PLAINTIFF'S EXHIBIT

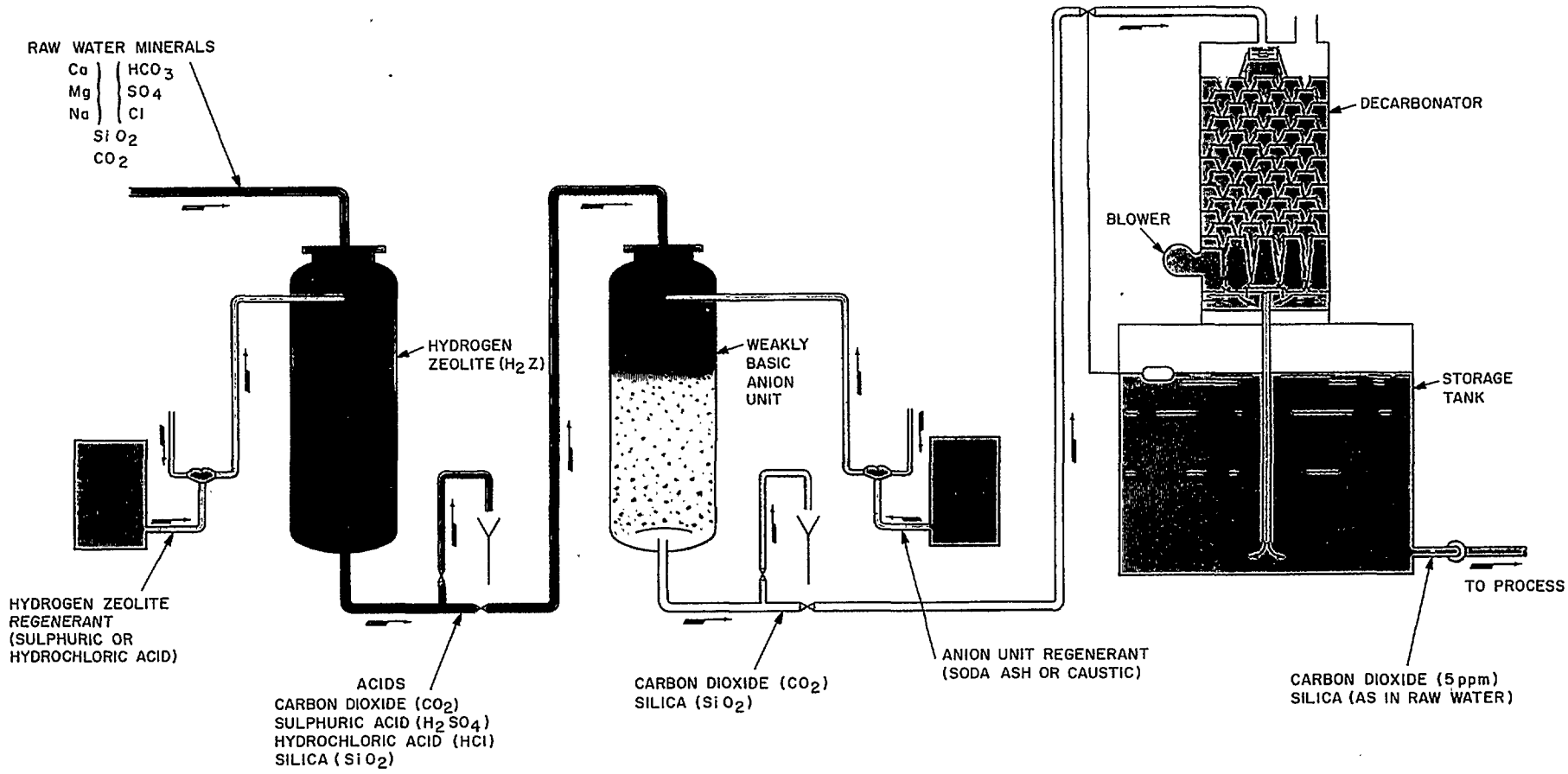
CRA-53

CRANE-COCHRANE

HANDBOOK ON DEMINERALIZING

THE PROCESS OF DEMINERALIZATION

with weakly basic anion exchanger



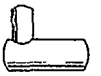
© Crane Co. 1966


Zeo-Flo Softeners


Uni-Pac Demineralizers


Heat Exchangers


Multiport Valves


Uni-Pac Deaerators


Zeolite Softeners


Filters


Waste Treatment

COCHRANE DIVISION
CRANE CO.

NAME_____ TITLE_____

COMPANY_____

ADDRESS (Street)_____

CITY_____ ZONE____ STATE_____

FORM 5675

I am interested in the specific equipment circled above and below:


Hot Process


Deaerators


Dealkalizers


Demineralizers


Reactors


Continuous Blow-Off


C-B Systems


Specialties

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 59, KING OF PRUSSIA, PA.

COCHRANE DIVISION
CRANE CO.
P.O. BOX 191
KING OF PRUSSIA, PA. 19406

HISTORY OF WATER TREATMENT

Demineralizing is the most recent development in water treatment to remove the dissolved chemical impurities that contaminate the pure rain water after it falls to the earth. To understand Demineralizing a brief history of water treatment methods that preceded it will be helpful.

The major dissolved impurities in water are silica, iron and manganese and the calcium, magnesium and sodium cations in various combinations with the bicarbonate, sulfate and chloride anions. Calcium and magnesium constitute the "hardness". Bicarbonates are called "alkalinity".

Water softening or hardness removal was the first problem tackled. The earliest method employed lime and soda ash first at cold water temperatures and later for boiler feed purposes at boiling water temperatures. The first method is called "cold process" lime-soda water softening and the latter "hot process".

Ion exchange, as a method of water treatment to remove dissolved impurities, began abroad about 1910 and was introduced into this country about 1912. It differs radically from lime-soda treatment. In the latter lime and soda ash are introduced into the raw water to form precipitates which are then separated from the water by settling and filtration. With ion exchange no chemicals are added to the water. Raw water is percolated through a column or bed of ion exchange material and a chemical reaction occurs during this passage of the water so that the effluent comes out purified. The ions in the raw water are exchanged for ions in the bed of exchange material. The exchange material does not go into solution and, periodically, when its capacity becomes exhausted, it is regenerated by passing a solution of regenerant through it. Thus ion exchange is a cyclic process of exhaustion followed by regeneration.

Sodium Zeolite Process

First ion exchange process developed, this method employs a sodium zeolite cation exchanger which converts the hardness of a water to the corresponding sodium salts. The ions, calcium and magnesium, in the raw water are exchanged for sodium ions loosely held by the zeolite. In the regeneration, ordinary sodium chloride brine is employed. This reverses the ion exchange reaction and displaces the calcium and magnesium ions from the exhausted zeolite by sodium from the brine.

Sodium zeolite was a revolutionary improvement over the lime-soda process:

(1) It produces a water of "zero" hardness (0-2 ppm expressed as $CaCO_3$).
(2) No chemical feeds are required to vary the dosage of reagent to match the variations in composition of the raw water—as with the lime-soda process. The only effect of a varying hardness on the sodium zeolite method is to increase the gallons of water softened between regenerations when the hardness is lower and vice versa.
(3) It prevents the formation of scale or other deposits which takes place when hard water is heated or evaporated in boilers.
(4) It avoids the destruction of soap and, therefore, prevents the formation of insoluble soap curds.

Consequently, sodium zeolite softeners are used extensively for:

(1) Households and institutions.
(2) Laundries.
(3) Textile plants.
(4) Cooling water.
(5) Low pressure boilers.

However, the sodium zeolite process only exchanges calcium and magnesium cations for sodium. It leaves the anions unchanged. So, in the softened water, there is just as much bicarbonate, sulfate and chloride anion present as in the raw water. These anions, particularly the sodium bicarbonate cause difficulties in many applications. For example:

(1) Sodium bicarbonate causes the cracking of raw water ice cakes.
(2) It destroys phosphoric and other acids which are used to impart a characteristic tang to many beverages.
(3) In cooling water systems, sodium bicarbonate forms soda ash which attacks the wood of the cooling tower and forms white deposits on buildings from the windage losses.
(4) It produces flat tasting beer.
(5) It is undesirable for watering many plants in hot houses and for irrigation purposes.
(6) It interferes with textile dyeing operations.
(7) The sodium bicarbonate decomposes to soda ash, caustic soda and carbonic acid in steam boilers. The caustic soda has been claimed to cause embrittlement of overstressed boiler seams. The carbonic acid is carried over with the boiler steam and when the steam is condensed the dissolved carbonic acid lowers the pH value causing return line corrosion. High sodium bicarbonate content also increases the tendency of boilers to foam or carry over boiler water in the steam, interfering with lubrication of engines.

Hydrogen Zeolite Process

The difficulties just described led water treatment chemists to search for an ion exchange method which would remove hardness without leaving sodium bicarbonate alkalinity. In 1935 the hydrogen zeolite process was developed to accomplish these results. This method differs from the sodium zeolite process in that the calcium, magnesium and sodium cations are now exchanged for hydrogen in the cation exchanger. To introduce the hydrogen ion into the exchanger, it was necessary to regenerate the latter with acid instead of brine. Therefore, the cation exchanger had to be able to withstand acids.

Prior to 1935 zeolites available were all subject to attack by acids. This made it necessary to develop a new exchange material. The first successful hydrogen zeolite was sulphonated coal (Cochranex CCA). Later, synthetic resins were developed (Cochranex CRW and CRZ) which had similar properties. These non-siliceous, carbonaceous, organic cation exchangers are immune to acid, so that they can be regenerated by either acid or salt. They can, therefore, be employed in the hydrogen as well as in the sodium cycle.

The hydrogen zeolite process exchanges the cations, calcium, magnesium and sodium, for hydrogen—thus converting the original salts in a raw water to their respective acids. The alkalinity is converted to carbonic acid, which can be easily removed from the water by aeration in a Degasifier or Decarbonator. The remaining acids which are usually sulphuric and hydrochloric acid (from the original sulfates and chlorides) must be neutralized. This is done either by adding an alkali, such as soda ash or caustic soda, or by mixing the acid effluent from a hydrogen zeolite unit with the alkaline effluent of a sodium zeolite unit.

This resulted in the development of the "split stream treatment" whereby part of the raw water is passed through a hydrogen zeolite unit and the remainder through a sodium zeolite unit. Both units remove the hardness and, after their effluents are blended and passed through a Degasifier or Decarbonator, the resulting effluent is a water of zero hardness with a minimum of alkalinity and with sodium sulfate and sodium chloride present in equivalent amounts to the original sulfate and chloride anions in the raw water.

Many "split stream" hydrogen sodium zeolite plants have been installed for boiler feed purposes. Not only have they kept the boilers

free from scale, but have reduced return line corrosion, foaming and embrittlement.

Hydrogen zeolite thus went a step further than the Sodium Zeolite in accomplishing the removal of alkalinity, i.e., it de-alkalized the water in addition to softening it. In so doing, however, it still left unsolved the removal of the sulfate, chlorides and silica which required the development of Demineralizing.

Demineralizing or De-ionizing Process

Demineralizing started about 1936. Research chemists found that the acidity in hydrogen zeolite effluents could be removed by an acid adsorbing anion exchange material. This led to the Demineralizing or De-Ionizing process which removes all the minerals or the ions present in the raw water. The resulting effluent is as free from ionic impurities as distilled water.

Demineralizing is a two-step process. The first "step", the hydrogen cation exchanger, converts all of the salts present in the raw water to their respective acids. The second, the anion exchanger, adsorbs these acids.

Weakly Basic Anion Exchangers

The first anion exchangers developed were weakly basic. They could only remove strong mineral acids such as sulphuric, hydrochloric and nitric acids. They could not adsorb weak acids, such as carbonic acid or silicic acid produced from the silica in the raw water. Demineralizing with such weakly basic anion exchangers was, therefore, limited to those applications where silica was unimportant. However, many of these Demineralizers have been installed for replacing distilled water for such applications as the cutting of alcohol in distilleries, manufacture of ceramics, production of glass, tin plating, etc.

Troubles Caused by Silica

The application of demineralizing – using weakly basic anion exchangers – was held back by its failure to remove silica. For silica was becoming recognized as an impurity that caused increasing difficulty in power plants.

As boiler pressures increased to over 450 psig, it was discovered that silica distills over with the steam. Then, when the steam is used in steam turbines for power generation, the silica is condensed and deposited on some of the intermediate pressure turbine blades as a hard glassy film. These deposits are difficult to remove and they seriously lower the efficiency of the turbine, so that it finally has to be shut down for cleaning. Since this operation is expensive, the removal of silica *from the feedwater* for these high-pressure boilers has become essential.

Strongly Basic Anion Exchanger

In 1947 strongly basic quaternary amine anion exchangers (Cochranex AT and AL) were developed. These possessed a high enough dissociation constant to adsorb even the weakly dissociated acids, such as carbonic or silicic acids. The anion exchangers are then regenerated with caustic soda. The first strongly basic anion exchangers developed are called Type I resins. They do an excellent job of removing the silica.

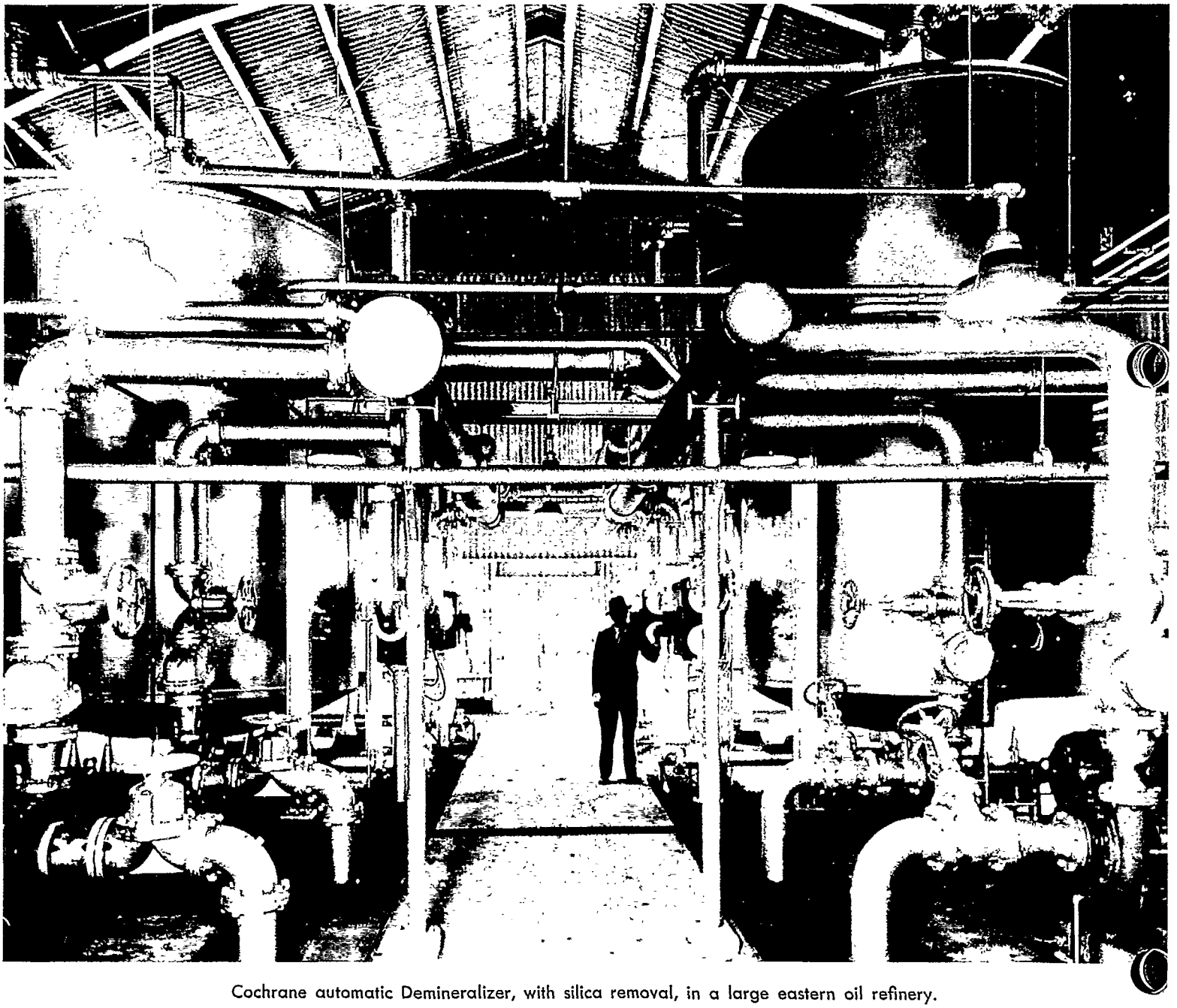
In 1949, slightly less strongly basic anion exchangers (Cochranex AP and AQ) were developed, which reduced the amount of

caustic soda required for regeneration. These are called Type II resins.

Mixed Bed Demineralizing

This development started about 1950. It differs from the standard 2-bed system of a separate cation exchanger followed by a separate anion exchanger, in that it employs only one unit. In this single shell both the cation and the anion exchange materials are mixed together for the normal operation during the exhaustion run. The beds are then separated hydraulically prior to regeneration.

The Mixed Bed or Mono-bed Demineralizer is capable of producing an effluent with more than 10,000,000 ohms resistance (containing under 0.04 ppm of electrolyte). Silica content is also very low, under 0.02 ppm.



Cochrane automatic Demineralizer, with silica removal, in a large eastern oil refinery.

DEFINITION OF TERMS

To understand the chemistry and technique of Demineralization, the definition of terms regularly used will be helpful.

Electrolyte

This is the total ionizable dissolved solids of the water. It is distinguished from non-ionic solids, such as organic matter or bacteria. Demineralizers remove electrolytes, not the non-ionic solids.

Conductance and Resistance (specific)

Conductance or conductivity is the ability of the water to conduct electric current from the positive to the negative electrodes placed in water. The cations move towards the negative, anions towards the positive electrode. The greater the number of ions present, the greater is the conductance, the ions carrying the electric current.

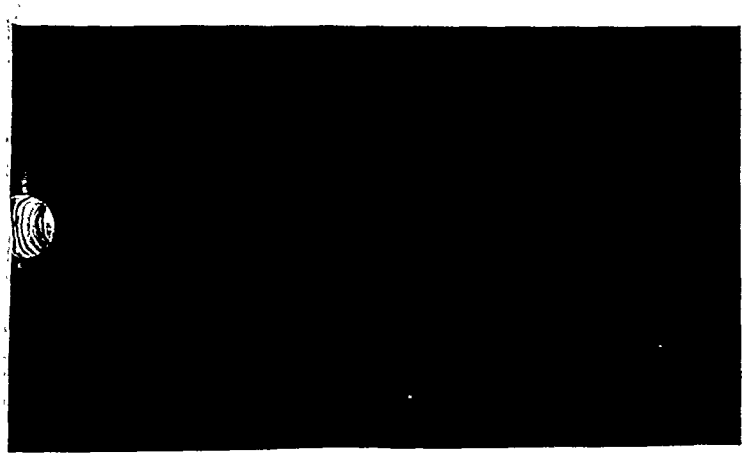
Resistance is the reciprocal of conductance. Usually resistance, rather than conductance, is the property measured. The usual solubridge conductivity indicator measures the specific resistance in ohms per centimeter cube by a Wheatstone bridge circuit. See Figure 1.

