eder associates
consulting engineers, p. c.

40598

November 10, 1993
File #497-14

Mr. Mike Gifford
United States Environmental Protection Agency
Region V
HS RW-6J
77 West Jackson Street
Chicago, IL 60604

Re: Revised Antidegradation Demonstration for National Presto Industries, Inc.

Dear Mike:

Enclosed are two copies of our revised antidegradation demonstration for National Presto Industries, Inc.'s (NPI's) treated groundwater discharge at the Riverview Park. The revised demonstration incorporates the changes which you requested in your November 1, 1993, letter to Mr. Rich Nauman of NPI.

Please call me if you have any questions.

Very truly yours,

EDER ASSOCIATES CONSULTING ENGINEERS, P.C.

Bruce A. Fenske

Bruce A. Fenske, P.E.

BAF/skk
Enc.

cc w/ enc:
D. Hantz (WDNR)
S. Thon (WDNR)
R. Riedl (WDNR)
J. Schmidt (WDNR)
R. Nauman (NPI)
D. Kugle (Eder)
W. Warren (Eder)
G. Rozmus (Eder)

BAF\4L497-14.002 11/10/93

8025 EXCELSIOR DRIVE, MADISON, WISCONSIN 53717-1900 • (608) 836-1500 • FAX (608) 831 [illegible]

CHAPTER NR 207 ANTIDEGRADATION INFORMATION REQUEST

NATIONAL PRESTO INDUSTRIES, INC.
3925 N. Hastings Way
Eau Claire, WI 54703

If you request an increase in any of your permit effluent limitations, you <u>must</u> provide all or part of the following information as required by Wisconsin Administrative Code, Chapter NR 207, Water Quality Antidegradation. You are advised to contact the permit drafter who is identified in the cover letter that accompanies this permit reissuance package before you begin work on this information request. The permit drafter will verify what information you must provide, identify the classification of your receiving water, provide you with a list of water quality indicator parameters if necessary and verify that significant lowering of water quality will or will not occur. All requirements of Ch. NR 207 must be satisfied before the Department can issue a permit containing an increased effluent limitation.

If your facility discharges to a receiving water that is classified as Exceptional Resource Waters, Great Lakes Waters or Fish and Aquatic Life Waters and you are proposing an increased discharge (as defined in Ch. NR 207), you must document the following:

I. An assessment of existing treatment capability which demonstrates:

A. Any of the following:

1. Your monthly average discharge equals or exceeds 85% of your monthly average permit limitation for 3 consecutive months;

2. Your daily discharge equals or exceeds 85% of your daily maximum permit limitation 5 or more times during a calendar year; or

3. Exceedances of any daily maximum, weekly average or monthly average permit limitation;

In a memorandum dated April 20, 1993, the Wisconsin Department of Natural Resources (WDNR) Bureau of Water Resources Management recommended a weekly average effluent limitation for cadmium of 0.035 lbs/day. At a maximum groundwater discharge rate of 380 gpm, the concentration limitation would be 7.7 $\mu g/\ell$. The WDNR calculated the weekly average limitation based on one-third of the Chippewa River's assimilative capacity at a river flow of 370 cfs. Because NPI needs a cadmium effluent limitation based on the full assimilative capacity of the Chippewa River, an antidegradation demonstration is required according to Chapter NR 207, Wisconsin Administrative Code.

Eder Associates Consulting Engineers, P.C.'s (Eder's) calculations indicate that a weekly average effluent limitation for cadmium would be 49 $\mu g/\ell$, if the full assimilative capacity of the Chippewa River and an updated Federal Energy Regulatory Commission (FERC) relicensing flow of 785 cfs for the Chippewa Falls Dam were used. The new FERC flow will become effective January 1, 1994. Without the antidegredation demonstration, NPI would be entitled to a weekly average cadmium effluent limitation of 16 $\mu g/\ell$, which is based on one-third of the Chippewa River's assimilative capacity at a river flow of 785 cfs.

To characterize water quality for the discharge, Eder did a 48-hour pumping test of recovery wells EW-3 and EW-4 from November 17 through November 19, 1992; a 14-day pumping test of recovery well EW-4 from March 3 through March 19, 1993; and a 44-hour pumping test of recovery wells EW-1 and EW-2 from April 14 through April 16, 1993. Cadmium levels in the samples collected from recovery well EW-3 ranged up to 19.6 $\mu g/\ell$. Cadmium levels in the samples collected from recovery well EW-4 ranged up to 49 $\mu g/\ell$. Cadmium was not detected in the samples collected from EW-1 and EW-2 at or above the method detection limit of 0.23 µg/ℓ.

Based on these cadmium results, Eder calculated an expected average cadmium concentration of about 18 µg/ℓ in the combined discharge from all four recovery wells. Because the expected discharge concentration is based on limited data, the long-term weekly average discharge concentration under continuous pumping conditions cannot be determined with statistical certainty. The weekly average cadmium concentration may at times be significantly greater than the expected average concentration of 18 µg/ℓ. A weekly average concentration at or above 18 µg/ℓ would exceed the 16 µg/ℓ limitation which is based on only one-third of the river's assimilative capacity. NPI needs a weekly average effluent limitation based on the full assimilative capacity because of the potential for exceeding the 16 µg/ℓ limitation.

B. The treatment facilities were maintained in good working order;

A cascade aerator will be used to remove VOCs from the pumped groundwater before discharge to the Chippewa River. This system will not have any moving parts; therefore, it will continue to operate in good working order. The cascade aerator cannot remove cadmium. Treatment to reduce cadmium levels is not feasible due to the low levels and no cost effective treatment alternatives (see Appendix A).

C. The treatment facilities were operated and maintained as efficiently as possible; and

Operation and maintenance of the cascade aerator will be performed according to the USEPA approved plan submitted with the Interim Remedial Action Design package. Although operation and maintenance will maintain the VOC removal efficiency, it will not affect the cadmium level.

D. The conditions documented in A, above were not due to temporary upsets.

The conditions documented in A are not related to potential upsets in the cascade aerator VOC removal system, which is not subject to breakdown. The conditions of an exceedance of cadmium permit limits would be caused by potential variations in cadmium levels in the groundwater discharge and the lack of an applicable cost effective cadmium reduction technology to meet the proposed limitation. Cadmium levels in the discharge are not related to an "upset" of the treatment system.

II. A demonstration that the proposed increased discharge will accommodate important economic or social development in any of the following ways:

A. You will be increasing your employment.

B. You will be increasing your production level.

C. You will be avoiding a reduction in your employment level.

D. You will be increasing your efficiency.

E. There will be industrial, commercial or residential growth in the community.

F. **You will be providing economic or social benefit to the community.**

G. **You will be correcting an environmental or public health problem.**

The pumping, treatment, and discharge of groundwater from the NPI site is consistent with the Interim Action Record of Decision issued by the USEPA on September 30, 1991, and the Remedial Design Package approved by the USEPA on June 10, 1993. Because this on-site interim remedial action will result in the removal of volatile organic compounds (VOCs) in the groundwater at the NPI site, an environmental problem will be corrected by this action.

III. **The following demonstration is optional. If you do not provide the information requested below, however, the Department will assume that your proposed increased discharge will significantly lower water quality and must comply with IV, below.**

A. **The expected levels of the indicator parameters in the discharge.**

The expected concentration of cadmium in the treated groundwater discharge will be 18 $\mu g/\ell$, although this concentration may vary under continuous pumping conditions.

B. **The existing levels of the indicator parameters upstream of, or adjacent to, the discharge site using applicable procedures in Chs. NR 102 and NR 106 or specified by the Department if none of those procedures apply. Existing levels shall be based on the earliest source of data after March 1, 1989 unless a demonstration is made that there has been a change in existing levels resulting in a change in the assimilative capacity of the receiving water, in which case the existing levels shall be based on the data used in the demonstration.**

In WDNR's April 20, 1993, memoranda recommending effluent limitations for the proposed discharge of treated groundwater by NPI, the background level of cadmium in the Chippewa River at Eau Claire was listed as 0.01 μg/ℓ.

C. **A calculation of expected levels in the receiving water of the indicator parameters as a result of the proposed increased discharge. In calculating expected levels in the receiving water, the following shall be used:**

1. **Applicable design low flow rates or dilution ratios for the receiving water. In chs. NR 102 or NR 106 or specified by the Department if none of those rates or ratios apply.**
2. **The yearly average discharge loading rates for the increased portions of the discharge.**

NPI will discharge between 330 and 380 gpm of treated groundwater to the Chippewa River. The Federal Energy Regulatory Commission regulated low flow of the Chippewa River will be 785 cfs as of January 1, 1994. Eder estimates that the yearly average cadmium discharge loading rate will be approximately 30 lbs per year (0.547 mgd x 0.018 mg/ℓ x 8.34 x 365 days/year) based on a discharge rate of 380 gpm and an average effluent concentration of 18 μg/ℓ. Based on the short term pumping test results, the yearly maximum cadmium discharge loading rate could be as much as 81.6 lbs/year (0.547 mgd x 0.049 mg/ℓ x 8.34 x 365 days/year) based on a discharge rate of 380 gpm and a maximum effluent concentration of 49 μg/ℓ.

D. **A comparison of the expected levels in the receiving water of each indicator parameter as calculated in C, above to:**

1. **The assimilative capacity multiplied by one-third for all indicator parameters except dissolved oxygen; or**

2. **The sum of the existing level multiplied by two-thirds and the water quality criterion multiplied by one-third for dissolved oxygen.**

Based on the new FERC flow of 785 cfs, one-third of the assimilative capacity of the Chippewa River for cadmium is 27.2 lb per year. The total assimilative capacity of the Chippewa River for cadmium is 81.6 lb per year (0.25 x 785 cfs x 0.646 mgd/cfs x 0.22 $\mu g/\ell$ x 8.34 x 365 days/year).

E. **For discharges to Great Lakes Waters, an indication of whether the discharge of any substance that has a bioaccumulation factor greater than 250 will be initiated or increased.**

The NPI treated groundwater discharge to the Chippewa River is not in the Great Lakes basin. The Chippewa River flows into the Mississippi River which flows to the Gulf of Mexico.

IV. **If your increased discharge is found to result in a significant lowering of water quality or if you have waived the demonstration for the lowering of water quality as outlined in III, above, then you must demonstrate the following:**

A. **The proposed significant lowering of water quality cannot be prevented in a cost effective manner by the following types of pollution control alternatives:**

1. **Use of conservation measures.**

The 380 gpm treated groundwater discharge rate cannot be reduced using conservation measures because a lower pumping rate would not effectively prevent the off-site migration of contaminated groundwater from the Melby Road Disposal Site and the southwestern portion of the NPI site.

2. **Use of recycling measures.**

The 380 gpm treated groundwater discharge rate cannot be reduced using recycling measures because NPI does not have a need at its facility for this volume of water.

3. **Use of other applicable wastewater treatment process or operational changes.**

The 380 gpm treated groundwater discharge rate cannot be reduced using applicable wastewater treatment processes, (See Nora Brew memoranda to Dennis Kugle, dated April 16, 1993, and to Bruce Fenske, dated July 14, 1993, included in Appendix A for a discussion of treatment processes) without reducing the groundwater recovery system's ability to prevent off-site migration of contaminated groundwater from the Melby Road Disposal Site and the southwestern portion of the NPI site.

The 380 gpm treated groundwater discharge rate cannot be reduced using operational changes because the discharge is unrelated to NPI production/manufacturing and does not result from NPI production/manufacturing related activities.

4. **Use of source reduction measures.**

The 380 gpm treated groundwater discharge rate cannot be reduced using source reduction because the discharge does not result from process operations and there is not a "source" to reduce. The discharge results from an on-site interim action to maintain groundwater plume contamination.

B. **If your proposal includes an expansion of your wastewater treatment plant, demonstrate whether or not there are alternative wastewater treatment technologies that:**

1. **Have documented performance levels for similar wastewater composition;**

2. **Have capital costs less than 110% of the capital costs (or present worth less than 115% of the related total present worth value) for alternative achieving the water quality based effluent limitations or treatment technology (categorical) effluent limitations, as appropriate; and**

3. **Would prevent a significant lowering of water quality.**

Manufacturers of cadmium removal technology have not demonstrated that their equipment is capable of consistently meeting a cadmium effluent limitation of 16 μg/ℓ. The preliminary cost estimates for a treatment system that may be able to meet a 16 μg/ℓ limitation range from $0.2 to $1.1 million with annual operating and maintenance costs between $0.3 and $0.4 million (see Appendix A). These capital cost estimates greatly exceed 110 percent of the on-site interim action groundwater remediation system. This system consists of two cascade aerators at a capital cost of $10,000.

