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63-3-2 ✓

CATALOGED BY ASTIA  
AS AD NO. 402421

Task Y-R011-01-052  
Type C

**402421**

TN-493

MAGNESIUM REMOVAL EXPERIMENTS FOR CONTROL

OF SCALE IN VC STILLS

28 March 1963

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APR 29 1963  
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ABSTRACT

An experimental study was initiated to determine the effect of the concentration of magnesium ion in sea water upon the scaling characteristics in vapor compression stills. An attempt was made to determine the rate of scale formation at reduced magnesium concentrations. The use of an ion-exchange resin was found to be impractical for maintaining a constant value for magnesium. Further investigation depends upon the feasibility of controlling magnesium by controlled precipitation and filtration.

## INTRODUCTION

The scale that is found in sea water evaporators operated at about atmospheric pressure consists almost entirely of magnesium hydroxide. Even though the mechanism of formation of magnesium hydroxide in boiling sea water has been known for more than 30 years<sup>1</sup>, the only effective method that has been found to prevent its precipitation as scale is the control of the pH of the feed water.

Scale which forms on heating surfaces can be removed by acidifying the water in the evaporator. This is done either by circulating a strong acid solution at intervals of several weeks or, by intermittent injections of small amounts of acid at eight hour intervals<sup>2</sup>. The latter method has been found to be less injurious to equipment than the former and is also less expensive than prevention by continuous pH control.

Since very little work has been done to investigate the formation of magnesium hydroxide scale on advanced base size evaporators, the present task was undertaken to obtain practical information that might aid in the solution of the problem of scale prevention or removal.

It was decided to conduct a series of experiments to determine what effect reduction of the magnesium concentration would have on the rate of scale formation in vapor compression stills operating at or near atmospheric pressure.

There is reason to believe that magnesium hydroxide scale is not dependent to any appreciable extent upon the concentration of the magnesium ion. In fact, evaluation tests of distillation units have indicated greater scaling tendencies at lower concentrations but with increased volume of flow. If this is the case, scaling is more apt to be a function of the bicarbonate alkalinity in the sea water. Therefore, under these conditions the reduction of magnesium ion would not be effective until the concentration was less than needed to react with the hydroxyl ion resulting from the thermal breakdown of the bicarbonate. Theoretically, approximately 24 ppm of magnesium would be precipitated by the presence of 130 ppm of bicarbonate ion. This would be equivalent to 58 pounds of magnesium hydroxide scale per 1,000,000 pounds of sea water fed to the evaporator. This figure checks quite closely with the actual amount of scale removed from equipment after processing that much water. However, there was no proof that this minimum magnesium concentration (24 ppm) would actually cause scaling. Neither was it known at exactly what concentration scaling would start to decrease. Therefore, it seemed worthwhile to conduct some experimental work to establish magnesium concentration limits for scale formation.

The various methods that have been used to eliminate the magnesium ion from the feed water were reviewed, including the softening experiments done by McIlhenny<sup>4</sup>, and it was decided to use an ion-exchange resin to remove the magnesium from the sea water, and to regenerate the resin with blowdown from the evaporator.

It was hoped that the magnesium concentration could be maintained constant at several values and that a comparison of scaling rate for each value could be obtained.

If this method was not successful, it was planned to use an alternate method for regulating magnesium concentration by controlled precipitation, clarification and subsequent adjustment. Magnesium can be removed by adding sodium hydroxide to the feed water, which is then filtered. The bicarbonate can then be regenerated by adjusting the pH.

#### DESCRIPTION OF EQUIPMENT

The equipment used for the experiments consisted mainly of a modified Cleaver-Brooks Distillation Unit, Model DVC-8, skid mounted, adapted with a 10-hp electric motor (instead of the diesel engine) to drive the compressor, and two immersion electric heaters to furnish the auxiliary heat normally supplied by the cooling jacket of the diesel engine. Figure 1 shows the position of the compressor, electric motor, and immersion heaters. The feedwater and blowdown pumps were driven by a 1-hp electric motor.

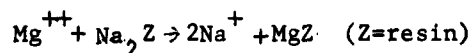
The feed was controlled by means of a water-level-float control connected to the water side of the evaporator. The feed flow rate was measured by a flowrater placed between the feed pump and the float control; a quantity meter was also used to measure the total feed to the evaporator. The blowdown was controlled by a float control in the discharge end of the blowdown line. A quantity meter was also used to measure the total blowdown flowing out of the evaporator. The blowdown and distillate flow rates were measured by the bucket and stop watch method.

