Chemical Processing
by ION EXCHANGE

Color Removal
Carry Over
Catalyst Recovery
Acid Removal
Deashing
Ammonia Removal
Amine Removal
Brine Purification

ROHM AND HAAS

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INDEX

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Chemical Processing By Ion Exchange

INTRODUCTION

The principles of ion exchange were recognized hundreds of years ago, but only in the last several decades have ion exchange resins been available that could be adapted for use in diverse applications. A considerable amount of information and literature is available covering the use of Amberlite ion exchange resins in water treatment. This manual discusses a few of the many non-water treatment applications for these resins and is written as a general introductory manual for these process applications. It is intended to stimulate ideas for further use of these versatile resins.

The ABC's of Ion Exchange

Ion exchange resins can be described simply as solid, insoluble acids or bases which are capable of entering into chemical reactions in the same way as their mineral or organic acid or base counterparts. Simply illustrated:

1. $H_2SO_4 + 2NaOH \leftrightharpoons Na_2SO_4 + 2H_2O$.
   In the above reaction we can substitute a strongly acidic cation exchange resin such as Amberlite IR-120 PLUS for the sulfuric acid and have:

2. Amberlite IR-120 PLUS (H) + NaOH $\leftrightharpoons$ Amberlite IR-120 PLUS (Na) + H_2O
   or similarly substitute a strongly basic anion exchange resin for the sodium hydroxide in the reaction and have:

3. H_2SO_4 + Amberlite IRA-400 (OH) $\leftrightharpoons$ Amberlite IRA-400 (SO_4) + H_2O.
   Salt splitting reactions can also occur in dilute solutions with a shift in the equilibrium becoming more favorable as the products of the reaction are removed. This condition is favored by columnar operation as compared to batch operation. Example:

4. Amberlite IR-120 PLUS (H) + Na_2SO_4 $\leftrightharpoons$ Amberlite IR-120 PLUS (Na) + H_2SO_4, or

5. Amberlite IRA-400 (OH) + Na_2SO_4 $\leftrightharpoons$ Amberlite IRA-400 (SO_4) + NaOH.

Combining the above reactions (4) + (3) or (5) + (2) can achieve deionization of dilute solutions of sodium sulfate. Ion interchange is also possible, as illustrated by the exchange of sodium on a cation exchange resin for calcium (or magnesium) in a water softner. In this reaction Amberlite IR-120 PLUS will hold the divalent ions more strongly than the monovalent cations (at low concentrations). The reaction below illustrates this phenomenon.

6. Amberlite IR-120 PLUS (Na) + $CaCl_2$ $\leftrightharpoons$ Amberlite IR-120 PLUS$_2$ (Ca) + NaCl.

The above reactions (4), (5) and (6) are all reversible and the regeneration process is carried out by increasing the concentration of the product acid (4), base (5) or salt (6). This will drive the reaction in the opposite direction and concentrate the removed ions in the regenerant.

Ion exchange reactions are influenced by many factors: mass action relationships, size of hydrated ions, valence of the ions, their atomic number and the system temperature. In addition, the acid or base strength of the exchange sites and the degree of crosslinking of the resin also affect the ion exchange process. Consideration of the foregoing factors can give some understanding of ion exchange reactions.

Ion Exchange Resin Chemistry and Structure

The development of ion exchange resins suitable for a wide range of process applications has progressed rapidly over the last forty years. Although many of the earlier ion exchange resins were relatively simple to synthesize, the present line of Amberlite and Amberlyst ion exchange resins are sophisticated polymers produced through complex and carefully controlled manufacturing processes necessary to achieve their unique properties. For a majority of the present Amberlite and Amberlyst ion exchange resins, the building blocks are styrene and divinylbenzene. There are, however, some important resins in which the polymer matrix is based on methacrylic or acrylic acid and divinylbenzene, condensation products of epichlorohydrin with amines, and others. In all cases, it is necessary to have a crosslinked structure to give water and solvent insolubility and physical strength. Divinylbenzene (DVB) is the most commonly used crosslinker, having two vinyl groups which can polymerize within separate styrene or acrylic polymer chains to give a thermoset or crosslinked resin structure. Higher crosslinker levels result in lower equilibrium moisture content in the resulting resin. However, the polymer structure of styrene and DVB alone in its normal state would be very

hydrophobic and have very little or no water of hydration if it were not for the ionically active functional group on the resin.

Cation exchange resins have anionic groups, such as SO_3^-, or COO^-, attached, to the crosslinked polymer matrix. A mobile cation such as H^+, Na^+, Ca^{++}, Mg^{++}, etc. can be attracted to the ion exchange site and exchange for the cation present, if conditions are favorable. Anion exchange resins, conversely, have a cationic group, such as RNH_3^+, R_2NH, attached to the crosslinked polymer structure. A mobile anion in solution, such as OH^-, Cl^-, HCO_3^-, SO_4^{--}, etc., can, under suitable conditions, be attracted to the exchange site on the resin, and exchange for the anion present.

The first styrene—divinylbenzene ion exchange resins were composed of a hydrated resin structure continuous through the bead. This is what we now refer to as a gelular or "gel" matrix structure. In gel resins, the degree of crosslinking determines the moisture content, the strength, the swelling characteristics in different solvents and with different solutes, and the resistance to osmotic and thermal shock. Crosslinking level and type can also affect the oxidation resistance of the resin, as well as the resin's selectivity for certain ions.

A new resin bead structure, developed by Rohm and Haas, was introduced to the market in 1959. This structure is called macroreticular and differs from the gel resins in that the macroreticular resin bead has the appearance, under high magnification, of compacted gel microspheres. This porous structure is created by polymerizing the styrene and divinylbenzene in the presence of a third ingredient in which the monomers are soluble but the resultant polymer is insoluble. The third ingredient is then removed from the resin structure leaving a resin bead that has both a continuous resin phase *and* a continuous pore phase, resulting in considerable internal surface area. The macroreticular matrix makes it possible to increase the crosslinker level to much higher values without significant loss of available exchange sites. At the same time, one obtains the advantages of higher crosslinking—improved strength, shock resistance and oxidation resistance. The unique fixed porosity of the macroreticular structure (as compared to a gel structure) means that the surface exchange sites are available even in nonaqueous media where there is no water for the hydration or swelling, necessary in gel resins. The effective resin surface in contact with the fluid to be processed is increased to many times that of a gel resin. Figure #1 shows the differences in gelular and macroreticular structure.

Polymeric Adsorbents

The logical extension of the macroreticular resin structure was the development of macroreticular polymeric adsorbent resins. In the manufacture of these resins, control of pore size, porosity and surface area, together with modification or change of the polymer chemistry, allows tailoring the adsorbent to a wide range of adsorption applications.[1]

Macroreticular adsorbents are available with either aromatic character, derived from the incorporation of styrenic monomers, or aliphatic character resulting from the use of acrylic monomers in their synthesis. These latter copolymers yield a more polar surface with hydrophilic characteristics. Modifying the resin structure by incorporating monomers of varying polarity allows production of adsorbents with a wide range of hydrophilic characteristics.

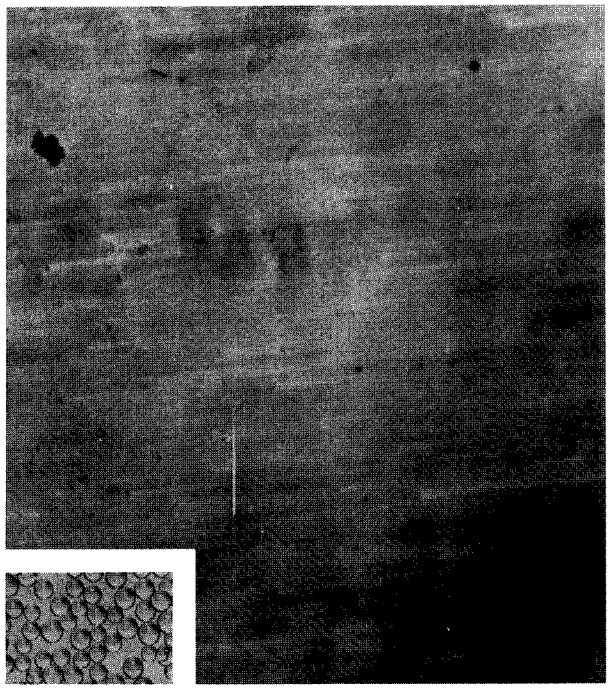
Regeneration or elution of the material adsorbed onto these synthetic adsorption resins can be accomplished by: solvents; a change in the ionic concentrations; acids; bases; or thermal elution. Since these adsorption resins are relatively inert they are very stable and can be used for multiple cycling without adverse effect on their adsorptive capacity and characteristics.