C. **Demonstrate whether or not there are other discharge locations or alternatives which would meet the conditions of B.2 and 3., above.**

The discharge location in the main channel of the Chippewa River off Riverview Park provides the greatest assimilative capacity for cadmium of the possible discharge locations. The other two locations discussed with WDNR staff are the backwater area of the Chippewa River in Riverview Park, and near the Highway 124 Bridge. These alternate locations would result in weekly average cadmium effluent limitations of approximately 0.23 $\mu g/\ell$ and 2.3 $\mu g/\ell$, respectively. Significant lowering of water quality could not be prevented at these alternate discharge locations. The main channel of the Chippewa River provides the discharge location with the greatest ability to assimilate the treated groundwater discharge from the NPI site.

Discharge to the city of Eau Claire sanitary sewer is not an option because of the likelihood the cadmium levels in NPI's treated groundwater discharge would cause the city to exceed the cadmium limitation in its WPDES permit. The city's discharge ranged between five and six mgd with an average cadmium level of 0.58 $\mu g/\ell$ for the February to July 1993 period. Monthly monitoring results ranged up to 2.2 $\mu g/\ell$, nearly equaling the city's 2.4 $\mu g/\ell$ weekly average cadmium limitation. On the average, NPI's discharge could not exceed 22 $\mu g/\ell$ without causing the city to violate its effluent limitation. An NPI discharge above 4.6 $\mu g/\ell$ would have caused the city to violate its effluent limitation in the month of its maximum observed discharge. With NPI's average discharge of 18 $\mu g/\ell$ and with discharge levels up to 49 $\mu g/\ell$, the city could not accept the NPI discharge without expecting to violate its cadmium effluent limitation.

APPENDIX A

eder associates consulting engineers, p.c.

MEMORANDUM

TO: Bruce Fenske

FROM: Nora Brew

DATE: July 14, 1993

RE: National Presto Industries, Inc.
Revised Cadmium Treatment Technologies and Costs

File #497-14
Doc. #TG3076

This memorandum supplements my April 16, 1993 memorandum to Dennis Kugle. Based on currently available data, Eder Associates estimates that groundwater recovered at the southwestern portion of the NPI site under the interim response action will contain approximately 49 ppb cadmium. The WPDES permit cadmium limitation for discharge to the main channel of the Chippewa River would be 16 ppb if WDNR does not approve an antidegradation demonstration. We contacted the vendors who provided the conceptual cadmium treatment schemes and costs, which are summarized in the April 16 memo, to obtain updated information based on the revised projections.

John Eason of NAPCO indicated that a system employing double pass reverse osmosis followed by metal selective ion exchange would probably achieve the desired cadmium removals. The distillation step described in NAPCO's April 7, 1993 letter would be eliminated. The estimated capital equipment costs for this treatment scheme are approximately $700,000 to $1.1 million. The estimated annual operating and maintenance costs for this system are approximately $175,000 to $250,000. The treatability study that would be required to confirm that the desired effluent levels could be consistently met and to refine the cost estimates would cost approximately $19,000. This information is summarized in a July 1, 1993 letter from NAPCO (attached).

MEMO TO: Bruce Fenske
DATE: July 14, 1993

Stanley Karrs of U.S. Filter Corporation indicated that the desired cadmium removals could probably be achieved using their sorption filter technology, eliminating the need for an ion exchange system. Treatability testing would be required to confirm this and to refine cost estimates. The estimated capital equipment costs for the sorption filter system are approximately $250,000. This information is summarized in a July 12, 1993 letter from U.S. Filter Corporation (attached).

EDER ASSOCIATES CONSULTING ENGINEERS, P.C.

NAPCO

Plymouth Industrial Park
Terryville, Connecticut 06786
203-589-7800 • FAX: 203-589-7304

RECEIVED
AT EA
~~JUL 06 1993~~

497-8

OTHER

July 1, 1993

Eder Associates
480 Forest Avenue
Locust Valley, NY 11560

Attention: Ms. Ellen Beacon

Reference: NAPCO Waste Treatment Proposal No. WA/13699

Dear Ms. Beacon:

I have reviewed this project based upon the new influent and effluent numbers of 49 PPB and 16 PPB respectively. Based upon this data it appears the best treatment method would still be 1 or 2 pass R.O. The reject would then be treated with metal selective ion exchange. The ion exchange stream would be recombined with the R.O. product water prior to discharge.

The ion exchange regenerate solution could be evaporated to a concentrated brine or batch chemically treated.

This treatment would eliminate the need for distillation equipment on the R.O. reject stream. This would significantly lower the unit operating costs. The estimated capital costs would also be reduced by $400,000.00 - $500,000.00.

The treatability work should still include R.O. testing utilizing a 1 GPM bench scale system. Metal selective ion exchange would be evaluated in the laboratory. Waste concentration and treatment options would also be evaluated. By eliminating the distillation evaluation the treatability testing would be reduced 30% resulting in a new price of $18,500.00.

I would be happy to meet with you and the client to review this project.

Sincerely,

John Eason

John Eason
Senior Product Manager
Waste Treatment

JE:ll
cc: L. Dallaire

U.S.FILTER
UNITED STATES FILTER CORPORATION

LANCY
SYSTEMS & EQUIPMENT
181 THORN HILL ROAD
WARRENDALE, PA 15086-7527
TEL 412-772-0044
FAX 412-772-1360

July 12, 1993

Eder Associates
480 Forest Avenue
Locust Valley, New York 11560

Attention: Ms. Ellen Beacon

Reference: Job No. 497-14

Dear Ellen:

This confirmatory letter is being written to follow-up our phone conversation of June 29, 1993. In that conversation you mentioned there had been a change in your influent feed on this project to 49 ppb and that your effluent limits were now 16 ppb.

At that effluent level, our sorption filter technology would be applicable. This stream would still require testing since we have so little data on it, but it's in the range where sorption filtration is suitable. The total equipment cost for the filter would be approximately $250,000. This would include a sludge holding tank and a small filter press to dewater the solids. Enclosed is a brochure on the filter which describes it.

Yours very truly,

UNITED STATES FILTER CORPORATION

Stanley R. Karrs

Stanley R. Karrs
Director of Process Engineering

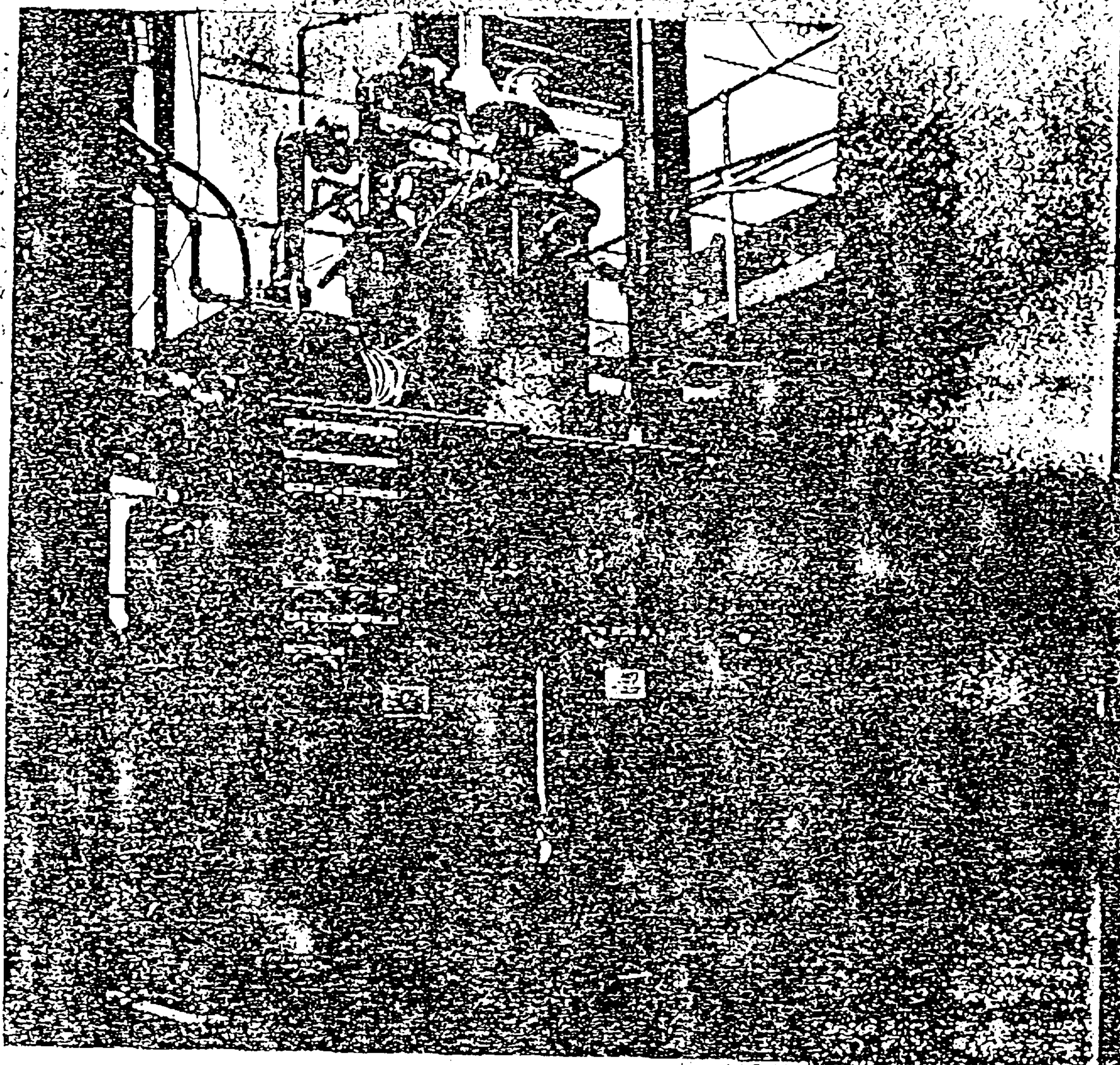
SRK/mn

Enclosure

cc: *U.S. Filter*
Mr. Thomas J. Whalen

Solutions Through Teamed Technologies

Lancy Sorption Filter Systems

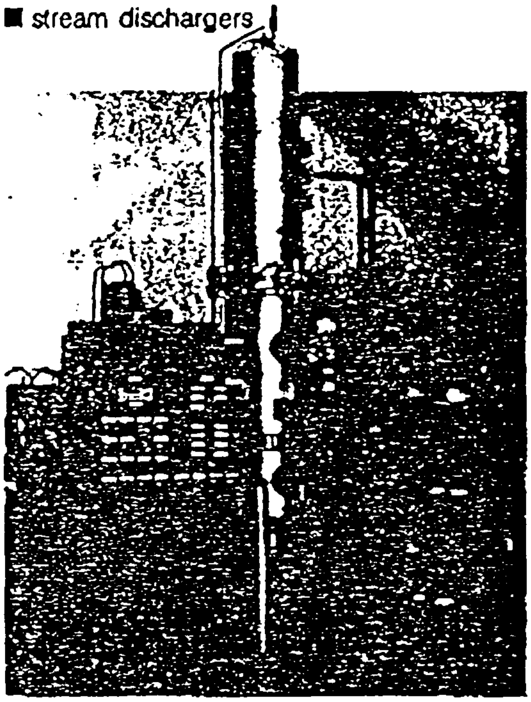


U.S. FILTER

Applications

The Lancy Sorption Filter is designed for treatment of segregated and non-segregated streams, stand alone treatment, polishing treatment, and retrofitting or upgrading of existing treatment systems. It consistently removes heavy metals to meet extremely low effluant levels for:

- contaminated groundwater applications
- electronics manufacturing (printed circuit board)
- metal finishing operations
- landfill leachate
- stream dischargers



Design Criteria

Lancy Sorption Filter units are designed to remove low levels of total suspended solids and heavy metals. Typical maximum incoming loadings are as follows:

Total heavy metals:
0-50 ppm total metals
>50 ppm, pre-treatment is required

Total suspended solids:
0-100 ppm
>100 ppm, pre-treatment is required

Total acidity:
Less than 100 ppm expressed as $CaCO_3$

The influent should be essentially free of emulsified oil and grease which drastically increases media consumption. Typically less than 10 ppm oil and grease is tolerable. Separate equipment can be provided to pretreat such streams.