Indicator-recorders were used to measure and record the pH of the feed and blowdown, the salinity of the distillate, and the distillate flow rate. The temperatures of the feed, distillate, and blowdown flows were recorded before and after going through the heat exchanger.

The ion-exchange equipment consisted of two cylindrical tanks, each loaded with 146 pounds of Dowex-50, 50-100 mesh cation-exchange resin, and provided with filter elements to prevent the resin from

flowing out of the tanks. The piping connections were made in such a manner that the operation of the tanks could be changed instantly from softening to regenerating operation.

Magnesium and calcium ions are removed from solution by the resin in a typical ion exchange reaction:



In order to weigh the scale deposited after every test, nine removable sample tubes were located in the calandria of the evaporator so that new sample tubes could be used for each test. To facilitate their removal at the end of each test, the tubes were held in place by O-rings inserted in grooves cut in the top and bottom tube sheets. Figure 2 shows the evaporator tubes. The nine sample tubes can be seen on close inspection.

#### TEST PROCEDURE

The first objective was to run a preliminary scaling test without magnesium removal, to establish the normal weight of scale that would occur on the sample tubes, and then to operate the unit with magnesium removal to see if any less scale would be deposited.

The preliminary test was conducted for a continuous period of 115 hours. The still was operated with a constant head pressure, with data recorded on operating factors listed under "Description of Equipment." At the end of the test, the removable tubes were pulled out and weighed to determine the amount of scale deposited on each tube. Figure 3 diagrams the position of the sample tubes and the amount of scale occurring during the test run. Table I. lists other pertinent data.

Table I. Test Data for 85 GPH Still Operating Without Special Scale Control Procedures

|  |      |
|--|------|
| Total testing time, hrs.                         | 115. |
| Dome pressure, in. Hg                            | 1.2  |
| Feedwater, gpm                                   | 2.3  |
| Blowdown, gpm                                    | 1.0  |
| Distillate, gpm                                  | 1.3  |
| Conc. Factor, vol. basis                         | 2.3  |
| Conc. Factor, Cl basis                           | 2.2  |
| Total alkalinity feedwater, as CaCO <sub>3</sub> | 124. |
| Total alkalinity blowdown, as CaCO <sub>3</sub>  | 86.  |
| Scale per tube, grams                            | 2.4  |
| Percent Mg in scale                              | 94.6 |
| Percent Ca in scale                              | 5.4  |

## MAGNESIUM CONTROL EXPERIMENTS

To determine the practical rate of removal of magnesium from the still feed water, a performance test on the ion-exchange equipment only was conducted. A flow rate of 2.5 gpm sea water was passed through the resin bed; samples of softened sea water were taken every 10 minutes for a period of 1 hour, and analyzed for magnesium and calcium content. The results of the analyses are presented in Figure 4. The curves in Figure 4 show how the concentration of magnesium in the softened sea water increased as the softening operation proceeded. A maximum removal of magnesium was apparent only during the first minutes of operation. Calcium ion removal is also shown in Figure 4. Since the experiment required that the magnesium ion concentration be maintained constant during the test, it was obvious that this softening process was inadequate. On the possibility that channeling might have occurred in the resin bed, tanks were modified to assure complete contact of all resin with the sea water. No improvement was found and the experiments were discontinued.

## DISCUSSION

The main objective of these studies was to determine the effect of reducing the magnesium concentration in the feedwater in relation to the formation of magnesium hydroxide scale. The magnesium removal by the resin was adequate only for a short time after regeneration so that a complete removal of magnesium is not possible unless the ion-exchange resin is available in a very large quantity and complete regeneration of the resin is accomplished for each cycle.

## CONCLUSION

The use of ion-exchange equipment to reduce the concentration of magnesium in feedwater is not practical. Chemical precipitation of the magnesium will permit greater reduction as well as better control of the concentration.



#### REFERENCES

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3. Badger, W. L. and Associates, "Critical Review of Literature on Formation and Prevention of Scale," Progress Report No. 25 to Office of Saline Water, BB161399, July 1959.
4. McIlhenny, W. F., "Seawater Softening by Ion Exchange as a Saline Water Conversion Pretreatment," Texas Division, Dow Chemical Co., Freeport, Texas.