The relation between resistance and conductance is:

$$\text{Resistance (in ohms)} = \frac{1{,}000{,}000}{\text{conductivity (in micromhos)}}$$

Thus: 200,000 ohms = 5 micromhos
100,000 ohms = 10 micromhos
50,000 ohms = 20 micromhos

Note that conductance is expressed in micromhos, which are millionths of one mho. "Mhos" are "Ohms" spelled backwards. The





size of the electrodes of the cell affect the resistance. A cell constant is applied to give the specific resistance, which is ohms for a cube, one centimeter on each side.

Relation of Micromhos, Conductance and Amount of Electrolyte

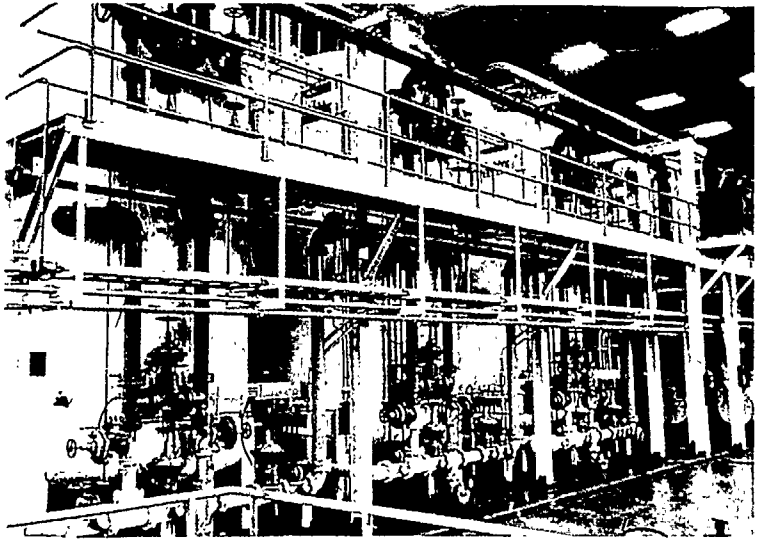
The various ions have different conductances. Also, the temperature affects the conductance.

For the average water the relation is:

2.5 micromhos specific conductance equal 1 ppm of electrolyte expressed as Calcium Carbonate ($CaCO_3$), when the electrolyte is Sodium Chloride (NaCl) measured at 25°C, if the water is free from gases such as Carbon Dioxide (CO_2) or Ammonia (NH_3), with mixed bed or two bed weakly basic demineralizers. For two bed strongly basic anion resin 5 micromhos equal 1 ppm.

If gases are present they affect the resistance. They must either be removed or determined and corrected for.

See Table I for relationship between conductance, resistance and total electrolyte in ppm (as $CaCO_3$).



Two Deck Demineralizer (cation over anion) at Automobile Manufacturing Plant in Detroit, Michigan.

Cation Leakage

This is the amount of cations present in the effluent of the first stage, Hydrogen Zeolite (H_2Z). Since divalent calcium and magnesium are more readily held by H_2Z than the mono-valent sodium, it is the sodium which leaks through first.

Such cation leakage cannot be removed by the anion second stage because the latter only removes acids not salts.

Comparison of Demineralizers with Evaporators

Before Demineralizing, evaporation was the only available method of producing water of low ionic solid content. The water is evaporated to steam or vapor which is condensed to produce distilled water. The evaporator uses live or bled steam as the heating medium in a coil in the evaporator shell.

Single effect evaporators contain one evaporator and one condenser. One pound of live steam produces approximately one pound of vapor. Multiple effect evaporators use a number of evaporator shells in series. The vapor from No. 1 acts as the heating steam for No. 2 unit. This saves steam but increases the investment.

Theoretically in multiple effect evaporators,
1 lb. steam = (N+1) lbs. distilled water
where N = number of effects.

If steam costs $1.00 per 1000 lbs., the cost of distilled water is $2.00 per 1000 gallons with triple effect evaporators operating at theoretical efficiency.

Compression stills, developed recently, are equivalent to 15 multiple effects. They can produce distilled water at about 50¢ per 1000 gallons. But they require careful insulation and in time the heat exchangers involved become scaled up if the water is hard, and this reduces the thermal efficiency of the still.

Evaporators do kill bacteria. In general, demineralized water is the chemical equivalent of evaporated or distilled water for most industrial applications. However, for certain pharmaceutical preparations, sterile pyrogen-free distilled water may be required.

For boiler feed make-up purposes, demineralizing equipment is rapidly gaining in popularity over evaporators because of:

(1) Lower investment.

(2) Lower operating cost because of the power loss in the degradation of the steam pressure through the evaporator.

(3) Greater flexibility of heat balance. Evaporator capacity depends on turbine load. Demineralizers are independent of turbine load. Changes in heat balance, such as increased sale of extraction steam to industrial users, are difficult to carry out with evaporators. Demineralizing, being a cold process method, permits such changes in heat balance without loss of efficiency.

(4) Evaporator vapor contains carbon dioxide (CO_2) which causes corrosion. Demineralized water can be delivered free from CO_2.

(5) Evaporators can prime and produce a poor quality of distilled water if overloaded or if operated at too high a water level. Silica has been reported to be selectively carried over and, in some cases of high pressure evaporators, distilled over.

BUILDING THE DEMINERALIZER SYSTEM

Details of Mechanical Equipment

The construction of either the cation or anion exchanger units is very similar to the sodium zeolite unit, except that:

(1) The shell and piping must be acidproof. For small units, 80 mil pvc lining and for larger units $\frac{3}{16}$" rubber lining are used on the inside of the pressure shells. The piping for the small diameter unit is made of plastic with screwed or welded joints. But for the larger sizes of piping, it is customary to use flanged piping with $\frac{1}{8}$" rubber lining.

(2) The regenerant distributor above the top of the resin bed (when used), as well as the underdrain system below the bed, must be acid-proof. The regenerant distributors are usually made of hard rubber, plastic or stainless steel depending on the size of the unit.
The underdrain system for small diameter units consists of a plastic or stainless steel screened perforated plate. For the larger diameters, the underdrain system consists of a number of plastic or stainless steel perforated laterals connected to hub or header. This avoids concrete subfill which could be attacked by acid. Flat bottom shells with screened laterals or flat screens can be used to eliminate anthracite supporting bed under the resin. This avoids hide-out of regenerant and thus reduces excessive rinse requirements.

(3) The external valve control for the backwash and regeneration operations consists either of a nest of rubber-lined valves of Saunders type or a single control multiport valve of acidproof construction. For small diameter units a solo lift-turn valve of acidproof material is used. For larger diameter units, the Hydromatic rubber-lined valve design is used.

(4) The regenerating equipment for the cation unit must be acidproof.

(5) In the case of the caustic soda for regenerating the strong-base anion resins, a heater is generally used to heat the dilution water for the caustic solution – the steam used in this heating operation should be thermostatically controlled. The caustic soda must be "mercury cell rayon" type, free from iron, silica, chlorides and chlorates.

(6) Fully automatic controls can be provided to backwash, introduce regenerants, rinse and return to service.

(7) In larger demineralizing installations liquid caustic soda (50% strength) and sulphuric acid (66° Be) may be stored in large storage tanks to permit economical purchase in tank car lots. From the storage tanks, these reagents can either be directed by gravity or pumped by transfer pumps to the regenerant measuring tanks or directly to the units.
In most cases, regenerant dilution tanks are entirely omitted and automatic dilution control instrumentation is provided on the discharge side of the regenerant pumps so that either the acid or the caustic can be taken directly from the original tank car storage or from strong regenerant measuring tanks and diluted on the way to the unit being regenerated.

(8) Purchaser should furnish acidproof sumps and drains. In some cases, acid neutralizing must be provided to avoid discharging acid water into the sewers.

(9) A Crane-Cochrane ion-exchange Neutralizer can be installed in the waste water lines to neutralize acid or caustic regenerant waste waters. See Catalog Index 17.14.

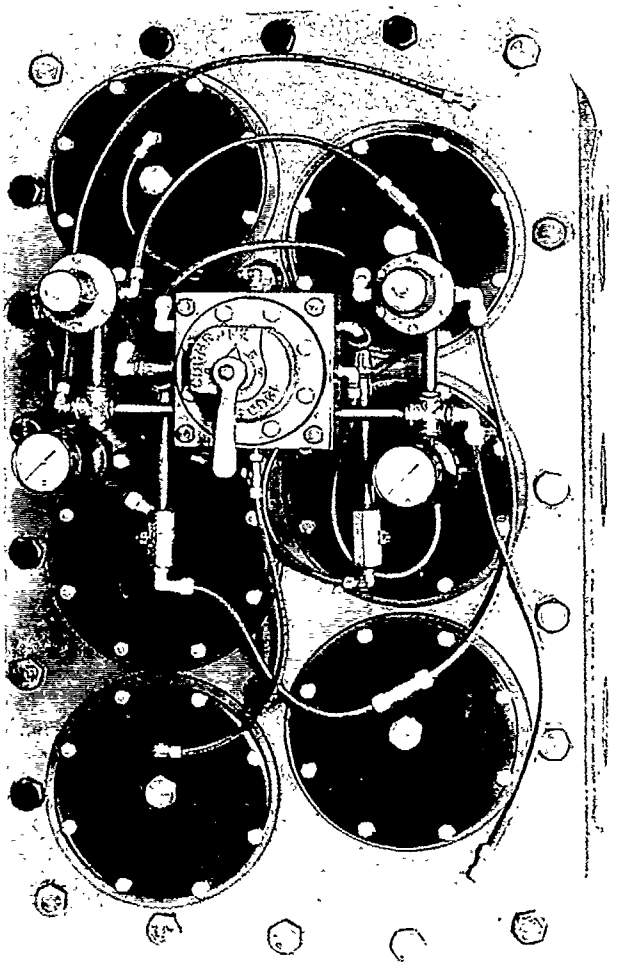
Hydromatic Valve

For the control of the various demineralizer operations we can supply either a Hydromatic valve or a nest of individual Saunders valves. The Hydromatic valve is a rubber-lined multiport valve illustrated below. These valves are made in sizes up to 6 inch. It is not a rotary disc single control valve which Crane-Cochrane abandoned some years ago because of leakage due to scoring by sand and warping of disc. Instead, it consists of six individual diaphragm operated valve members inside the rubber-lined cast iron body. These valve members are hydraulically operated through a small pilot valve. (See illustration on this and next page.)

The valve members are single seated valves faced with soft rubber so that the rubber compresses and therefore, seats tightly. The valves are drop tight. The four operating positions of the pilot valve are spaced at 90° intervals. In any operating position, the rotary slide encompasses an area, at the center of which is a drain connection leading to the sewer, at atmospheric pressure.

In any operating position, two of the six individual diaphragm valves are connected to this drain connection, so that they are therefore opened, the diaphragms being "collapsed" by the water pressure surrounding them in the main Hydromatic valve casting. Simultaneously, the remaining four diaphragm valves are "pressurized" and therefore, tightly closed. The enlarged view of an open valve shows how the force of water pressure within the main casting causes the valve to open when the pressure below the diaphragm is relieved to the drain. Application of raw water pressure to this diaphragm when the pilot valve is repositioned will close it, due to the combined forces of raw water plus spring pressure, acting on the entire diaphragm area.

The sectional view through the pilot valve assembly shows how raw water "pressurizes" and closes the diaphragm valves which are connected to the pilot valve area within the bonnet but outside the slide, while the area under the slide exhausts and opens the other



CRANE-COCHRANE HYDROMATIC, RUBBER-LINED MULTIPORT VALVE

diaphragm valves directly connected to it.

Each Hydromatic valve has only two sizes of diaphragm valve members, and valve members of a size are completely interchangeable. This simplifies handling of spare parts.

Photographs of plants with Hydromatic valves are shown on pages 6, 15, and 26.

NEST OF INDIVIDUAL VALVES

As an alternate to the Hydromatic valve, we can supply a nest of rubber-lined individual Saunders valves.

Photograph of actual plant with these valve nests is on pages 8, 14, 25, and 36.

AUTOMATIC CONTROLS

The value of automatic control during regeneration is not only the saving in labor but the assurance of fool-proof, trouble-free operation. The trend is definitely towards automatic.

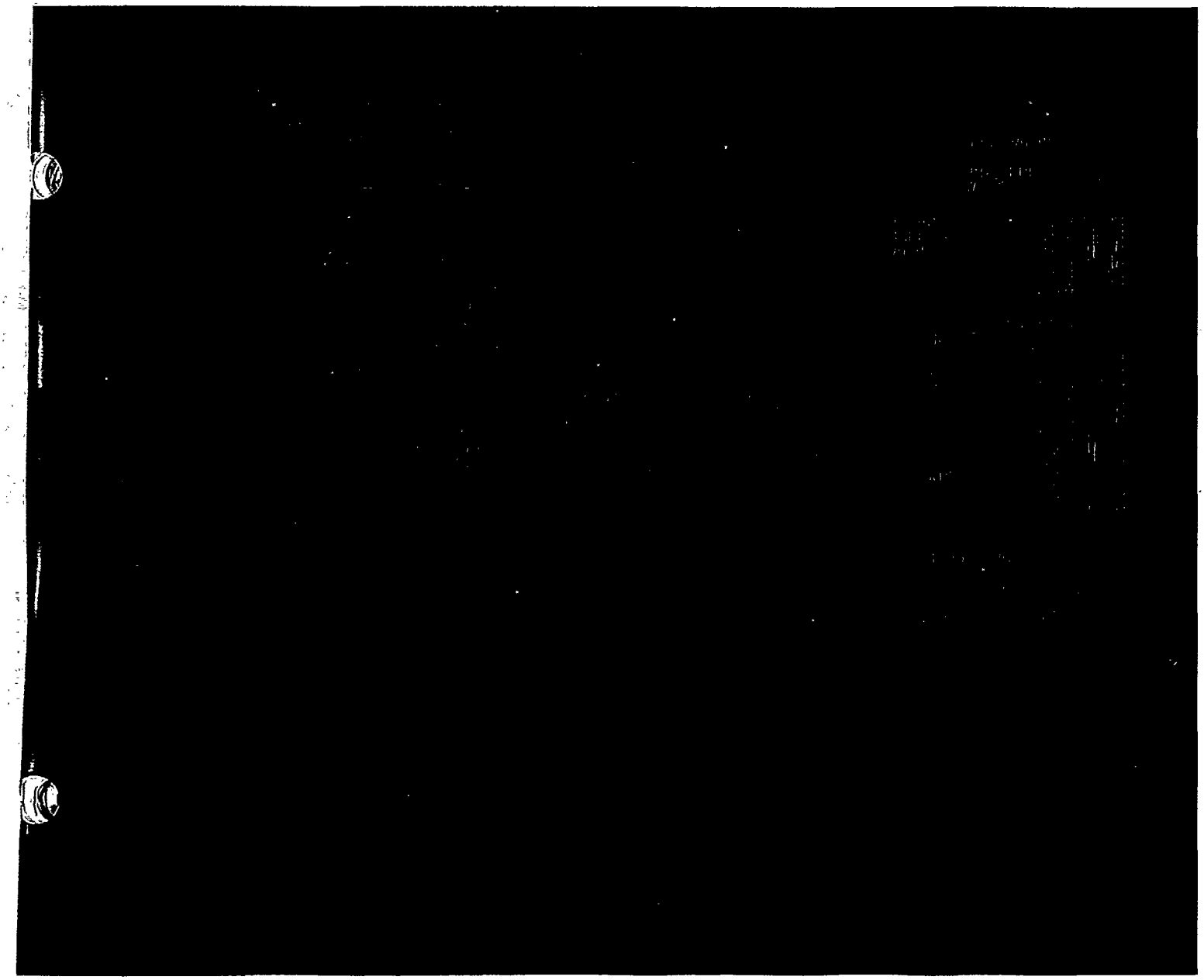
The initiation of the automatic regeneration can be either by:—

(1) Push-button, when an alarm sounds indicating exhaustion of the resin.

(2) Contactor on a water meter, when the desired number of gallons of water has passed through the unit.

(3) Conductivity of effluent of the unit.

For Hydromatic valves, Crane-Cochrane has a standard automatic control Cabinet (see illustration on page 12). A 16 watt motor and



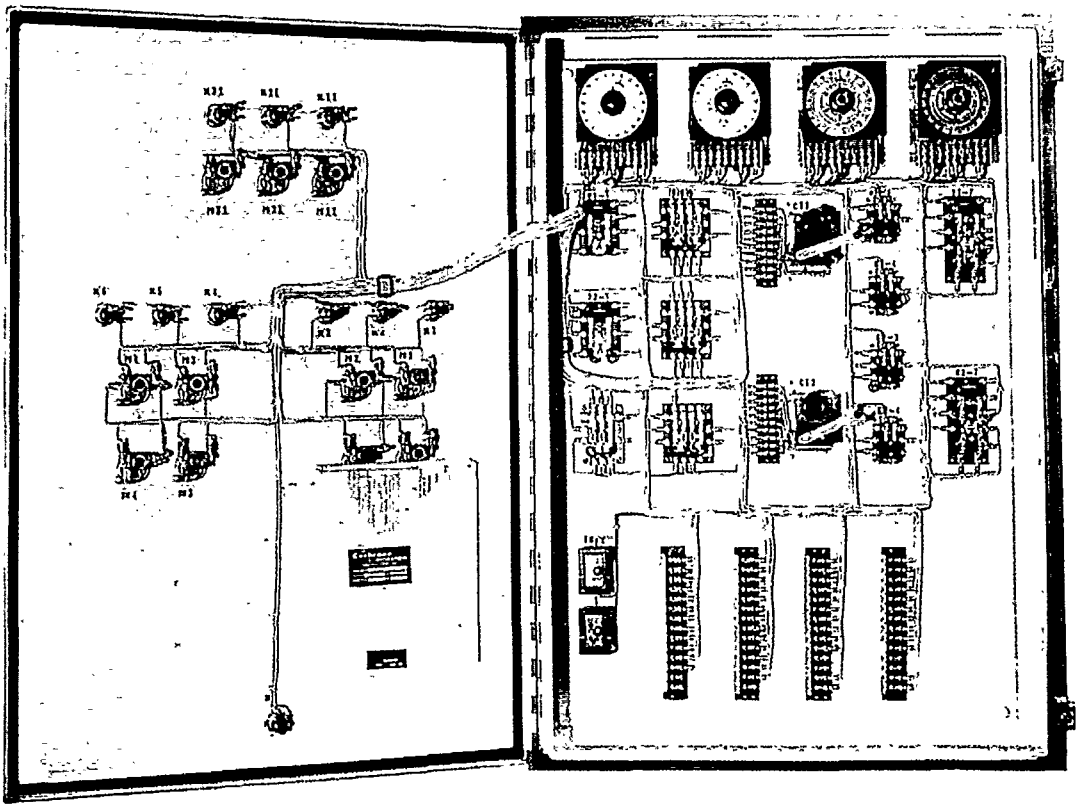
gears are provided for the pilot valve and this motor turns the pilot valve to the various positions such as backwash, regenerant introduction, rinse and service. The duration of these steps of operation are automatically timed. An interlock is included so that only one unit can be regenerated at a time.