Strong Electrolyte versus Weak Electrolyte Ion Exchange Resins

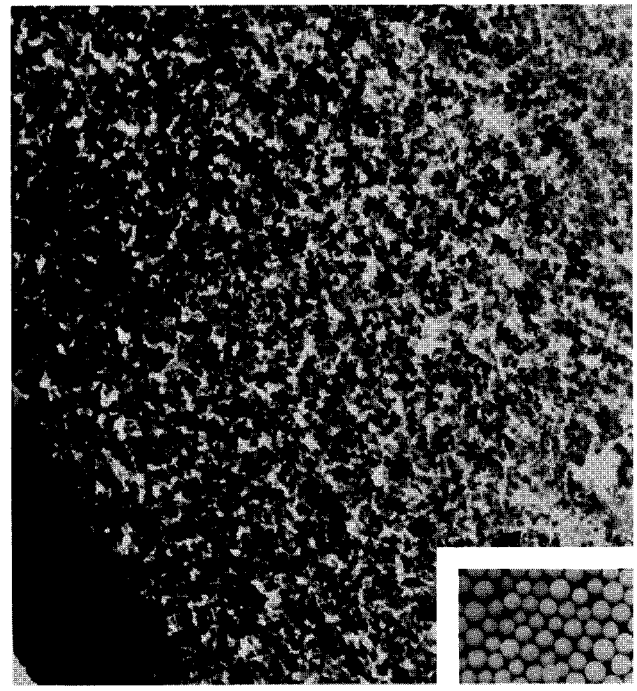
In a previous section we discussed strong electrolyte (strongly acidic or strongly basic) ion exchange resins. However, it is possible to synthesize ion exchange resins with a considerable variation of acid and base strength. In general, a strong electrolyte ion exchange resin differs from a weak electrolyte resin in its ability to split neutral salts (such as NaCl or $NaNO_3$). For example, the salt splitting cation capacity (SSCC) of a strongly acidic cation exchanger, such as Amberlite IR-120 PLUS, is over 98% of its total capacity, while some weakly acidic cation exchangers may

1. Amberlite Ion Exchange Resin Bulletins IE-172, IE-204, IE-159, IE-89-65

FIGURE 1



ELECTRON PHOTOMICROGRAPH OF GELULAR ION EXCHANGE RESIN. (INSET SHOWS RESIN UNDER LESS MAGNIFICATION.)



ELECTRON PHOTOMICROGRAPH OF MACRORETICULAR ION EXCHANGE RESIN. (INSET SHOWS RESIN UNDER LESS MAGNIFICATION.)

exhibit a small amount of salt splitting capacity. Similarly, the same relationship exists with strong electrolyte anion exchangers versus weak electrolyte anion exchangers. Strong electrolyte ion exchange resins can be used over most of the pH scale, while weak electrolyte ion exchangers will have an applicable pH range cut short 3 to 6 pH units from the extreme acid side (0) for cation exchange resins or from the extreme base side (14) for anion exchange resins. The most useful application areas are above pH 6 for weakly acidic cation exchange resins and below pH 8 for weakly basic anion exchange resins.

Regeneration of weak electrolyte resins to acid form (cation resins) or base form (anion resins) can be accomplished with near theoretical or stoichiometric regeneration levels. Strong electrolyte resins generally require over approximately 300% of the theoretical ion exchange capacity of regenerant in order to achieve a substantial conversion to usable capacity level.

The weak electrolyte resins have greater total capacities as well as better regeneration efficiencies than do strong electrolyte resins. These properties are due mainly to increased availability of ion exchange sites and the weak bonding of ions to those sites. Their pH limitations and their inability to remove certain weakly ionized anions or cations from solution limit their application. Nevertheless, the use of weak electrolyte resins in combination or conjunction with strong electrolyte resins can provide a means of combining high capacity with good regeneration efficiency along with favorable removal (low leakage) of weakly ionized cations or anions.

Liquid Ion Exchangers

Mention of liquid ion exchange media (used in solvent extraction) is in order, since both anionic and cationic insoluble liquids are used in applications in which their function is similar to the bead-type ion exchange resins.[2] The advantage of these liquid exchangers is their ability to work in truly countercurrent, continuous-type service, both in loading and stripping operations. This allows treatment of solutions containing higher concentrations of

2. Amberlite LA-1, IE-41

dissolved solids than would be practical with solid ion exchange resin systems. Most of the available liquid exchangers are in the category of weakly basic anion exchangers such as Amberlite LA-1 and Amberlite LA-2.

Ion Exchange in Non-Aqueous Media

Some of the same properties of ion exchange resins that influence reactions in *aqueous media* also affect reactions in *non-aqueous media.* The basic difference is availability of exchange sites on the resins. In aqueous media, the resin is fully hydrated and expanded to the maximum degree the crosslinkage will permit. In non-aqueous media, the solvent action of the media on the resin usually causes less swelling, thereby reducing the availability of exchange sites for reactions. It follows that the more polar a solvent (higher dielectric constant), the more favorable will be the rate of exchange. Other factors such as molecular weight, ionic size and temperature will influence rate of exchange and capacity, just as in aqueous media.

Macroreticular resins, with their fixed porosity in the resin matrix, are usually more efficient in non-aqueous applications. The continuous pore phase of these resins allows a non-aqueous phase to fill these pores, thereby gaining access to the exchange sites which exist on the internal surfaces of the resin beads. The diffusion path length into the gel phase is substantially shortened with these resins, thus reducing their dependency upon gel phase swelling as compared to gel resins.

In applications in which the medium is not water soluble, regeneration of Amberlyst or Amberlite ion exchange resins is generally accomplished by using an intermediate solvent such as alcohol (or one miscible with both the solvent and water). This is done so that an aqueous regeneration system can be used to regenerate the resin with appropriate acid or base. The displacement of the water used in the regeneration and rinsing step can then be carried out with the intermediate solvent, which in turn would be displaced with the solvent or non-aqueous media to be used.[3]

Batch versus Column Operation

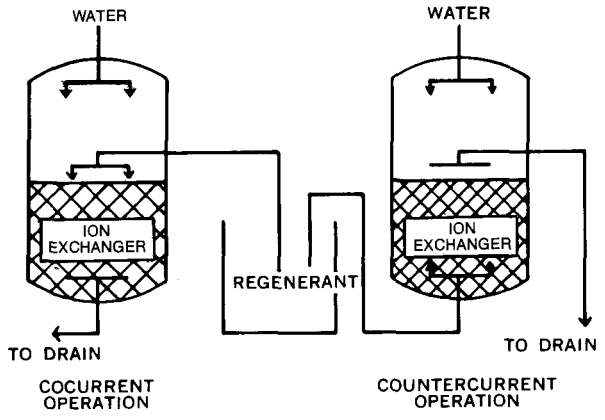
In batch or equilibrium operation the ion exchange resin is contacting the whole of the electrolyte solution to be treated and the reaction will reach an equilibrium (depending on time). The extent to which the reaction is completed will be dependent upon the equilibrium constant for the exchange system. In reactions (2) and (3) (Page 2), the reactions will go to completion. In reactions (4), (5), and (6) it would be necessary to go through several contacts of the electrolyte solution with freshly regenerated resin to approach completion of the reaction. In commercial practice, a countercurrent batch contact approach is used when there may be reason to filter or screen off the resin between contacts. This can be due to suspended material in the electrolyte solutions, such as resin-in-pulp treatment for uranium recovery. The equilibrium reached in each stage will determine the number of stages of contact necessary to achieve the separation required.

In column or dynamic operation, one can visualize each layer of beads as being a batch contact where a certain degree of equilibrium is reached (depending upon time of contact or flow rate). As the solution passes on to the next bead, the equilibrium is further driven toward completion, and so on down the column. With the almost infinite number of contacts available, the equilibrium is driven to a high degree of completion. The degree of completion will be dependent upon: 1) the equilibrium constant, 2) the degree of regeneration of the resin, 3) the contact time or flow rate, 4) bed depth of resin, 5) concentration of the exchanged electrolyte and other background ions, 6) distribution of flow, 7) temperature, and 8) particle size of the resins.

Since regeneration of an ion exchange column is usually at 70% of total capacity (or less), there will be a band of resin left in the column which is regenerated to a lesser degree than the rest of the column. The location of this band of partially regenerated resin will depend upon the direction of flow of the regenerant solution relative to the service or loading flow. If the regeneration flow is the same direction as the service or loading flow (cocurrent) the band of partially regenerated resin will be on the bottom of the column (assuming downflow operation). By reversing the direction of flow of the regenerant solution relative to that of the service or loading flow (countercurrent), the resin on the bottom of the column (assuming downflow operation) would be most completely regenerated (*See Figure #2*). The resin on top would be only partially regenerated. Now, as the loading solution is passed down the column,

3. Amber-hi-Lites No. 126

FIGURE 2—COMPARISON OF COCURRENT AND COUNTERCURRENT (COUNTER FLOW) OPERATION



the partially regenerated resin on the top would remove some electrolyte from the concentrated loading solution. The solution will then contact resin regenerated to a greater degree as it proceeded down the column at lower and lower concentrations of electrolyte to be removed. Countercurrent operation is more effective in driving the equilibrium to completion while achieving minimum leakage and longer cycle times.