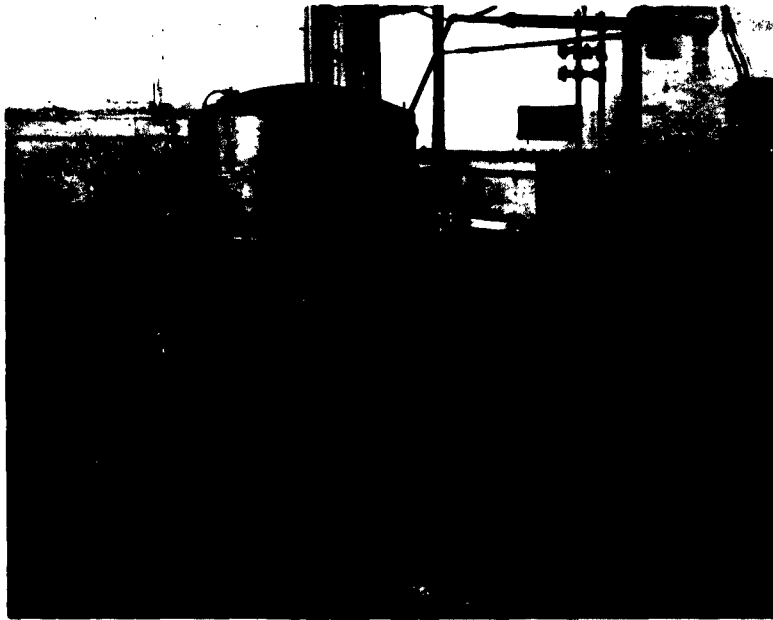


Figure 1. Showing compressor, electric motor, and immersion heater tank behind compressor.



Figure 2. Top tube sheet showing compressor discharge end on bottom, right.

