88%	84%	87%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	55°	56°	57°	56°
Solubles, Total lbs.	3450	3700	3760	3420
Total Hardness, gpg	390	410	445	420
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	40A,41A,42A			43A,44A,45A
Volume, Gallons	900			900
Insolubles, lbs.	4275 / 4350			4340 / 4495
Solubles, lbs.	495 / 420			710 / 555
REDUCTION OF WASTE %				
Volume	89.3			89.1
Solubles	95.7 / 96.3			93.9 / 95.2

REMARKS: **The average dosage of soda ash and hydrated lime for these demonstration runs are 86.5% and 66% respectively. The average residual hardness in the reclaimed brine is 415 gpg.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	46A	47A	48A	49A
DATE	6/6/72	6/7/72	6/8/72	6/12/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	58°	56°	57°	58°
Solubles, Total lbs.	4100	3700	3760	4100
Magnesium Hardness, gpg	515	525	550	525
Calcium Hardness, gpg	1755	1865	1810	1865
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	64%	67%	64%	63%
Soda Ash, lbs.	850	800	800	900
% Theoretical	86%	83%	84%	87%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	57°	55°	56°	57°
Solubles, Total lbs.	3760	3620	3420	3770
Total Hardness, gpg	425	430	450	430
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			46A,47A,48A	
Volume, Gallons			900	
Insolubles, lbs.			2415 / 2520	
Solubles, lbs.			825 / 720	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			92.8 / 93.7	

REMARKS: **The average dosages of soda ash and hydrated lime are 85% and 64.5% respectively.**

The average residual hardness in the reclaimed brine is 435 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	50A	51A		
DATE	6/13/72	6/14/72		
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700		
Strength, °Salometer	56°	56°		
Solubles, Total lbs.	3700	3700		
Magnesium Hardness, gpg	535	540		
Calcium Hardness, gpg	1795	1760		
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100		
% Theoretical	66%	65%		
Soda Ash, lbs.	800	800		
% Theoretical	84%	86%		
RECLAIMED BRINE				
Volume, Gallons	2700	2500		
Strength, °Salometer	55°	55°		
Solubles, Total lbs.	3620	3350		
Total Hardness, gpg	440	425		
Purity, % Na/Solubles	95%	95%		
WASTE				
Cumulated for Test numbers		49A,50A,51A		
Volume, Gallons		900		
Insolubles, lbs.		2540 / 2675		
Solubles, lbs.		700 / 565		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		93.9 / 95.1		

REMARKS: **The average dosages of soda ash and hydrated lime are 85% and 65.5% respectively.**

The average residual hardness in the reclaimed brine is 433 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	52A	53A	54A	55A
DATE	6/16/72	6/19/72	6/20/72	6/21/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	57°	57°	58°	56°
Solubles, Total lbs.	4050	3760	3840	3960
Magnesium Hardness, gpg	520	545	530	520
Calcium Hardness, gpg	1900	1835	1810	1760
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	64%	65%	67%	64%
Soda Ash, lbs.	900	800	800	850
% Theoretical	85%	83%	85%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	56°	56°	57°	55°
Solubles, Total lbs.	3700	3700	3480	3600
Total Hardness, gpg	445	455	410	435
Purity, % Na/Solubles	95%	94.5%	95%	95%
WASTE				
Cumulated for Test numbers			52A,53A,54A	
Volume, Gallons			900	
Insolubles, lbs.			2825 / 2950	
Solubles, lbs.			955 / 830	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			91.8 / 92.8	

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 65% respectively.

The average residual hardness in the reclaimed brine is 435 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	56A	57A	58A	59A
DATE	6/22/72	6/26/72	6/27/72	6/28/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, $^{\circ}$Salometer	57°	57°	58°	58°
Solubles, Total lbs.	3760	3760	4080	3830
Magnesium Hardness, gpg	540	550	525	530
Calcium Hardness, gpg	1820	1840	1895	1800
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	64%	63%	67%
Soda Ash, lbs.	800	800	900	800
% Theoretical	84%	83%	86%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, $^{\circ}$Salometer	56°	56°	57°	57°
Solubles, Total lbs.	3700	3420	3760	3760
Total Hardness, gpg	440	460	445	430
Purity, % Na/Solubles	95%	94%	95%	95%
WASTE				
Cumulated for Test numbers		55A,56A,57A		
Volume, Gallons		900		
Insolubles, lbs.		2340 / 2395		
Solubles, lbs.		460 / 405		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		96.0 / 96.5		

REMARKS: The average dosages of soda ash and hydrated lime are 84% and 65% respectively.