For a nest of individual Saunders valves, the automatic controls include equipping the individual valves with diaphragm operators pneumatically serviced. A central panel is provided with a time cycle-controller which controls the sequence of steps of operation as well as their duration. The panel may be pneumatic or electrical. In the former the actuating air goes through the panel and directly out to the individual diaphragm operated Saunders valves by air tubing. In the electric panel, electric wiring connects the panel with solenoid valves located at each Saunders valve so that the air tubing is on these valves and not on the panel.

The individual Saunders valves can be equipped with micro-switches to indicate when they are closed or open and connecting with lights on the panel.

On the panel it is possible to supply a graphic diagram with these valve lights in position as well as the necessary flow meters, conductivity indicators and recorders. On-off manual switches can be included to operate the individual Saunders valves manually from the panel.

Photographs of such automatic panels are on pages 26 and 32.



AUTOMATIC CONTROL CABINET

Cation Exchange Materials

Hydrogen Cycle

Several available types of cation exchangers are employed regularly in Crane-Cochrane installations. Selection of the type to use depends on the analysis of the influent water.

(1) *COCHRANEX CCA:* This material—the first successful hydrogen cation exchanger—is made by sulfonation of coal particles. It is non-siliceous, and therefore, does not cause silica pickup. It is used less seldom today but is suited to raw cold waters high in alkalinity and low in TMA. Its range of capacity is about 4000 to 8000 grains of cations per cubic foot with regenerant dosages as low as 2 lbs. of sulfuric acid (H_2SO_4) per cubic foot of the exchanger.

(2) *COCHRANEX CRW, CRJ and CRZ:* These are non-siliceous sulfonic styrene high capacity strong acid resins, produced in bead form.

The capacity depends on influent analysis and acid regenerant dosage; but the range of its capacity is 11,000 to 16,000 grains per cubic foot at a regenerant level of about 5 lbs. sulfuric acid (H_2SO_4) per cubic foot. Higher capacities are obtainable with certain waters at higher H_2SO_4 dosages. Capacities of 25,000 grains per cubic foot may be realized using hydrochloric acid (HCl) for regeneration.

(3) *COCHRANEX CRX, CRS and CRK:* These are also styrene strong acid high capacity resins but with higher crosslinkage (or divinylbenzene content) of 10% compared to CRW, J and Z (8% crosslinkage). The higher crosslinkage results in higher density beads of lower water content. They are recommended for applications where the resins are subjected to oxidation by chlorine or oxygen.

(4) *COCHRANEX CRB and CRC:* These are strain-free varieties of CRW and CRX. They resist bead breakage.

(5) *COCHRANEX CRV and CMV:* These are macroreticular strong acid resins of greater physical and chemical stability to resist degradation and sloughage. They have 10-15% less capacity than the other cation resins.

(6) *COCHRANEX CRI and CRT:* These are weak acid cation resins containing carboxylic groups efficient for removal of alkalinity using lower acid levels (110% to 120% of theoretical).

Anion Exchange Material

Weak Base Type

The following weak base anion resins are available:

(1) *COCHRANEX AV and AW:* These are epoxy amine resins having an initial capacity of about 20,000 grains per cubic foot when regenerated with either 4 lbs. of caustic soda, 6 lbs. of soda ash, or 2 lbs. of ammonia (as NH_3) per cubic foot of resin.

(2) *COCHRANEX AE:* This is a macroreticular weak base anion resin of similar capacity to AV and AW; but, it resists organic fouling, has good stability and requires no increase in rinse water on aging at cold water temperatures.

Strong Base Type

The following strong base anion exchangers are available:

(1) *COCHRANEX AT and AL* (Type I alkyl resins): These strong base quaternary amine anion resins can adsorb weak acids such as carbonic and silicic acids as well as the stronger mineral acids.

They are more strongly basic than Type II resins (see below) and therefore produce effluents lower in silica from waters higher in silica content.

Capacity of the AT and AL varies with caustic regenerant levels and with the percentage of weak acids present in the influent. Capacity ranges from 10,000 to 13,000 grains per cubic foot at regenerant levels of 4 to 8 lbs. of caustic soda (NaOH) per cubic foot.

(2) *COCHRANEX AM, AY and AC:* These are also Type I anion resins but are a more porous variety, easier to clean with brine for removing organic foulants from the resin. They have about 10% more capacity than AT and AL.

(3) *COCHRANEX AP, AQ and AJ* (Type II alkanol resins): These are also strong base quaternary amine types, but somewhat less strongly basic than Type I resins. They have somewhat greater initial capacities at lower caustic regenerant levels than Type I—12,000 to 16,000 grains per cubic foot with 4 to 6 lbs. of caustic soda per cubic foot.

However, they do not remove silica as completely as Type I, if the raw influent has a high percentage of silica compared to other anions present. Also silica is more likely to

break through earlier when cation leakage occurs.

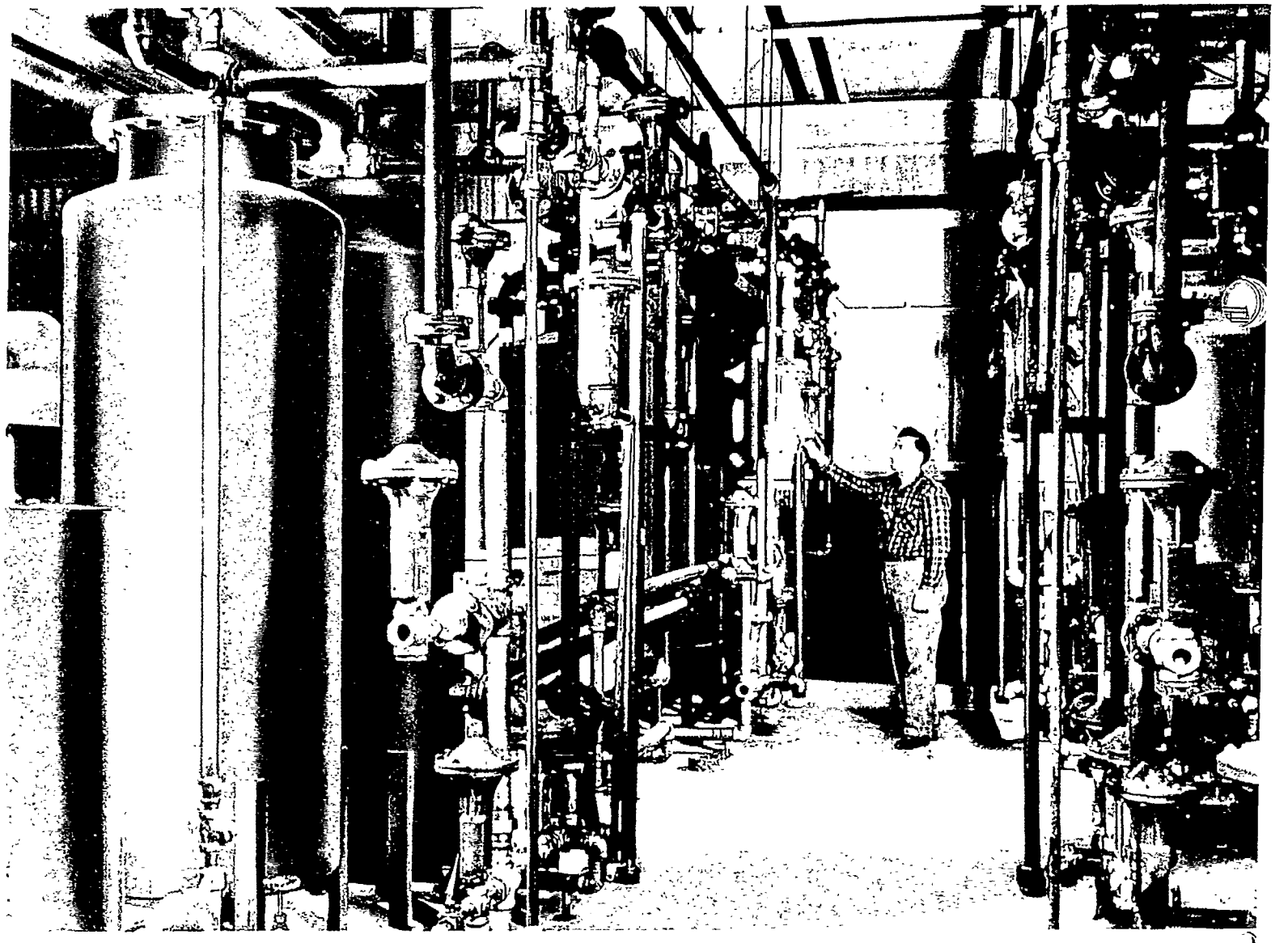
Type II resins are less stable, losing basicity (strongly basic property) more rapidly than Type I. Loss of capacity of Type II has been 50% to 60% compared to 20% to 30% for Type I in a few years time.

The loss of capacity of Type II resins is somewhat. decreased if the influent is low in dissolved oxygen (as following a vacuum deaerator).

However, the trend is towards the use of Type I resins for most demineralizers.

PRECAUTIONS AGAINST FOULING

All of these anion resins are subject to fouling by iron and organic matter. Such fouling causes loss of capacity in addition to that caused by basicity decrease. Therefore, every precaution should be taken to eliminate iron and organic matter by proper pretreatment. The caustic soda used for regeneration should be rayon grade, mercury cell type of lowest iron and other impurities. Occasional warm caustic brine treatments remove organic foulants from the resin. Brine tank and piping should be provided for this purpose on waters of surface origin.



Automatic Demineralizer (valve nest type) with silica removal in television tube factory.

Cation Exchanger Hydrogen Zeolite (H_2Z)

First Stage of Demineralizer

Chemical Reactions

In this first stage of two-bed demineralizing, the cations in the water—calcium, magnesium and sodium—are exchanged for hydrogen during the exhaustion run. The chemical reactions are as follows:

(1) Bicarbonate Reactions:

$$\left.\begin{matrix}Ca(HCO_3)_2\\Mg(HCO_3)_2\\2NaHCO_3\end{matrix}\right\} + \quad H_2Z \quad \longrightarrow \quad \left.\begin{matrix}Ca\\Mg\\Na_2\end{matrix}\right\}Z + 2H_2CO_3$$

The carbonic acid (H_2CO_3) decomposes to carbon dioxide (CO_2) and water (H_2O). The CO_2 is removable by decarbonation. This shows how the alkalinity in the raw water is normally removed by H_2Z.

(2) Sulfate and Chloride Reactions:

$$\left.\begin{matrix}CaSO_4\\MgSO_4\\Na_2SO_4\end{matrix}\right\} + \quad H_2Z \quad \longrightarrow \quad \left.\begin{matrix}Ca\\Mg\\Na_2\end{matrix}\right\}Z + H_2SO_4$$

Similar reactions hold true for the chlorides. In other words, the sulfates and chlorides are converted to their respective acids, sulphuric and hydrochloric. The sulfates and chloride anions, therefore, are not removed by hydrogen zeolite (H_2Z).

Effect of Type of Anion Present on the Capacity

The carbonic acid produced in equation (1) is a weak acid and the sulphuric and hydrochloric acids in equation (2) are strong. These strong acids in the effluent act as a "back pressure" hindering the reaction. The weaker carbonic acid (H_2CO_3) or silicic acid (H_2SiO_3) does not have this effect. That is why waters high in alkalinity and low in sulfates and chlorides are easier to handle by H_2Z, resulting in a higher capacity for any given amount of acid used in its regeneration resulting in higher acid regeneration efficiency expressed in lbs. acid used per 1000 grains of cations (as $CaCO_3$) removed. The sum of sulfates, chlorides and nitrates is called the "theoretical mineral acidity" (TMA). The capacity of the zeolite is thus greater with higher ratios of alkalinity to TMA in the raw water.

Effect of Type of Cation Present

Since H_2Z has less affinity for monovalent cations such as sodium (Na), the sodium cation leakage increases if the sodium to total cation ratio is greater. As this ratio increases, greater acid dosages are therefore required to reduce the cation leakage.

Effect of Acid Dosage or Regenerant Level in Regeneration

Acid dosage or regenerant level also influences capacity. The more acid the greater the capacity up to about 10 lbs. of H_2SO_4 per cu. ft. Beyond that the increase tapers off.

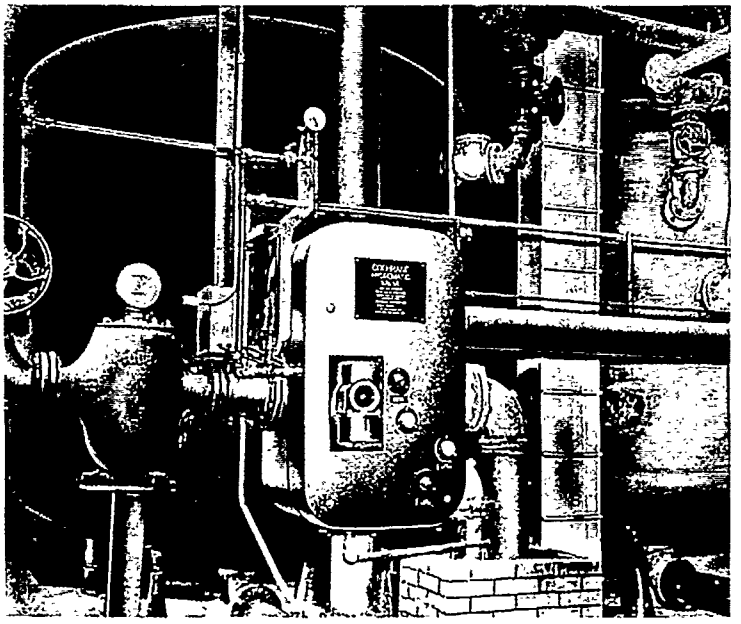


FIG. 2 DEMINERALIZER WITH SILICA REMOVAL, USING RUBBER LINED HYDROMATIC VALVES, IN PAPER MILL.

Sulphuric Acid (H_2SO_4) vs. Hydrochloric Acid (HCl) for Regeneration

The regeneration reactions are:

$$\left.\begin{matrix}Na_2\\Ca\\Mg\end{matrix}\right\}Z \quad + \quad \begin{matrix}H_2SO_4\\or\\2HCl\end{matrix} \quad \longrightarrow \quad H_2Z \quad + \quad \left.\begin{matrix}Na_2\\Ca\\Mg\end{matrix}\right\}\begin{matrix}SO_4\\or\\Cl_2\end{matrix}$$

Sulphuric acid is generally preferred for regeneration because:

(1) It costs less per pound and is therefore more economical.

(2) It is easier to handle, producing no strong fumes as does hydrochloric acid.

However, the capacity of the styrene type of cation exchanger obtainable between successive regenerations is less with sulphuric acid than with hydrochloric acid. This is due to the fact that when considerable calcium cation is displaced from the bed, this calcium joins with the excess sulfate anion from the acid, precipitating calcium sulfate. These precipitates form on the hydrogen zeolite granules, interfere with complete regeneration and prevent the attainment of full capacity on the next run. They may also cause some hardness to be present at the start of the run until the deposits are dissolved.

To minimize this calcium sulfate deposit effect, it is advisable to use the sulphuric acid in progressively increasing strengths, starting with 2% and ending with as high as 8%. This can be done either in several steps or by continuously increasing the strength. The low strength of acid at the start will displace the calcium ions from the bed without precipitating the calcium sulfate and the higher strength of acid toward the end will insure the completeness of the regeneration by forcing the hydrogen ions into the cation exchanger to displace the other cations in exhausted resin. The greater the ratio of calcium to total cations in the raw water, the more important this progressive regeneration technique becomes. Also, it is important to speed up the flow rate of acid through the cation resin or to reduce the time of contact if the percent calcium is higher. This reduces the allowable time for calcium sulphate precipitates to form.

However, the sulphonated coal type of cation exchanger (Cochranex CCA) does not need this progressive method of increasing the strength of the sulphuric acid to avoid calcium sulfate deposits. Instead, the exchanger can be regenerated completely with a single low strength of 2% sulphuric acid. This is due to the fact that Cochranex CCA has more carboxylic and less sulphonic groups than the higher capacity styrene cation resins. The former groups are readily regenerated with weak acids alone.

Hydrochloric acid, when employed for regeneration, causes no deposits because the calcium chloride which forms (when the calcium is displaced by the hydrogen during the regeneration) is soluble. Therefore, it is possible to use single strengths of hydrochloric acid which are very much higher and thus force the hydrogen completely into the zeolite during regeneration. Consequently, the same Cochranex CRW or CRZ when regenerated with low dosages of sulphuric acid, may have a capacity of 8 to 12 kgrs/cu. ft. But when regenerated with hydrochloric acid the capacity obtainable may be 20 to 25 kgrs/cu. ft. A greater capacity than 8 to 12 kgrs/cu. ft. may be also obtained with sulphuric acid if care is employed in applying progressively increasing strengths of acid and the bed is mixed up from top to bottom after regeneration.

Hydrochloric acid, however, is available usually as 30% muriatic acid and its cost is high compared to that of sulphuric acid. The regenerant level will vary with the analysis of the raw water and the acid cost will vary with location of the plant and the quantity purchased at one time.

Although hydrochloric acid is usually much higher than sulphuric acid in operating cost, the use of the hydrochloric acid may frequently reduce the first cost because the higher capacity obtainable would permit the use of less cation resin. Usually hydrochloric acid is justified only for the relatively small plant where operating cost is less important than first cost. In some cases hydrochloric acid may be available at low cost due to its use for other purposes in the plant. In a few cases a waste hydrochloric acid may be available for use from some process operations.

Steps in Calculating the Capacity of Hydrogen Zeolite

In determining the capacity of any of the cation hydrogen zeolites available, the procedure to follow is:

(1) From the analysis of the raw water, calculate the percent alkalinity and percent sodium and the total theoretical mineral acidity (sulfates plus chlorides).