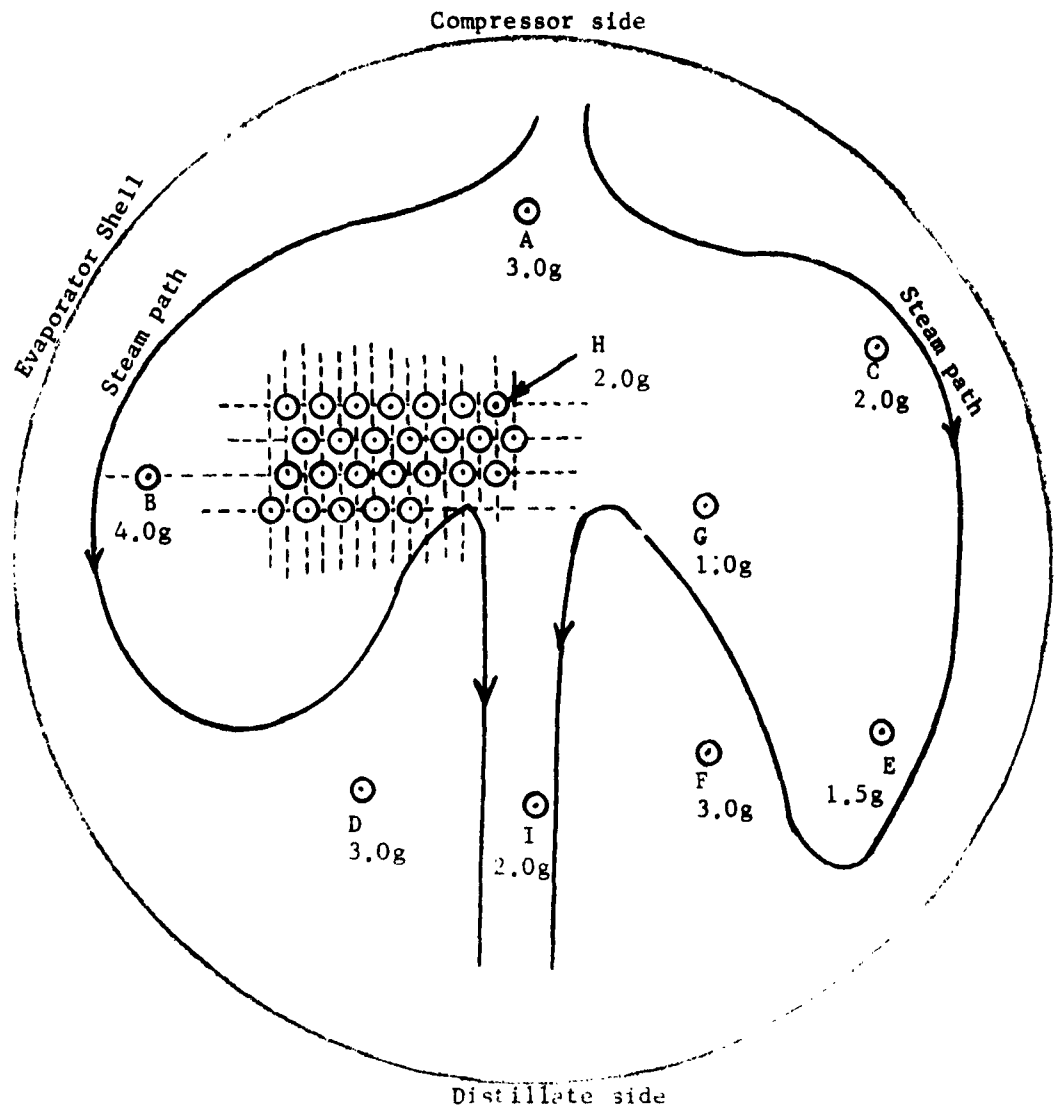


Figure 3. Removable Tubes Diagram.

This figure shows the tube location and amount of scale deposited during the preliminary test.