The average residual hardness in the reclaimed brine is 445 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	60A	61A	62A	63A
DATE	6/29/72	7/3/72	7/5/72	7/6/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	57°	58°	57°	56°
Solubles, Total lbs.	3760	4120	3780	3700
Magnesium Hardness, gpg	545	515	525	530
Calcium Hardness, gpg	1905	1765	1835	1740
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	64%	68%	67%
Soda Ash, lbs.	850	850	800	800
% Theoretical	85%	85%	84%	87%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	56°	57°	56°	55°
Solubles, Total lbs.	3420	3780	3680	3350
Total Hardness, gpg	420	435	435	390
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	58A,59A,60A			61A,62A,63A
Volume, Gallons	900			900
Insolubles, lbs.	1720 / 1720			3540 / 3715
Solubles, lbs.	1080 / 1080			690 / 515
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	90.7 / 90.7			94.1 / 95.6

REMARKS: **The average dosages of soda ash and hydrated lime are 85% and 66% respectively.**

The average residual hardness in the reclaimed brine is 420 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	64A	65A	66A	67A
DATE	7/7/72	7/10/72	7/11/72	7/12/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	57°	56°	56°	57°
Solubles, Total lbs.	4050	3700	3700	4050
Magnesium Hardness, gpg	510	540	540	525
Calcium Hardness, gpg	1820	1860	1820	1745
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	66%	66%	63%
Soda Ash, lbs.	900	850	800	850
% Theoretical	88%	87%	84%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	56°	55°	55°	56°
Solubles, Total lbs.	3700	3620	3350	3700
Total Hardness, gpg	410	390	435	410
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			64A,65A,66A	
Volume, Gallons			900	
Insolubles, lbs.			3825 / 3825	
Solubles, lbs.			405 / 405	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			96.5 / 96.5	

REMARKS: **The average dosage of soda ash and hydrated lime are 86% and 65% respectively.**

The residual hardness on the reclaimed brine is 410 gpg.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	68A			
DATE	7/13/72			
UNTREATED WASTE BRINE				
Volume, Gallons	2700			
Strength, °Salometer	55°			
Solubles, Total lbs.	3620			
Magnesium Hardness, gpg	540			
Calcium Hardness, gpg	1860			
CHEMICALS ADDED				
Hydrated Lime, lbs.	100			
% Theoretical	66%			
Soda Ash, lbs.	850			
% Theoretical	88%			
RECLAIMED BRINE				
Volume, Gallons	2700			
Strength, °Salometer	54°			
Solubles, Total lbs.	3340			
Total Hardness, gpg	350			
Purity, % Na/Solubles	95.5%			
WASTE				
Cumulated for Test numbers				
Volume, Gallons				
Insolubles, lbs.				
Solubles, lbs.				
REDUCTION OF WASTE %				
Volume				
Solubles				

REMARKS:

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	69A	70A	71A	72A
DATE	7/17/72	7/18/72	7/19/72	7/20/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	56°	53°	56°	55°
Solubles, Total lbs.	3660	3760	3660	3620
Magnesium Hardness, gpg	540	510	525	510
Calcium Hardness, gpg	1390	1970	1695	1460
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	65%	67%	65%
Soda Ash, lbs.	700	900	800	800
% Theoretical	86%	84%	88%	89%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	55°	55°	55°	54°
Solubles, Total lbs.	3360	3620	3620	3280
Total Hardness, gpg	380	265	365	395
Purity, % Na/Solubles	96%	97%	96%	95%
WASTE				
Cumulated for Test numbers	67A,68A,69A			70A,71A,72A
Volume, Gallons	900			900
Insolubles, lbs.	3410 / 3615			3050 / 3105
Solubles, lbs.	820 / 615			865 / 810
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	92.8 / 94.6			92.2 / 92.7

REMARKS: The average dosages of soda ash and hydrated lime are 87%and 66% respectively. The average residual hardness in the reclaimed brine is 350 gpg with a purity level of 96%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	73A	74A	75A	76A
DATE	7/24/72	7/25/72	7/26/72	7/27/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	56°	58°	57°	56°
Solubles, Total lbs.	4000	3840	3760	3960
Magnesium Hardness, gpg	465	525	555	480
Calcium Hardness, gpg	1685	1805	1745	1740
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	70%	67%	64%	68%
Soda Ash, lbs.	800	800	800	800
% Theoretical	85%	84%	86%	83%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	55°	57°	56°	55°
Solubles, Total lbs.	3600	3760	3450	3620
Total Hardness, gpg	390	405	395	405
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			73A,74A,75A	
Volume, Gallons			900	
Insolubles, lbs.			3110 / 3465	
Solubles, lbs.			940 / 585	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			91.9 / 94.9	