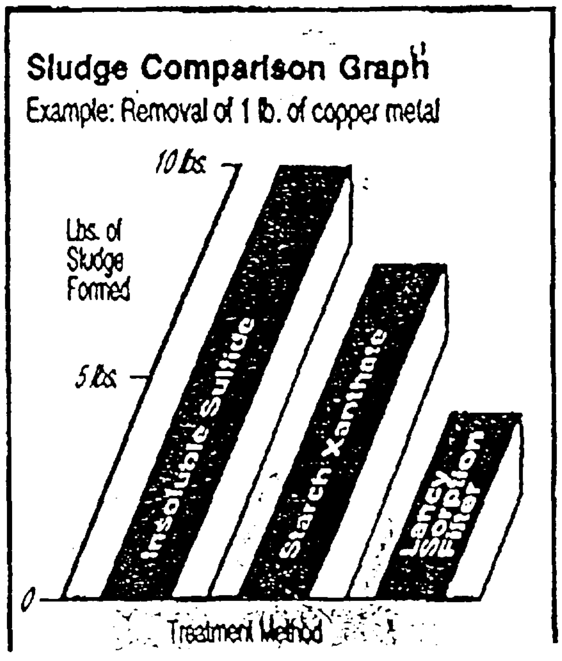
All chemical feed concentrations and chemical feed pump rates are based on these parameters. Consult the factory for alternatives if these loadings are exceeded

Features

- Removes chelated and non-chelated heavy metals from segregated or mixed waste streams
- Specialized proprietary filter media for removal of heavy metals and residual soluble sulfides
- Patented sulfide control
- Pre-piped and pre-wired skidded unit with built in chemical feed modules
- Fully automatic and continuous operation for four standardized sizes: 20, 80, 160, 240 gpm
- No internal moving parts
- PLC controlled operation
- Unique backwash system which utilizes compressed air to drive filtered water back through the filter tubes

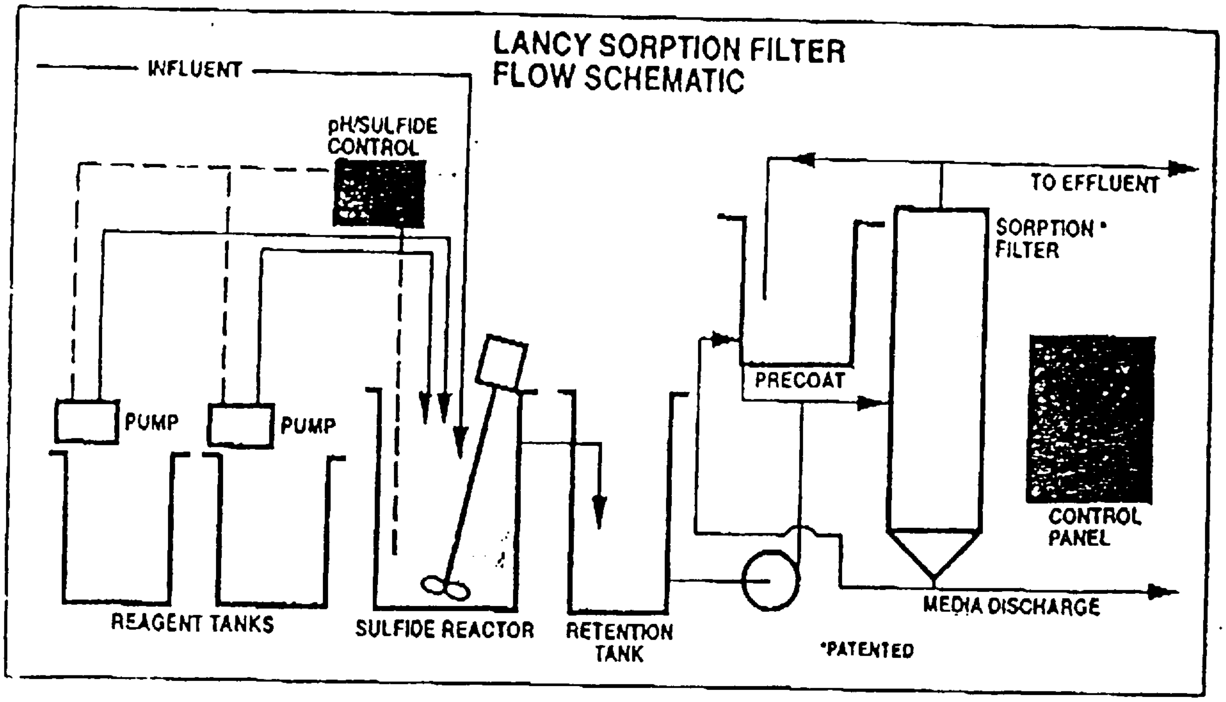
Benefits

- Zinc, silver, copper, lead, cadmium can be reduced to < 0.05 ppm and other metals to < 0.1 ppm
- Mercury can be reduced to < 2.0 ppb
- Continuously recycles and reuses the media for maximum solids handling capacity
- Easy installation
- Minimal operator attention required
- Can be designed into new or existing treatment systems
- No additional solids are added to the waste stream to remove heavy metals
- Low sludge generation
- Capital and operating costs are typically lower than cross flow microfilters
- Process guarantees are provided based on treatability



Sludge Comparison Graph

Example: Removal of 1 lb. of copper metal



Process Description

The Sorption Filter process uses sodium sulfide chemistry to precipitate heavy metals to meet very low effluent limits.

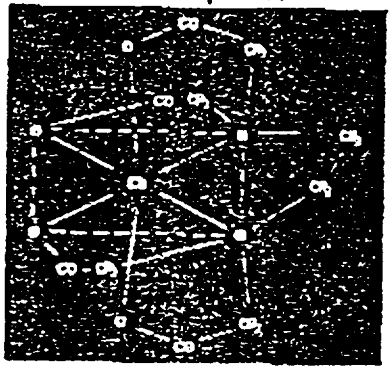
Wastewaters to be treated by the Lancy Sorption Filter are directed to the integral pH adjustment - sulfide reactor. Here the pH is raised automatically by caustic addition. Simultaneously, sodium sulfide is added via a patented sulfide sensing device to the wastewater. Safety interlocks are included to insure that the pH is a minimum of 9.5 before sulfide can be added.

The wastewater then overflows to the retention tank, which serves as a pump down/holding vessel. From the retention tanks, the wastewater is pumped to the filter body where it is filtered through a proprietary reactive media which performs two functions. First, it filters out the fine, colloidal metal sulfide precipitate formed in the reaction module. Second, it absorbs any residual soluble metals and unreacted sulfides remaining in the solution.

Sizing Chart Flow Rate gpm	Filter Area sq. ft.	Overall System L x W x H
20	40	11' x 8' x 12'
80	160	18' x 8½' x 13'
160	320	Multiple skids
240	480	Multiple skids

Equipment arrangement is flexible and can, if required, be supplied to fit other equivalent plan area dimensions.

As the liquid passes through the numerous filter tubes contained in the filter body, suspended solids and metals are deposited on the outside of the tubes. Filtrate passes up through the inside diameter of the tubes, into the filtrate headers and on to the main outlet.



At the end of the filter cycle, air trapped in the top of the filter cap is released causing the filter tubes to expand and "bump" the filter cake along the entire length of the tube. Filtered liquid is forced back through the tubes, carrying the accumulated solids and liquid to waste in a matter of seconds. At this time, the solution in the filter system is recycled back through a separate precoat tank until the media is recoated on the filter fingers, therby exposing new sites for filtration and adsorption.

While the filter precoats, the incoming waste is accumulated in the retention tank. After the precoat cycle is completed, the filter resumes processing of the accumulated wastewater.

Capabilities

Whether you are integrating a Lancy Sorption Filter into a new or existing treatment design, or depending on the sorption filter to consistently perform as a stand-alone treatment process, US Filter has the in-house capabilities to help.

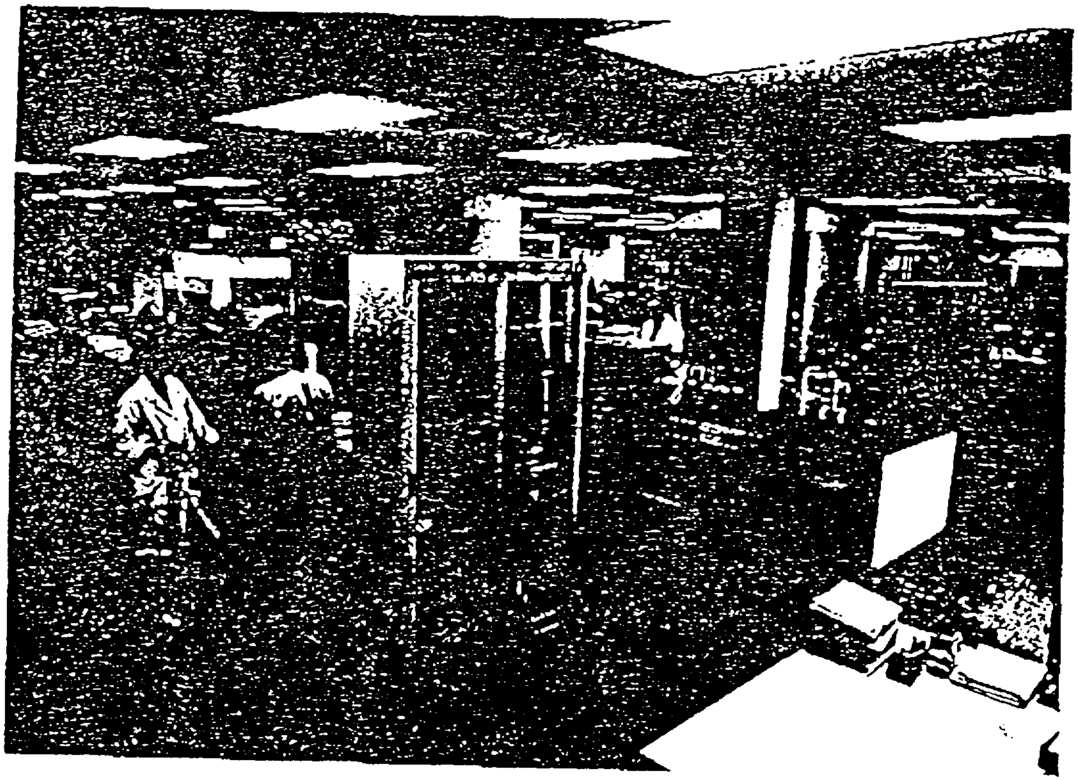
Based on conclusive laboratory treatability work as well as our experience with hundreds of applications, US Filter will provide in writing, a straight forward performance guarantee in addition to our mechanical warranty.

Once sizing is confirmed, you get equipment that performs reliably for years. The reliability starts with professional start-up assistance and continues with uninterrupted customer service. If you prefer, we can also install any of the equipment we supply. Our installation experience includes hundreds of turnkey and equipment supply projects. By choosing US Filter, you get more than a good piece of equipment, you get professional, experienced assistance with your treatment solution.

With environmental regulations continuing to become more stringent, the Lancy Sorption Filter effectively reduces heavy metals in a contaminated stream to the part per billion range. The Lancy Sorption Filter provides an exceptionally efficient method for the continuous removal of both chelated and non-chelated heavy metals using proven sulfide chemistry and specialized adsorption media.

Options

1. Stainless steel filter body
2. 3-channel chart recorder
3. Materials of construction for piping - PVC, CPVC
4. Alternate medias including diatomaceous earth and cellulose fiber
5. Sludge handling equipment
6. Pre-treatment equipment



Lancy Systems and Equipment
181 Thorn Hill Road

eder associates consulting engineers, p.c.

MEMORANDUM

TO: Dennis Kugle
FROM: Nora Brew
DATE: April 16, 1993
RE: Cadmium Treatment Technologies
National Presto Industries, Inc.

File #497-14
Doc. #MW2460
cc: R. Nauman

Based on the November 1992 48-hour pumping test results, Eder Associates estimates that 180 gpm of groundwater containing 10 to 30 ppb cadmium will be recovered at the southwestern portion of the NPI site under the interim response action. Groundwater discharged to the backwater area of the Chippewa River would be subject to a 0.23 ppb WPDES limit on cadmium, with no dilution allowed. This memorandum summarizes Eder's evaluation of the cadmium removal technologies available to achieve the 0.23 ppb discharge limit.

Eder searched USEPA's RREL Treatability Program Data base to identify technologies that could be used to remove cadmium from groundwater. Most of the cadmium treatability information in this data base is for treatment of wastewaters with influent cadmium levels significantly greater than the influent levels expected at NPI. Therefore, the cadmium removal efficiencies for various technologies presented in USEPA's data base cannot be directly applied to NPI.

Eder contacted USEPA's Risk Reduction Engineering Laboratory Superfund Technology Demonstration Division for recommendations on cadmium removal technologies. Doug Grosse (USEPA) suggested cation exchange and in-situ precipitation. Mr. Grosse indicated that ion exchange could achieve the 0.23 ppb discharge limit if a resin that selectively binds cadmium is used. This is a costly technology. Mr. Grosse suggested that Eder contact vendors such as Rohm & Haas

____ w ____ is the two units together ie. UFwPAC - Ultrafiltration using Powdered Activated Carbon.

____(B) is batch instead of continuous flow.

Scale

B - Bench Top
P - Pilot Plant
F - Full Scale

Number after letter refers to the plant number in a specific reference (ex. F7 - plant 7 is the seventh full scale plant in the indicated report).

Matrix

C - Clean water (ex. distilled)
D - Domestic wastewater
GW - Groundwater
HL - Hazardous leachate
I - Industrial wastewater
ML - Municipal leachate
RCRA - RCRA listed wastewater
S - Synthetic wastewater
SF - Superfund wastewater
SP - Spill
T - Tap water
TSDF - Commercial treatment, storage and disposal facility - liquids
W - Surface water

SIC (Standard Industrial Classification) Codes

For industrial wastewaters a 2 digit SIC code will be given following the letter designation, i.e. I 22 is a Textile Mill Products wastewater. If the SIC code is unknown a U will be shown, I U.