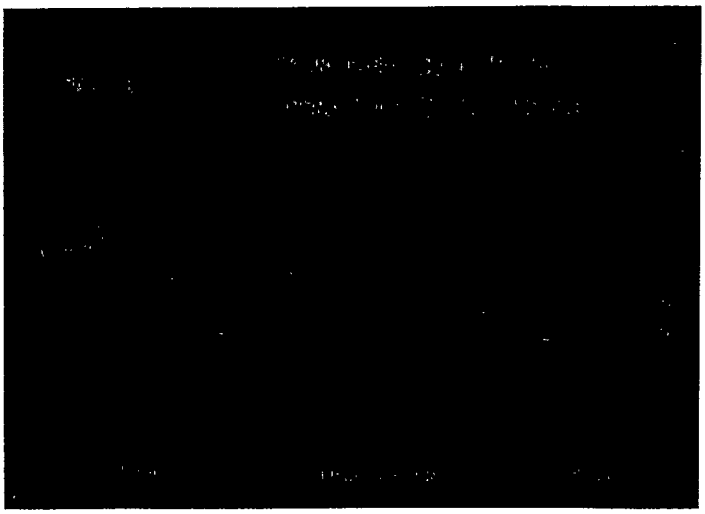
(2) Calculate allowable cation leakage in percent of the cations present in the raw water. For example, if it is desired that the final demineralized effluent have a total ionic dissolved solids content or electrolyte of 3 ppm or lower, and if the raw water has 100 ppm of total cations, the allowable cation leakage is under 3%. As explained previously, cation leakage through the first stage or hydrogen zeolite unit is not removable by the second or anion stage which follows. Therefore, the amount of cation leakage that can be tolerated must be less than the desired maximum amount of electrolyte in the demineralized effluent. To reduce cation leakage, it is necessary to use more excess acid in the regeneration of the hydrogen zeolite. Accordingly, the regenerant dosage in pounds of acid per cu. ft. of the hydrogen zeolite selected is dependent on this allowable cation leakage.

Since the monovalent sodium is less tightly bound by the hydrogen zeolite than the divalent calcium and magnesium, the usual cation leakage consists of sodium. If the ratio of sodium to the total cations present is high, there will be more likelihood of sodium cation leakage than when this ratio is low.

(3) The dosage of regenerant thus selected then determines the capacity of the resin depending on the percent sodium and percent alkalinity present.

Starting Point and Endpoint of Exhaustion Runs. In the operation of a hydrogen zeolite unit, the acid employed in the regeneration is in considerable excess over the theoretical requirement. In other words, if the amount of acid employed and the amount of cation removed are put on an equivalent basis, the acid used is equal to 3 or 4 times the equivalent cations removed. The acid efficiency, which can be defined as the ratio of the cations removed to the total acid employed on an equivalent basis, would therefore be 25 to 33%.

This acid excess, required to force the regeneration reactions to go in the reverse direction to the usual cation removal reactions, must be rinsed thoroughly to the sewer. The hydrogen zeolite unit is not put on the line until this rinsing is fairly complete. Usually, the unit is rinsed until the effluent acidity fairly closely approaches the free mineral acidity (FMA) to be expected normally during the run. The theoretical mineral acidity (TMA) is equal to the sum of the sulfates, chlorides and nitrates in the raw water. But due to the cation leakage, the FMA actually present is less than the TMA by the percent of cation leakage allowable. In other words, cation leakage equals TMA minus FMA. Rinsing continues until acidity drops down to the normal FMA anticipated. This is the start of the run and the unit is put into service. The exhaustion run is then continued until the acidity drops below the normal FMA. This is the end of the run and the unit is then regenerated. See Figure 3.



Cation Stage Must Produce Anion Waste Water. In determining the size of the cation unit and the amount of hydrogen zeolite which it contains, it is necessary to consider the amount of cation effluent required to backwash and regenerate and rinse the anion stage. This is due to the fact that the anion stage should be regenerated with treated water to avoid deposits on the anion resin. Such deposits would take place if raw water were used. Percentage-wise, the amount of this additional cation effluent required is small and it is simplest and most economical to provide additional capacity in the cation unit for this purpose.

Furthermore, the area of the cation unit must take care of the additional flow rate that the regeneration of the anion unit might require. This is particularly true if the Demineralizer consists of a multi-unit cation battery followed by a multi-unit anion battery and where there is inadequate storage of demineralized water available. With such plants, while regeneration of any unit is taking place, the remaining units should be large enough to deliver the required maximum rate of flow of effluent. But in addition, the cation stage in such cases must have sufficient area to treat not only the service rate but the backwash or rinse rate of the anion unit.

With multi-unit plants it is possible to avoid enlarging the cation unit area to take care of anion unit backwashing and rinsing if the amounts of cation and anion resin are so matched that a cation and an anion unit regeneration take place at one time. Then particularly in an automatic plant the operations can be so telescoped that anion rinsing takes place after the regenerated cation unit has been returned to service.

In the case of a single unit Demineralizer consisting of one cation unit and one anion unit, the area of the cation unit would not have to be increased because when either is regenerated the Demineralizer is not producing treated effluent. Usually, storage tanks are then employed to provide treated water during the outage period of regeneration.

In the case of multi-unit cation and anion Demineralizers where storage is available, it is possible to avoid enlarging the cation stage to provide additional water for regenerating the anion stage if the storage is ample in volume. Then, during regeneration, the service rate could be decreased sufficiently through the remaining units in operation so that the cation units would not be overloaded in supplying the anion waste water.

Anion Exchanger

Second Stage of Demineralizer

This second stage can use either one of the weakly basic or strongly basic anion resins. The strongly basic is used only when silica removal is required.

WEAK BASE ANION RESIN APPLICATIONS:

There are many industrial applications where the removal of silica is not important and where the removal of electrolyte permits the demineralized water to replace the usual distilled water.

Typical applications are:

(a) Mirror silvering.

(b) Processing of ceramics.

(c) Deproofing of alcohol in the manufacture of hard liquors.

(d) Rinse water in plating operations, particularly tin plating.

(e) Other electro-plating operations.

(f) Rinse water for glass manufacture.

Chemical Reactions

The anion resin adsorbs only the strong acids, such as sulphuric (H_2SO_4), hydrochloric (HCl) and nitric (HNO_3). These constitute the acids normally present in the cation effluent.

The chemical reactions can be written in two possible ways:

(a) Complete adsorption.

$$H_2SO_4 + A \longrightarrow A.H_2SO_4$$

The same reactions are true for the other acids.

(b) Anion exchange of hydroxyl radical (OH) for the other anions Thus:

$$H_2SO_4 + 2A.OH \longrightarrow A_2.SO_4 + 2H_2O$$

Regeneration Reactions

Either soda ash, ammonia or caustic soda may be employed in regeneration. The chemical re-

action during regeneration may be written as follows:

$$A.H_2SO_4 + Na_2CO_3 \longrightarrow A + Na_2SO_4 + H_2CO_3$$

Similar reactions can be written for the exhausted resin containing hydrochloric acid or nitric acid.

Effect of Type of Anion

Divalent ions, such as sulfate, are more easily removed and held during the exhaustion run than the monovalent ions, such as chloride, nitrates and bicarbonate. Therefore, the small anion leakage which occurs during demineralizing will consist principally of bicarbonate and chloride. rather than sulfate.

Capacity

The initial capacity is about 20 kgrs/cu. ft. expressed as $CaCO_3$ when regenerated with 4 lbs. of caustic soda per cu. ft. or about 0.2 lbs. of caustic soda per thousand grains of anions removed.

STRONG BASE ANION RESIN APPLICATIONS:

The main application for Demineralizers or deionizers employing strong base anion resin is for boiler feed purposes where silica removal is very essential in order to avoid deposits either in the boilers or in the turbines. In this application it competes effectively with evaporators.

However, there are other applications, such as the manufacture of television tubes, where even the presence of such weakly dissociated impurities as silica might influence the final picture obtained with the tube. Also, there are pharmaceutical applications where the presence of silica, even in small amounts, is undesirable if the final effluent is to meet the stringent requirements of the pharmacopoeia.

Chemical Reactions

These may also be written either as a total acid adsorption or anion exchange. Using the latter method of expression, the chemical reactions during the exhaustion run are:

(a) $H_2SO_4 + 2A.OH \longrightarrow A_2.SO_4 + 2H_2O$

(b) $H_2CO_3 + 2A.OH \longrightarrow A_2.CO_3 + 2H_2O$

(c) $H_2SiO_3 + 2A.OH \longrightarrow A_2SiO_2 + 2H_2O$

Reaction (a) is typical of the removal of the strong acids by this resin. Reactions (b) and (c) represent the removal of the weakly dissociated carbonic acid and silicic acid, which only the strong base anion resins can accomplish.

Anion Leakage

The weaker anions, silica and bicarbonate, are less strongly held by the anion resin than the strongly dissociated anions, sulfate, chloride and nitrate. Therefore, the silica and the bicarbonate anions are more likely to break through and leak through first as this anion resin approaches exhaustion.

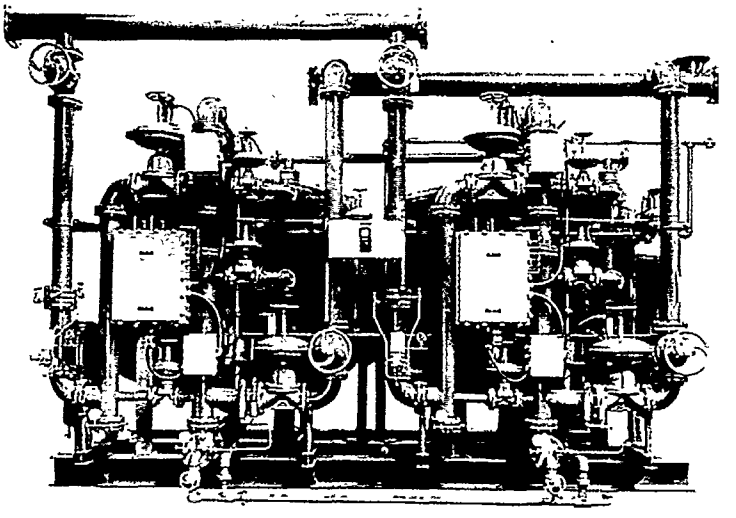
Regeneration Precautions

To aid in the complete elution of silica from the resin, which is necessary to assure very low silica in the final effluent it has been found advisable to take the following precautions:

(a) The strength of caustic soda solution should be about 2 to 4%.

(b) This caustic soda solution should be heated to about 95°F. for Type II and 120°F. for Type I resin. (Lower temperatures for Type I resins may be possible if the percent silica in the raw water is quite low.)

(c) The rate of flow of the caustic solution through the resin during regeneration should be controlled at a sufficiently low flow to provide about 60 to 90 minutes time of contact.



Skid mounted shop assembled Demineralizer for leading film manufacturer for their 1425 psi boilers.

Calculation of Capacity of Strong-Base Anion Resin

The silica in the raw water is usually expressed as SiO_2. In order to express it in terms of calcium carbonate, it is necessary to multiply it by 0.83.

The residual carbon dioxide in the Decarbonator effluent is usually expressed as CO_2, but in order to express it in terms of $CaCO_3$ it is necessary to multiply it by 1.15.

In order to obtain the total exchangeable anions (TEA) in grs/gal, expressed as $CaCO_3$, required in the calculation of the capacity of these resins, the following steps are required:

(a) Multiply ppm SiO_2 in raw water by 0.83 = ...

(b) Multiply ppm residual CO_2 after Decarbonator by 1.15 = ...

(c) TMA in raw water (ppm as $CaCO_3$) = ...

(d) Cation leakage .....

Total Exchangeable Anions (ppm as $CaCO_3$) (TEA) = ...

$$\frac{TEA}{17.1} = \text{grs/gal of TEA to be removed}$$

Endpoint of Demineralizer Exhaustion Run

Conductivity indicators or recorders are always included with demineralizing plants to give the conductance of the effluent. When this conductivity rises above the allowable limit, it is time to regenerate. This is the endpoint of weak base anion units where silica is not removed.

In the case of strong base anion resins, silica may break through before the conductivity rises; therefore, silica should be tested in the effluent to determine the endpoint.

To avoid testing silica it is often found advisable to regenerate after a predetermined number of gallons which is slightly less than full capacity thus anticipating the silica break through.

With a single pair of cation-anion units, the increase in conductivity may be due to cation leakage caused by cation unit exhaustion rather than anion unit exhaustion.

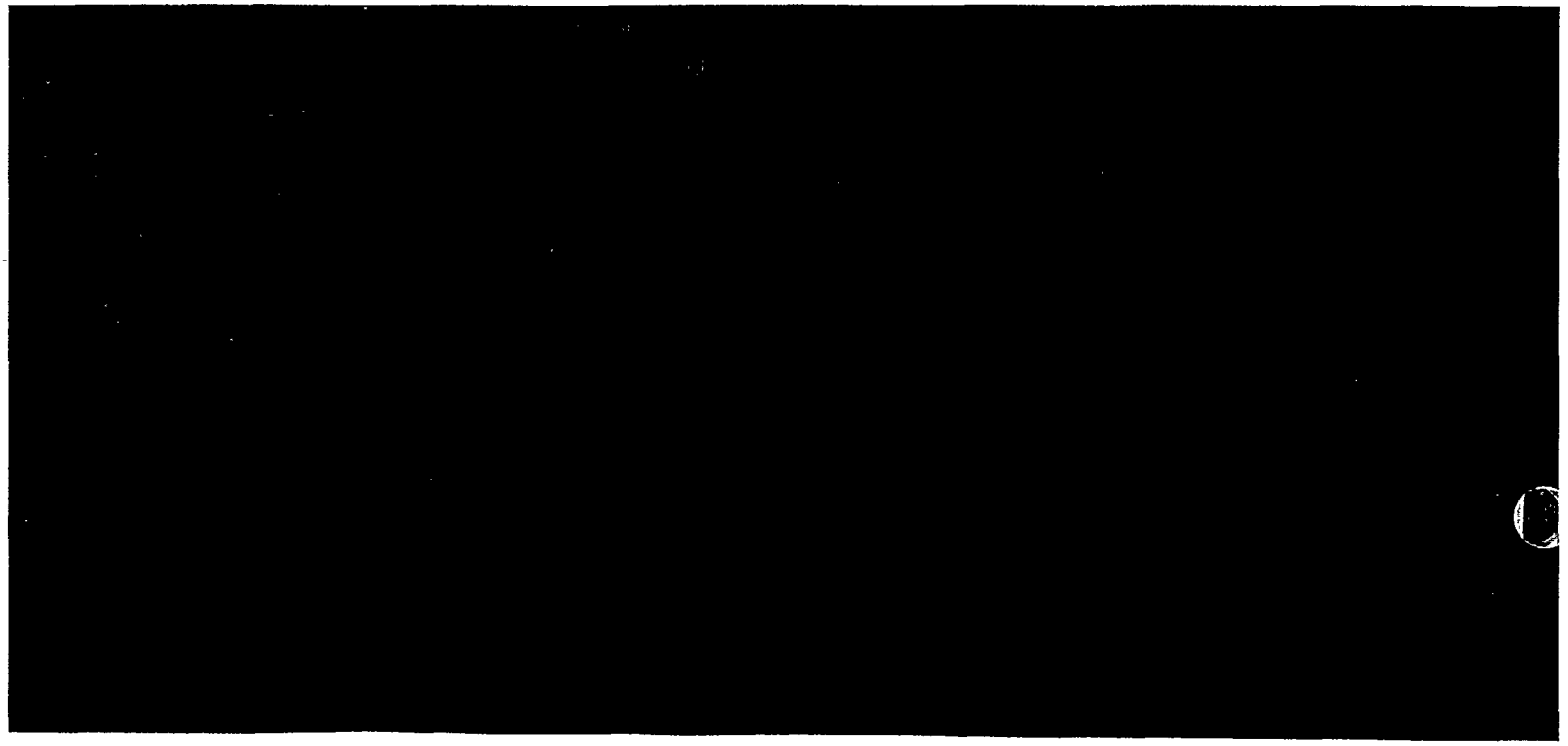
Low Flow Rate Recycling

If the flow rate through two bed systems drops to below 1 to 2 gpm/sq. ft. of area of the exchange units the quality of the effluent may suffer. Therefore a recycling pump and line from the final effluent to the common inlet should be included to permit recycling at such times so that the rate through the units will be kept high enough.

Anion Rinse Recycling

The rinsing of excess caustic soda from anion units down to low micromhos of conductivity in the rinse effluent will take considerable water (over 100 gals./cu. ft.) in many cases. Such water is expensive because it has passed through the Demineralizer and has used up some cation and anion exchange resin capacity.

A considerable part of this rinse water can be saved by recycling it back to the common inlet as soon as the rinse effluent dissolved solid content has dropped to that of the raw water. (See Fig. 5.) Recycling piping and equipment should be included for this purpose in the case of Demineralizer plants of relatively large capacity.



Decarbonator

Location and Application

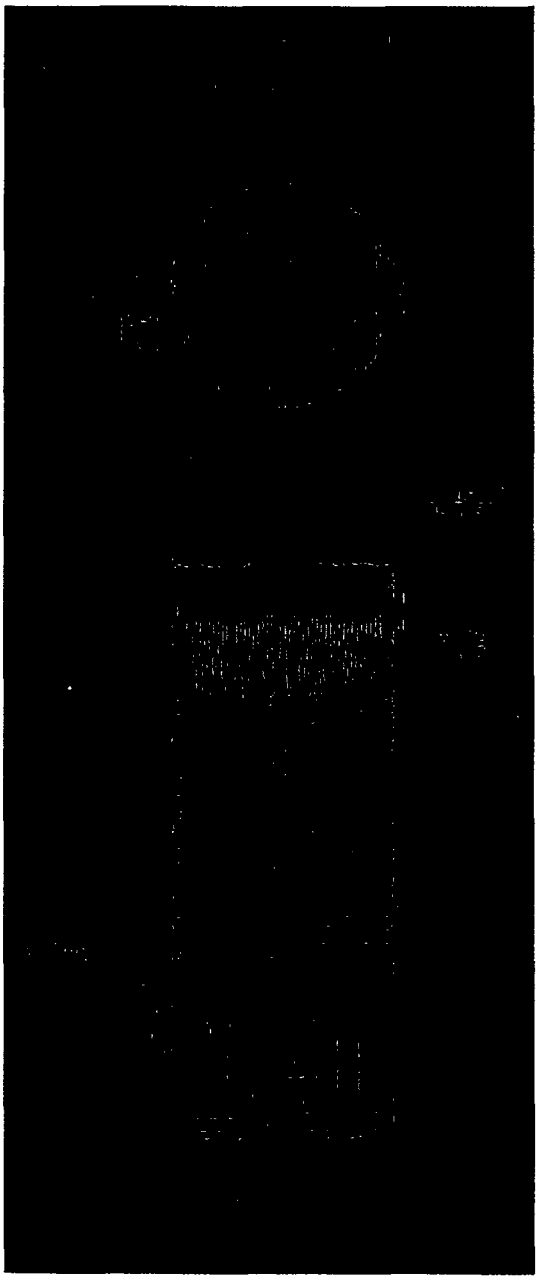
Decarbonators or Degasifiers are used in Demineralizer installations in order to remove carbonic acid by aeration. These Decarbonators are usually made of wood and consist of a series of staggered wood trays or slats over which the water trickles downward, countercurrent to a blast of low pressure air blown upward. See Fig. 6. Where available clearance height is limited, Raschig rings may be employed instead of wood trays, resulting in a lower height of unit. The amount of residual carbon dioxide that is left in the Decarbonator effluent depends upon the area of the Decarbonator, its height, the amount of air introduced and the influent carbon dioxide and temperature of the water. In the case of demineralizing plants, it is usually desirable to reduce the carbon dioxide content to under 10 ppm and for the strong base anion resin Demineralizer to under 5 ppm.