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 67% respectively. The average residual hardness in the reclaimed brine is 400 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	77A	78A	79A	80A
DATE	7/31/72	8/1/72	8/2/72	8/3/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	57°	56°	58°	56°
Solubles, Total lbs.	3760	3700	4100	3700
Magnesium Hardness, gpg	555	530	525	535
Calcium Hardness, gpg	1775	1770	1875	1735
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	64%	66%	63%	66%
Soda Ash, lbs.	800	800	900	800
% Theoretical	84%	86%	83%	87%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	56°	55°	57°	55°
Solubles, Total lbs.	3700	3340	3760	3620
Total Hardness, gpg	465	405	475	375
Purity, % Na/Solubles	95%	95%	94%	96%
WASTE				
Cumulated for Test numbers		76A,77A,78A		
Volume, Gallons		900		
Insolubles, lbs.		2810 / 2985		
Solubles, lbs.		970 / 795		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		91.5 / 93.0		

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 65% respectively. The average residual hardness in the reclaimed brine is 430 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	81A	82A	83A	84A
DATE	8/7/72	8/8/72	8/9/72	8/10/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	60°	61°	53°	56°
Solubles, Total lbs.	3970	4350	3480	3680
Magnesium Hardness, gpg	250	390	380	410
Calcium Hardness, gpg	2340	2280	2090	2090
CHEMICALS ADDED				
Hydrated Lime, lbs.	50	75	75	100
% Theoretical	71%	64%	69%	69%
Soda Ash, lbs.	900	1000	800	900
% Theoretical	86%	86%	83%	85%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	57°	59°	52°	55°
Solubles, Total lbs.	3480	3900	3500	3360
Total Hardness, gpg	310	425	420	410
Purity, % Na/Solubles	96%	95%	95%	95%
WASTE				
Cumulated for Test numbers	79A,80A,81A			82A,83A,84A
Volume, Gallons	900			900
Insolubles, lbs.	3390 / 3515			3470 / 3720
Solubles, lbs.	1010 / 885			855 / 605
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	91.4 / 92.4			92.6 / 94.8

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 68% respectively. The average residual hardness in the reclaimed brine is 390 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	85A	86A		
DATE	8/14/72	8/15/72		
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700		
Strength, °Salometer	57°	58°		
Solubles, Total lbs.	4100	3820		
Magnesium Hardness, gpg	500	540		
Calcium Hardness, gpg	1825	1735		
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100		
% Theoretical	66%	65%		
Soda Ash, lbs.	850	800		
% Theoretical	84%	86%		
RECLAIMED BRINE				
Volume, Gallons	2700	2700		
Strength, °Salometer	56°	57°		
Solubles, Total lbs.	3680	3760		
Total Hardness, gpg	415	400		
Purity, % Na/Solubles	95%	95%		
WASTE				
Cumulated for Test numbers				
Volume, Gallons				
Insolubles, lbs.				
Solubles, lbs.				
REDUCTION OF WASTE %				
Volume				
Solubles				

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 66% respectively. The average residual hardness in the reclaimed brine is 410 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	87A	88A	89A	90A
DATE	8/16/72	8/17/72	8/21/72	8/22/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	57°	56°	57°	59°
Solubles, Total lbs.	3760	3960	3760	3920
Magnesium Hardness, gpg	535	510	510	525
Calcium Hardness, gpg	1860	1830	1860	1895
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	65%	69%	67%
Soda Ash, lbs.	850	900	850	850
% Theoretical	87%	88%	88%	86%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	56°	55°	56°	58°
Solubles, Total lbs.	3520	3620	3690	3550
Total Hardness, gpg	385	390	375	390
Purity, % Na/Solubles	95%	95%	96%	95%
WASTE				
Cumulated for Test numbers	85A,86A,87A		88A,89A,90A	
Volume, Gallons	900		900	
Insolubles, lbs.	3230 / 3300		3230 / 3375	
Solubles, lbs.	1000 / 930		640 / 495	
REDUCTION OF WASTE %				
Volume	89.1		89.1	
Solubles	91.4 / 92.0		94.5 / 95.7	

REMARKS: The average dosages of soda ash and hydrated lime are 87.0% and 67.0% respectively. The average residual hardness in the reclaimed brine is 385gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	91A	92A	93A	94A
DATE	8/23/72	8/24/72	8/28/72	8/29/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	56°	57°	57°	58°
Solubles, Total lbs.	3960	3760	3760	4100
Magnesium Hardness, gpg	490	550	520	470
Calcium Hardness, gpg	1910	1790	1815	1890
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	67%	63%	68%	69%
Soda Ash, lbs.	900	800	800	800
% Theoretical	86%	84%	83%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	55°	56°	56°	57°
Solubles, Total lbs.	3620	3690	3420	3760
Total Hardness, gpg	405	435	430	380
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		91A,92A,93A		
Volume, Gallons		900		
Insolubles, lbs.		2190 / 2295		
Solubles, lbs.		690 / 585		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		94.0 / 94.9		