10 - Metal mining
12 - Coal mining
13 - Oil and gas extraction
20 - Food and kindered products
22 - Textile mill products
24 - Lumber and wood products
26 - Paper and allied products except computer equipment
27 - Printing and publishing
28 - Chemicals and allied products
29 - Petroleum refining and related
30 - Rubber and misc. plastic products
31 - Leather and leather products
33 - Primary metals industries
34 - Fabricated metal products except machinery & transportation equip.
36 - Electronic and electric equipment
37 - Transporation Equipment
39 - Misc. manufacturing industries

47 - Transportation services
49 - Electric, gas, and sanitary
99 - Nonclassifiable establishments industries

Effluent Concentration

Effluent concentration will be given as a arithmetic mean to two significant figures. The number of samples used to calculate the mean is given after concentration as (n) (ex. 13 (5) - 13 is the mean of 5 sample values).

% Removal

Percent removal will be calculated on a concentration basis. If data are available, it will also be calculated on a mass basis for physical/chemical systems. Those values calculated on a mass basis will be noted by a (m). An example would be:

% Removal: 99.95 99.95 is based on concentration
98(m) 98 is based on mass

where $$\% \text{ Removal} = \frac{\text{Influent} - \text{Effluent}}{\text{Influent}}$$

Reference Quality Codes

A - Papers in a peer reviewed journal.
B - Government report or database.
C - Reports and/or papers other than in groups A or B not reviewed.
D - Group C papers and/or reports which have been given a "good" quality rating by a selected peer review.
E - Group C papers and /or reports which have been given a "poor" quality rating by a selected peer review. These data will only be used when no other data are available.

Additional Codes Following Reference Codes

V - Volatile emissions data available in Reference
S - Sludge data available in Reference
$ - Costs data available in Reference

Physical/Chemical Properties Data

(c) - Values presented are values that were reported calculated in the reference as is and are only used where measured are not available.
NA - Values for the particular property have not been found in literature to date.

RREL TREATABILITY PROGRAM

Treatment Technologies

AAS - Activated Alumina Sorption
AFF - Aerobic Fixed Film
AL - Aerobic Lagoons
API - API Oil/Water Separator
AS - Activated Sludge
AirS - Air Stripping
AlkHyd - Alkaline Hydrolysis
AnFF - Anaerobic Fixed Film
AnL - Anaerobic Lagoons
BGAC - Biological Granular Activated Carbon
CAC - Chemically Assisted Clarification
ChOx - Chemical Oxidation (Parantheses shows oxidation chemical ie. ChOx(Oz) is ozone, ChOx(Cl) is chlorine, ChOx(Sur) is surfactant, and ChOx(H2O2wOz) is peroxide with ozone.)
ChOx/Pt - Chemical Oxidation/Precipitation
ChPt - Chemical Precipitation
ChRed - Chemical Reduction
DAF - Dissolved Air Flotation
ED - Electrodialysis
Fil - Filtration
GAC - Activated Carbon (Granular)
IE - Ion Exchange
KPEG - Dechlorination of Toxics using an Alkoxide (Formed by the reaction of potassium hydroxide with polyethylene glycol (PEG400))
PACT - Powdered Activated Carbon Addition to Activated Sludge
RA - Resin Adsorption
RBC - Rotating Biological Contactor
RO - Reverse Osmosis
SBR - Sequential Batch Reactor
SCOx - Super Critical Oxidation
Sed - Sedimentation
SExt - Solvent Extraction
Soft - Water Softening
SS - Steam Stripping
TF - Trickling Filter
UF - Ultrafiltration
UV - Ultraviolet Radiation
WOx - Wet Air Oxidation

NOTES:

____ + ____ is the first process unit followed in process train by the second ie. AS + Fil - Activated Sludge followed by Filtration.

If you have any questions, please feel free to call me at (412) 772-1265.

Sincerely,

U.S. FILTER, INC. WARRENDALE, PA

Stanley R. Karrs

Stanley R. Karrs
Director, Process and Application Engineering

cc: John W. Lowry
G. Kent Peterson
Thomas J. Whalen

U.S.FILTER
UNITED STATES FILTER CORPORATION

April 14, 1993

LANCY™
SYSTEMS & EQUIPMENT
181 THORN HILL ROAD
WARRENDALE, PA 15086-7527
TEL: 412-772-0044
FAX: 412-772-1360

Eder Associates
480 Forest Avenue
Locust Valley, New York 11560
(516) 671-8440

Attention: Ms. Nora Brew

Reference: Job No. 497-14

Dear Ms. Brew:

After reviewing the revised influent and effluent numbers and flow data received on April 5, 1993, we still feel that an ion exchange approach would be best (for either scenario) to reach the very low cadmium number you wish to achieve.

As mentioned in our September 2, 1992 letter to Mr. Valenti, we still need more detailed analytical information (i.e., a balanced water analysis for all inorganics, residual levels of organics present, plus total dissolved solids and total suspended solids levels).

If we were to assume there are no organics and no suspended solids and that all metals are soluble, a duplex set of chelating resin columns with counterflow regeneration and the use of our sorption filter to treat the regenerant may be adequate to meet both scenarios. The cost of equipment only for this type of system would be between $650,000 and $700,000.

If there are organics present and suspended metals are present but total dissolved solids are low (<200 ppm) we would suggest microfiltration, cation and anion columns with counterflow regeneration followed by a polishing mixed bed unit. The regenerant would again be run through a sorption filter and blended with the effluent from the mixed bed unit. Equipment only for this type of system would cost between $1,200,000 and $1,300,000.

As you can see, more information would be helpful. In any event, with effluent limits this low, a treatability study would be required to determine whether these limits could be reliably met. In order to propose treatability at a reasonable cost, more information is needed.

II. DISTILLATION EVALUATION

Samples of the raw well water and the R.O. reject would be distilled in the laboratory to determine the minimum waste concentration attainable without contaminating the distillate with cadmium. A larger scale vapor compression still would then be tested to verify the distillation results on an energy efficient system. This would also allow direct scale up of the component sizing.

III. WASTE CONCENTRATION

The still bottoms would be treated with metal selective ion exchange, and by chemical methods to determine if further waste concentration was possible.

The cost for the treatability study would be as follows:

Labor & Expenses	$ 14,250.00
Equipment & Rentals	$ 6,370.00
Analytical	$ 5,700.00
Total	$ 26,320.00

The estimated capital cost of a complete system is $1.2 - 1.5 million. This cost would be further defined along with system operating costs, and presented in the treatability report.

It may be possible to do a laboratory evaluation of the distillation and R.O. technologies for less money if financing the treatability phase is a problem. This data would still have to be tested at the pilot plant level to have validity.

Please let me know if you have any questions.

Sincerely,

John Eason

John Eason
Senior Product Manager
Waste Treatment

JE:ll
cc: L. Dallaire

to obtain additional information on ion exchange systems. As an alternate, Mr. Grosse suggested an innovative in-situ metals precipitation approach. This approach injects chemicals into the aquifer to precipitate metals which then bind onto clay particles or other aquifer heterogeneities. Mr. Grosse indicated that in-situ precipitation of chromium has been tested, but cadmium precipitation has not yet been attempted.

Eder contacted Rohm & Haas and Bill Waitz said that they have little experience in cadmium removal. The majority of Rohm & Haas' ion exchange systems were used to treat aqueous streams with much higher influent concentrations of metals than the NPI groundwater. Therefore, Mr. Waitz indicated that he was uncomfortable with NPI's cadmium treatment requirements and did not wish to develop a conceptual ion exchange system.

Eder described NPI's treatment needs to Napco. Napco was surprised at the low influent cadmium levels expected and the degree of removal required, and indicated that it was very difficult to accurately measure levels of cadmium below 1 ppb. John Eason indicated that a system employing double pass reverse osmosis followed by distillation and ion exchange would probably achieve the desired cadmium removals. However, Mr. Eason said that an extensive treatability study (estimated cost = $30,000) would be required to confirm that the desired effluent levels could be consistently met and to refine the system installation costs and operating and maintenance costs. Napco's proposal is attached. Napco submitted a preliminary estimate indicating that the capital equipment costs for the proposed treatment scheme would be between $1.2 and $1.5 million. Based on information obtained from Napco, Eder estimates that the annual operating and maintenance costs for this system would be between $400,000 and $500,000.

Eder also received conceptual cadmium treatment information from U.S. Filter Corporation. Stanley Karrs indicated that an ion exchange approach would be appropriate to achieve the 0.23 ppb cadmium discharge limit. Mr. Karrs recommended using a duplex set of chelating resin ion exchange columns if the groundwater contains only soluble metals and no organics or suspended solids. Mr. Karrs estimated that the equipment cost would be between $650,000 and $700,000. If the groundwater contains organics, suspended metals, and less than 200 ppm total dissolved solids, Mr. Karrs suggests using microfiltration, cation and anion exchange. The estimated equipment cost would be between $1.2 and $1.3 million. Mr. Karrs said that a treatability study would be required to determine whether the cadmium discharge limit can be reliably met and to refine equipment and operating and maintenance costs.

The cadmium levels detected in groundwater at the NPI site are lower than levels typically encountered in industrial applications. Eder has evaluated similar cadmium removal problems for other facilities that have been required to meet stringent metals discharge limits based on surface water standards. In these situations, many vendors are reluctant to discuss possible treatment scenarios to achieve these low levels of cadmium and other metals when the influent concentrations are so low. None of the vendors that Eder contacted would guarantee that their systems could meet the 0.23 ppb discharge limits for cadmium. Full scale application of ion exchange or other technologies suggested by the vendors and USEPA may or may not consistently achieve the desired levels, thus the costs required to implement these options cannot be justified.

EDER ASSOCIATES CONSULTING ENGINEERS, P.C.

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To Ms. Nora Brew	From John Eason
Co. Eder Associates	Co. NAPCO, INC.
Dept.	Phone # (203) 589-7800
Fax # (516) 671-3349	Fax # (203) 589-7304

NAPCO
Plymouth Industrial Park
Terryville, Connecticut 06786
203-589-7800 • FAX: 203-589-7304

April 7, 1993

Eder Associates
480 Forest Avenue
Locust Valley, NY 11560

Attention: Ms. Nora Brew

Reference: NAPCO Waste Treatment Proposal No. WA/13699

FAX: (516) 671-3349

Dear Ms. Brew:

The technology exists to meet the 0.23 ppb cadmium limit for the ground water stream in question.

We would propose to use double pass R.O. to purify the main stream. Approximately 20% of the initial stream would be rejected containing the cadmium. The stream would be distilled with the cadmium and other metals concentrating in the still bottoms. It may then be possible to further concentrate the waste stream using metal selective ion exchange or chemical treatment.

NAPCO proposes to perform a treatability test to allow proper sizing of the system and to identify the operating costs. The treatability work would consist of the following:

I. R.O. EVALUATION

A stream from the well would be passed through a double pass R.O. system. The system would be sized to process about 1 GPM of feed water. Samples of the permeate would be collected and tested for cadmium to determine the minimum concentration attainable. Sufficient testing would be performed to determine what the minimum reject volume would be and approximate system operating costs. This work could be performed at the site or in the laboratory.