EQUIPMENT USED FOR ION EXCHANGE

Laboratory Techniques

In most process applications the techniques described in the *Amberlite Ion Exchange Resins Laboratory Guide* IE-85 will be adequate to permit setting up bench scale experiments. Some additional comments and precautions[4] should be noted when working with systems other than dilute aqueous types. Some unusual physical, chemical or thermal conditions, such as may be encountered in process applications areas, are as follows:

1. Liquids should never be added to dry resins in a column since hydration or solvation may cause swelling with sufficient force to shatter the column.

2. Changing from one solvent medium to another should not be done without testing the swelling or shrinkage that may occur in an open vessel with large diameter and height. Where a large amount of swelling is observed, it is best to agitate the resin and introduce the new solvent upflow while maintaining a loosely packed resin bed. As a precaution, the columns should be shielded. For background information on this subject, refer to the article, "Behavior of Ion Exchange Resins in Solvents Other Than Water," by Bodamer and Kunin, Ind. Eng. Chem. Vol. 45, Page 2577-2580, Nov. 1953.

3. The viscosity of solutions being treated may be sufficiently high to cause excessive pressure drop across the resin bed. High pressure, when used to achieve flow, may cause disruption of the column by blowing out stopper connections or shattering the column. Heating or addition of a diluent to the solution may lower the viscosity sufficiently to alleviate excessive pressure problems.

4. Using a heated solution will require water jackets or heating mantels to maintain temperatures through the column. If this is not done crystallization and precipitation may occur as the solution passes through the column.

5. Test column materials may have to be modified or changed to be compatible with different solutions, solvents, or regenerants. Two cases which illustrate these compatibility problems are: hydrofluoric acid attacking glass and aromatic solvents swelling or dissolving rubber tubing or stoppers.

6. In most cases, all liquids to be treated should have suspended, particulate matter removed by satisfactory filtration. This will prevent plugging and fouling of the resin bed. It should also be recognized that in the service or regeneration cycle it may be possible to form precipitates that could hinder or stop flow. In some cases operation upflow with an unrestricted bed will allow the precipitate or suspended material formed to pass through the expanded resin bed and out of the column.

7. Formation or release of dissolved gases during the operation of the column may cause partial or complete blockage of flow. Removal of dissolved gases in the feed stream or keeping them in solution by operation under high pressure may solve this problem.

4. Amber-hi-Lites No. 153

Plant Equipment

The ultimate application of ion exchange resins or polymeric adsorbents is usually full scale plant operation. This requires design and/or specification of full size equipment for the purposes required. Ion exchange processes can be scaled up directly to full plant size operation from data derived from 1 inch diameter columns.

Discussion of the types of systems available for full scale operating plants could be endless, but for the purpose of this manual, some general comments, limiting factors and alternate choices are given.

The main categories of use for ion exchange are:

1. Interchange of ionic constituents.
2. Fractionation of ionic substances.
3. Concentration of ionic substances.
4. Removal of ionic substances.
5. Miscellaneous applications (including catalysis and adsorption).

Often, after a brief laboratory test or theoretical calculation, a possible application for ion exchange is identified. It is then necessary to evaluate the practical potential of the ion exchange process by making a few brief calculations from the laboratory or bench scale test results. These calculations are carried out to justify proceeding. To have a better basis for making these calculations, one must be familiar with equipment designs and variations in processes using ion exchange resins.

Ion exchange equipment provides a means of containing the resin in proper configuration, with distribution systems to handle the loading, regeneration, and backwash solutions. These distribution systems also handle rinsing or air agitation and provide uniform flow over the entire area of the resin bed under varying flow rates, temperature and viscosity conditions. The larger the unit, the more difficult the design problems.

It is important that valves chosen have the ability to be operated with varying opening and closing speeds and also accurately control flow under a variety of pressure conditions. These factors will prolong resin life and help to provide a smooth performing operation.

Instrumentation

Various forms of instrumentation are available to carefully control and monitor the process as it proceeds. Instrumentation also allows for varying degrees of automation in the unit's operation. This is a complex area, but considerable advancement has been made in the recent past.

Much of the experience gained in water treatment applications can be useful in designing equipment for processing applications. As a result, many manufacturers of equipment for water treatment applications are already involved in the design of equipment for process applications.

An important factor to be considered in design of equipment is resin bed configuration.

The ratio of bed depth to bed height can be a significant factor, depending upon the process and ion exchange resin involved. Weakly acidic cation exchange resins, many weakly basic anion exchange resins and most strongly basic anion exchange resins expand and contract by 20% or more on regeneration and exhaustion depending on the degree of site utilization. In changing the liquid medium or solvent in contact with the resin, swelling or shrinkage of considerable magnitude may occur. If the bed depth is much greater than the diameter of the column, the swelling can cause severe packing of the bed, resulting in resin breakage, channeling of liquid flow through the bed and increased pressure drop. The swelling characteristics of the resin must be taken into account when considering the positioning of the regenerant or elution distributors so the resin in the loaded or exhausted state will be approximately six inches below the distributors.

The depth of the resin will also fix, to some extent, the height of the tank containing the resin. In most ion exchange or adsorption resin operations a backwash is necessary or desirable in order to:

1. flush any fine particulate material that may have been filtered out by the resin bed during the service or loading cycle,
2. remove any resin particles or fines that resulted from resin breakdown,
3. reclassify the resin bed to assure good hydraulic characteristics with uniform flow of regenerant, and loading solutions.

The backwash flow should be sufficient to expand the resin bed at least 40% and in many cases 50-100%. Provisions for greater bed expansion during the backwash of low density resins is desirable to insure a flow sufficient to remove particulate material and resin fines. This expansion space is called "freeboard." In some cases it is desirable to keep this freeboard space to a minimum. This reduces the amount of liquid that causes dilution and mixing with the product solution during regeneration, and again when going back into service. Using air or water domes in this space will remove the dilution problem and still allow incorporation of the freeboard for backwashing. This is done while flow enters through a distributor just above the resin bed.

In order to reduce the problems associated with resin swelling and suspended material in the feed solution it is frequently desirable to operate in an upflow fashion. The freeboard space necessary in upflow operation will be determined by the service flow rate.

The effect of temperature on the viscosity of the backwash liquid must be taken into consideration when adjusting backwash flow to compensate for the variations expected.

Distributor designs are many, ranging from the inlet pipe being directed at the domed head of small vessels to slotted pipes, drilled pipes, screen-wound drilled pipes, and Johnson Vee-Wire screens, etc. Arrangements of the distributors are also numerous, included are hub and laterals, header and laterals, and nozzles attached to a flat plate.

Many times multiple distributors are necessary to handle the wide ranges of flow that may be necessary. This is due to flow rates running as low as 0.25 to 0.5 gpm/ft^3 (2.0 to 4.0 l/hr/l) for regenerants or elution, while service or loading flows may be as high as 2 to 5 gpm/ft^3 (16.0 to 40.1 l/hr/l).

Sizing of the tank or vessel is also dependent upon the flow to be handled, since distribution and pressure drop across the resin bed must be considered. Generally, rates below 0.5 gpm/ft^3 (4.0 l/hr/l) or above 5 gpm/ft^3 (40.1 l/hr/l) should be cause for concern due to distribution problems on the low end, and pressure drop on the high end. However, special equipment designs can handle up to 50 gpm/ft^3 (401 l/hr/l) or higher.

Using water systems again as the benchmark, flow rates ranging from 0.25 to 5 gpm/ft^3 (2.0 to 40.1 l/hr/l) are satisfactory. Rates higher than 5 gpm/ft^3 (40.1 l/hr/l) are used only in special cases. The flow rates in gpm/ft^3 (l/hr/l) determine contact time of the fluid with the resin. Flow rate also affects the capacity of weak electrolyte ion exchange resins to a large degree. Strong electrolyte resins are not as sensitive to contact time, thus their capacity is less dependent upon flow rate.

Ion Exchange Systems

The types of systems available in ion exchange equipment are so numerous that only a few representative systems will be discussed here. The simplest is used for *batch operation* in which the only requirement is a means of separating the resin from the solution. A screening device or basket is used commercially. Large bead resins are available and are used for resin-in-pulp (RIP) processes in the uranium industry that concentrate uranium from dilute leach liquor containing very fine ore particulates. Elution of the uranium can also be carried out in a batch elution. In this case, several stages of contact are used for both loading and elution.

The next simplest system is a *one-column resin process* such as is used in the deacidification of formaldehyde. In this system a weakly basic resin such as Amberlite IRA-68 or Amberlite IRA-94 is used to remove formic acid. Regeneration is carried out with ammonia or other bases.

A two-bed ion exchange system using both cation (Amberlite 200) and anion (Amberlite IRA-94) exchangers is illustrated by a chromate recovery system used for treating chrome plating rinse water (*See Figure #3*). The strongly acidic cation exchanger removes the trivalent chromium (and other cations present) while the weakly basic anion resin removes the hexavalent chromium as an anion. Regeneration of the cation exchanger with sulfuric acid produces a fairly concentrated solution of the trivalent chromium as the sulfate salt (which can be disposed of by precipitation). The hexavalent chromium is eluted from the anion exchanger with ammonia or sodium hydroxide in a concentrated solution. This solution can be recycled to the plating bath by passage through a strongly acidic resin in the hydrogen form. This produces a dilute chromic acid solution that can be concentrated by evaporation and returned to the plating bath.