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 66% respectively. The average residual hardness in the reclaimed brine is 410 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	95A	96A	97A	98A
DATE	8/30/72	8/31/72	9/5/72	9/6/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	57°	57°	58°	56°
Solubles, Total lbs.	3760	3760	4100	3690
Magnesium Hardness, gpg	535	515	470	525
Calcium Hardness, gpg	1845	1880	1990	2005
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	68%	69%	67%
Soda Ash, lbs.	850	850	900	900
% Theoretical	88%	87%	83%	87%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	56°	56°	57°	55°
Solubles, Total lbs.	3690	3420	3760	3620
Total Hardness, gpg	395	370	400	365
Purity, % Na/Solubles	95%	95%	95%	94%
WASTE				
Cumulated for Test numbers		94A, 95A, 96A		
Volume, Gallons		900		
Insolubles, lbs.		1990 / 2085		
Solubles, lbs.		710 / 615		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		93.9 / 94.7		

REMARKS: The average dosages of soda ash and hydrated lime are 86% and 67.5% respectively. The average residual hardness in the reclaimed brine is 385 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	99A	100A	101A	102A
DATE	9/7/72	9/8/72	9/11/72	9/12/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	58°	58°	58°	57°
Solubles, Total lbs.	3830	4100	3800	3760
Magnesium Hardness, gpg	540	510	515	530
Calcium Hardness, gpg	1920	1905	1940	1910
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	65%	68%	67%
Soda Ash, lbs.	850	900	850	850
% Theoretical	85%	85%	85%	86%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	57°	57°	57°	56°
Solubles, Total lbs.	3490	3760	3760	3420
Total Hardness, gpg	405	415	390	395
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	97A, 98A, 99A			100A, 101A, 102A
Volume, Gallons	900			900
Insolubles, lbs.	3535 / 3655			3400 / 3590
Solubles, lbs.	865 / 745			920 / 730
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	92.6 / 93.6			92.1 / 93.7

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 66.5% respectively. The average residual hardness in the reclaimed brine is 400 gpg with the purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	103A	104A		
DATE	9/13/72	9/14/72		
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700		
Strength, °Salometer	58°	59°		
Solubles, Total lbs.	4100	3940		
Magnesium Hardness, gpg	490	520		
Calcium Hardness, gpg	1885	1870		
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100		
% Theoretical	67%	68%		
Soda Ash, lbs.	900	800		
% Theoretical	86%	83%		
RECLAIMED BRINE				
Volume, Gallons	2700	2700		
Strength, °Salometer	57°	58°		
Solubles, Total lbs.	3760	3830		
Total Hardness, gpg	390	425		
Purity, % Na/Solubles	95%	95%		
WASTE				
Cumulated for Test numbers				
Volume, Gallons				
Insolubles, lbs.				
Solubles, lbs.				
REDUCTION OF WASTE %				
Volume				
Solubles				

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 67.5% respectively. The average residual hardness in the reclaimed brine is 407 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	105A	106A	107A	108A
DATE	9/18/72	9/19/72	9/20/72	9/21/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	57°	59°	58°	57°
Solubles, Total lbs.	3760	4190	3840	3760
Magnesium Hardness, gpg	550	590	520	460
Calcium Hardness, gpg	1930	2010	2240	2160
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	150	100	100
% Theoretical	64%	64%	68%	75%
Soda Ash, lbs.	900	1000	1000	900
% Theoretical	89%	88%	89%	85%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	55°	57°	57°	55°
Solubles, Total lbs.	3350	3760	3760	3350
Total Hardness, gpg	340	535	175	230
Purity, % Na/Solubles	95%	94%	98%	97%
WASTE				
Cumulated for Test numbers	103A, 104A, 105A			106A, 107A, 108A
Volume, Gallons	900			900
Insolubles, lbs.	4605 / 4775			3980 / 4130
Solubles, lbs.	795 / 625			870 / 720
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	93.3 / 94.7			92.6 / 93.8