CADMIUM

AQUEOUS TREATMENT TECHNOLOGY DATA INFLUENT CONCENTRATION: 0-100 ug/L

TECHNOLOGY	SOURCE MATRIX	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D	F	0.20 (36)	17	54E---
AS	D	F2	0.3	90.9	243A-S-
AS	D	F3	1	97.8	167E-S-
AS	D	F4	<1	>90.9	167E-S-
AS	D	F	<7 (16)	>30	201B-S-
AS	D	F1	1.0	85	243A-S-
AS	D	F2	<0.1 (7)	>99.47	234A---
AS	D	F1	<0.1 (7)	>99.41	234A---
AS	D	F3	5.5 (7)	68	234A---
AS	D	F28	7 (6)	86	1B-S-
AS	D	F1	<1	>95.2	167E-S-
AS	D	F36	6 (6)	40	1B-S-
AS	D	F4	<0.1 (7)	>95.8	234A---
AS	D	F17	5 (6)	82	1B-S-
AS	D	F37	<3 (6)	>95.5	1B-S-
AS	D	F19	<2 (6)	>80	1B-S-
AS	D	F1	<5 (7)	>58	1B-S-
AS	D	F2	<2 (7)	>60	1B-S-
AS	D	F5	<2 (6)	>67	1B-S-
AS	D	F58	3 (6)	62	1B-S-
AS	D	F2	1	93.3	167E-S-
AS	D	F38	<2 (6)	>87	1B-S-
AS	D	F4	<10 (3)	>0	35E-S-
AS	D	F4	1.8 (23)	77	52A---
AS	D	F3	1.9 (23)	75	52A---
AS	D	F10	10 (2)	75	35E-S-
AS	D	F5	<20 (2)	>0	35E-S-
AS	D	F1	5 (23)	32	52A---
AS	D	F	8	38	59E---
AS	D	F2	0.6 (23)	86	52A---
AS	D	F1b	<0.95 (24)	>89	67B---
AS	D	F1a	<0.58 (22)	>90.4	67B---
AS	D	F2b	4.0 (23)	82	67B---
AS	D	F2a	4.4 (15)	75	67B---
AS	D	F6	5.5 (23)	91.3	52A---
AS	D	F5	0.9 (23)	25	52A---
AS	D	F7	0.6 (23)	50	52A---
AS	D	P	7.9 (14)	62	16A-S-
AS	D	F1	1 (30)	67	35E-S-
AS	D	F7	10 (2)	0	35E-S-
AS	D	F4	5 (1)	0	31B---
AS	D	F2	10 (4)	50	35E-S-
AS+Fil	D	F3a	<0.75 (22)	>90.0	67B---
AS+Fil	D	F3b	<0.50 (12)	>91.1	67B---
CAC	D	F4	5 (1)	0	31B---
ChPt	D	F2	8.7 (9)	74	1682B---
ChPt	D	F1	2.0 (32)	92.3	1682B---
ChPt	D	F	2.7 (106)	82	1830B---

Fil	D		F	6	25	59E---
Fil	D		F	6.3	49	33D-S-
RO	D		P1	<1.2 (35)	>90.9	18B---
Sed	D		F12	0.6 (23)	14	52A---
Sed	D		F3	5 (3)	38	35E-S-
Sed	D		F10	0.8 (23)	20	52A---
Sed	D		F5	20 (2)	50	35E-S-
Sed	D		P	0.86 (3)	36	44E-S-
Sed	D		F11	1.0 (23)	0	52A---
Sed	D		F2	20 (4)	0	35E-S-
Sed	D		F7	10 (2)	50	35E-S-
Sed	D		F1	3 (30)	50	35E-S-
TF	D		F37	16 (6)	76	1B-S-
TF	D		F17	<2 (6)	>92.6	1B-S-
TF	D		F8	0.8 (23)	11	52A---
TF	D		F9	1.2 (23)	62	52A---
TF	D		F3	3 (3)	40	35E-S-
GAC	GW		F2	<4 (1)	>43	87B---
AnFF	I	10	B	5 (5)	58	45E---
CAC	I	28	F	5.3	44	393A---
CAC	I	31	F1	16 (1)	0	31B---
CAC	I	28	F9	<1 (1)	>80	32B---
CAC(B)	I	49	B2	70 (1)	0	638B---
ChOx (C1)	I	28	F34	<3 (1)	>25	87B---
ChPt	I	34	B21	3 (1)	67	29B--$
ChPt	I	34	B74	<5 (1)	>91.4	29B--$
ChPt	I	34	B59	1 (1)	97.0	29B--$
ChPt	I	34	B51	15 (1)	67	29B--$
ChPt	I	36	B1	2 (1)	75	29B--$
ChPt	I	36	B4	1 (1)	88	29B--$
ChPt	I	34	B31	27 (1)	64	29B--$
ChPt	I	34	B56	20 (1)	41	29B--$
ChPt	I	34	B34	25 (1)	67	29B--$
ChPt	I	34	B61	21 (1)	38	29B--$
ChPt	I	34	B24	<3 (1)	>67	29B--$
ChPt	I	34	B71	7 (1)	88	29B--$
ChPt	I	34	B54	11 (1)	76	29B--$
ChPt	I	34	B64	1 (1)	97.0	29B--$
ChPt+Fil	I	34	B72	12 (1)	79	29B-
ChPt+Fil	I	34	B35	20 (1)	74	29B--$
ChPt+Fil	I	34	B55	7 (1)	84	29B--$
ChPt+Fil	I	34	B52	8 (1)	82	29B--$
ChPt+Fil	I	34	B57	1 (1)	97.0	58B--$
ChPt+Fil	I	34	B73	<5 (1)	>91.4	29B--$
ChPt+Fil	I	34	B60	1 (1)	97.0	29B--$
ChPt+Fil	I	34	B65	1 (1)	97.0	29B--$
ChPt+Fil	I	36	B2	<1 (1)	>88	29B--$
ChPt+Fil	I	36	B3	<1 (1)	>88	29B--$
ChPt+Fil	I	34	B22	<3 (1)	>67	29B--$
ChPt+Fil	I	34	B32	16 (1)	79	29B--$
ChPt+Fil	I	34	B33	22 (1)	71	29B--$
ChPt+Fil	I	36	B5	<1 (1)	>88	29B--$
ChPt+Fil	I	34	B25	<3 (1)	>69	29B--$
ChPt+Fil	I	34	B23	<3 (1)	>67	29B--$
ChPt+Fil	I	34	B75	<5 (1)	>91.4	29B--$
ChPt+Fil	I	34	B63	1 (1)	97.0	29B--$

ChPt+Fil	I 34	B62	21 (1)	38	29B--$
ChPt+Fil	I 34	B57	20 (1)	41	29B--$
ChPt+Fil	I 34	B53	20 (1)	56	29B--$
ChPt+Fil	I 34	B58	1 (1)	97.0	29B--$
ChPt+Fil (B)	I 10	B2	<10 (1)	>67	66B---
Fil	I 28	P7	34 (13)	40	254B---
Fil	I 33	P	34	0	53B--$
PACT	I 31	F1	16 (1)	0	31B---
RA (B) + FIL	I 28	F20	<4 (1)	>38	87B---
SExt	I 28	F8	8 (2)	0	87B---
SExt (B)	I 28	F32	12 (2)	0	87B---
SS	I 28	F33	4 (1)	0	87B---
SS	I 28	F7	<4 (1)	>5[illegible]	87B---
SS	I 28	F6	12 (3)	0	87B---
AnFF	ML	P	19 (8)	30	41A-S-
ChPt	ML	F	22 (21)	59	36E--$
AS	S	B	4.7 (5)	58	25A-S-
API	SF	F3	<3.7 (1)	>20	245B---
AS	SF	F6	<5 (1)	>17	245B---
AirS	SF	F4	<4.3 (2)	>19	245B---
DAF	SF	F3	5 (1)	0	245B---
Fil	SF	F8	8 (4)	0	245B---
Fil	SF	F2	13 (1)	0	245B---
Fil	SF	F3	<3.7 (1)	>26	245B---
GAC	SF	F2	<3.7 (1)	>23	245B---
GAC	SF	F4	9 (2)	0	245B---
GAC	SF	F8	<5 (2)	>23	245B---

CADMIUM

AQUEOUS TREATMENT TECHNOLOGY DATA INFLUENT CONCENTRATION: >100-1000

TECHNOLOGY	SOURCE MATRIX	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D	F12	15 (6)	91.2	1B-S-
AS	D	F57	96 (6)	90.1	1B-S-
AS	D	F	12	95.1	33D-S-
Sed	D	F	250	41	33D-S-
AL	I 28	F11	<40 (1)	>75	87B---
AS	I 28	F3	28	77	975B--$
CAC (B)	I 49	B1	30 (1)	75	638B---
ChPt	I 33	P	20	94.1	53B--$
ChPt	I 34	B9	140 (1)	48	29B--$
ChPt	I 10	P1	10 (12)	98.9	51B---
ChPt	I 99	P1	97	76	7E---
ChPt	I 99	P2	110	71	7E---
ChPt	I 34	B19	55 (1)	86	29B--$
ChPt	I 34	B16	98 (1)	76	29B--$
ChPt	I 34	B6	180 (1)	33	29B--$
ChPt (B) + FIL	I 28	F19	6.5 (1)	99.28	87B---
ChPt+Fil	I 99	P1	31	92.2	7E---
ChPt+Fil	I 34	B10	19 (1)	92.9	29B--$

ChPt+Fil	I 34	B8	23 (1)	91.4	29B--$
ChPt+Fil	I 34	B20	29 (1)	92.8	29B--$
ChPt+Fil	I 99	P2	25	93.3	7E---
ChPt+Fil	I 34	B18	16 (1)	96.0	29B--$
ChPt+Fil	I 34	B17	11 (1)	97.2	29B--$
ChPt+Fil	I 34	B7	22 (1)	91.8	29B--$
ChPt+Fil (B)	I 10	B1	60 (1)	76	66B---
RO	I 10	P2	3 (4)	99.64	51B---
IE	W	P	2 (3)	99.07	42A---

CADMIUM

AQUEOUS TREATMENT TECHNOLOGY DATA INFLUENT CONCENTRATION: >1-10 mg/L

TECHNOLOGY	SOURCE MATRIX	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D	F6	65 (6)	94.1	1B-S-
ChPt	D	P2	18	99.30	55E---
RO	D	P2	160 (4)	85	18B---
RO	D	P4	1,700 (7)	81	18B---
RO	D	P3	620 (7)	86	18B---
ChPt	I 34	B69	73 (1)	94.8	29B--$
ChPt	I 34	B66	430 (1)	69	29B--$
ChPt	I 34	F	93 (15)	95.7	89B--$
ChPt + Fil (B)	I U	B3	20 (1)	98.4	88E---
ChPt + Fil (B)	I 28	B2	20 (1)	98.4	88E---
ChPt+Fil	I 34	B70	66 (1)	95.3	29B--$
ChPt+Fil	I 34	B67	360 (1)	74	29B--$
ChPt+Fil	I 34	B68	70 (1)	95.0	29B--$
ChPt	SF	F2	13 (1)	99.31	245B---
ChPt	SF	F8	6 (5)	99.70	245B---

CADMIUM

AQUEOUS TREATMENT TECHNOLOGY DATA INFLUENT CONCENTRATION: >10-100 mg

TECHNOLOGY	SOURCE MATRIX	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
ChOx/Pt (B)	I 34	B2	900 (1)	91.3	248A---
ChOx/Pt (B)	I 34	F3	13,000	72	62E---
ChPt	I 33	B39	50 (1)	99.67	29B--$
ChPt	I 34	B49	26 (1)	99.955	29B--$
ChPt	I 34	B46	1,100 (1)	98.0	29B--$
ChPt	I 33	B36	80 (1)	99.47	29B--$
ChPt+Fil	I 33	B37	7 (1)	99.953	29B--$
ChPt+Fil	I 34	B50	<10 (1)	>99.983	29B--$
ChPt+Fil	I 33	B38	4 (1)	99.973	29B--$
ChPt+Fil	I 34	B48	<10 (1)	>99.983	29B--$
ChPt+Fil	I 33	B40	2 (1)	99.987	29B--$
ChPt+Fil	I 34	B47	920 (1)	98.4	29B--$

CADMIUM

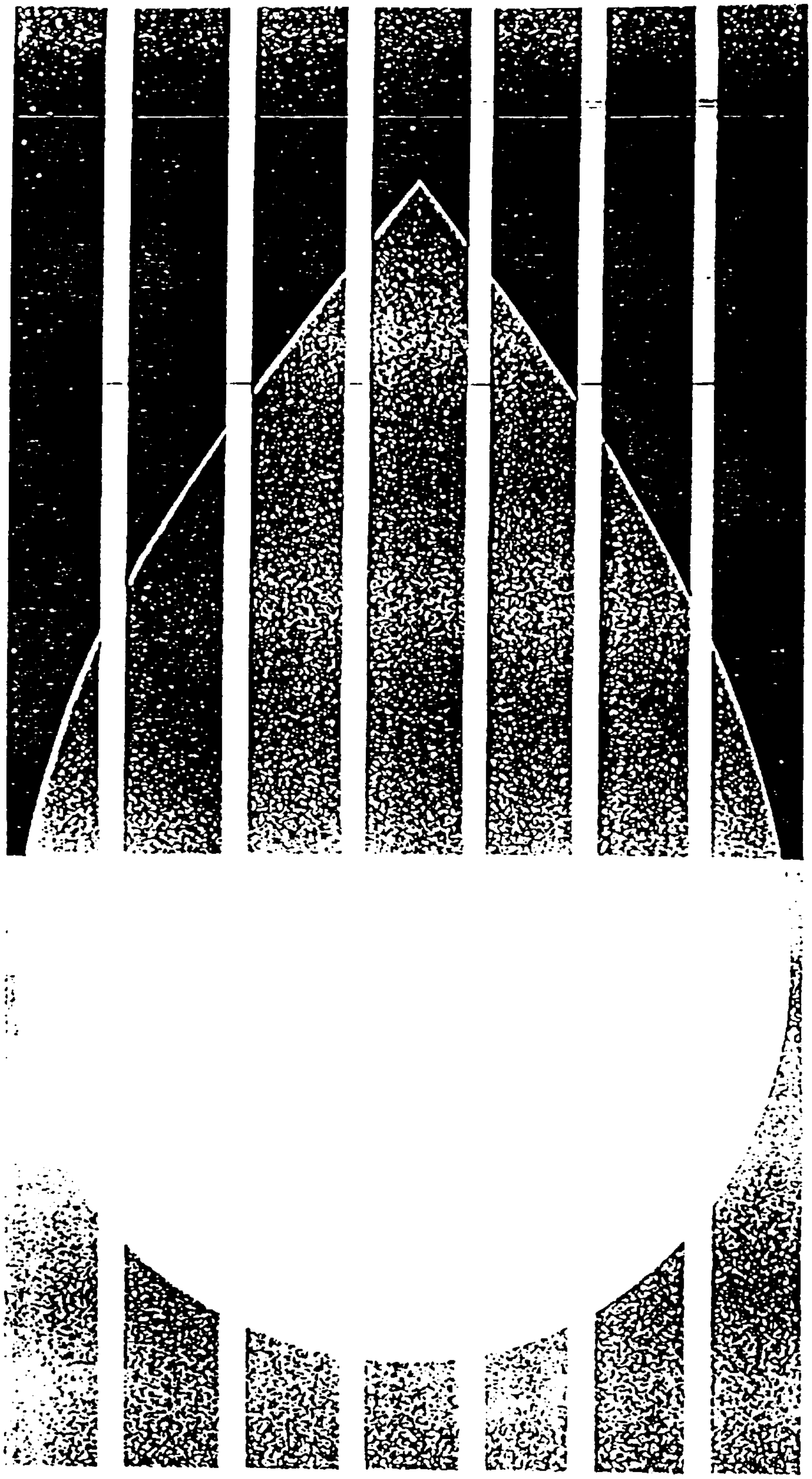
AQUEOUS TREATMENT TECHNOLOGY DATA INFLUENT CONCENTRATION: >10-100 mg

TECHNOLOGY	SOURCE MATRIX	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
ChPt (B)	S	B1	240 (1)	98.4	43E---
ChPt (B)	S	B2	<50 (1)	>99.67	43E---
Fil+GAC	TSDF	F3	690 (3)	96.5	28BVS-