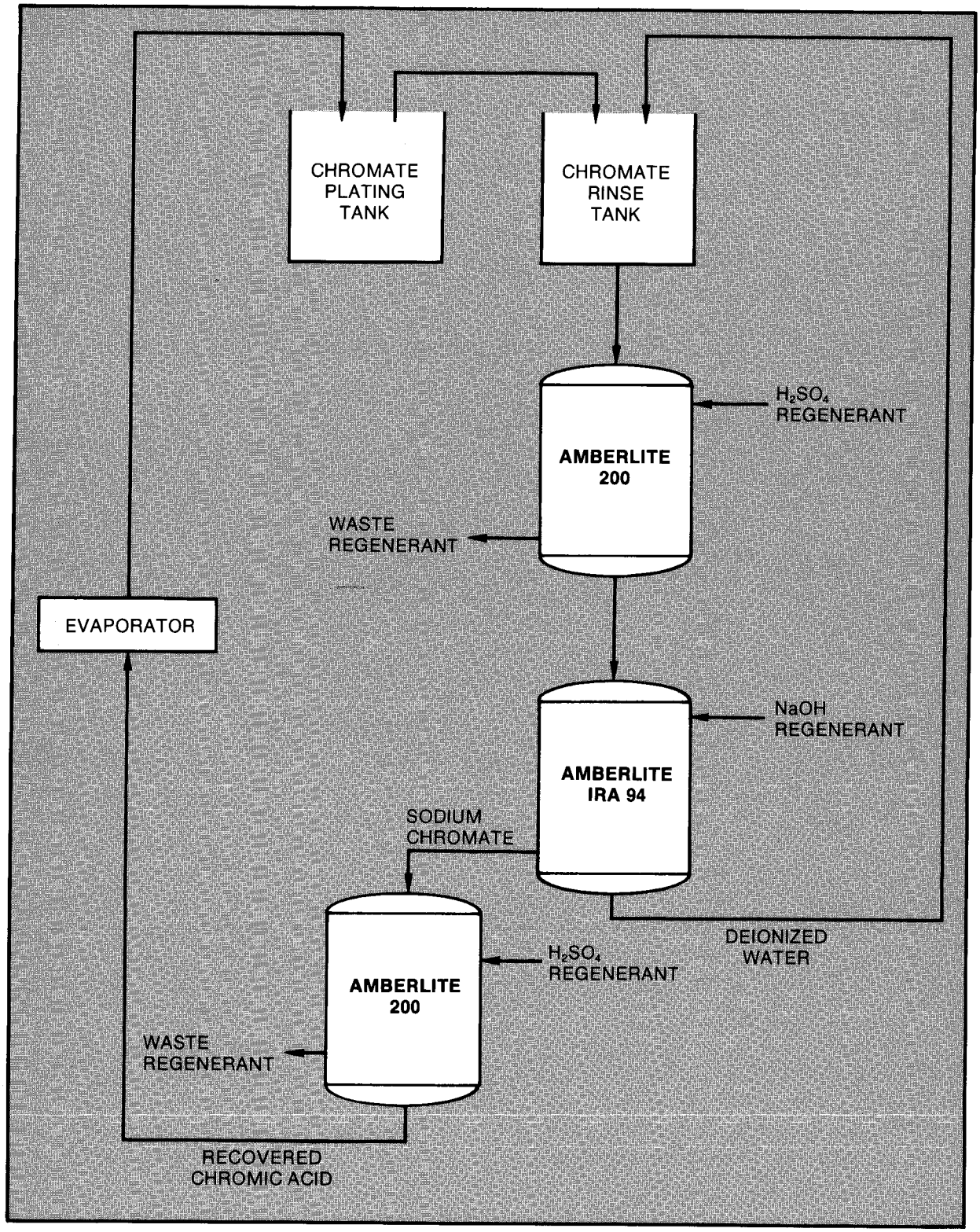


FIGURE 3
RECOVERY OF CHROMATE FROM CHROME PLATING RINSE WATER

Multibed systems employing combinations of cation and anion exchange resins are being used in many processing applications areas. The possible combinations are efficient and economic while separating the ionic constituents of the media to be treated (strong electrolytes from weak electrolytes or separation of ionic species of varying ionic strengths or valences). Some of the configurations possible are:

1. Strongly acidic cation (SAC) — weakly basic anion (WBA) — strongly basic anion (SBA),
2. SAC — WBA — SAC — SBA
3. Weakly acidic cation (WAC) — SAC — WBA — SBA
4. SAC — SBA — Monobed® or Mixed bed — (MB)

Where carbonates or bicarbonates are present in the medium to be treated, it is often advantageous to remove the carbon dioxide (formed after treatment with the cation exchanger in the hydrogen form). This is done by a deaeration or vacuum degassing device, rather than utilizing the capacity of a strongly basic anion exchanger to do the job.

Some economies in equipment costs are possible utilizing a *Stratabed® or layered bed* approach. The weakly acidic cation exchange resin can be put in the same vessel with a strongly acidic cation exchanger and the bed functions in two separate layers. This produces results similar to those of these resins in separate beds. The same approach is also possible with weakly basic and strongly basic anion exchangers. Special Stratabed grade resins are available for this service.

Monobed® resin systems in which cation and anion resins are intimately mixed for service flow and hydraulically separated for regeneration, offer advantages over separate bed systems. They provide a higher degree of ion removal plus maintaining controlled pH. The booklet "Monobed Deionization With Amberlite Ion Exchange Resins" IE-26, can be referred to for a more detailed description.

Regeneration or elution of an ion exchange system for maximum efficiency is becoming more important with increasing chemical costs, which can be a very significant part of operating expenses. Maximum efficiency is also highly important in eluting products to be recovered so that less energy or chemicals are needed to obtain a concentrated solution or solid product.

Highly concentrated regenerants or eluting solutions would appear to be desirable in shifting the exchange equilibrium by mass action. The product or waste is concentrated in a minimum volume. However, some of the limiting factors are:

1. osmotic shock on the resin causing high breakdown and loss,
2. limited solubility of the product or waste (such as calcium precipitation when regenerating a cation exchanger in the calcium form with sulfuric acid),
3. use of regenerants or eluting agents that have oxidizing potential (peroxides, potassium permanganate, nitric acid,* etc.).
4. total volume of highly concentrated regenerants or eluants may be too small to give adequate uniform contact with all the resin.
5. dilution of the concentrated regenerant by water in the resin bed may result in the heat of dilution raising temperatures above those recommended for the resin.

Generally, 10% concentration of acids or bases would be the practical upper limit in most ion exchange operations; however, in certain cases a concentration of 20% or slightly higher, can be utilized. There are some cases in which lower concentrations will do a superior job in achieving more complete elution in fewer bed volumes (particularly with adsorption resins).

The shape of the regeneration or elution curve can be influenced by regenerant concentration, temperature and rate of flow. It is important to determine this curve by analysis of the emerging solution during the regeneration or elution step (*See Figure #4*). This curve will aid in optimization of regeneration variables. Also, by analyzing for the eluted ion product, one can determine which portion of regenerant (usually the last ⅓ to ½ of the elution or regeneration cycle) can be saved and reused for the first portion of the next regeneration cycle. This will decrease the total regenerant or eluting solution, as well as increase the concentration of the product or waste. The displacement rinse that follows the regeneration should be at the

*See Safe Handling Information Section

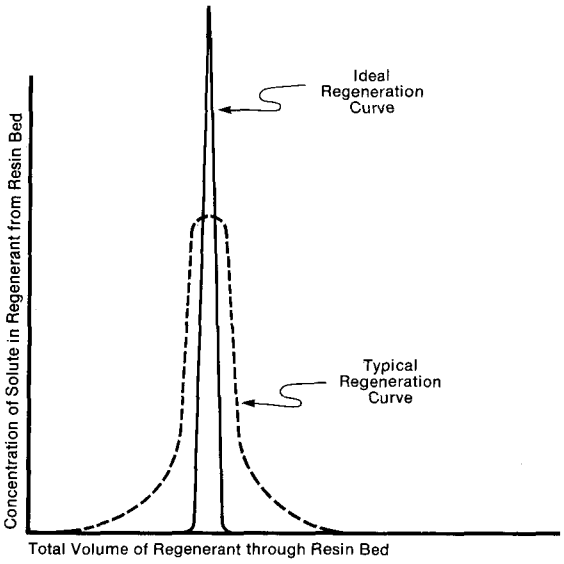


Figure 4—Ideal vs. typical regeneration curve

same flow rate as the regeneration or elution step. This will remove the last of the regenerant solution that is still in the resin column.

When an acid-regenerated cation exchange resin is followed by an alkali regenerated anion exchange resin, it is desirable to mix the regenerants to obtain a neutral waste.

Sometimes it is necessary to use a step-wise increase in the concentration of the regenerant in order to remove a portion of an adsorbed solute from the resin bed. This is done so as not to exceed the solubility limit of a particular ion in the regenerant solution (such as calcium sulfate in sulfuric acid). Automated controls are available for such procedures.