REMARKS: The average dosages of soda ash and hydrated lime are 88% and 68% respectively. The average residual hardness in the reclaimed brine is 320 gpg with a purity level of 96%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	109A	110A	111A	112A
DATE	9/25/72	9/26/72	9/27/72	9/28/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	58°	57°	57°	59°
Solubles, Total lbs.	4100	3760	3760	4250
Magnesium Hardness, gpg	360	530	475	510
Calcium Hardness, gpg	2310	2035	1970	1920
CHEMICALS ADDED				
Hydrated Lime, lbs.	75	100	75	100
% Theoretical	69%	66%	63%	65%
Soda Ash, lbs.	1000	900	800	900
% Theoretical	85%	87%	83%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	57°	56°	56°	58°
Solubles, Total lbs.	3760	3680	3420	3840
Total Hardness, gpg	380	385	440	415
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			109A, 110A, 111A	
Volume, Gallons			900	
Insolubles, lbs.			broken sample	
Solubles, lbs.			bottle	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles				

REMARKS: The average dosages of soda ash and hydrated lime are 85.0% and 66% respectively. The average residual hardness in the reclaimed brine is 405 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	113A	114A	115A	116A
DATE	10/2/72	10/3/72	10/4/72	10/5/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	58°	56°	58°	57°
Solubles, Total lbs.	3840	3690	4100	3760
Magnesium Hardness, gpg	540	525	510	530
Calcium Hardness, gpg	1870	1900	1885	1825
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	67%	64%	66%
Soda Ash, lbs.	850	850	900	800
% Theoretical	87%	87%	86%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	57°	55°	57°	56°
Solubles, Total lbs.	3760	3350	3760	3690
Total Hardness, gpg	405	375	410	440
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		112A, 113A, 114A		
Volume, Gallons		900		
Insolubles, lbs.		~~2740~~ 2940		
Solubles, lbs.		~~1040~~ 840		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		~~91.2~~ 92.5		

REMARKS: ____________________

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	117A	118A	119A	120A
DATE	10/9/72	10/10/72	10/11/72	10/12/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	58°	57°	58°	59°
Solubles, Total lbs.	3830	4100	3830	3910
Magnesium Hardness, gpg	535	500	540	540
Calcium Hardness, gpg	1870	1925	1850	1900
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	66%	65%	66%
Soda Ash, lbs.	850	900	850	850
% Theoretical	87%	85%	88%	85%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	57°	56°	57°	58°
Solubles, Total lbs.	3480	3680	3760	3550
Total Hardness, gpg	390	410	385	420
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	115A, 116A, 117A			118A, 119A, 120A
Volume, Gallons	900			900
Insolubles, lbs.	3035 / 3165			3325 / 3500
Solubles, lbs.	745 / 615			855 / 680
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	93.6 / 94.7			92.8 / 94.3

REMARKS: The average dosages of soda ash and hydrated lime are 86% and 66% respectively. The average residual hardness in the reclaimed brine is 400 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	121A	122A	123A	124A
DATE	10/17/72	10/18/72	10/19/72	10/20/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	57°	57°	56°	57°
Solubles, Total lbs.	4050	3760	3680	4050
Magnesium Hardness, gpg	510	545	530	525
Calcium Hardness, gpg	1910	1855	1800	2100
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	64%	65%	67%	63%
Soda Ash, lbs.	900	850	800	1000
% Theoretical	85%	87%	86%	87%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	56°	56°	55°	56°
Solubles, Total lbs.	3680	3680	3350	3690
Total Hardness, gpg	430	405	435	415
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			121A, 122A, 123A	
Volume, Gallons			900	
Insolubles, lbs.			3425 / 3515	
Solubles, lbs.			805 / 715	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			93.0 / 93.8	

REMARKS: The average dosages of soda ash and hydrated lime are 86% and 65% respectively. The average residual hardness in the reclaimed brine is 420 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	125A	126A	127A	128A
DATE	10/23/72	10/24/72	10/25/72	10/26/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, $^{\circ}$Salometer	57°	56°	59°	57°
Solubles, Total lbs.	3760	3690	4200	3760
Magnesium Hardness, gpg	520	545	500	525
Calcium Hardness, gpg	1870	1890	1910	1825
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	68%	64%	65%	67%
Soda Ash, lbs.	850	850	900	800
% Theoretical	87%	85%	85%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, $^{\circ}$Salometer	56°	55°	58°	56°
Solubles, Total lbs.	3690	3350	3820	3690
Total Hardness, gpg	395	425	420	400
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		124A, 125A, 126A		
Volume, Gallons		900		
Insolubles, lbs.		3665 / 3800		
Solubles, lbs.		610 / 475		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		94.7 / 95.9		