CADMIUM

AQUEOUS TREATMENT TECHNOLOGY DATA INFLUENT CONCENTRATION: >100-1000

TECHNOLOGY	SOURCE MATRIX	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
ChOx/Pt (B)	I 34	B1	0.8 (1)	99.65	248A---
ChOx/Pt (B)	I 34	B4	6.3 (1)	96.1	37E--$
RO	I 33	P	0.007	99.996	39E---



DUOLITE GT·73

MERCURY REMOVAL

In the early '70's Akzo Chemicals Co. of the Netherlands developed a process for the removal of mercury using Duolite GT-73*. The process, which has been well documented in the literature[1-5] involves the following steps;

(a) Oxidation—Duolite GT-73 reacts only with ionic mercury, therefore any metallic mercury must be converted to the ionic form. This is readily accomplished by chlorination with the pH of the solution maintained at 3 to prevent iron from precipitating. In order to prevent clogging of the downstream resin beds, a good filtration system is essential. Metal hydroxides and unreacted mercury are readily filtered using either sand or cloth filters.

(b) Dechlorination—The thiol groups of Duolite GT-73 are readily oxidized. Therefore, removal of chlorine introduced in step (a), or from other sources is essential in order to retain resin activity. The Akzo process employs a two stage dechlorination, first reaction with $NaHSO_3$, Na_2SO_3 or SO_2, then passage through a special activated carbon. The carbon is housed in a column having the same dimensions as the ion exchange columns.

(c) Ion Exchange—Two beds are used in series operating in a counter-current mode. One bed acts as a roughing unit and the other as a scavenger.

A schematic representation of the process is shown in Figure 1.

---

*Duolite GT-73 was then called Imac TMR. Rohm and Haas offers Duolite GT-73 commercially and Akzo licenses a technology package for mercury recovery. Those wishing to purchase a technology package should contact:
Akzo Zout Chemie
Boortorenweg 20
7554 RS Hengelo (0)
The Netherlands

INTRODUCTION

Duolite GT-73 is a macroporous ion exchange resin based on a crosslinked polystyrene matrix. The functionality of this resin is provided mainly by the thiol (-SH) group, with minor quantities of sulfonic acid groups.

It has long been recognized that the mercury-sulfur bond is a very strong one, and, in fact, organic species that contain -SH groups are named mercaptans which arises from the Latin *mercurium captans*, "seizing mercury." Because Duolite GT-73 contains -SH functional groups it has a very high selectivity for mercury and also a high tendency to bind certain metal ions such as copper, silver, cadmium and lead. The selectivity sequence is: Hg> Ag> Cu> Pb> Cd> Ni> Co> Fe> Ca> Na.

ION EXCHANGE WITH DUOLITE GT-73

Because the thiol (-SH) groups in Duolite GT-73 form such a strong bond with ionic mercury, even very stable complexes such as $HgCl_4^{=}$ can be removed because they exist in equilibrium with the preferred ions, $HgCl^{+}$ and Hg^{++} as outlined below:

$$Hg^{++} + 4\,Cl^{-} \rightleftharpoons HgCl^{+} + 3\,Cl^{-} \rightleftharpoons HgCl_2 + 2\,Cl^{-} \rightleftharpoons HgCl_3^{-} + Cl^{-} \rightleftharpoons HgCl_4^{=}$$

CAPACITY

Duolite GT-73 has a total capacity of at least 1.2 eq/liter of -SH units and more typically 1.4 eq/liter. The equilibrium capacity of Duolite GT-73 is dependent on mercury concentration in the liquid phase but is independent of pH (between 1 and 13) and NaCl concentration (between 0 and 310 grams of NaCl/l). Figures 2 and 3 illustrate Duolite GT-73 capacity for mercury at various concentrations.

In the treatment of chlor-alkali waste water, it has been demon-

Figure 1
Akzo Process for Mercury Removal

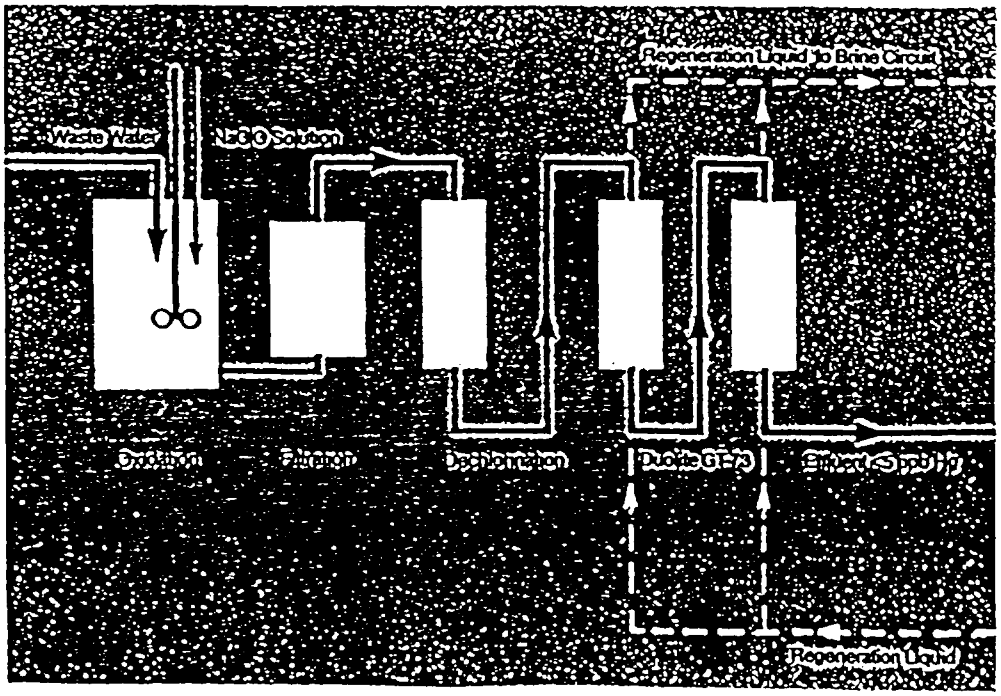


Figure 2
Capacity of Duolite GT-73 Relative to the Concentration of Mercury in the Feed

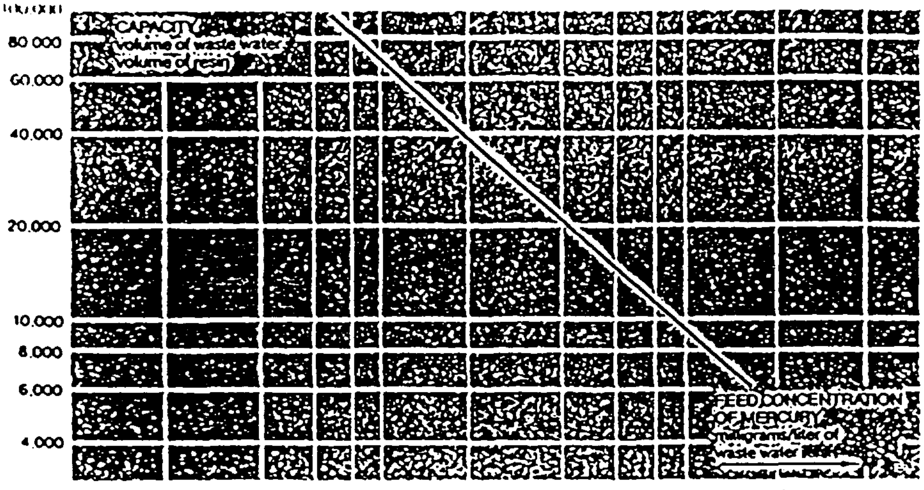
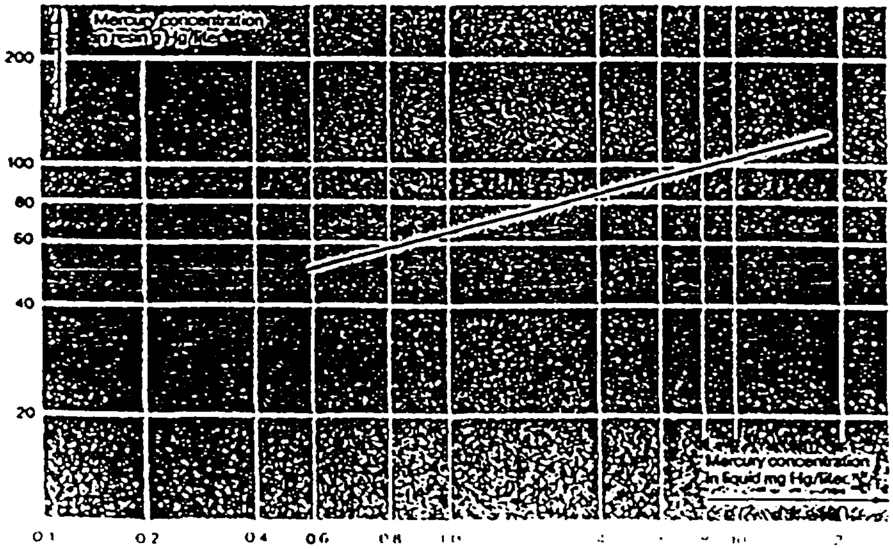


Figure 3
Equilibrium Curve of Duolite GT-73



strated that maintenance of flowrate at 10 bed volumes per hour (1.25 gpm/ft³) will produce an effluent with a mercury concentration well below 5 ppb. A typical breakthrough curve is presented in Figure 4.

SELECTIVITY

The affinity of Duolite GT-73 for metal ions parallels the solubility product of the metal sulfides. The metal with the lowest sulfide solubility product has the highest affinity for the resin. For example when a solution containing [illegible] ppm each of Hg, Cu, Pb and Cd was is passed through Duolite GT-73 mercury breaks through well after the other metals. This is graphically illustrated in Figure 5

REGENERATION

Duolite GT-73 is readily regenerated with mineral acids such as HCl. A typical regeneration curve is presented in Figure [illegible]

RESIN LIFE

Chemical damage to Duolite GT-73 is expected in the form of oxidation of -SH groups. This can be accomplished by oxidizing agents such as chlorine and other strong oxidants along with oxygen in the presence of ferric ions. The oxidation proceeds as follows:

(1) 2 R-SH + oxidant $\rightleftharpoons$ RS-SR + 2H [illegible]
(2) 3 R-S-SR + oxidant $\rightleftharpoons$
2RSOH + 2RSO₂H + [illegible]
sulfenic sulfinic [illegible]

Reaction 1 is easily reversible whereas reaction 2 is not. Akzo Zout Chemie offers a proprietary reactivation procedure which reverses reaction 1 and therefore extends resin life. Figure 7 shows resin life to be highly dependent on whether a reactivation procedure is employed. Reduction of the disulfide linkage is well documented in the literature with reducing agents such as triphenylphosphine[6,7], 1-4-dithiothreitol,[8] strong alkali,[9] sodium hydrosulfite,[10] sodium bisulfite,[11] and sodium sulfite.[12]

OTHER METALS

The high selectivity of Duolite GT-73 for various metals is shown in Figure 6 as a function of pH. All data were determined in a 1N solution of $NaNO_3$. The resin has a pronounced preference for copper, lead and cadmium ions, which are removed in considerable quantities even from solutions containing only 1 meq/l of metal and a large excess of Na^+ ions. The data indicate the possibility of selective separation of these metals.