Utilization of something less than total capacity is often a way of gaining greater efficiency from the regenerant used, particularly with strong electrolyte resins. The last 30% of the total capacity is obtained only with great excesses of regenerant. With weak electrolyte resins it is generally possible to operate at a level of 110 to 130% of theoretical regenerant required for the capacity utilized.

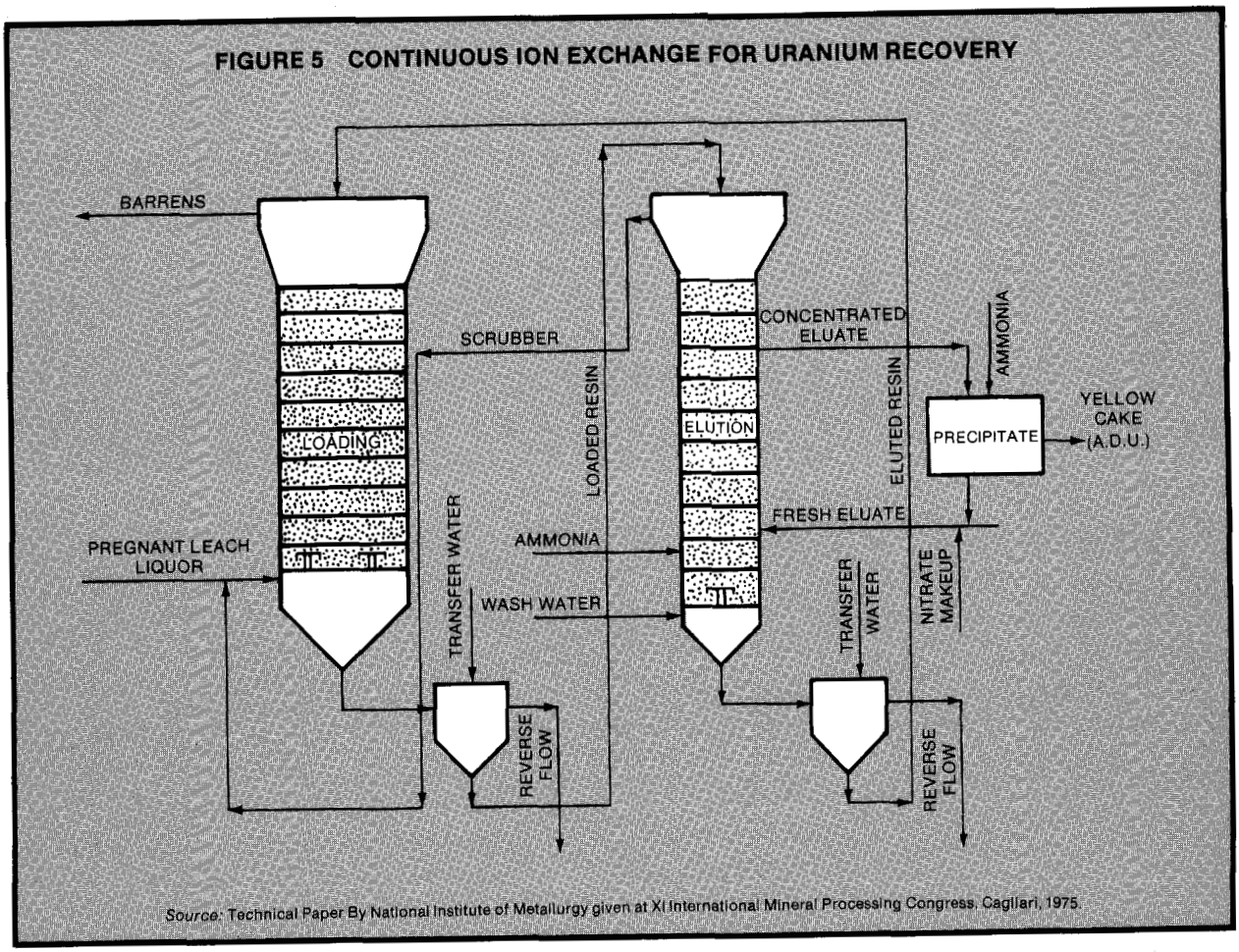
In previous discussions (Batch vs. Column Operation), mention was made of cocurrent versus countercurrent regeneration. It was pointed out that lower ion leakage and more efficient regenerant usage was possible with countercurrent operation. It is important to maintain a packed bed when regenerating or eluting the resin, since intimate contact of all the resin beads with regenerant or eluting solution is necessary to get maximum efficiency.

If the service flow is downward, countercurrent operation requires that the regenerant or eluting solution be passed upflow through the resin bed. Due to moderately high ionic concentration most regenerants are higher in density than water. The expansion of the resin bed even with low flow rates in an upflow direction can be significant, causing separation of the resin beads from one another. A slippage of the regenerant through the voids then occurs and the regenerant fails to contact all the resin. This can result in a less efficient regeneration process unless the bed is held in place in a packed configuration. Various means of maintaining a packed bed are available commercially through the use of such devices as a buried top take-off distributor, or by blocking the flow of water coming from the top distributor to the regenerant distributor while the regenerant is simultaneously passing up from the bottom to the regenerant distributor. Other methods include placement of inert low density resin granules or beads packing the freeboard space, or operating the service cycle upflow[5]. This is carried out at a flow rate sufficient to keep the resin bed compacted against the top distributor and regenerating downflow with the settled bed compacted on the bottom distributor.

In recent years there has been increased interest in equipment which is capable of approaching true continuous, countercurrent operation. Currently, several different approaches have been reduced to practice. In all such "continuous" ion exchange equipment designs, the ion exchange resin is moved, in pulses, in a direction counter to or opposite the flow of the solution being treated. Resin is then removed from the loading section or chamber and transferred to an elution or regeneration section where the flow of regenerant is usually counter to the flow of resin. Most such devices operate upflow in the loading section, with resin moving downward through the loading zone. Examples of this type of apparatus include the U. S. Bureau of Mines column, developed by engineers at the Bureau's Salt Lake City facility; the Porter columns, developed by Robert Porter Associates, Salt Lake City; the NIMCIX column, designed by the National Institute of Metallurgy in Johannesburg, South Africa; the Himsley column designed and marketed by Himsley Engineering, Limited in Toronto. One

5. Amber-hi-Lites No. 112

FIGURE 5 CONTINUOUS ION EXCHANGE FOR URANIUM RECOVERY



Source: Technical Paper By National Institute of Metallurgy given at XI International Mineral Processing Congress, Cagliari, 1975

continuous design, developed by Chemical Separations Corporation in Oak Ridge, Tennessee, utilizes a packed bed loading chamber, with process liquor moving downflow through the ion exchange resin. The resin is pulsed upwards through the loading section, then to an external loop where the resin is backwashed, regenerated and rinsed prior to re-entering the loading section. Figure 5 is an example of a continuous process for uranium recovery.

Rinsing excess regenerant from the ion exchange resin or removing the remaining quantities of a loading solution from the resin before regeneration is a matter of concern with regard to reducing the waste water or diluting a product stream. In the regeneration step, it was previously mentioned that it is important to keep the displacement flow at the same rate as the regenerant. Since there is still regenerant in the resin bed and the regeneration process is continuing, the flow must be kept uniform, as this last portion of regenerant is being swept through the column and out of the unit with the displacement rinse. When the displacement rinse is completed, it is desirable to sweep out the remaining entrained and adsorbed regenerant. This is best accomplished by increasing the flow rate, thereby flushing out the remaining amounts of regenerant.

It is beyond the scope of this publication to describe in detail the operational features of each column design. All are capable of at least closely approaching the thermodynamic ideal of true continuous countercurrent operation. The proper selection of such a column design can aid considerably in increasing the loading of ion exchange resins, a consideration of importance in processes where the ion concentration is somewhat high. Resin inventory in some cases can be reduced through the use of continuous ion exchange equipment.

CHEMICAL PROCESS APPLICATIONS

In the context of this manual, chemical process applications are defined as those dealing

primarily with the manufacturing processes of chemicals. Catalysis, which should be included under this definition, will not be covered here, since separate literature is available in this specialized area (Ref: Ion Exchange Catalysis and Matrix Effects—Rohm and Haas Bulletin IE-214). Waste treatment is included because of the possible recycle of the streams back to the manufacturing process.

Purification

Dimethyl Formamide

Cations and color bodies are removed from dimethyl formamide by using a strongly acidic cation exchanger such as Amberlite IR-120 PLUS, Amberlite 200 or Amberlite 252. This purification process is described in U.S. Patent 2,942,027 awarded to Du Pont. The resins are used in a Monobed® or mixed bed system with a weakly basic anion exchange resin such as Amberlite IRA-93 or Amberlite IRA-94, for removing formic acid and color.