REMARKS: The average dosages of soda ash and hydrated lime are 85% and 66% respectively. The residual hardness in the reclaimed brine is 410 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	129A	130A	131A	132A
DATE	10/30/72	10/31/72	11/1/72	11/2/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	58°	58°	56°	57°
Solubles, Total lbs.	3840	4100	3690	3760
Magnesium Hardness, gpg	550	495	535	530
Calcium Hardness, gpg	1820	1910	1870	1900
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	64%	66%	66%	66%
Soda Ash, lbs.	850	900	850	850
% Theoretical	88%	86%	87%	86%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	57°	58°	55°	56°
Solubles, Total lbs.	3480	3760	3620	3420
Total Hardness, gpg	405	400	385	390
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	127A, 128A, 129A			130A, 131A, 132A
Volume, Gallons	900			900
Insolubles, lbs.	2870 / 3065			1730 / 1880
Solubles, lbs.	1090 / 895			970 / 820
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	90.8 / 92.4			91.6 / 92.9

REMARKS: **The average dosages of soda ash and hydrated lime are 87% and 65.5% respectively. The residual hardness in the reclaimed brine is 395 gpg with a purity level of 95%.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	133A	134A	135A	136A
DATE	11/6/72	11/7/72	11/8/72	11/9/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, ^{o}Salometer	570	590	570	580
Solubles, Total lbs.	4050	3900	3760	4100
Magnesium Hardness, gpg	495	545	540	510
Calcium Hardness, gpg	1860	1785	1870	1910
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	65%	65%	65%
Soda Ash, lbs.	900	800	850	900
% Theoretical	88%	86%	87%	85%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, ^{o}Salometer	56^{o}	58^{o}	56^{o}	57^{o}
Solubles, Total lbs.	3690	3840	3420	3760
Total Hardness, gpg	375	395	390	415
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			133A, 134A, 135A	
Volume, Gallons			900	
Insolubles, lbs.			3275 / 3270	
Solubles, lbs.			535 / 540	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			95.4 / 95.3	

REMARKS: The average dosages of soda ash and hydrated lime are 86.5% and 65% respectively. The average residual hardness in the reclaimed brine is 395 gpg with the purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	137A	138A		
DATE	11/13/72	11/15/72		
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700		
Strength, °Salometer	56°	57°		
Solubles, Total lbs.	3690	3760		
Magnesium Hardness, gpg	540	550		
Calcium Hardness, gpg	1840	1890		
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100		
% Theoretical	65%	64%		
Soda Ash, lbs.	850	850		
% Theoretical	88%	85%		
RECLAIMED BRINE				
Volume, Gallons	2700	2500		
Strength, °Salometer	55°	56°		
Solubles, Total lbs.	3560	3420		
Total Hardness, gpg	390	405		
Purity, % Na/Solubles	95%	95%		
WASTE				
Cumulated for Test numbers		136A, 137A, 138A		
Volume, Gallons		900		
Insolubles, lbs.		3605 / 3595		
Solubles, lbs.		635 / 645		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		94.5 / 94.4		

REMARKS: The average dosages of soda ash and hydrated lime are 86.5% and 64.5% respectively.

The average residual hardness is 397 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	139A	140A	141A	142A
DATE	11/16/72	11/17/72	11/20/72	11/21/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, $^{\circ}$Salometer	56°	58°	58°	57°
Solubles, Total lbs.	3960	3830	3830	4050
Magnesium Hardness, gpg	500	535	545	505
Calcium Hardness, gpg	1910	1900	1875	1905
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	70%	66%	65%	65%
Soda Ash, lbs.	900	850	850	900
% Theoretical	86%	86%	86%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, $^{\circ}$Salometer	55°	57°	57°	56°
Solubles, Total lbs.	3620	3760	3490	3690
Total Hardness, gpg	345	395	400	410
Purity, % Na/Solubles	96%	95%	95%	95%
WASTE				
Cumulated for Test numbers			141A, 139A, 140A	
Volume, Gallons			900	
Insolubles, lbs.			2980 / 3230	
Solubles, lbs.			930 / 680	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			92.0 / 94.1	

REMARKS: The average dosages of soda ash and hydrated lime are 86% and 66% respectively. The average residual hardness on the reclaimed brine is 390 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	143A	144A	145A	146A
DATE	11/22/72	11/27/72	11/28/72	11/30/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	58°	56°	57°	57°
Solubles, Total lbs.	3840	3690	4050	3760
Magnesium Hardness, gpg	550	540	505	530
Calcium Hardness, gpg	1860	1910	1930	1885
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	64%	65%	65%	67%
Soda Ash, lbs.	850	850	900	850
% Theoretical	87%	85%	85%	86%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	57°	55°	56°	56°
Solubles, Total lbs.	3760	3350	3690	3690
Total Hardness, gpg	415	425	420	395
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		142A, 143A, 144A		
Volume, Gallons		900		
Insolubles, lbs.		3370 / 3650		
Solubles, lbs.		905 / 625		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		92.2 / 94.6		