Decarbonators can be located either before or after the weak basic units. Locating it after those units avoids its handling acid water and the booster pumps following the Decarbonator can also be non-acid proof. Locating it before has the advantage of a more constant CO_2 to the Decarbonator.

In many weak base anion resin plants, the presence of carbonic acid in the effluent may be tolerated for the particular application involved, and in such cases no Decarbonator is required. However, the pH value of the demineralized water is likely to be low and the service piping through which the demineralized water passes should, therefore, be capable of handling low pH water.

In the case of strong base anion resins, the location of the Decarbonator is between the cation and anion stages. This is due to the fact that the strong base anion resin would remove the carbonic acid present in the cation effluent, thereby using up some of its capacity and consequently increasing the operating cost for caustic soda required in its regeneration. The removal of carbonic acid ahead of the anion resin usually saves enough operating cost to pay for the Decarbonator in a reasonable time. However, for raw waters low in alkalinity, the Decarbonator can be omitted to save its first cost as well as the cost of the clear well under it and the acidproof booster pumps following it.

Vacuum Deaerators may be used instead of Decarbonators where it is desired to remove oxygen as well as carbon dioxide. This will help prolong the life of strong base anion exchangers. This will also help protect piping after the Demineralizer, and will often permit the use of plain steel pipe, unlined, particularly if the pH of the water is slightly increased by addition of some alkali.



Where Vacuum Deaerators are employed following a weak base anion resin Demineralizer plant, it is important to design the Vacuum Deaerator of ample carbon dioxide removal capacity. This is due to the fact that the weak base anion resin does remove a small amount of carbon dioxide in the beginning of the run and gives it up toward the end of the run. The Vacuum Deaerator must be capable of handling this increased amount of carbon dioxide if it is located after the weak base anion resin unit.

THREE-BED DEMINERALIZER

This consists of:

(1) Cation unit, first stage.
(2) Weak base anion unit, second stage.
(3) Decarbonator.
(4) Strong base anion unit, third stage.

See Figure 7 which shows the arrangement in a schematic treatment.

The Decarbonator, if made acidproof, can be located before rather than after the weak base anion resin unit as shown. This avoids the problem of high carbon dioxide at the end of the weak base resin run previously mentioned.

This three-stage system is justified to treat waters high in sulfates and chlorides because it saves caustic soda.

The weak base resin has a capacity of about 20 kgr./cu. ft. of resin with 4 lbs./cu. ft. of NaOH. Type I strong base resin has about 10 to 13 kgr./cu. ft. capacity with 4 to 8 lbs./cu. ft. of NaOH. Therefore with high amounts of TMA ($SO_4+Cl+NO_3$) considerable NaOH can be saved by using weak base resin for TMA removal, and using the strong base resin for CO_2 and SiO_2 removal only.

Usually both the weak base and strong base anion resin beds are regenerated at the same time passing all the NaOH countercurrently first through the strong base resin and then through the weak base resin. This saves still more NaOH than separate regenerations of the two beds. Actually the total amount of NaOH is very little more than that required for the weak base resin bed alone. The NaOH passing through the strong base resin becomes partly converted to Na_2CO_3 when it removes the CO_2 from the resin. This Na_2CO_3 is just as effective as NaOH for regenerating the weak base resin.

Furthermore with high percentage of silica present it takes considerable excess of NaOH to dislodge the silica from the strong base resin. Such excess is usually available in this countercurrent regeneration of 3 bed systems without using very much more than required to regenerate the weak base resin bed alone.

Also by using an excess of strong base anion resin and regenerating both anion beds at the same time, the strong base anion resin is not exhausted when regeneration takes place. This avoids silica break through and insures the best quality of final effluent at all times.

Finally the 3 bed system may in some cases permit eliminating a decarbonator for CO_2 removal, saving its cost as well as the transfer pumps. This is possible with waters containing not too high an alkalinity, because the CO_2 formed from the alkalinity by the cation unit is absorbed by the strong base anion resin. In such cases the amount of strong base anion resin used has sufficient capacity to take care of this CO_2 as well as the silica without increasing the caustic soda requirement.

FOUR-BED OR FOUR-STAGE SYSTEMS

These consist of:

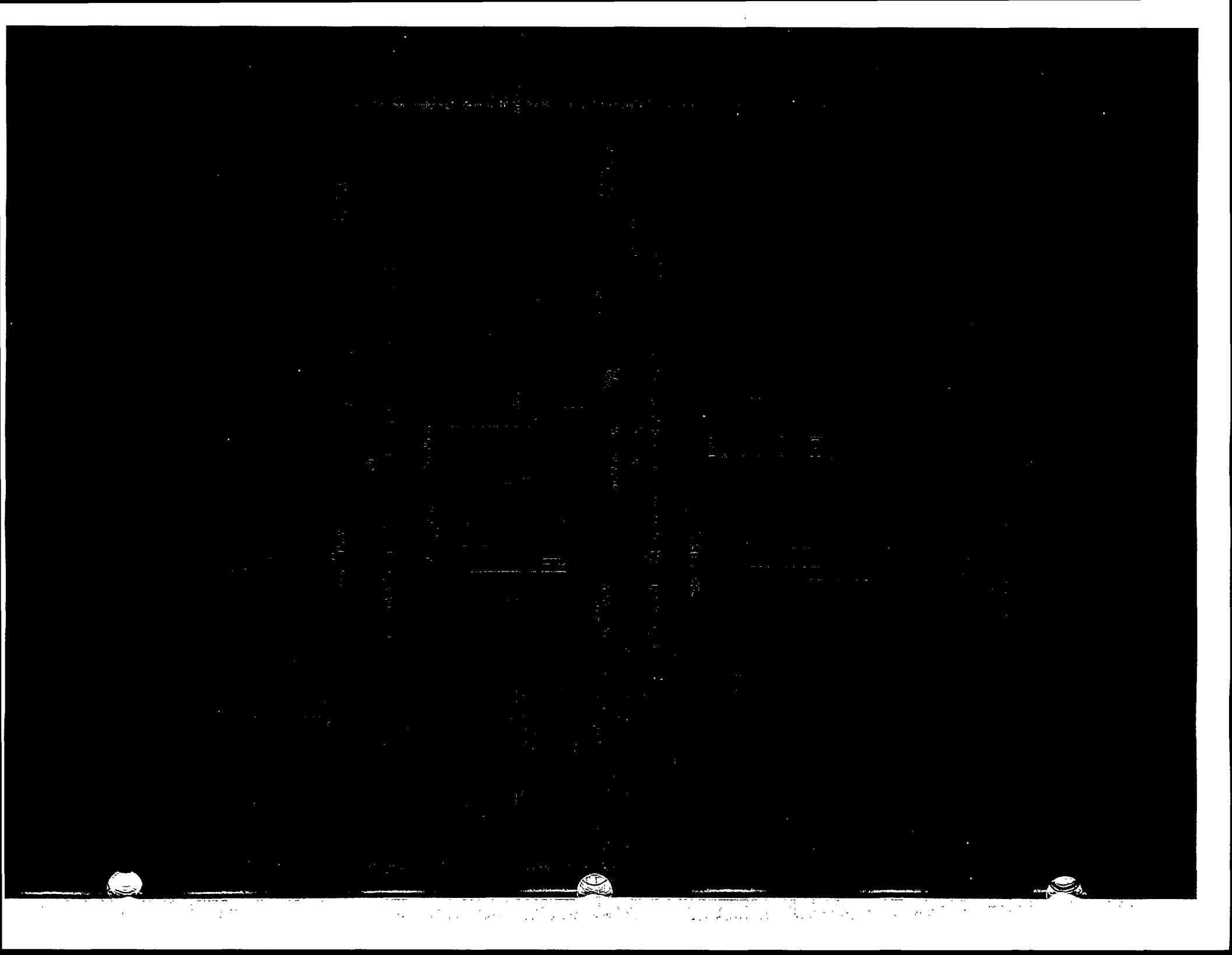
(1) Cation unit—stage No. 1.
(2) Weak base anion unit—stage No. 2.
(3) Decarbonator.
(4) Cation unit—stage No. 3.
(5) Strong base anion unit—stage No. 4.

Figure 8 shows this arrangement in schematic form.

The Decarbonator, if made acidproof, can be advantageously located before rather than after the weak base anion resin unit for reasons previously discussed.

Such four-bed systems are applicable when the raw water is very high in its electrolyte content and particularly when an extremely low electrolyte content is desired in the final effluent.

In this arrangement, it is possible to regenerate the cation units, stages No. 1 and No. 3 countercurrently, i.e., the acid used in the regeneration of No. 3 is then passed through No. 1 unit. The same is true for the caustic soda in the regeneration of stages No. 2 and No. 4. This countercurrent method of regeneration has two advantages:



(a) It saves operating cost because the polishing units No. 3 and No. 4 are thereby regenerated free of charge. The amount of acid or caustic used is not appreciably increased over the requirement for the primary units.

(b) The polishing units No. 3 and No. 4 are thereby always kept in a partially exhausted condition. They are not allowed to approach exhaustion. This assures the lowest possible electrolyte and silica in the final effluent.

Four-bed, as compared to three-bed systems, permit saving of acid in the regeneration of the primary cation unit. By having a secondary cation unit to remove cation leakage from the primary unit the amount of acid used to regenerate the latter can be appreciably reduced.

Another advantage of three-bed or four-bed systems is that the primary units act as prefilters and thereby protect the final secondary or polishing units. Turbidity or suspended matter will be removed by the primary units and thereby keep the secondary units cleaner so that they produce a higher effluent quality. However, dissolved organic matter is not removed by cation or weak base anion beds and are adsorbed by and cause fouling of the strong base anion resin beds.

Three- or four-bed systems are becoming more and more popular particularly for boiler pressures exceeding about 1000 psig. In some cases mixed bed units are used instead of the secondary two-bed system for the final polishing (see Case 2, page 31.) Here strong base anion resin is used in the third as well as in the final mixed bed stage so that the latter is protected from organic fouling.

The secondary units can be operated at much higher rates than the primary system. Thus smaller units are frequently employed in the secondary stages.

TWO BED-FOUR BED SYSTEMS

Where the makeup required for high pressure boiler plants may vary, the 2 bed-4 bed system shown in Fig. 9 is applicable.

With low makeup this operates as a 4 bed system, demineralizing through the primary and secondary pairs of units in series. But with higher makeup it operates as a 2 bed system by putting both pairs in parallel.

Both primary and secondary anion resin beds are of the strong base type. This has the advantage that the secondary anion bed is protected from fouling by the primary anion bed.

In general where the lowest possible silica is desired, the use of strong base resin in both primary and secondary anion units is indicated. Where the TMA is high, then the use of 3 bed primary followed by a 2 bed or a mixed bed secondary system is used. (See Case 2, page 31.)

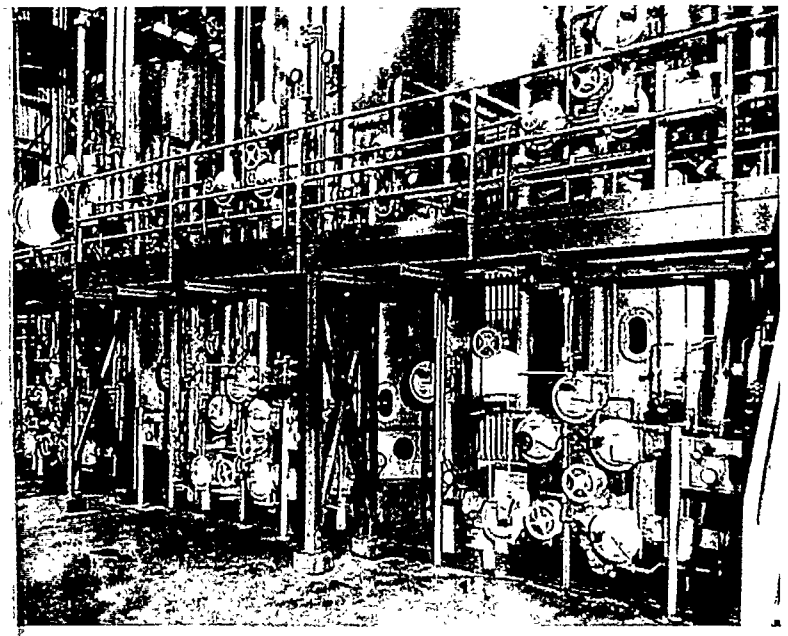
Mixed Bed (Mono-Bed) Demineralizers

The mixed bed Demineralizer was developed in 1950 and differs from the standard two-bed system in employing only one shell. In this single shell, both the cation and the anion exchange materials are placed. Prior to normal operation they are mixed together by blowing compressed air through the beds. This thoroughly mixes the cation and anion exchange material.

During the normal exhaustion run the cation and anion exchange particles work side-by-side. As soon as a cation exchange particle converts some of the salts to acids, an anion exchange particle is right at hand to adsorb these acids. This prevents a back pressure from developing on the cation exchanger particle operation and allows it to operate more efficiently without interference from the acid products formed. Thus, low pH values are not produced in the treated water at any stage of operation. This is advantageous in many applications of Demineralizers.

The mixed bed system may be compared to a number of two-bed systems in series. As explained above, four-bed systems which demineralize the water twice produce a purer effluent than two-bed systems. Likewise, mixed bed systems produce a purer effluent than two-bed systems.

The mixed bed system also has the advantage over the two-bed system in avoiding



Mixed Bed Demineralizers at an Uranium Plant.

appreciable pick-up of electrolyte when the Demineralizer stands idle and requiring less rinse water when starting up again.

In regenerating, the cation and anion resin beds are first separated by hydraulic classification or backwashing. The anion exchanger bed, being lighter, comes to the top and the cation exchanger bed at the bottom. This difference in density between the two resins makes the mixed bed system possible. After separation, the two beds are regenerated with caustic soda and acid. Rinsing of excess regenerant then follows. The mixing of the two beds by compressed air is repeated, and a final rinse applied before the unit is put into operation.

Several construction features are important:

(1) Regenerant effluent collector must be located accurately at the interface between the two resin beds.

(2) During regeneration, the acid flows upward through the cation bed and out of the interface collector, and the caustic soda flows downward through the anion bed and out of the interface collector.

(3) Since the anion resin is light, backwashing rate must be limited to avoid washing the anion resin to the sewer. Consequently dirt must not be allowed to enter a mixed bed Demineralizer, for it would be difficult to remove by backwashing. Influent to a mixed bed unit should be crystal-clear.

Where the raw water contains high alkalinity, the mixed bed unit should be preceded by a hydrogen zeolite unit and Decarbonator. This will reduce the carbon dioxide, which the anion resin in the mixed bed would have to remove, and thereby save operating cost. Also the hydrogen zeolite would preclarify the water and thus keep the anion bed cleaner.

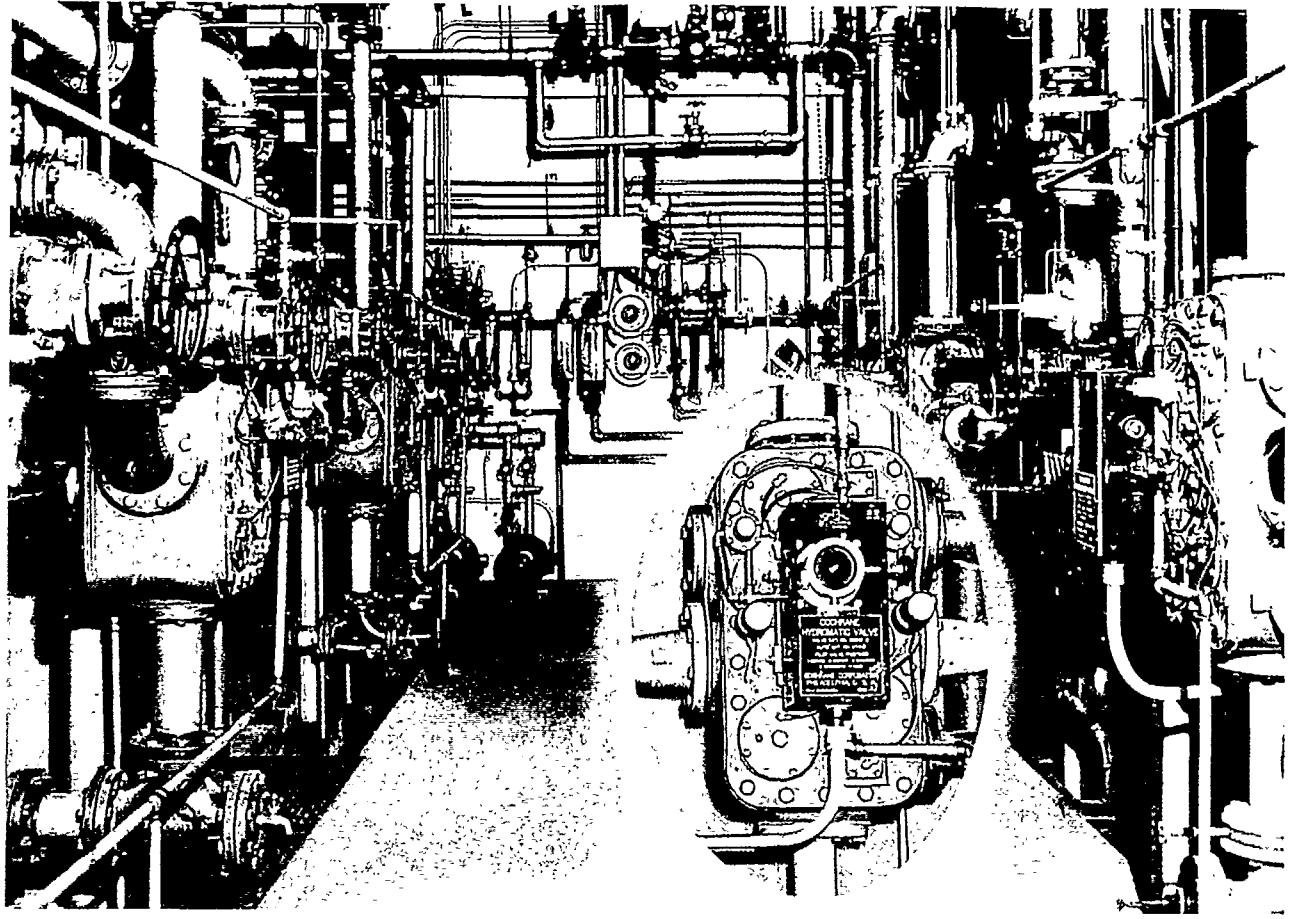
If Mixed Bed Demineralizers are used in a primary position to treat waters of surface origin, the anion resin will become fouled by organics in a short time, requiring frequent resin replacement to avoid poor effluent quality. This is true even on city waters made by filtering a river supply. Enough dissolved organic matter is left in the city water to cause this fouling of anion resin. Even carbon filters preceding the mixed bed units have not prevented this fouling. A primary two bed Demineralizer preceding the mixed bed units using the latter as polishing units regenerated infrequently has helped. Several case histories in Crane-Cochrane Reprint 4.44 show that when this was done, resin fouling as well as frequent resin replacement was avoided.