Examples:

1. Removal of lead from waste water.
   Influent
   Composition

Pb^{++}	6 ppm
Sb^{+++}	0.3 ppm
Na^{+}	100 ppm
pH	= 2.5

The solution is passed through a column of Duolite GT-73 at a flowrate of 15 m/h (6.1 gpm/ft^2)

Figure 4
Typical breakthrough curve
Chlor-alkali plant brine, pH 2,
mercury concentration in feed 20-50 mg/l.

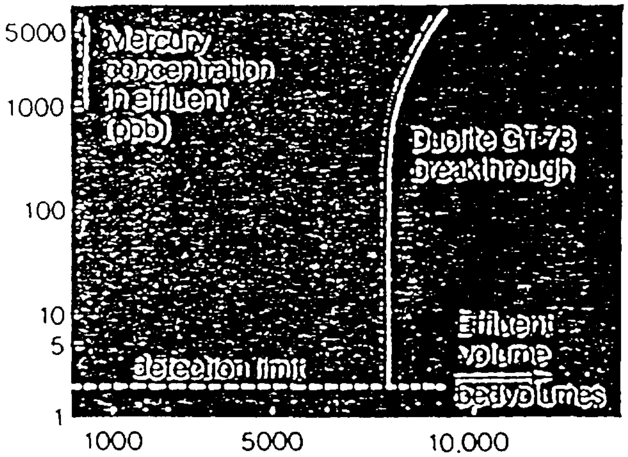
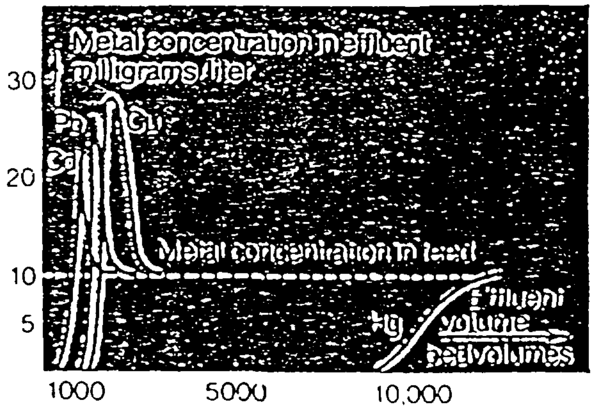


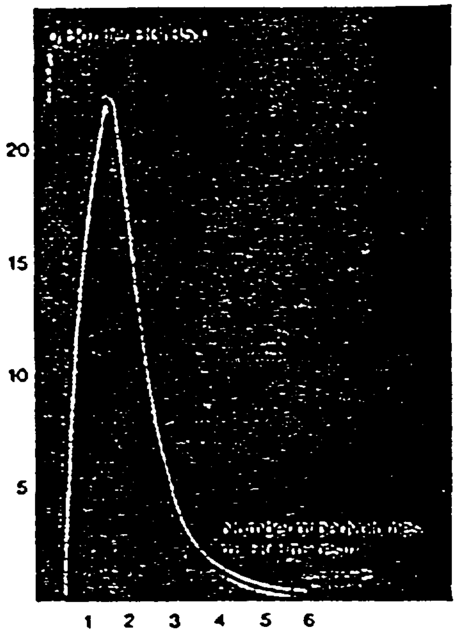
Figure 5
Replacement of the ions of Cd, Pb and Cu by Hg-ions when percolating a solution containing 10 ppm of each specimen



The effluent contains less than 0.01 ppm Pb. After passage of 700 liters (185 gal) of the solution through 1 liter of resin the effluent composition was still unchanged.

Regeneration with a nitric acid solution proved successful without deterioration of the resin

Figure 6
Regeneration of Duolite GT-73 with concentrated HCl. Regeneration rate 1 m³ HCl/m³ resin hour
Mercury concentration of resin prior to regeneration 35 g Hg/liter resin



2. Removal of copper from nickel solution
   Influent
   Composition
   Cu⁺⁺ 100 ppm
   Ni⁺⁺ 40 g/l
   Na⁺ 40 g/l

   Flowrate 15 m/h (6.1 gpm/ft²). The effluent contains less than 0.25 ppm Cu after passage of 200 liters (53 gal) solution/liter of resin. After 250 liters (66 gal). of solution the leakage has increased to 5 ppm Cu.

3. Ag removal from fixing-bath solution.
   Influent
   Composition
   Ag 10 g/l
   $(NH_4)_2S_2O_3$ 150 g/l

   Flow rate: 3 m/h (1.2 gpm/ft²)
   Effluent
   Composition: Ag 25 ppm

Figure 7
Change of Duolite GT-73 operating capacity as a function of time

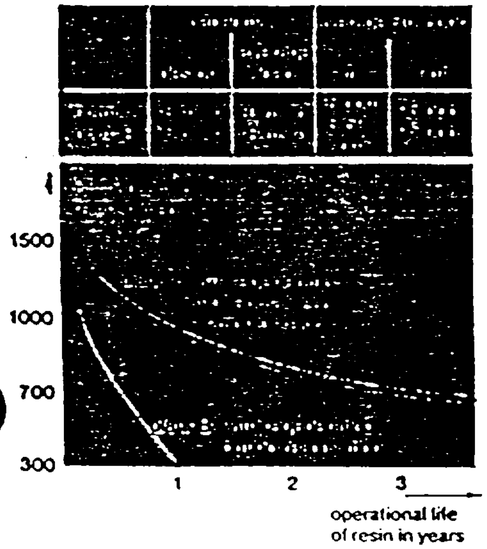


Figure 8
Duolite GT-73 Ion Exchange Equilibria in 1 N. $NaNO_3$ Solution
Metal concentration: 1 meq/l metal ions.

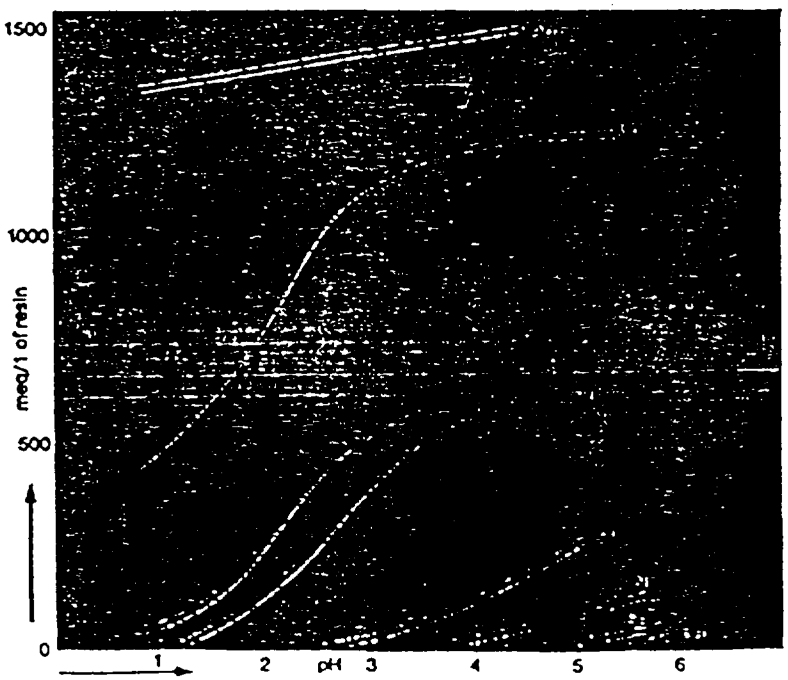


Table #1 lists the basic characteristics of Duolite GT-73. Figure 9 and 10 show the hydraulic expansion and pressure drop.

SAFE HANDLING INFORMATION:

A Material Safety Data Sheet is available for Duolite GT-73. To obtain a copy, contact your Rohm and Haas representative.

CAUTION:

Acidic and basic regenerant solutions are corrosive and should be handled in a manner that will prevent eye and skin contact.

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.

TABLE 1
DUOLITE GT-73* CHARACTERISTICS

Resin Characteristics:

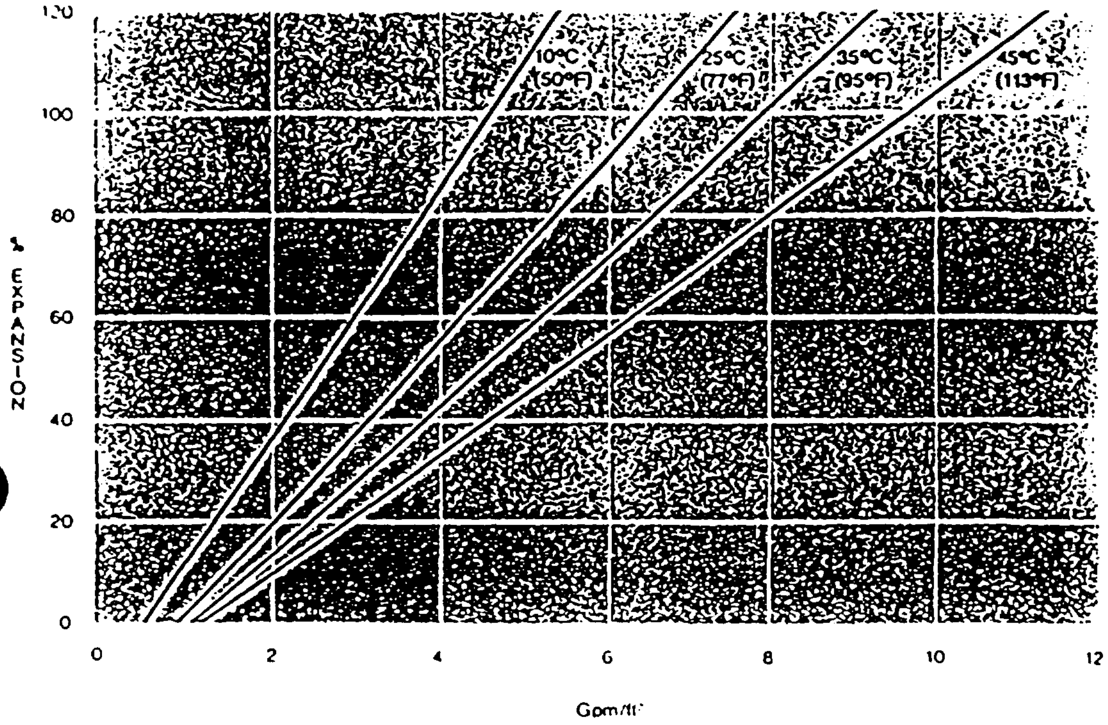
Chemical Structure	: macroporous polystyrene beads with weakly acidic active sites
Particle size distribution	: 0.3 - 1.2 mm
Density as shipped	: 800 g/l (50 lbs/ft^3)
Delivery form	: H^+
Total capacity	: 1.4 eq/l (30.6 Kgrs as $CaCO_3/ft^3$)
pH-range	: 1-13
Moisture content	: 50-60%
Swelling:	
$H \longrightarrow Na$	: 40%
$H \longrightarrow Cu$	: 5%
$H \longrightarrow Hg$	: 5%

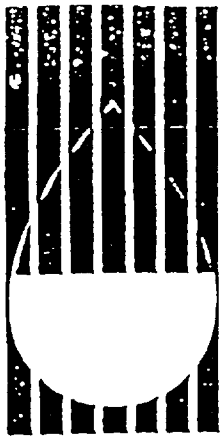
Recommended Operating Conditions:

Recommended flow rate	: 5-20 m/h (2-8 gpm/ft^2)
Backwash flow rate	: 10-12 m/h (4-5 gpm/ft^2)
Bed depth	: 0.5-1.75 m (1.6-5.7 ft)
Operating capacity	: 300-1000 meq/l, dependent on application conditions (6.5 to 21.8 Kgrs as $CaCo_3/ft^3$)
Regeneration	: Mineral acids (HCl, H_2SO_4)