REMARKS: **The average dosages of soda ash and hydrated lime are 86% and 65% respectively. The average residual hardness on the reclaimed brine is 415 gpg with a purity level of 95%.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	147A	148A	149A	150A
DATE	12/1/72	12/4/72	12/5/72	12/6/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	58°	57°	56°	58°
Solubles, Total lbs.	3830	4050	3690	3830
Magnesium Hardness, gpg	545	480	525	530
Calcium Hardness, gpg	1870	1890	1910	1855
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	69%	67%	66%
Soda Ash, lbs.	850	900	850	850
% Theoretical	86%	86%	86%	88%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	57°	56°	55°	57°
Solubles, Total lbs.	3480	3690	3620	3480
Total Hardness, gpg	410	375	390	405
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	145A, 146, 147A			148A, 149A, 150A
Volume, Gallons	900			900
Insolubles, lbs.	3410 / 3705			3055 / 3390
Solubles, lbs.	1100 / 805			995 / 660
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	90.6 / 93.1			91.4 / 94.3

REMARKS: The average dosages of soda ash and hydrated lime are 86.5% and 67% respectively. The average total hardness in the reclaimed brine is 395 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	151A	152A	153A	154A
DATE	12/7/72	12/11/72	12/12/72	12/13/72
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	58°	56°	56°	58°
Solubles, Total lbs.	4120	3690	3690	4150
Magnesium Hardness, gpg	510	540	525	490
Calcium Hardness, gpg	1875	1870	1900	1865
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	65%	66%	67%	67%
Soda Ash, lbs.	900	850	850	900
% Theoretical	87%	87%	86%	87%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	57°	55°	55°	57°
Solubles, Total lbs.	3760	3600	3350	3760
Total Hardness, gpg	390	380	390	375
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers			151A, 152A, 153A	
Volume, Gallons			900	
Insolubles, lbs.			3080 / 3350	
Solubles, lbs.			830 / 550	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			92.8 / 95.2	

REMARKS: The average dosages of soda ash and hydrated lime are 87% and 66% respectively. The average total hardness in the reclaimed brine is 385 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	155A	156A	157A	158A
DATE	12/14/72	12/19/72	12/20/72	12/21/72
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	57°	55°	56°	56°
Solubles, Total lbs.	3760	3620	3960	3690
Magnesium Hardness, gpg	520	555	530	525
Calcium Hardness, gpg	1910	1955	1890	1955
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	68%	64%	63%	67%
Soda Ash, lbs.	850	900	900	850
% Theoretical	86%	88%	85%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	56°	54°	55°	55°
Solubles, Total lbs.	3690	3320	3620	3620
Total Hardness, gpg	400	395	435	410
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		154A, 155A, 156A		
Volume, Gallons		900		
Insolubles, lbs.		2965 / 3170		
Solubles, lbs.		860 / 655		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		92.7 / 94.4		

REMARKS: The average dosages of soda ash and hydrated lime are 86% and 65.5% respectively. The residual total hardness in the reclaimed brine is 410 gpg with a purity level of 95%.

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	159A	160A	161A	162A
DATE	12/22/72	12/26/72	12/29/72	1/2/73
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	55°	51°	51°	55°
Solubles, Total lbs.	3620	3580	3340	3620
Magnesium Hardness, gpg	535	480	510	550
Calcium Hardness, gpg	2040	1980	1975	2015
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	69%	69%	64%
Soda Ash, lbs.	900	950	900	900
% Theoretical	86%	88%	89%	86%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	54°	51°	51°	54°
Solubles, Total lbs.	3280	3340	3340	3280
Total Hardness, gpg	405	385	375	415
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	157A, 158A, 159A			160A, 161A, 162A
Volume, Gallons	900			900
Insolubles, lbs.	2660 / 2760			4175 / 4700
Solubles, lbs.	760 / 660			955 / 430
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles	93.2 / 94.1			91.0 / 95.9