Glycerin

Ion exchange is used commercially for the production of refined glycerin from crude glycerin solutions. Both deionization and color removal are important. The choice of ion exchange resins and systems will vary, depending upon the composition of the crude glycerin solution, and the nature of the impurities to be removed. A strongly acidic cation exchanger, such as Amberlite IR-120 PLUS, Amberlite 200 or Amberlite 252, followed by a weakly basic anion exchanger, such as Amberlite IRA-93, Amberlite IRA-94, Amberlite IRA-45 or Amberlite IRA-68, are used to remove the major impurities. In most cases, further polishing of the glycerin solution with another two-bed system is desirable. This two-bed system should consist of the same cation exchanger used in the first train, followed by a strongly basic anion exchange resin such as Amberlite IRA-900 or Amberlite IRA-910. For maximum deashing and decolorizing, some processes use an additional Monobed system to further upgrade the product. This Monobed system would generally use the same resins as chosen for the second two-bed train. The use of Amberlite 252 as the cation exchanger offers the advantage of better visual separation since this resin is black whereas anion exchangers are light colored.

Alcohol

Residual ammonia and amines are removed from alcohols by using Amberlite IR-120 PLUS, Amberlite IRC-84, Amberlyst 15 or Amberlite IRC-50S. Regeneration is carried out with an acid.

Formic Acid Removal from Formaldehyde

Weakly basic anion exchange resins, such as Amberlite IRA-68, Amberlite IRA-93 and Amberlite IRA-94, have been used successfully in the deacidification of formaldehyde.[6] The quantities of methanol and other minor constituents in the formaldehyde will affect the resin choice and performance. Capacities ranging from 1.5 to 4 lbs of formic acid/ft³ (24 to 74 g/l) of resin have been obtained. Ammonia or sodium hydroxide are the preferred regenerants. *Strongly basic* anion exchangers are generally not used because of their promotion of paraformaldehyde formation. If iron or copper contamination is a problem, Amberlite IRC-50S or Amberlite IRC-84 might be considered as a means of removing these troublesome cations.

Deacidification of Phenol-Acetone Streams

In the production of phenol by acid catalysis of cumene hydroperoxide, deacidification of the resulting phenol-acetone stream is necessary prior to distillation of the acetone. Formic acid and acetic acids may also be present. Under the conditions for deacidification, it is desirable to use the Amberlyst macroreticular resins. Both weakly basic Amberlyst A-21 and strongly basic Amberlyst A-26 have been used effectively in this application.

Phosphoric Acid

Removal of aluminum or ferrous iron from phosphoric acid by cation exchange resins such as Amberlite 200 or Amberlite IR-120 PLUS has been demonstrated. Amberlite 200 is preferred because of its superior durability, particularly when working with high concentrations of phosphoric acid. Capacities for aluminum and iron as high as 2.5 lbs/ft³ (40 g/l) of resin have been obtained, depending on concentrations, conditions of flow, and regeneration conditions. High levels (20 lbs/ft³ [320 g/l] or more)

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6. Amber-hi-Lites No. 113

and high concentrations (20%) of sulfuric acid are needed to obtain good regeneration and capacity.

Brine

Membrane cell technology is expected to find increasing use in future chlorine-caustic plants. Purification of the NaCl brine prior to electrolysis in these cells requires hardness removal to below 100 ppb. Amberlite IRC-718, a chelating ion exchange resin has proved effective for calcium and magnesium removal in this application. Regeneration is carried out using HCl followed by NaOH.

The electrolytic production of magnesium requires reduction of the boron level in the $MgCl_2$ brine. Amberlite IRA-743, a boron specific resin, is used, successfully in this application. Regeneration is carried out using acid followed by base. This may be reduced to a single step regeneration at the expense of lowering the capacity of the resin for boron.

Desiccation of Hydrocarbon Solvents

Moisture contamination of chlorinated hydrocarbons such as methylene chloride and trichloroethylene solvents is a problem. Strongly acidic cation resins such as Amberlite IR-120 PLUS and Amberlite 252 in the sodium or potassium form are effective dessicants. Regeneration is achieved by using a hot gas (100-150°C) such as air or nitrogen.

Metals Recovery

Metals removal and recovery is necessary in many chemical process streams. These metals may be present as a result of corrosion of process equipment, raw material contamination, catalyst carryover or a plating rinse stream. The metal ion can occur as cationic or anionic metal complexes.

Iron Removal From Concentrated Hydrochloric Acid

One of the earlier, rather unique, applications for metal ion removal is that of iron removal from concentrated hydrochloric acid.[7] In concentrated hydrochloric acid iron is known to be present as an anionic chloride complex and Amberlite IRA-400 has been used successfully to remove this complex. Since at low chloride concentration the anionic complex does not exist, the iron can be eluted from the resin by a water rinse.

Iron Removal from Glacial Acetic Acid

Amberlyst 15 has been used successfully for the removal of iron from glacial acetic acid. The resin exhibits a capacity of 1.9 lbs Fe^{3+}/ft^3 when treating an acid stream containing 240 ppm of iron. Regeneration with 10% hydrochloric acid removes 90% of the loaded iron in 2 bed volumes.

Nickel Removal From Sorbitol For Use In The Synthesis of Ascorbic Acid

The presence of nickel in sorbitol, obtained from contact with Raney nickel catalyst, has been found objectionable for subsequent synthesis of ascorbic acid. Removal of nickel by a strongly acidic cation exchanger such as Amberlite IR-120 PLUS or Amberlyst 15 in the hydrogen form has proven successful in several commercial installations. An anion exchange resin, such as Amberlyst A-26, is used to remove the sulfuric acid and color which are also found in this product.

Copper and Vanadium Catalyst Carryover in Adipic Acid Manufacture

The recovery of carryover copper and vanadium catalyst in adipic acid manufacture is done with Amberlite IR-120 PLUS, Amberlite IR-122 or Amberlite 200. These metals are recovered for recycle by elution of the loaded resin with strong acid.

Palladium and Tungsten Recovery

These metals are recovered as anionic complexes using strongly basic anion exchange resins such as Amberlyst A-26 or Amberlyst A-27. Regeneration is typically carried out using caustic.

Plating Rinse Streams

The concentration and recovery of alloy metals from plating rinse streams not only eliminates a waste problem, but in addition allows recycle of the water. Copper, zinc, chromium, silver and nickel may be removed with strongly acidic cation exchange resins such as Amberlite IR-120 PLUS, Amberlite 252 or Amberlite 200; with weakly acidic cation resins such as Amberlite IRC-84 or Amberlite DP-1; and a chelating resin such as Amberlite IRC-718.

7. Amber-hi-Lites No. 71 and 114

The recovery of gold from plating rinse waters with ion exchange resins is almost standard practice in the plating industry. Strongly basic anion exchange resins such as Amberlite IRA-400 and Amberlite IRA-900 are most commonly used; however, all of the other strongly basic Amberlite ion exchange resins have been used at one time or another for this purpose and the choice depends upon operating conditions.

The strong attraction of the anionic gold cyanide complex, $Au(CN)_2^{-2}$, for the quaternary ammonium exchange site on the resin results in high loadings in the range of 20 to 200 troy oz./ft³ of resin. The gold cyanide complex is selectively removed from the rinse water in spite of other anions generally present. Incineration of the loaded resin under controlled conditions is most frequently used to recover the metal directly.

Several companies supply cartridges of various sizes containing strongly basic anion exchange resins for small scale gold recovery from rinse water. Many of these firms have facilities for recovering the gold from the loaded resin by incineration or other means.

Removal of Aluminum from Anodizing Baths

Control of the aluminum content in anodizing baths can be achieved with Amberlite IR-120 PLUS or Amberlite 252. Capacities vary, depending upon the type and concentration of acid in the bath (sulfophthalic, sulfosalicylic, oxalic or sulfuric acids), and the aluminum concentration, but generally from 0.2 to 0.8 lbs/ft³ (3.2 to 12.8 g/l) of resin can be expected. Oxalic acid baths are the exception, with capacities over 1.2 lbs/ft³ (19.2 g/l) achievable. Regeneration must be carried out with 15 to 20% sulfuric acid at 20 to 25 lbs of acid/ft³ (320 to 400 g/l), however, only the first half of the regenerant goes to neutralization and precipitation. The last half is recycled to be the first half of the following regeneration.

Synthesis and Chemical Conversion

The use of ion exchange in the synthesis or conversion of chemicals to a more salable product has not been used extensively (outside of catalytic applications) because of high capital, regenerant and resin replacement costs. However, there has been some work done in this area with new resins and techniques that may change this situation:

Ion Exchange in the Solvay Process

By substituting an anion exchange resin for the ammonia used in the Solvay Process,
$R\text{-}N + CO_2 + MCl + H_3O \rightleftharpoons R\text{-}NHCl + MHCO_3$,
almost any bicarbonate can be produced. The resin can be regenerated with ammonia,
$R\text{-}NHCl + NH_3 \rightarrow R\text{-}N + NH_4Cl$,
and the ammonia recovered as in the Solvay Process. A lime slurry can also be used for regeneration
$R\text{-}NHCl + Ca(OH)_2 \rightarrow R\text{-}N + CaCl_2 + 2H_2O$.
The selectivity coefficient for the chloride to bicarbonate form of Amberlite IRA-68 is favorable for the formation of bicarbonate salts. This is also the basis of the Desal® Process, which is used for the treatment of acid mine drainage and other waste streams. Similarly, sulfur dioxide, phosphoric acid or organic acids can be used in place of CO_2. The corresponding acid salt can be prepared from the chloride salt using the same resin or liquid amines such as Amberlite LA-1 (the liquid amine used in a liquid-liquid extraction system).