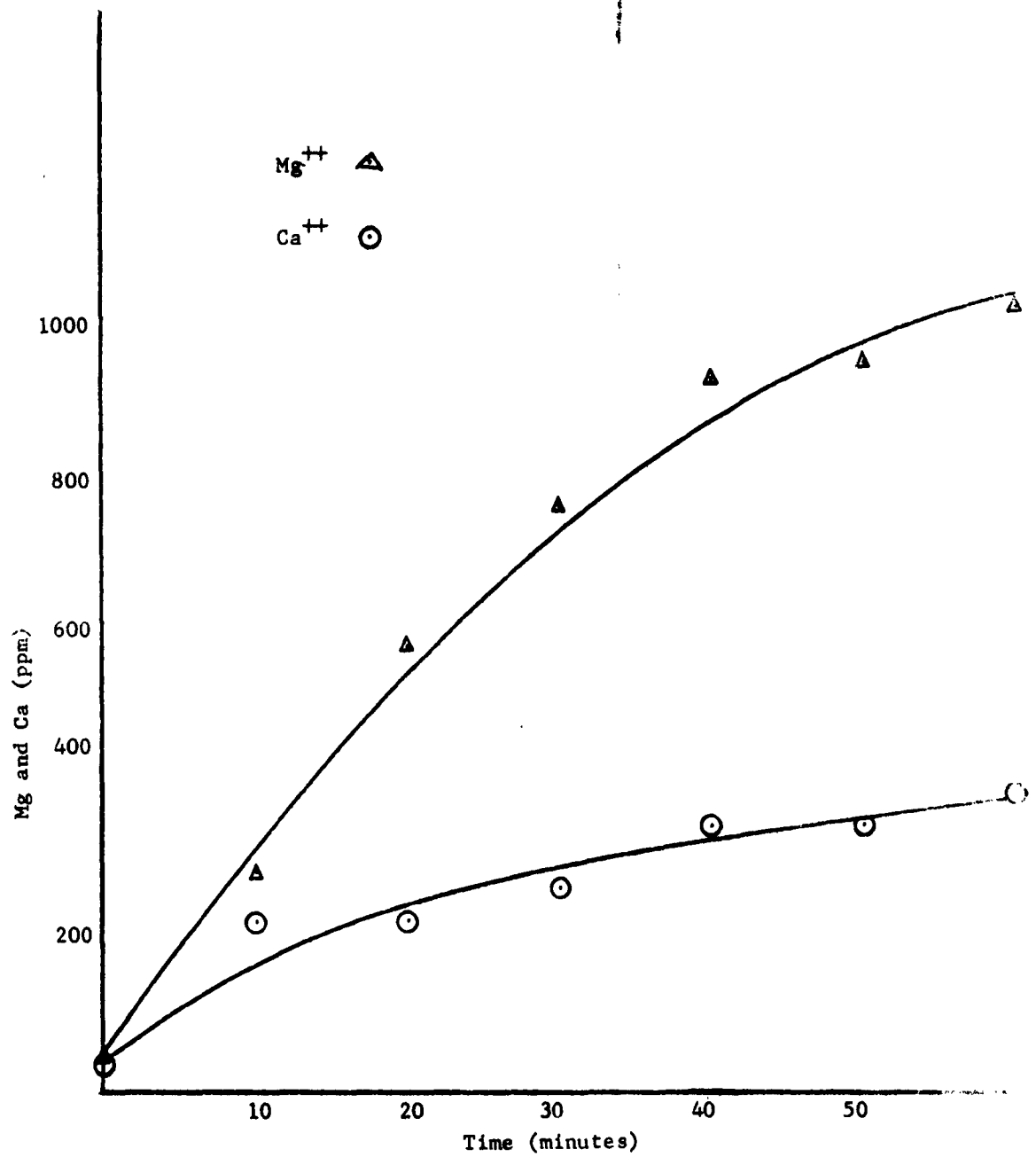


Figure 4. Sea Water Softening Test, Regenerated Resin.

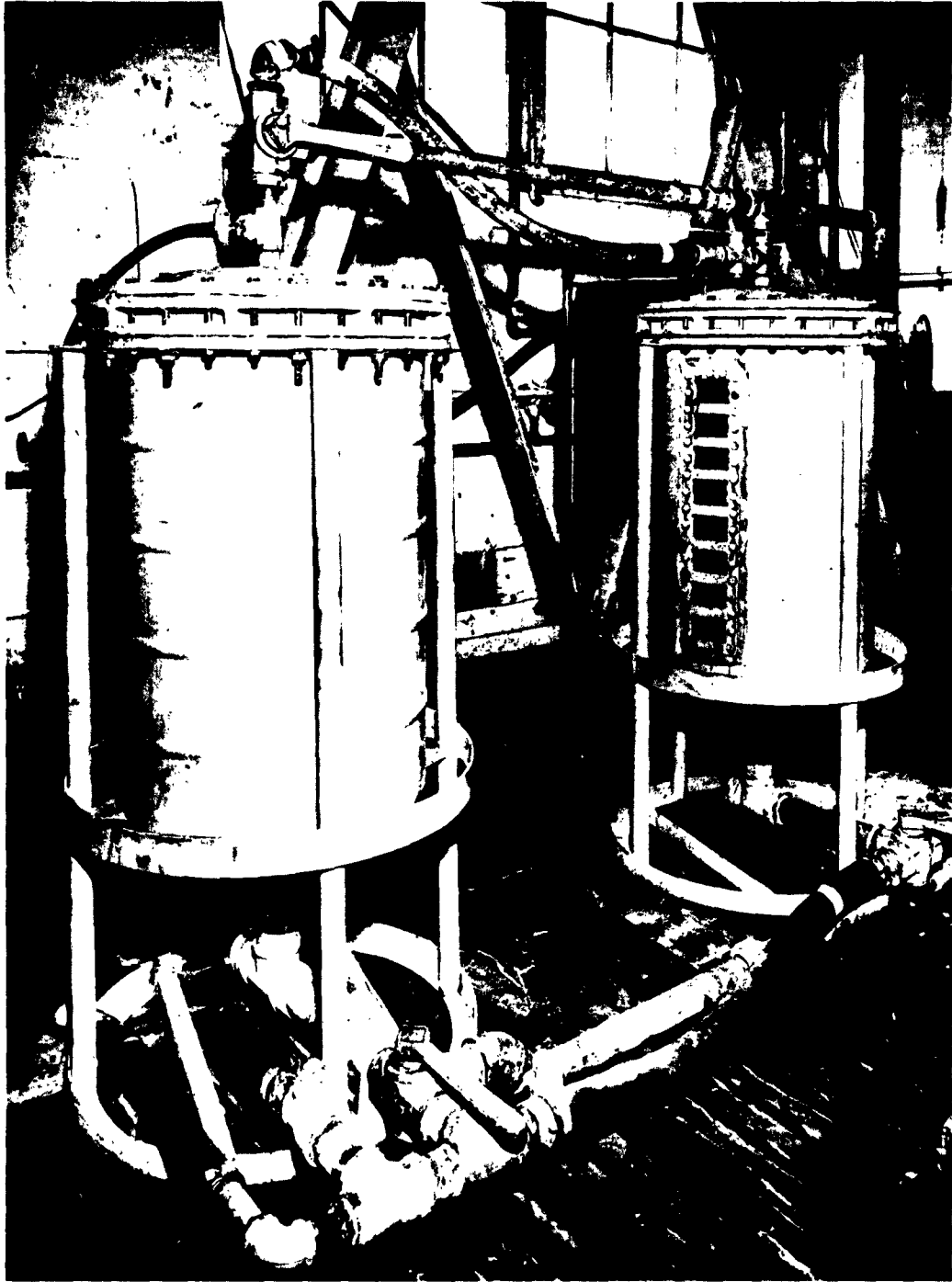


Figure 5. Combination exchanger and filter units.