REMARKS: __________

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	163A	164A	165A	166A
DATE	1/2/73	1/4/73	1/5/73	1/8/73
UNTREATED WASTE BRINE				
Volume, Gallons	2900	2700	2700	2900
Strength, °Salometer	53°	56°	56°	56°
Solubles, Total lbs.	3740	3690	3690	3960
Magnesium Hardness, gpg	475	520	555	510
Calcium Hardness, gpg	2105	1985	1990	1910
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	69%	68%	64%	64%
Soda Ash, lbs.	1000	900	900	900
% Theoretical	88%	88%	86%	85%
RECLAIMED BRINE				
Volume, Gallons	2700	2700	2500	2700
Strength, °Salometer	52°	55°	55°	55°
Solubles, Total lbs.	3400	3620	3350	3620
Total Hardness, gpg	360	375	410	435
Purity, % Na/Solubles	96%	95%	95%	95%
WASTE				
Cumulated for Test numbers			163A, 164A, 165A	
Volume, Gallons			900	
Insolubles, lbs.			3330	
Solubles, lbs.			990	
REDUCTION OF WASTE %				
Volume			89.1	
Solubles			91.1	

REMARKS: **The average dosage of soda ash and hydrated lime are 87% and 66% respectively. The average residual hardness in the reclaimed brine is 395 gpg with a purity level of 95%.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	167A	168A	169A	170A
DATE	1/9/73	1/10/73	1/11/73	1/15/73
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2700	2900	2700
Strength, °Salometer	55°	56°	55°	55°
Solubles, Total lbs.	3620	3690	3880	3610
Magnesium Hardness, gpg	535	540	490	515
Calcium Hardness, gpg	1885	1860	1925	1810
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	66%	66%	67%	69%
Soda Ash, lbs.	850	850	900	800
% Theoretical	86%	88%	85%	84%
RECLAIMED BRINE				
Volume, Gallons	2700	2500	2700	2700
Strength, °Salometer	54°	55°	54°	54°
Solubles, Total lbs.	3540	3350	3540	3540
Total Hardness, gpg	410	385	390	430
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers		166A, 167A,168A		
Volume, Gallons		900		
Insolubles, lbs.		3205 / 3610		
Solubles, lbs.		755 / 350		
REDUCTION OF WASTE %				
Volume		89.1		
Solubles		93.3 / 96.9		

REMARKS: **The average dosages of soda ash and hydrated lime are 86% and 67% respectively. The average residual total hardness is 405 gpg in the reclaimed brine and a purity level of 95%.**

BRINE RECLAMATION TEST RUN DATA

TEST RUN NUMBER	171A	172A	173A	174A
DATE	1/17/73	1/18/73	1/19/73	1/22/73
UNTREATED WASTE BRINE				
Volume, Gallons	2700	2900	2700	2700
Strength, °Salometer	57°	54°	55°	57°
Solubles, Total lbs.	3760	3800	3610	3760
Magnesium Hardness, gpg	530	500	535	510
Calcium Hardness, gpg	1870	1820	1805	1795
CHEMICALS ADDED				
Hydrated Lime, lbs.	100	100	100	100
% Theoretical	67%	66%	66%	67%
Soda Ash, lbs.	850	900	800	800
% Theoretical	87%	89%	84%	85%
RECLAIMED BRINE				
Volume, Gallons	2500	2700	2700	2500
Strength, °Salometer	56°	53°	54°	56°
Solubles, Total lbs.	3420	3490	3540	3420
Total Hardness, gpg	390	375	415	405
Purity, % Na/Solubles	95%	95%	95%	95%
WASTE				
Cumulated for Test numbers	169A, 170A,171A			172A, 173A,174A
Volume, Gallons	900			900
Insolubles, lbs.				
Solubles, lbs.				
REDUCTION OF WASTE %				
Volume	89.1			89.1
Solubles				

REMARKS: The average dosage of soda ash and hydrated lime are 86% and 66.5% respectively. The average residual total hardness in the reclaimed brine is 395 gpg with a purity level of 95%.

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16. Abstract

There are two alternatives for discharge of water softener regenerant brines to receiving streams: (1) truck to approved dumping site; (2) reclaim for reuse.

Brine reuse has been studied at a central regeneration facility for portable water softeners. Reclamation used modified lime-soda softening for the waste brine to produce an acceptable regenerant brine. Regenerant wastes were reduced by 89% to produce an environmentally acceptable sludge.

The process is feasible technically, marginal economically. The added costs for lime and soda ash are less than is the value of salt and water reclaimed by their use. That is, the process is cheaper chemically; however, equipment and labor costs negate this savings. Depreciation and operating costs were high at the test location: total costs favor trucking wastes to an approved dumping site.

Capital and operating costs may be reduced under annew project following the report's recommendations.

17a. Descriptors

*water softening, *chemical precipitation, *brines, hardness (water), water pollution treatment lime.

17b. Identifiers

*regenerant reuse, lime soda softening, regenerant disposal.

17c. COWRR Field & Group 05D, 05E, 05B

18. Availability

19. Security Class. (Report)

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