Final effluents from mixed bed units contain less electrolyte than is possible to produce by any other method. It is purer than the A.S.T.M. requirements for reagent water (See their D-1193-51T). The resistance of the effluent during the run rises to as high as 24,000,000 ohms per cm. The average resistance throughout the run is frequently higher than 10,000,000 ohms per cm., equivalent to 0.04 ppm electrolyte. The silica content is under 0.02 ppm.

Case 1, page 31, describes a larger automatic mixed bed plant used in atomic work.

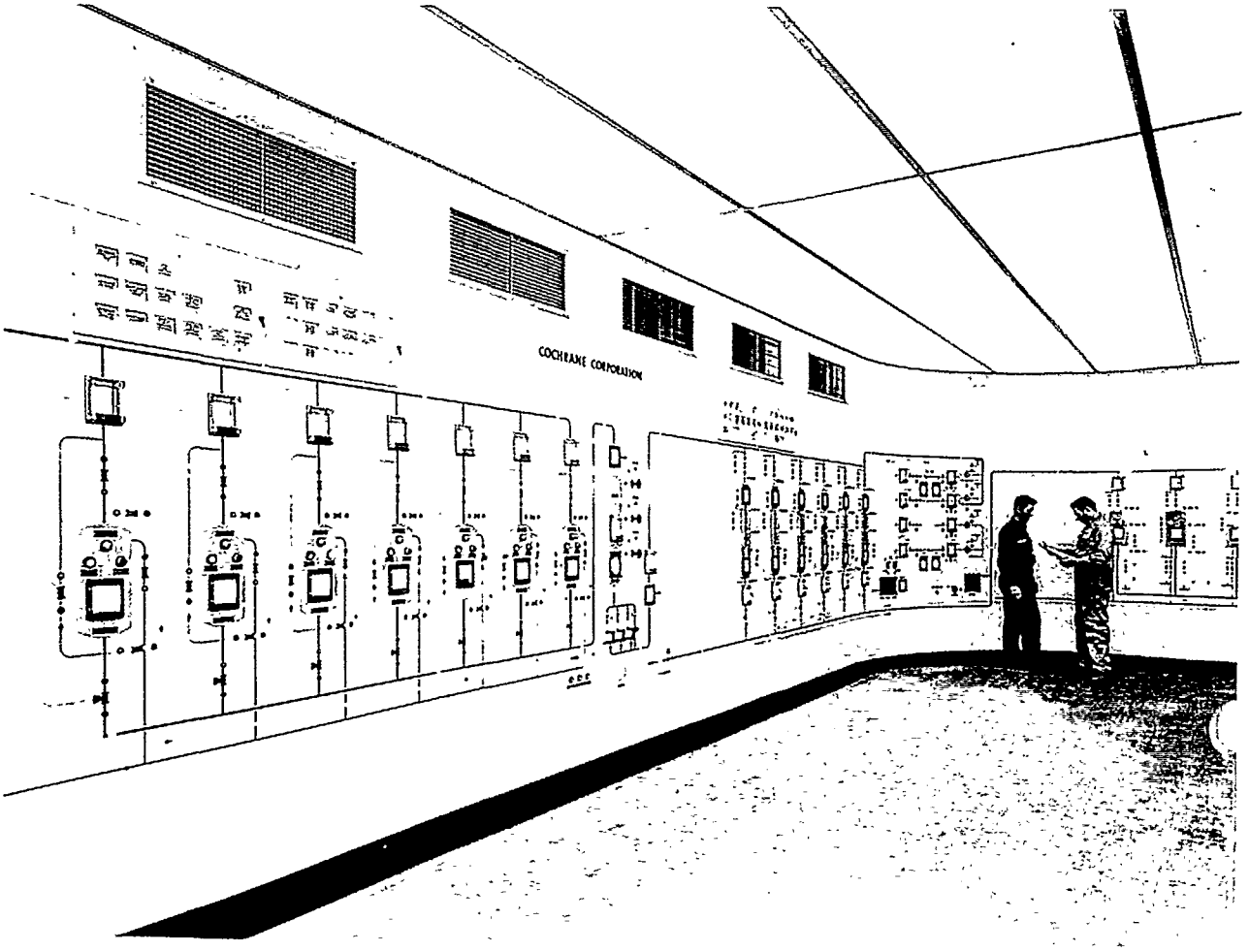
Case 2, page 31, uses a final battery of automatic mixed bed Demineralizers as polishing units.

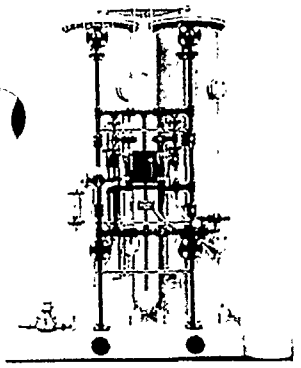
Cases 3, 4 & 5, pages 32, 33 & 34, describe large automatic condensate scavenger plants with Hi-Rate Mixed Bed Demineralizers.



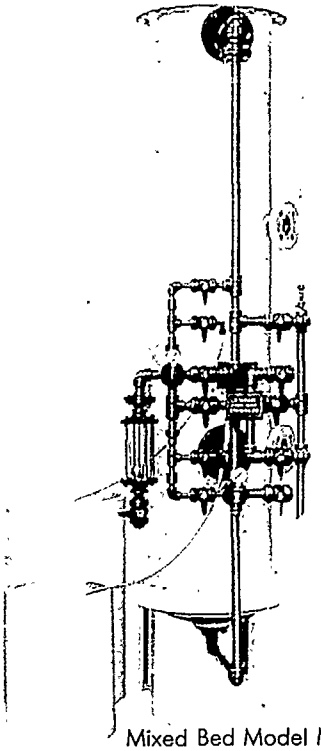
Demineralizers for a Transistor Plant in Ohio.

Panel for Demineralizer at Power Plant in New Jersey. (See Case 2—Page 32)





Two-Bed Model D
Demineralizer
(Manual Control)



Mixed Bed Model M
Demineralizer
(Manual Control)

Package Demineralizers

Shown above are standard package Demineralizers made in sizes 12″ to 30″ diameter for manual operation and regeneration. These units are completely assembled in the shop and shipped with piping attached and with the resin in place so that erection in the field is reduced to connecting raw and treated water lines, air supply and drain to the unit.

Piping and valves are of PVC construction using union end ball valves with Teflon seats and position indicating handles. The shell itself is lined with a seamless, nonporous, chemical resistant abrasion proof PVC coating, permanently bonded to the metal. Two sight glasses are provided in the shell for visual inspection of the ion exchange material. Internal Distributors are also included.

Two regenerant tanks of polyethylene construction are provided for the acid and alkali regenerant together with suitable hydraulic eductors, rate of flow indicator and conductivity solubridge indicator to control operations. Fully automatic models are also available.

These Demineralizers are used in numerous process water applications among which may be mentioned:

Industrial Users of Demineralized Water

Aircraft Plants	Mirror Manufacturers
Airports for Engines	Missile Washing
Aluminum Extrusion Cooling	Ordnance Plants
Ammonia Manufacturers	Paper & Pulp Plants
Anodizing Plants	Pencil Manufacturers
Automobile Plants for Painting	Pharmaceutical Manufacturers
Bottling Plants	Photographic Film
Catalyst Manufacturers	Plastic Manufacturers
Ceramic Manufacturers	Pottery Manufacturers
Chemical Plants	Radio & Television Tube Plants
Cosmetic Manufacturers	Rubber Plants
Cutlery Manufacturers	Silverware Manufacturers
Distillery Plants	Starch Manufacturing Plants
Dye-Stuffs	Steam Generating Plants
Electro-Plating Plants	Steel Tin Plate Manufacturers
Emulsions	Storage Battery Manufacturers
Explosive Manufacturers	Sugar Plants
Extract Manufacturers	Synthetic Detergents
Foil for Dielectric	Synthetic Fibre Manufacturers
Food Processors	Television Stations
Gelatin Manufacturers	Television Tube Plants
Glass Manufacturers	Textile Plants
Ice Plants	Toilet Preparations
Jet Engine Manufacturers	Transistor Manufacturers
Laboratories	Uranium Plants
	Vanadium Plants

HIGH RATE MIXED BED CONDENSATE SCAVENGING UNITS

In supercritical or subcritical once-through boiler plants the condensate needs a scavenging treatment to remove corrosion products and impurities introduced by condenser leakage. Water of the utmost purity (10,000,000 ohms resistance) is needed for such applications.

Mixed Bed Demineralizers are usually installed for such purposes. (See Cases 1 and 3 described on pages 31 and 32.)

Higher flow rates may be used for such scavenging systems. Whereas, the usual flow rates for primary makeup demineralizers are 6 to 12 gpm/sq. ft. of area and for secondary systems 15 to 25 gpm/sq. ft., it is possible to use rates of 50 gpm/sq. ft. or higher for scavenger mixed bed demineralizers.

Preceding the mixed beds, some plants use solka-floc pre-filters but the trend today is to omit such filters.

EXTERNAL REGENERATION

Instead of regenerating in place, the resin is hydraulically transferred out of the main shells into external regenerating vessels where the regeneration takes place. This system provides several advantages:

(1) It avoids direct connections of regenerant lines to the main Demineralizer shells, thus preventing the possibility of regenerant entering the boiler feed lines by mistake.

(2) The resin is cleaned in the external vessels. Most plants, therefore, omit pre-filters ahead of the demineralizers.

(3) Average time during regeneration is reduced because an extra charge of regenerated resin on hand in a resin storage tank can be transferred into the main shells directly after the exhausted resin is sluiced out. Thus the Demineralizer can be returned to service in 20-30 minutes instead of waiting 3-4 hours for in-place regeneration. This is important during emergency condenser tube failures when the scavenger Demineralizer is depended on for removing the impurities introduced by the condenser leakage.

(4) Final air-mixing of the main shells is avoided, decreasing the amount of dissolved oxygen in the main condensate stream at the start of runs.

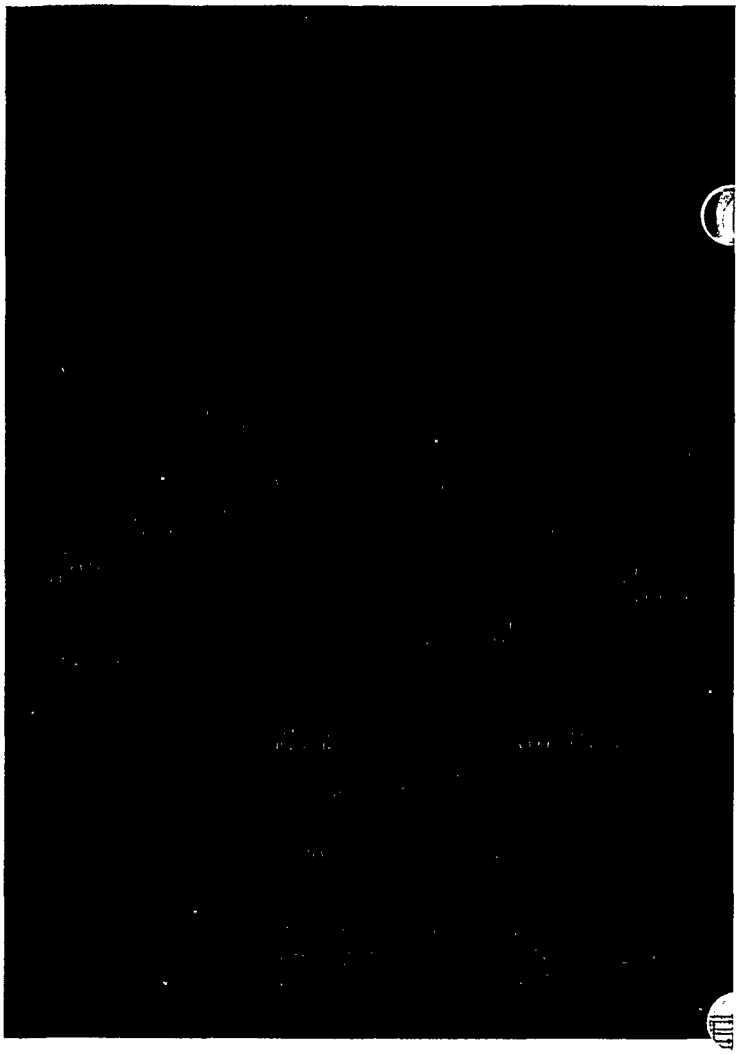
(5) The main Demineralizer shells and piping need not be made acid proof and the valve nest is simplified.

Figure 13 illustrates an External System in actual use.

Two case histories of large Condensate Scavenger Plants using external regeneration are appended, see cases #4 and 5 on Pages 33 and 34. See Fig. 18 for diagram of the external regeneration system.

NUCLEAR APPLICATIONS

A variety of nuclear cycles are being developed and studied at present. The two types that prevail on a large scale in the U. S. A. right now are:



(1) Pressurized Light Water Reactor—enriched uranium.

(2) Boiling Light Water Reactor—enriched uranium.

England is specializing on the gas-cooled graphite type. Canada and Sweden are concentrating on the heavy water moderated, natural Uranium type. The discussion that follows will be on the two U. S. A. types.

(a) Pressurized Light Water

This type has been used in the Nautilus and other submarines and later on a larger scale (60,000 KW) at Duquesne Light, Shippingport, Pa. The largest plant (275,000 KW) of this type is at the Consolidated Edison Co. plant, Indian Point, New York.

Figure 10 shows a simplified flow diagram of the latter plant together with the Crane-Cochrane Mixed Bed Demineralizers being used to purify the primary loop.

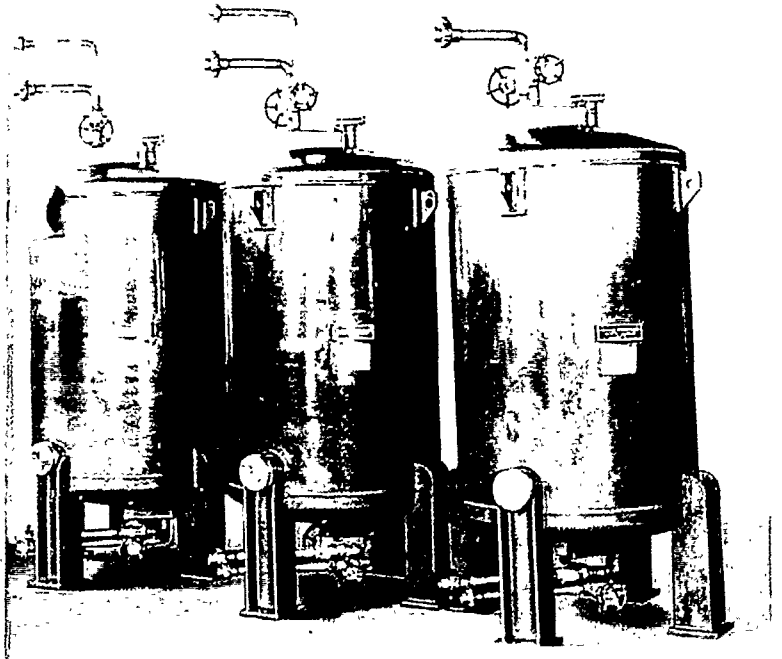


FIG. 11
THREE DEMINERALIZER UNITS USED IN ATOMIC POWERED MERCHANT SHIP

A considerable flow of light water is circulated in the primary loop to pick up the heat from the fission reactions in the nuclear reactor. By pressurizing this loop sufficiently, no steam is formed. The heat in this primary coolant stream is then transferred to a secondary loop through a heat exchanger which generates the steam for the turbine. The secondary loop is quite conventional except for the stainless steel used in the heat exchangers, etc. This pressurized water type was first developed because of its greater safety, inasmuch as it reduced the hazard to the operators of exposure to radio-activity. The heat exchanger confines the radio-activity mostly to the primary loop so that the turbine, condenser, etc., in the secondary loop do not have to be shielded. In addition, the use of primary water loops permitted the use of a number of loops in parallel, increasing reliability.

The makeup water to the secondary loop is treated by Mixed Bed Demineralizers.

The primary loop must be purified mainly to remove radio-active corrosion and fission products, called CRUD, down to under 1 ppm. Otherwise, these products would form deposits on the fuel elements reducing their efficiency. Also the coolant must promote cleanliness of heat transfer in the heat exchanger. This is accomplished by cooling a small by-pass fraction (under 0.3%) and then filtering and demineralizing it. A special gas stripper deaerator is also used to remove Xenon, Krypton and similar gases before returning the treated stream to the primary loop. Besides removing CRUD, the treatment also removes dissolved solids, particularly chlorides to minimize stress corrosion of the stainless steel used in the cycle. The primary loop water is therefore maintained to contain under 1.0 ppm of solids of which the chlorides will be only a trace amount.

The anion units shown in Figure 10 serve the purpose of removing boric acid from the primary loop at each start up. The boric acid is added as an additional means of controlling the fission reactions, besides the control rods. At start-up, the boric acid must then be removed.

The other Demineralizers shown are to keep the spent fuel cooling pit water purified and to polish distillate from an evaporator that treats the plant liquid wastes for their disposal.

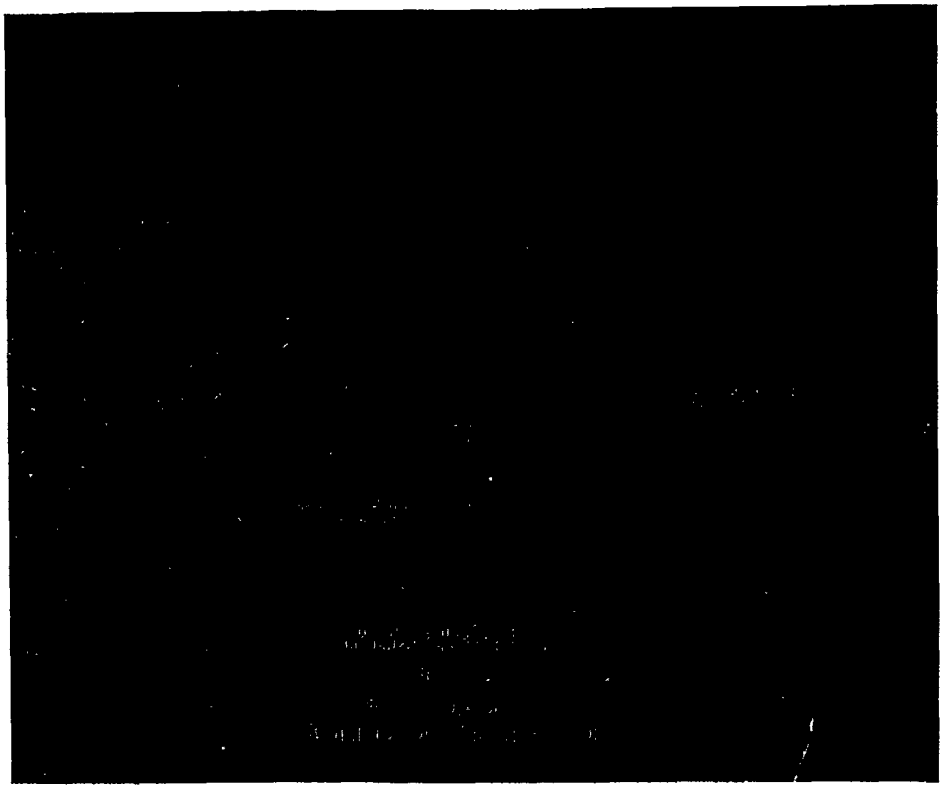
The resin in these Demineralizers is not regenerated but when it is exhausted, it is hydraulically sluiced out of the units into storage where its radioactivity is allowed partially to decay. Then it is sluiced out of storage to a drumming operation where it is mixed with concrete and placed in drums for ultimate disposal in the ocean. Regeneration would only increase the disposal problem because of the large volumes of regenerant rinse water formed.