Recovery of Potassium by Chemical Precipitation and Ion Exchange

This process involves the precipitation of potassium perchlorate from the bitterns resulting from solar evaporation of sea water. The sea water is used to produce sodium chloride by addition of sodium perchlorate. The potassium is then removed from the resulting solution of dissolved perchlorate salt by a strongly acidic cation exchanger such as Amberlite IR-120 PLUS, Amberlite 200 or Amberlite 252 in the sodium form. The sodium perchlorate can then be recycled. The potassium can be eluted with sodium chloride, sulfate or carbonate to obtain the corresponding potassium salt.

Production of Polysilicic Acid

There are numerous patents covering the formation of silica salts by ion exchange. Basically, passing sodium silicate through a strongly acidic cation exchange resin in the hydrogen form will convert the salt of silicic acid to the free acid, which polymerizes in the acid environment. Amberlite 200, a macroreticular exchange resin, has shown advantages over the

gelular type resins in durability and long term operation owing to its large pores and higher oxidative resistance.

Wine Treatment

Undesirable potassium acid tartrate is precipitated when wine is chilled. This can be prevented by using Amberlite IR-120 PLUS in the sodium form to exchange potassium for sodium. The wine industry also uses Amberlite IR-120 PLUS for removal of metal contaminants such as iron and copper from raw wine prior to fermentation.

Waste and Pollution Control

With the increasing concern for improving the environment, there has been a rapid expansion of interest in the use of ion exchange resins and polymeric adsorbents for solving pollution problems. The ability of ion exchange and adsorption techniques to (1) remove and concentrate products otherwise lost in waste streams (perhaps for subsequent recycle), (2) remove contaminants from a process stream or bath to prolong its useful life, (3) recover valuable substances from very dilute wash or rinse water, and (4) recover water for recycle, has aroused this recent interest.

The following description of ion exchange or adsorption processes is far from a complete listing, but will serve to illustrate the diverse way in which these resins have been put to use. General discussions of some of the processes will be made and an additional list of references to others will be given under the four categories indicated above.

Ammonium Nitrate Removal*

Fertilizer manufacturing facilities producing ammonium nitrate have several waste streams in which ammonia, nitrate salts or dilute ammonium nitrate are present. The ammonia is concentrated on a strongly acidic cation exchanger in the hydrogen form (Amberlite 252 and Amberlite 200 are particularly suitable), then eluted from the resin using nitric acid to give a concentrated ammonium nitrate product. Likewise, the nitrate can be removed on a weakly basic anion exchanger (Amberlite IRA-93 or Amberlite IRA-94) and eluted from the resin using ammonium hydroxide to produce another concentrated ammonium nitrate product for recycle.

*Caution; See Safe Handling Section.

Two publications which describe these processes are Rohm and Haas Technical Bulletin IE-221 and Chemical Separations Corp. Bulletin, "Unique Closed Cycle Water System for an Ammonium Nitrate Producer".

Sulfite Pulping

In the sulfite pulping process, loss of sodium (or ammonia) in the spent sulfite liquors is reduced by an ion exchange process called "The Pritchard-Fraxon Process". This process uses a strongly acidic cation exchange resin, such as Amberlite IR-120 PLUS in the hydrogen form, for the removal of sodium or ammonia (as well as calcium, magnesium, iron and manganese that may be present as contaminants) from the spent sulfite liquor. The stripping (or regenerating) solution used is a mixture of acetone and sulfur dioxide. The excess sulfur dioxide and acetone are stripped from the resulting product (for recycle) and the divalent sulfite salts are precipitated by raising the pH with a monovalent base (sodium or ammonia). The precipitate is filtered off, leaving a solution that, after fortifying with sulfur dioxide, is recycled back to the pulping process. This process is discussed in the article "Soluble Base Recovery from Spent Sulfite Liquor Successfully Piloted", by Spanger and Daris, Pulp and Paper, December 19, 1966.

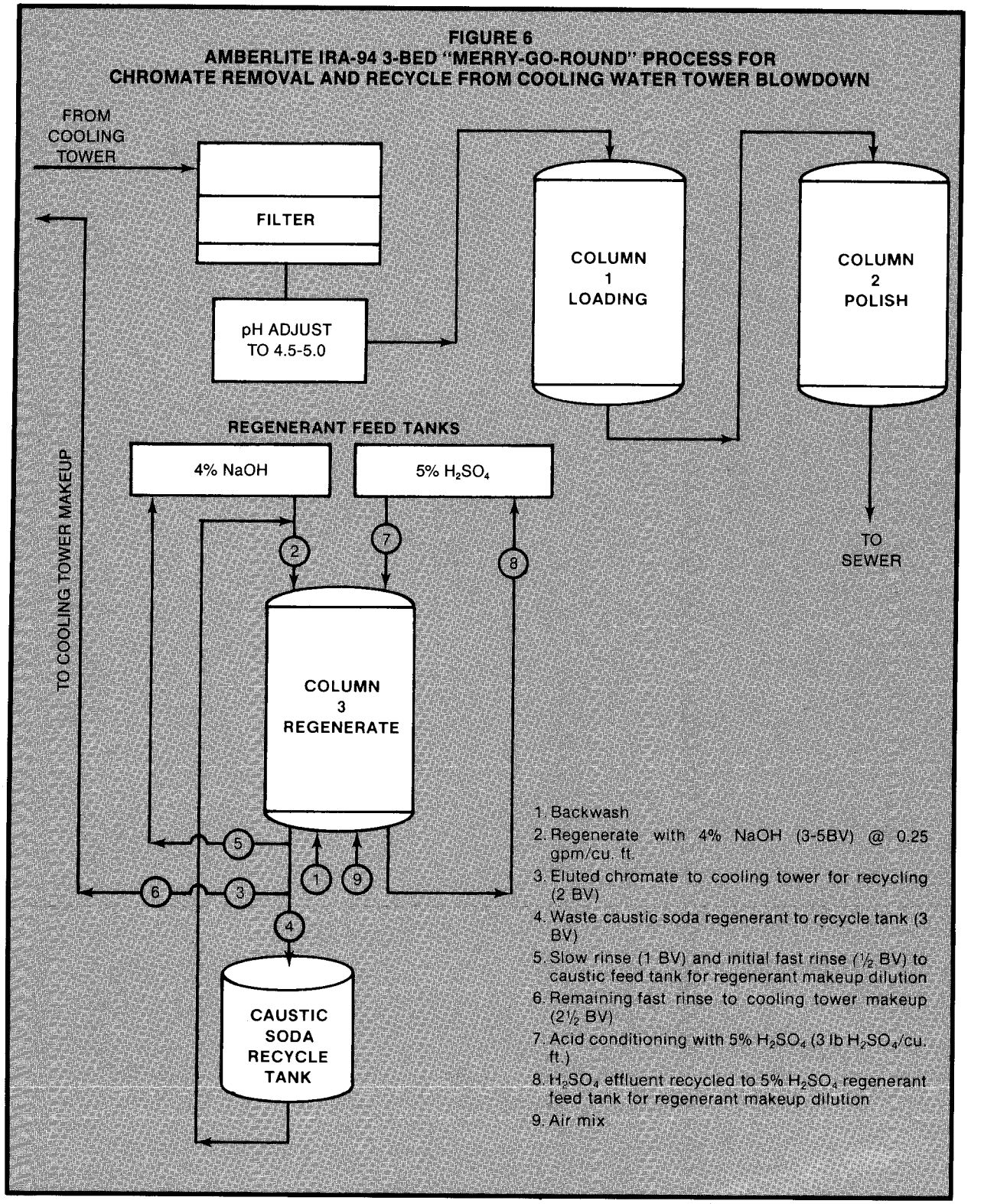
Chromate Recovery

For several years *strongly basic* anion exchange resins have been used to a minor extent in the recovery of chromate from cooling tower blowdown. Chromate is added to those systems to control corrosion. Problems of organic fouling, low concentration of the eluted chrome product, and low capacity have hampered large scale application. Recently, a weakly basic anion exchange approach has eliminated most of these problems. In this process the free base form of Amberlite IRA-94 is partially sulfated with sulfuric acid prior to the service cycle. Loadings of 2.0 to 4.5 lbs of $CrO_4^{=}/ft^3$ (32 to 72 g/l) can be obtained. The elution or regeneration with sodium hydroxide produces a concentrated sodium chromate solution for recycle to the make-up feed for the cooling tower (*See Figure #6*). Amberlite DP-1 can be used following the Amberlite IRA-94 for removal of zinc and trivalent chrome, if desired.