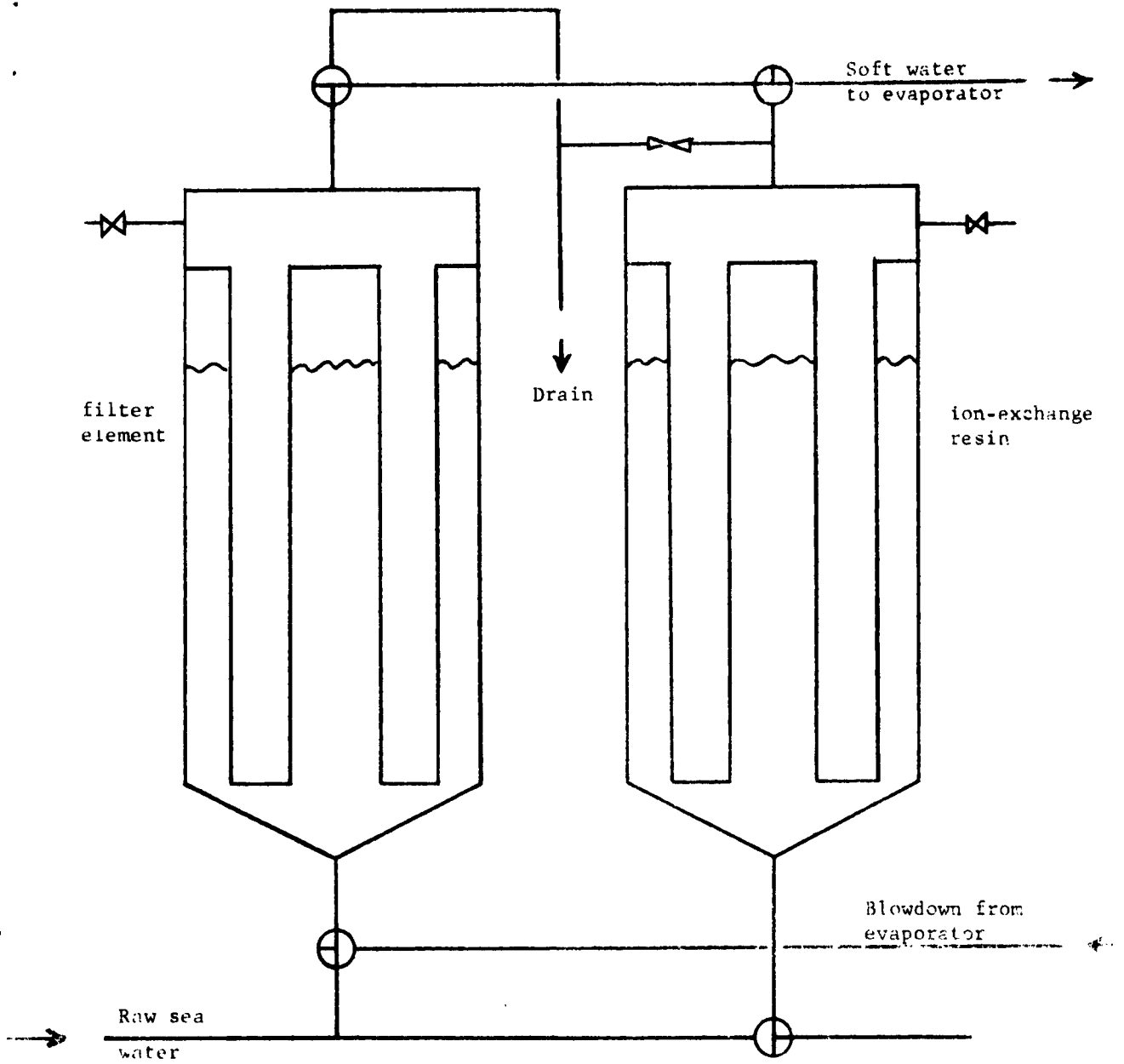


Figure 6. Softening and Regeneration Flows