The Demineralizers and resin storage tanks are all made of stainless steel and located in a shielded pit. Resin loading and unloading sluicing operations are remotely controlled.

Figure 11 shows three Crane-Cochrane Mixed Bed Demineralizers furnished for the nuclear merchant ship "Savannah" to purify the primary coolant loop of the pressurized light water reactor used on this vessel.

These Demineralizer shells are covered with lead shields to avoid escape of radioactivity.

The resins will not be regenerated but on exhaustion will be sluiced to waste and replaced with new active freshly regenerated resins.



(b) Boiling Water Reactor (Dual Cycle Type)

Figure 12 shows a flow diagram of this type. The nuclear reactor forms saturated steam for the turbine directly and the turbine condensate is all returned to the reactor.

Steam produced by the secondary generator enters intermediate stages of the turbine for greater efficiency.

Here the treatment of a small fraction of the circulated stream (as used with the pressurized reactor type) is not feasible. It is necessary to scavenge 100% of the returning condensate stream before it enters the nuclear reactor, to avoid any solids entering the reactor.

The usual limit of impurities in the reactor water is 600 parts per billion (ppb) of total solids and 100 ppb of chlorides (conductance was to be under 1.0 mmho).

To accomplish this, a clean up Demineralizer is used on a by-pass system, treating a small stream of Reactor water. This Demineralizer is not regenerated because of the radioactive products removed by the resin. When exhausted the resin is sluiced out for disposal.

However, the main condensate scavenger Demineralizer handles the whole condensate stream.

Here, the need for high rate demineralization is apparent to reduce first cost. It has been found feasible to operate such Demineralizers at a rate of 50 gpm/sq. ft., instead of the usual 15 to 25 gpm/sq. ft. rate heretofore used even for polishing or for secondary demineralizers. Instead of regenerating in the unit, resin is transferred from the demineralizer shells into external containers where the regeneration takes place.

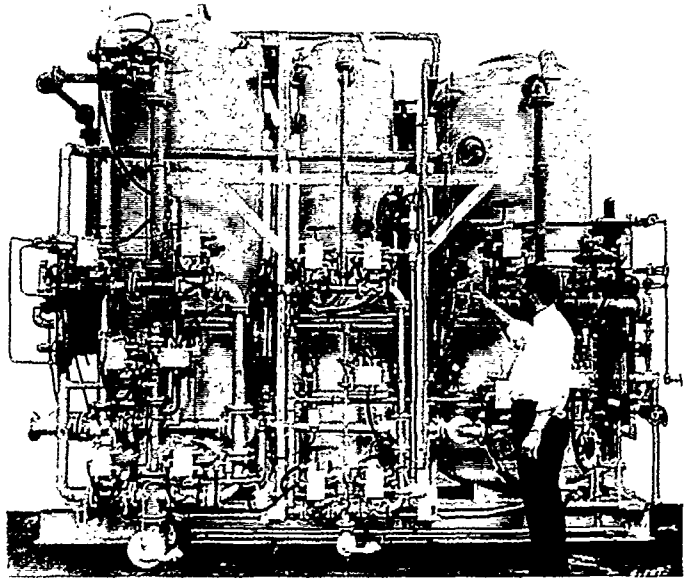
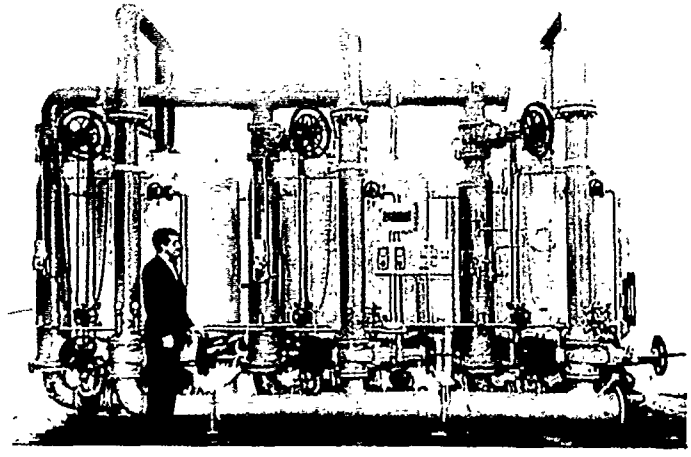


FIG. 13

AUTOMATIC EXTERNAL REGENERATION equipment for CONDENSATE SCAVENGER DEMINERALIZER shown at right. Resin is hydraulically transferred from the Demineralizer into these vessels where it is regenerated with acid and caustic. This avoids the danger of regenerant leaking into the boiler. All necessary piping, valves and controls were pre-packaged, erected and pre-tested in CRANE-COCHRANE's shop before shipment.



A large Eastern utility received this CRANE-COCHRANE triple unit MIXED BED DEMINERALIZER in one pre-assembled, shop-tested package. Manually operated Chapman valves and color-coded piping were included. The units scavenge (clean-up) the utility's main condensate to remove sea water impurities due to condenser leakage. They treat 1,270,000 lbs. per hour of feedwater for the 2450 psi boiler.

Case Histories

Case No. 1

Large Automatic Mixed Bed Demineralizer in Uranium Plant (See Fig. 14)

This plant has a capacity of 800 gpm and the water is used in atomic work. It consists of 3 parts:

(1) Four activated carbon filters 8′ dia. to absorb organic matter to reduce organic fouling of anion resins.

(2) Three mixed bed Demineralizers 10′ dia. X 16′ H with flat bottoms reinforced by welded on beams on the outside and stainless steel inlet distributor, caustic distributor, interface distributor and underdrains. The shells were built for 125 psig per ASME Code. These flat bottoms are the best design to avoid caustic hide-out during rinsing. The resins used were Cochranex CRZ cation material and Cochranex AY the more porous form of Type I anion resin.

(3) Vacuum deaerator to remove dissolved gases. The effluent quality is a specific conductance of under 0.25 micromhos or over 4,000,000 ohms or less than 0.1 ppm of electrolyte and silica of under 0.05 ppm.

(4) Graphic panel – see Fig. 15..

Case No. 2

Large Automatic Four Bed System Using Mixed Bed Final Polishing Units

The flow diagram of this plant is in Figure 16. It has a capacity of 3200 gpm for an Eastern power plant using 30 to 100% makeup for boilers of 1900 psig and 2600 psig pressure.

The plant consists of:

(1) A pretreatment plant of 3750 gpm to clarify the surface supply. This includes coagulation Solids-Contact Reactors and four gravity anthracite filters, annular in shape and partially surrounding and integral with the reactors.

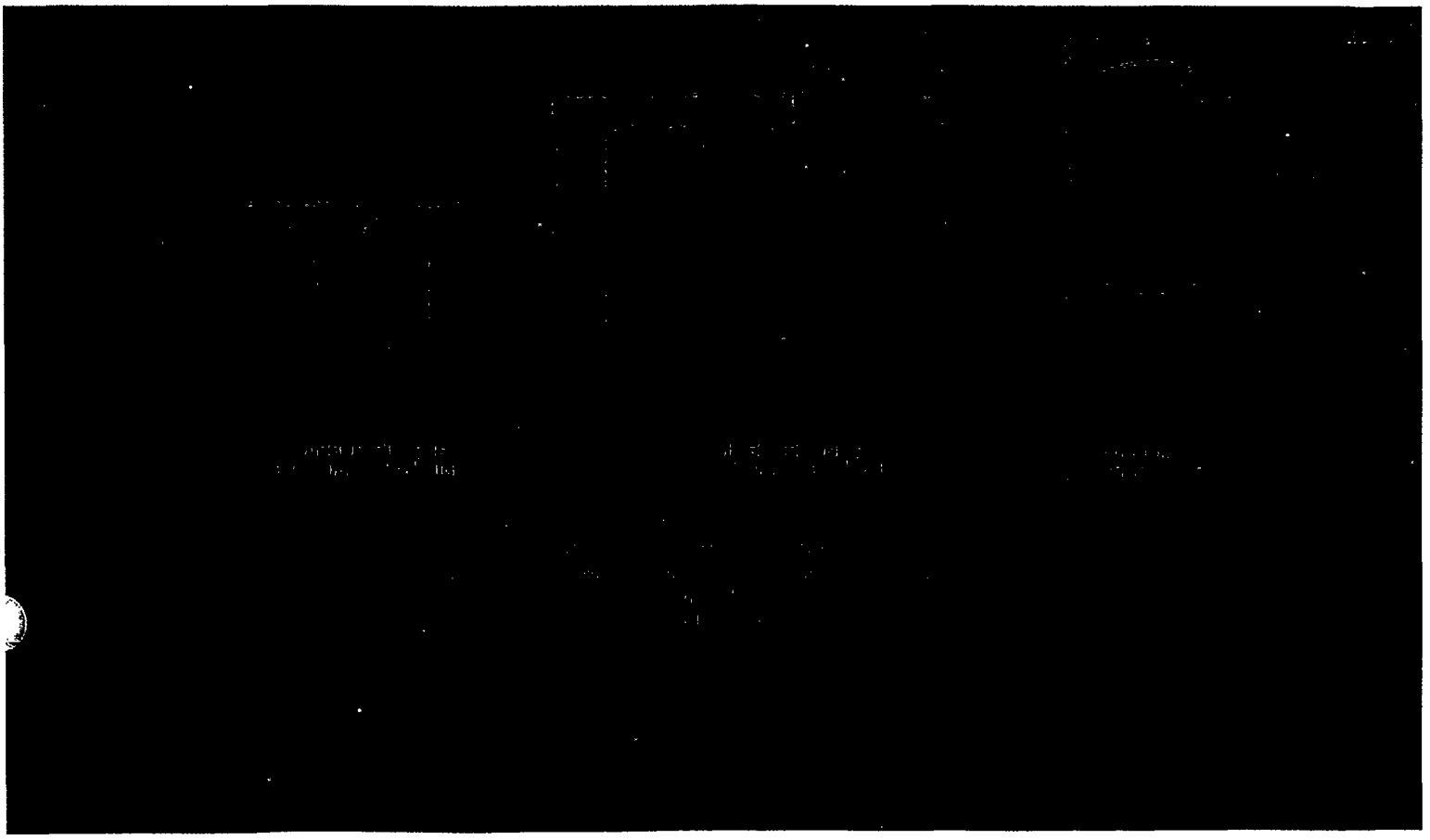
(2) Seven cation units 12′ dia. with Cochranex CRZ.

(3) One Vacuum Deaerator (rubber-lined) 14′ dia.

(4) Six weak base anion units 12′ dia. with Cochranex AV.

(5) Six strong base anion units 12′ dia. with Cochranex AM-AY, the more porous variety of Type I resin.

(6) Five mixed bed units 12′ dia. with Coch-



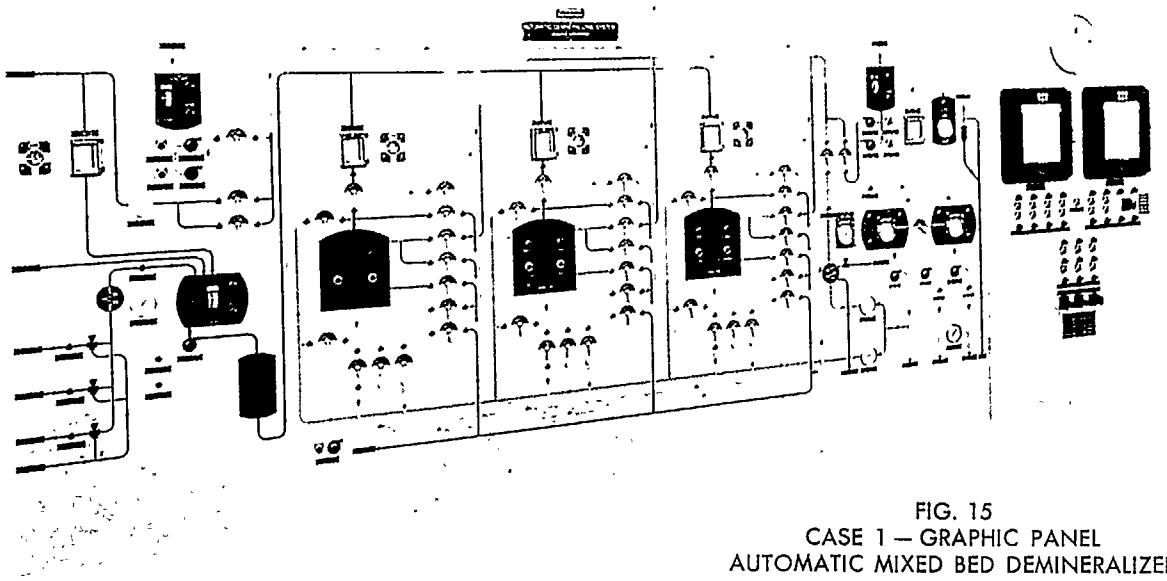


FIG. 15
CASE 1 — GRAPHIC PANEL
AUTOMATIC MIXED BED DEMINERALIZER

ranex CRZ and AM-AY with flat bottom lower heads with welded on beams, shells designed for 125 psi pressure.

(7) Fully automatic controls and graphic panel. (See page 26)

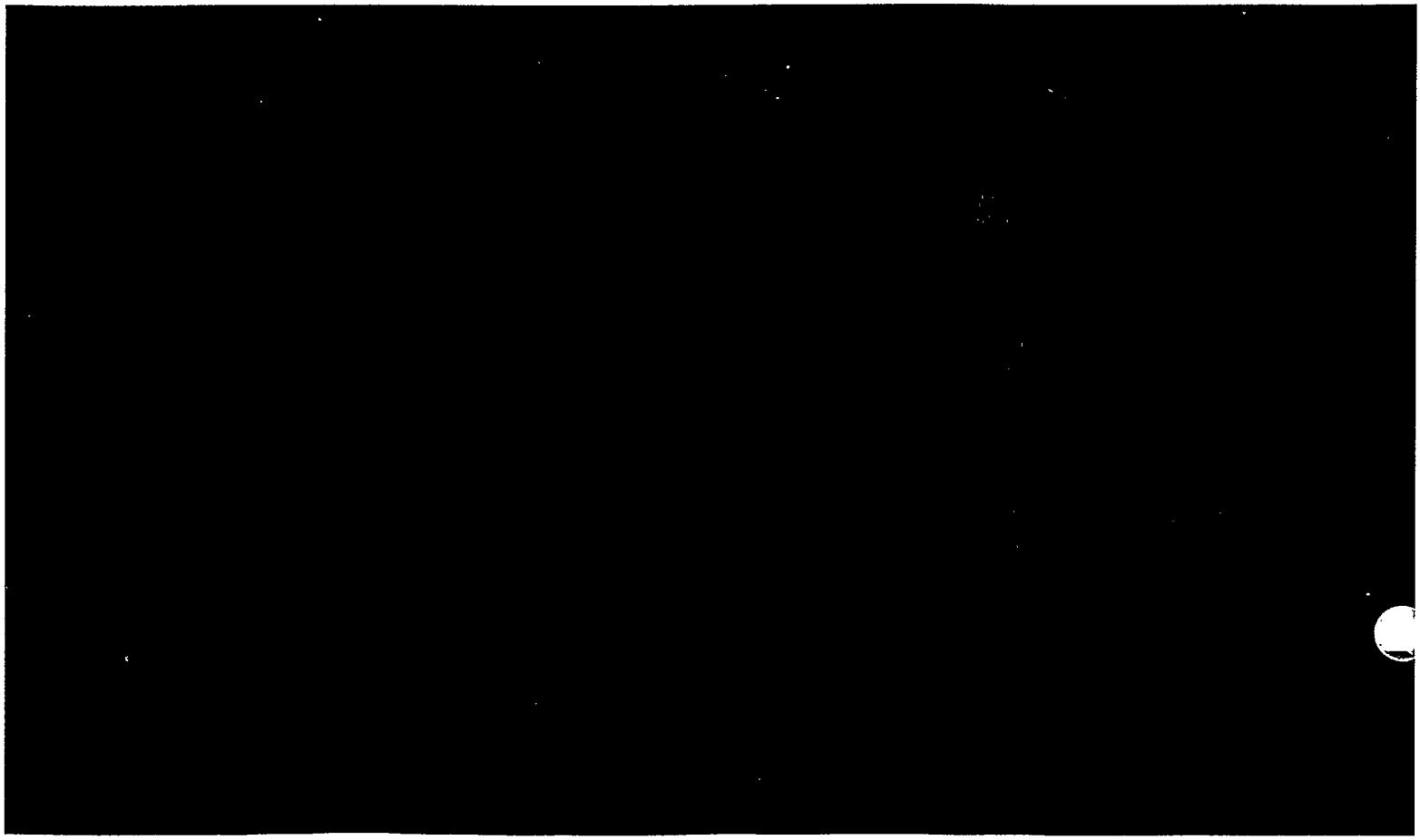
The quality of effluent is:

Total dis. solids not to exceed 0.2 ppm.
Conductivity not to exceed 0.5 micromhos
Dis. silica not to exceed 0.01 ppm as SiO_2
Dis. oxygen not to exceed 0.1 ppm

Case No. 3

Supercritical Pressure
Boiler Plant in Ohio

The boiler in this case is rated at 1,725,000 lbs./hr. at 3500 psi and has no drums. Any impurities in the condensate which constitutes 99% of the feed water would form deposits in the small tubes of the once-through boiler or in the turbine.



Therefore the makeup which comes from Lake Erie is lime softened and then passed through a 2 bed demineralizer. In addition the condensate plus this demineralized make-up is further scavenged by a mixed-bed demineralizer. (See Fig. 17)

The mixed Bed Demineralizer units are designed to handle up to 2500 gpm. in case of condenser tube failure. There are 3 fully automatic 10'6" dia. x 9'0" H designed with reinforced flat bottoms. They are guaranteed to produce an effluent of 10,000,000 ohms resistance. (See photo on back cover)

Case No. 4

Condensate Scavenger Plant
Once-through Boiler
Plant in Alabama

This is a 500 megawatt unit boiler designed for 2400 psi. Condensate flow is 4900 gpm or 2,450,000 lbs./hr.

The makeup system includes a 2 Bed Make-up Demineralizer for 65 gpm.

The scavenger system includes:

(1) The pre-filters, tubular filter element type, using cellulose filter aid (filter area 1245 sq. ft.).
(2) Two Hi-Rate Mixed Bed Demineralizers 10' dia.
(3) Four Post filters, cartridge type.

The scavenger plant is fully automatic with external regeneration.