Nitrate Reduction

The increased use of nitrogen fertilizers in agriculture has led to elevated nitrate

FIGURE 6
AMBERLITE IRA-94 3-BED "MERRY-GO-ROUND" PROCESS FOR CHROMATE REMOVAL AND RECYCLE FROM COOLING WATER TOWER BLOWDOWN



contamination of surface and ground waters. With more stringent standards being placed on potable water supplies, many municipal and private wells will exceed the limits on nitrate levels. Ion exchange can combat this problem, since strongly basic anion exchange resins in the chloride form are capable of reducing nitrate levels. Strongly basic anion exchange resins, such as Amberlite IRA-410, are expected to give the highest capacity, contribute less objectionable taste characteristics and have the best regeneration efficiency. Brine or sodium

chloride is one of the best regenerants for this resin. Capacities in the range of 5 to 15 kgr/ft³ (11.5 to 34.4 g/l) of resin are expected (depending upon the total ion concentration and ratio of nitrate to other anions).

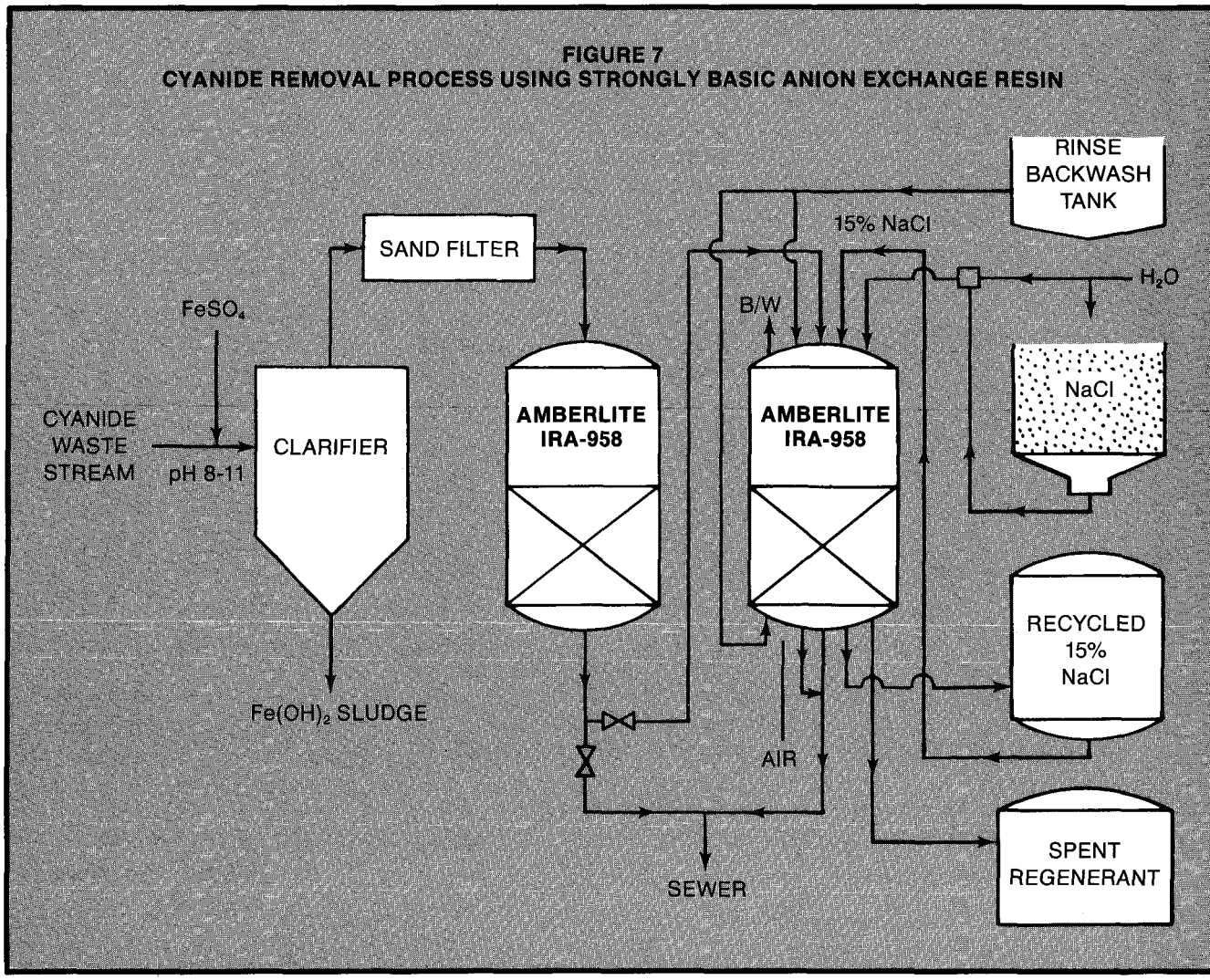
Cyanide Removal

A strongly basic anion exchange resin, Amberlite IRA-958, is highly selective for ferrocyanide (formed by the addition of ferrous ion to complex the cyanide) even in the presence of other anions and organics. This resin is efficiently regenerated by a few bed volumes of dilute sodium chloride (*See Figure #7*). A unique feature of Amberlite IRA-958 is its ability to adsorb cyanide without adsorbing thiocyanates frequently present in cyanide-bearing wastes. The cyanide can be converted to Prussian Blue by acidification and precipitation of the regenerant with an excess of iron salts. The Prussian Blue produced thus becomes a salable by-product of this process.

Radium Removal

Radium is often present in ground water supplies where mining of uranium is carried out. It is also present in the tailings solutions from uranium mills. Radium can be removed and concentrated on a strongly acidic cation exchange resin such as Amberlite IR-120 PLUS operated in the sodium form. Since the selectivity for radium is greater than that for calcium and magnesium, a hardness break is a safe control point for operation of the column. Brine regeneration will elute the radium in a concentrated waste or the radium-loaded resin can be sealed and disposed of in a suitable landfill.

FIGURE 7
CYANIDE REMOVAL PROCESS USING STRONGLY BASIC ANION EXCHANGE RESIN



Deionization of Waste Water

The Desal or Modified Desal Process, as described in Bulletin IE-114, has application for removal of cations and anions from waste streams such as acid mine drainage, steel mill pickling rinse water and tin plating rinse water. After treatment, this process will allow the recycle or discharge of water used in the aforementioned processes.

Kraft Pulp Mill Effluents

Large quantities of water are used in bleaching cellulose derived from wood fibers in kraft pulp mills. This results in highly colored waste streams. The polymeric adsorbent, Amberlite XAD-8, is effective in decolorizing this water. For more detail on this system see Rohm and Haas Bulletin IE-75.

Phenol Removal and Recovery

Amberlite polymeric adsorbents are being used commercially for removal and recovery of phenolic materials from waste streams.[8] Substituted phenolic compounds usually have an even greater affinity for adsorption. These compounds are easily eluted in high concentration by solvents or dilute caustic soda solutions. In a phenol-formaldehyde resin facility, it has been found possible to elute the phenol from the resin using formaldehyde as the elutant for convenient recycle of the recovered phenol. Basically, the phenols are better adsorbed at a pH below 7 and generally the higher the background ionic concentration, the better the adsorption. Amberlite XAD-4 has been used widely for phenol removal with capacities from 1 to 5 lbs of phenol/ft^3 (16 to 80 g/l) of resin (capacity dependent on influent concentration). Acetone regeneration, with distillation recovery of the phenol and recycle of the solvent, works well in commercial operations.[9]

Ethylene Dichloride Removal and Recovery

Amberlite XAD-4 is commercially used for EDC (ethylene dichloride) removal and recovery from a vinyl chloride monomer process. A discharge of less than 1 ppm is attainable. Low pressure steam is used for regeneration and the condensate sent to a phase separator from which the EDC can be recovered and recycled back into the process.

This technology shows advantages over steam stripping with lower steam consumption and improved removal efficiency particularly for higher boiling EDC homologues.

8. Amber-hi-Lites No. 123
9. Plant Uses Prove Phenol Recovery With Resins, C. R. Fox, Hydrocarbon Proc., Nov. 1978.

Other Special Applications for Amberlite Ion Exchange Resins

The brochure "Ion Exchange and Polymeric Adsorption Technology in Medicine, Nutrition, and the Pharmaceutical Industry" (Rohm and Haas Bulletin IE-218-75) will be of interest to those wishing more information in these areas of application for ion exchange and adsorption resins.

The use of ion exchange in analytical chemistry is a growing area and is covered in some detail in Chapter 13 of the book "Ion Exchange Resins" by Robert Kunin, published in 1972 by Robert E. Krieger Publishing Company.

SAFE HANDLING INFORMATION

Caution:

Acidic and basic regenerant solutions are corrosive and should be handled in a manner that will prevent eye and skin contact. In addition, the hazards of other organic solvents should be recognized and steps taken to control exposure.

Nitric acid and other strong oxidizing agents can cause explosive type reactions when mixed with ion exchange resins. Proper design of process equipment to prevent rapid buildup of pressure is necessary if use of an oxidizing agent such as nitric acid is contemplated. Before using strong oxidizing agents in contact with ion exchange resins, consult sources knowledgeable in the handling of these materials.

A Material Safety Data Sheet is available for all Amberlite and Amberlyst Ion Exchange resins. To obtain a copy for the specific resin you are interested in contact your Rohm and Haas representative.