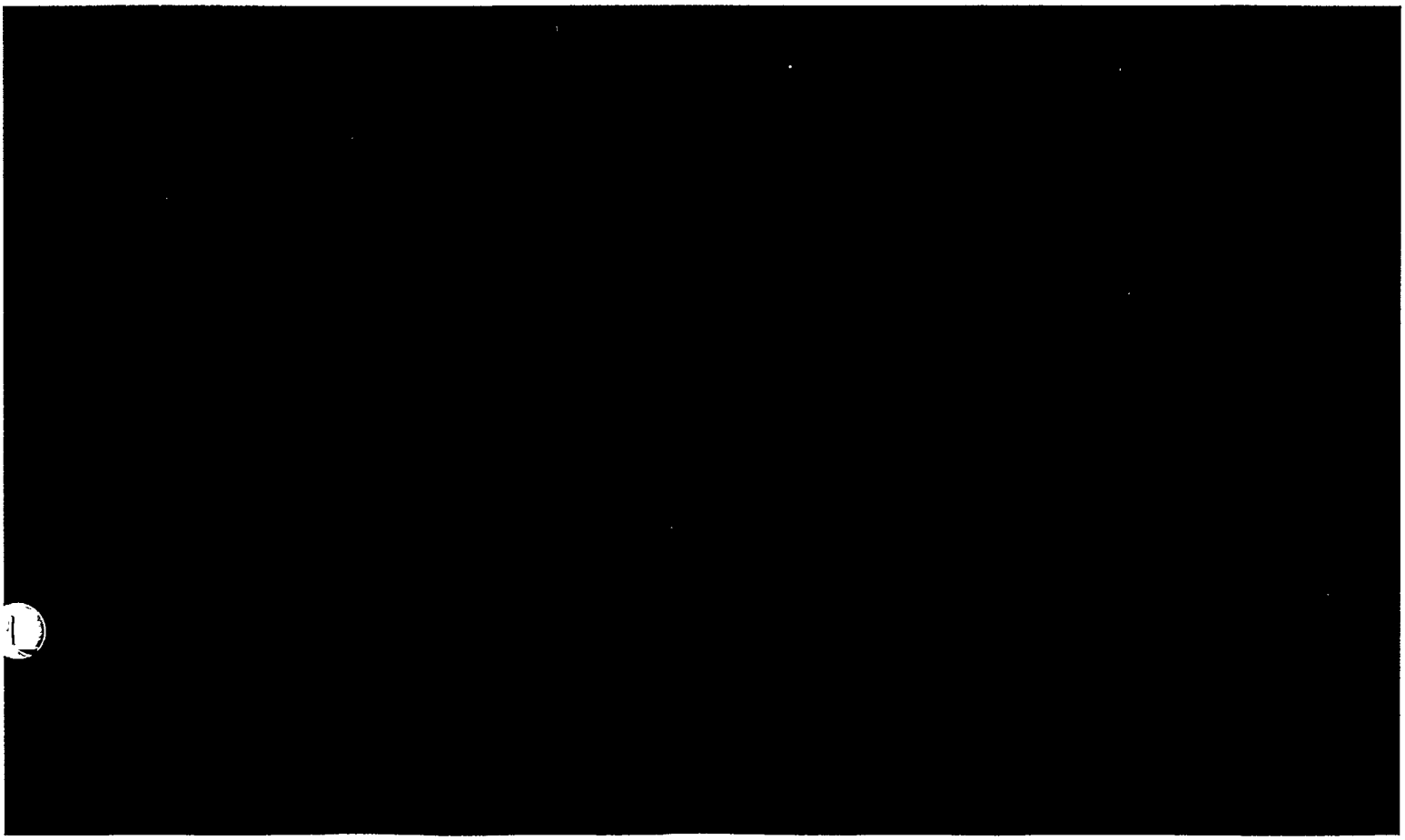
Case No. 5

Make-up and
Condensate Scavenger Plant
Once-through Boiler Plant
in Illinois

Boiler pressure is 2500 psi—capacity 2,500,000 lbs./hr. Condensate flow treated is 4500 gpm.

The raw make-up is from a surface supply. It is pre-chlorinated, lime pre-softened and then passed through a 2-bed demineralizer.

The makeup pretreatment plant for 500 gpm consists of:

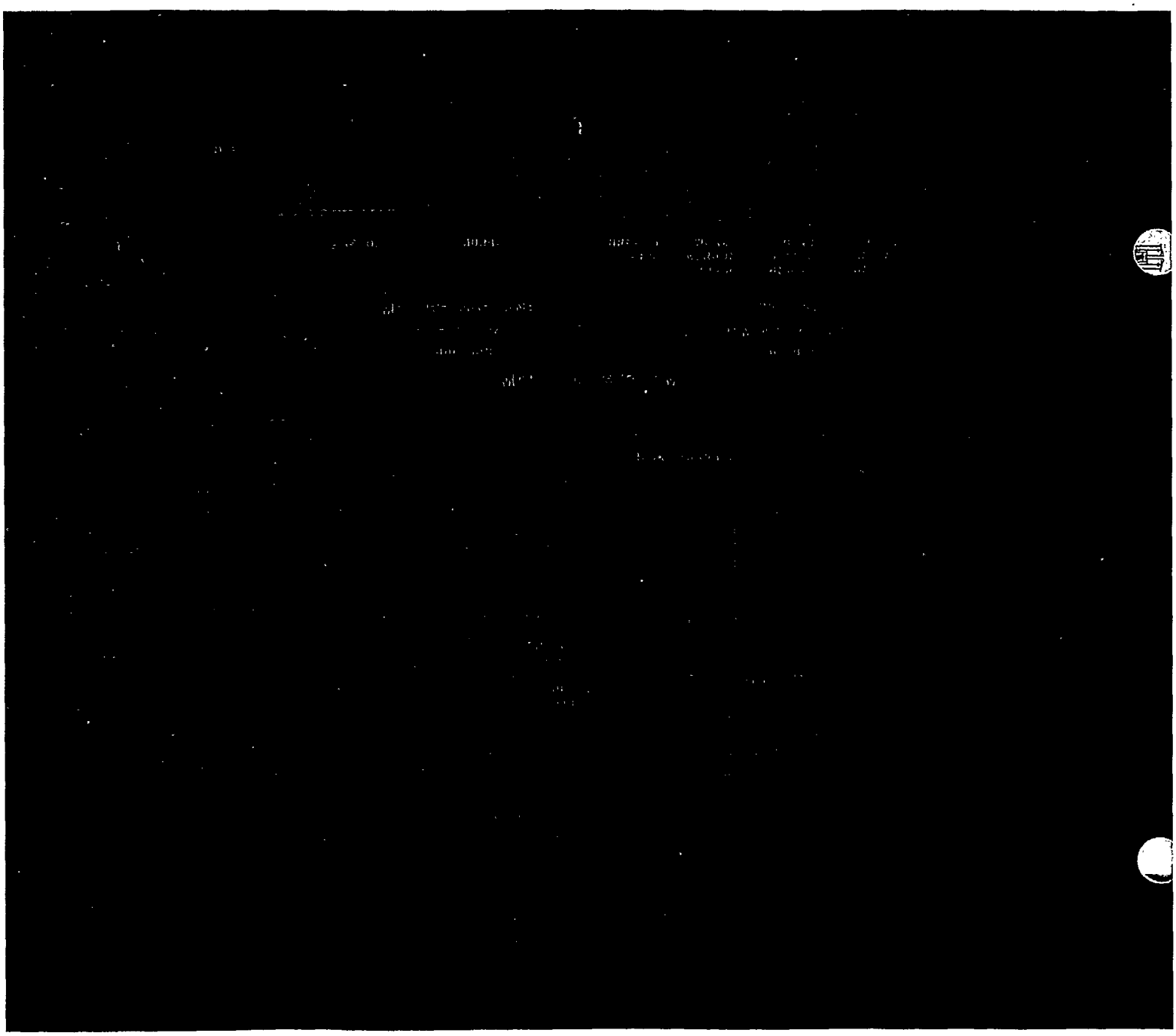


(1) A Solids Contact Reactor, 22′ dia. and chemical feeds, surge tank and pumps.
(2) 3 automatic pressure anthracite filters, 8′6″ dia.

The automatic makeup demineralizer for 150 gpm consists of:
(3) 2 carbon filters, 4′6″ dia.
(4) 2 cation units, 5′0″ dia.
(5) 2 anion units, 5′0″ dia.

The Condensate Scavenger System (for 4500 gpm) is designed for 400 psi operating pressure and consists of:
(a) 3 mixed bed demineralizers, 7′6″ dia. (operating at 50 gpm per sq. ft. rate with one unit off).
(b) 3 resin traps with internal stainless steel screen.
(c) External regeneration facilities:
Resin separation and cation regeneration—5′6″ dia.
Anion regeneration vessel—3′6″ dia.
Resin storage vessel—5′6″ dia.
Acid and caustic storage tanks and controls.
Ammonia storage tank for ammoniating the resin.
Panel, instruments and automatic controls.

Fig. 18 is a simplified flow diagram of this plant.



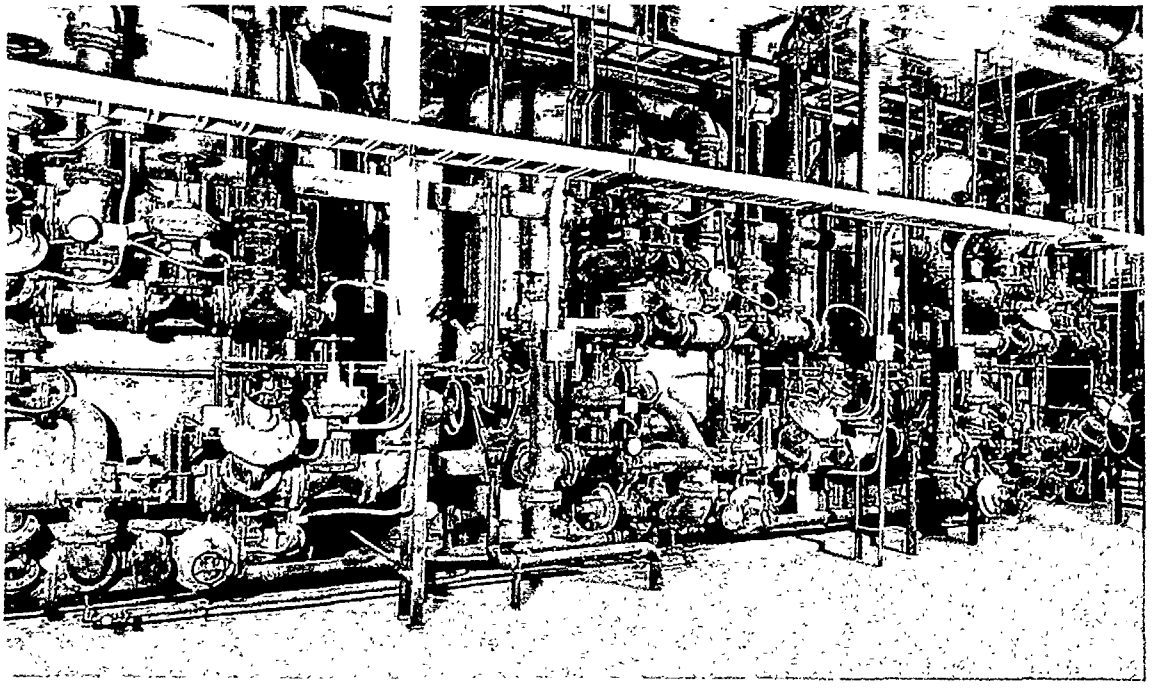
PARTIAL LIST OF CRANE-COCHRANE DEMINERALIZERS FOR MAKEUP AND CONDENSATE TREATMENT FOR FOSSIL-FUEL AND NUCLEAR PLANTS

M=Makeup C=Condensate N=Nuclear GPM=Capacity

User and Location	Type	GPM
ALABAMA		
Paper Co.	M	350
Electric Power Co.	M	260
Electric Power Co.	C	4900
ALASKA		
Pulp Co.	M	500
Pulp Co.	M	350
CALIFORNIA		
Electric Power Co.	C	10400
Electric Power Co.	C	10400
Electric Power Co.	N	100
CONNECTICUT		
Electric Power Co.	C	2100
FLORIDA		
Paper Co.	M	810
Electric Power Co.	M	250
Electric Power Co.	C	3000
ILLINOIS		
Electric Power Co.	M	150
Electric Power Co.	C	4500
Electric Power Co.	C	5660
Electric Power Co.	C	5660
Electric Power Co.	M	250
KANSAS		
Chemical Co.	M	220
LOUISIANA		
Oil Company	M	1200
Electric Power Co.	C	6390
Electric Power Co.	C	3000
Electric Power Co.	M	110
MAINE		
Paper Co.	M	200
Paper Co.	M	600
MARYLAND		
Naval Plant	M	620
MASSACHUSETTS		
Electric Power Co.	M	400
MICHIGAN		
Auto. Manufacturer	M	1600
Electric Power Co. (3)	M	610
		160
		160
Electric Power Co.	M	200
NEW HAMPSHIRE		
Paper Co.	M	300
Electric Power Co.	C	4200
NEW JERSEY		
Oil Company	M	845
Electric Power Co.	M	3200
Electric Power Co.	M	200
Electric Power Co.	M	250
Electric Power Co.	C	4800
Electric Power Co.	C	7400
Electric Power Co.	N	15300
NEW YORK		
Electric Power Co.	N	300
Electric Power Co.	N	320
Chemical Co.	N	100
NORTH CAROLINA		
Chemical Co.	M	300
Paper Co.	M	218
Paper Co.	M	1500
OHIO		
Electric Power Co.	M	200
Electric Power Co.	C	2500
Electric Mfgr.	N	200
Electric Power Co. (2)	M	250
		120
PENNSYLVANIA		
Electric Power Co.	N	60
Electric Power Co.	C	18400
Electric Power Co.	C	4200
Electric Power Co.	C	9000
TENNESSEE		
Atomic Plant	N	800
Paper Co.	M	1050
TEXAS		
Oil Company	M	2500
Electric Power Co.	C	6000
VIRGINIA		
Textile Plant	M	700
WASHINGTON		
Pulp Co.	M	1200
Pulp Co.	M	500
CANADA		
Pulp Mill	M	300
Auto Mfgr.	M	366
FRANCE		
Electric Power Co.	N	10560
INDIA		
Electric Power Co.	N	8000
ITALY		
Electric Power Co.	C	3500
Electric Power Co.	M	440
Electric Power Co.	N	90
Electric Power Co.	N	460
JAPAN		
Electric Power Co.	C	560
Electric Power Co. (2)	M	2@120 ea.
Electric Power Co.	M	100
PUERTO RICO		
Electric Power Co.	C	2400
Chemical Co.	M	300
Electric Power Co.	M	450

RELATED PUBLICATIONS AVAILABLE FROM CRANE-COCHRANE

(1) Sodium Zeolite Softeners.....Index 3.01
(2) Hydrogen Zeolite Cation Exchange Softeners.....Index 3.02
(3) Experiences with Salt Splitting De-Alkalizers.....Index 3.15
(4) Demineralizers vs. Evaporators.....Index 4.06
(5) Automatic Water Demineralization Accelerates Tin Plate Production.....Index 4.08
(6) How An Automatic Demineralizer Handles Longview Fibre Needs.....Index 4.10
(7) New Way to Remove Feedwater Silica.....Index 6.02
(8) Demineralizers Replacing Evaporators—Ford Motor Company—River Rouge.....Index 4.40
(9) Water Treatment at Public Service Electric & Gas Co., Linden, N. J.....Index 4.41
(10) Scavenger Condensate Demineralizers Combat Deposits for Potential 1% Heat Rate Gain.....Index 4.42
(11) Water Conditioning Trends in the Paper Industry.....Index 4.43
(12) Two Bed Primary System Solves Mixed Bed Demineralizer Problems.....Index 4.44
(13) Modern Water Treatment Developments for Boiler and Nuclear Plants.....Index 4.45
(14) Desilicizer Feedwater Process Aids Scovill.....Index 4.48
(15) Ion-Exchange Columns Neutralizer.....Index 17.14
(16) New Regenerable Process Upgrades Condensate for Boiler Feed.....Index 2.80
(17) Cleaning Up Condensate.....Index 2.82
(18) Producing High Purity Water.....Index 4.54
(19) Demineralization Systems.....Index 4.55

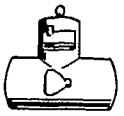


Scavenger Demineralizers in Supercritical Pressure Boiler Plant (See Case 3 —Page 32)



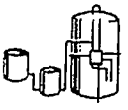
HOT PROCESS SOFTENER

Highly efficient precipitation at high temperatures reduces hardness, silica, alkalinity and total dissolved solids. Publication No. 2.01



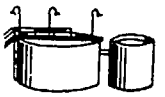
JET TRAY DEAERATOR

Delivers deaerated water with an oxygen content not to exceed 0.005 cc per litre—less than 7 parts per billion! Publication No.1.16



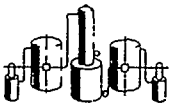
ZEOLITE SOFTENER

Provides high quality effluent at minimum cost. Crane-Cochrane Hydromatic Single Control Valve provides positive, accurate control of all phases of the softening and regenerating cycle. Publication No. 3.01



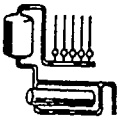
SOLIDS CONTACT REACTOR

Slurry blanket principle efficiently removes solids, turbidity, color, taste, silica, fluorides; reduces alkalinity and hardness from water for boiler feed industrial process and municipal purposes. Publication No. 7.00



DEMINERALIZERS

Crane-Cochrane ion exchange units deliver a continuous supply of demineralized silica-free water at extremely low cost.



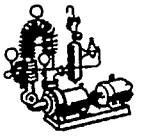
CONTINUOUS BLOWOFF SYSTEMS

Recover heat ordinarily lost when boilers are blown directly to sewer. Saves heat and fuel; maintains uniform boiler concentrations; quickly returns original investment. Publication No. 8.01



CRANE-COCHRANE SPECIALTIES

Multiport Relief Valves, All Service Separators, Multiport Drainers, Steam Purifiers.



CONDENSATE RETURN SYSTEM

Returns condensate to boiler or "make-up" system without appreciable temperature or pressure drop. Increases production, lowers fuel costs, improves quality and uniformity of product. Publication No. 14.01

CRANE VALVES • PUMPS • FITTINGS • WATER TREATMENT • PIPING • PLUMBING • HEATING • AIR CONDITIONING

CRANE CO., P.O. BOX 191, KING OF PRUSSIA, PENNSYLVANIA, 19406

Representatives in principal cities in U.S., also Santiago, Chile; Paris, France; Rotterdam, Holland; LaSpezia, Italy; Mexico City, Mexico; Manila, Philippine Islands; Santurce, Puerto Rico; Caracas, Venezuela.
HEAT TRANSFER DEPARTMENT, 300 Park Ave., New York, N.Y. 10022. Shell heat exchangers and cooling sections.

Bulletin No. ADC4—1071—2.5M966

Printed in