*Formerly known as Imac TMR and Imac GT-73

Figure 9
HYDRAULIC EXPANSION
Duolite GT-73





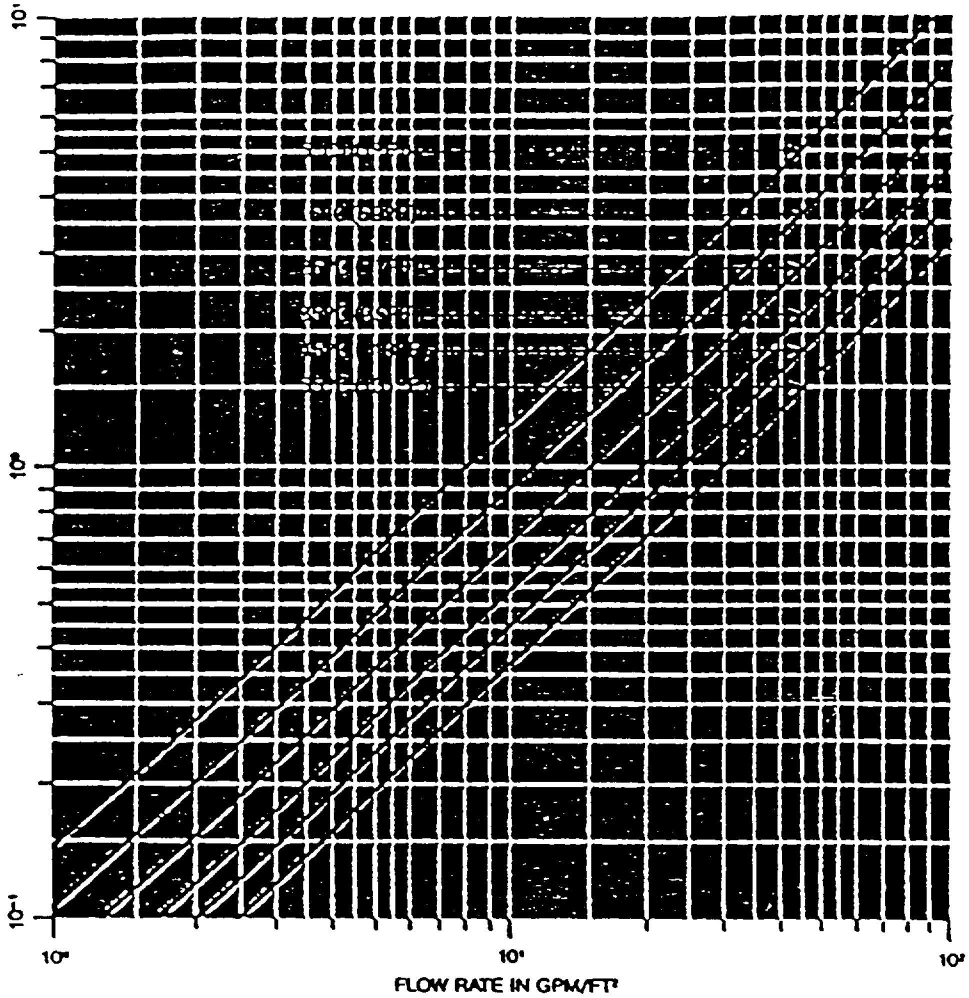


Figure 10
Pressure Drop
Duolite GT-73

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ROHM AND HAAS COMPANY
PHILADELPHIA, PENNSYLVANIA 19105
FLUID PROCESS CHEMICALS

AMBERLITE ION EXCHANGE RESINS

AMBERLITE DP-1

Amberlite DP-1 is a macroreticular weakly acidic cation exchange resin based upon a crosslinked methacrylic acid copolymer structure. Its unusually high exchange capacity is derived from carboxylic acid groups. Amberlite DP-1 effectively removes soluble iron and other metal cations from potable water and is essentially free of taste, odor, and colorthrow.

IMPORTANT FEATURES OF AMBERLITE DP-1

STABILITY—Amberlite DP-1 has exhibited excellent resistance to physical attrition and is stable in the presence of strong alkalies and acids, aliphatic and aromatic solvents. On prolonged contact with certain organic solvents, the resin swells to some extent, but no breakage of the beads has been observed.

SELECTIVITY—In the sodium form, Amberlite DP-1 softens water in the same manner as does a strongly acidic cation exchanger. The selectivity of Amberlite DP-1 for hardness ions is, however, considerably greater than that of the sulfonic acid cation exchange resins such as Amberlite IR-120. The hydrolytic behavior of the sodium salt of Amberlite DP-1; its selectivity for divalent cations, and the ease with which the sodium salt of this resin reacts with hydrogen ions to neutralize water are the keys to the unique behavior of this product for water conditioning.

HIGH CAPACITY—With an acid-alkali regeneration, Amberlite DP-1 has an operating exchange capacity of over 40 kgr/ft³ (91 g/l). For convenience, Amberlite DP-1 can be regenerated with a mixture of sodium citrate, sodium hydroxide and sodium chloride to yield a softening capacity of approximately 17 to 21 kgr/ft³ (39 to 48 g/l). The neutralization capacity of Amberlite DP-1 is far superior to a sulfonic acid cation exchanger.

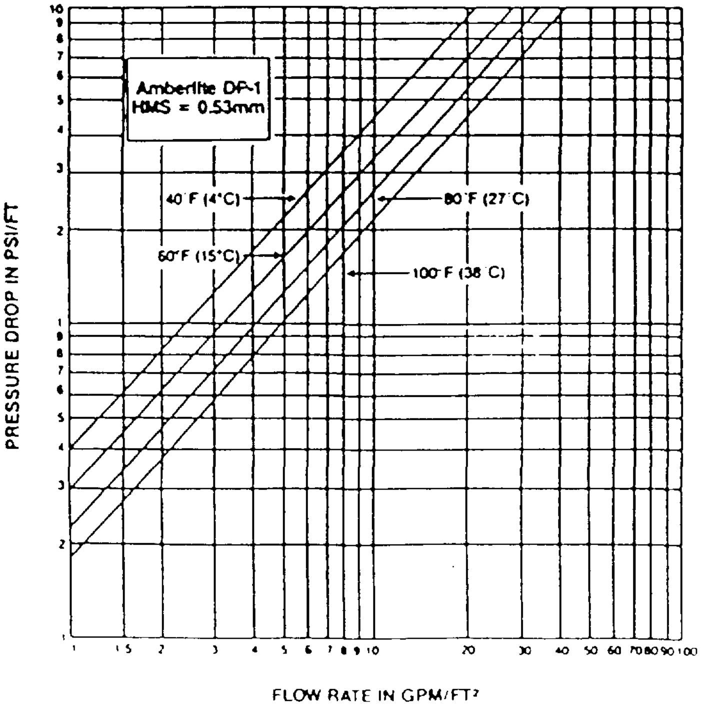
STABLE OVER THE ENTIRE pH RANGE

INSOLUBLE IN ALL COMMON SOLVENTS

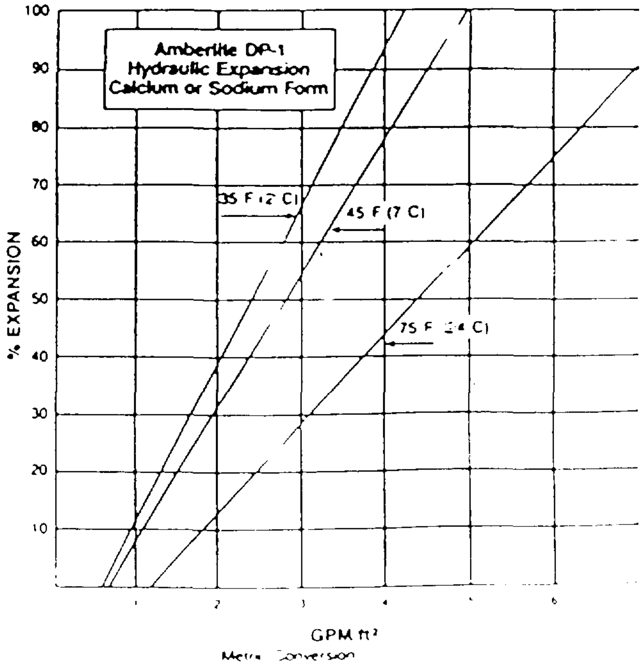
HYDRAULIC CHARACTERISTICS

PRESSURE DROP—The approximate pressure drop for each foot of Amberlite DP-1 bed depth, in normal downflow operation, at various water temperatures and rates of flow is shown in the graph below.

BACKWASH—After each service cycle, Amberlite DP-1 should be backwashed with water for approximately 10 minutes to purge the bed of any suspended insoluble material that may have collected on the resin. The resin bed should be expanded a minimum of 50% during backwash.



METRIC CONVERSION
GPM/ft² to M/hr — GPM/ft² x 2.45
PSI/ft to MH₂O/M resin — PSI/ft x 2.30



Metric Conversion
GPM — to M/hr — gpm/ft² x 2.45

PHYSICAL CHARACTERISTICS

YSICAL FORM—White opaque spherical particles shipped in dium form in a moist condition.

IPPING WEIGHT—46 lbs/ft³ (736 g/l)

MOISTURE CONTENT—60 to 70%*

REEN GRADING (WET)—16 to 50 mesh (U.S. Standard Sieves)

FECTIVE SIZE—0.45 mm*

SWELLING—100% (hydrogen to sodium)

pproximate

SUGGESTED OPERATING CONDITIONS

pH range	4.5-14
aximum Temperature	250°F (121°C)
inimum Bed Depth	24 in. (0.61 m)
Backwash Flow Rate	See detailed information
Service Flow Rate	2-4 gpm/ft³ (16 to 32 l/hr/l)
generation Level	See detailed information
Regeneration Flow Rate	0.25-0.50 gpm/ft³ (2.0 to 4.0 l/hr/l)
nse Flow Rate	Same as regeneration flow rate initially, then 2 gpm/ft³ (16 l/hr/l)
Rinse Water Requirements	25-50 gal/ft³ (3.35 to 6.7 l/l)
change Capacity	See detailed information

EXCHANGE CAPACITY AND REGENERATION

mberlite DP-1, which contains slightly ionized carboxylic acid oups, shows a very high affinity for hydrogen ions. Consequently, complete regeneration of this resin may be accomplished with the following low levels of acids.

Acid	Amount (lbs/ft³)	Amount (g/l)	Concentration (% solution)
HCl	6.25	100	5.0%
H_2SO_4	8.4	134	2.0%

convert the resin back to the sodium form, 6 lbs of NaOH/ft³ 6 g/l) as a 4% solution are required.

For a water containing 500 ppm hardness at 75°F (24°C), flowing at 2 gpm/ft³ (16 l/hr/l), a capacity of over 40 kgr (91 g/l) can be pected when using Amberlite DP-1 in the sodium form. A wer temperature or higher flow rate will decrease the capacity Amberlite DP-1.

applications where it is not desirable to use acid regenera- on, such as in home water softeners, Amberlite DP-1 can be regenerated with a 9% solution of sodium chloride, sodium hydroxide and sodium citrate. Capacities for several solutions e shown below.

Solution Composition (lbs regenerant/ft³ resin)			g/l of resin			Total Regenerant		Capacity	
Cl	NaOH	Na_3 Citrate	NaCl	NaOH	Na Citrate	(lbs/ft³)	(g/l of resin)	(kgr/ft³)	($gCaCO_3/l$)
7	.5	1	112	8	16	8.5	136	17.3	39.6
10	.5	1	160	8	16	11.5	184	18.7	42.8
10	.5	2	160	8	32	12.5	200	21.4	49.0

APPLICATIONS

SOFTENING—Amberlite DP-1 in the sodium form has proven to be effective in softening waters for home and industrial use. In industrial and domestic exchange tank applications, Amberlite DP-1 offers a very high capacity when acid-alkali regeneration is used. For automatic home water softening and neutralization, regeneration is conveniently accomplished with a 9% aqueous solution containing sodium citrate, sodium chloride and sodium hydroxide.

DEALKALIZATION—The reduction of bicarbonate and carbonate concentrations and the removal of alkaline metals, particularly from waters having a hardness to alkalinity ratio greater than unity, may efficiently and economically be accomplished by utilizing Amberlite DP-1 in the hydrogen form. In the hydrogen form, Amberlite DP-1 converts bicarbonate salts to carbonic acid, which breaks down to yield carbon dioxide and water. Once formed, the carbon dioxide may be removed with simple aeration.

WASTE CONTROL—Amberlite DP-1 effectively removes many trace metals such as zinc, copper, cobalt, chromium and cadmium from municipal and industrial waste streams. These metals are removed while permitting alkali metals and alkaline earths to remain in solution. The resin is then regenerated with a dilute acid solution to yield a concentrated waste more amenable to disposal or, in some cases, recovery of the metals.

FDA—When employing Amberlite DP-1 in the processing or production of any food material which is to be consumed by humans or animals, precautions must be taken to avoid contamination that may result from extractables, bacterial action or introduction of extraneous poisonous materials. Preconditioning treatment is necessary to reduce the extractables to levels complying with Food and Drug Administration Regulation 21CFR173.25. A suggested preconditioning treatment is to subject the resin to at least three cycles of exhaustion using 150 gal (568 l) of a 0.5% solution of sodium hydroxide per cubic foot of resin (28.3 l). Following each of the three preconditioning exhaustion steps, the resin should be regenerated with 35 gal (132 l) of a 5.0% sulfuric acid solution per cubic foot of resin (28.3 l). This preconditioning treatment will put the resin in the hydrogen form. If operation in the sodium form is desired, the resin must be regenerated with sodium hydroxide.

SAFE HANDLING INFORMATION—A Material Safety Data Sheet is available for Amberlite DP-1. To obtain a copy contact your Rohm and Haas representative.

CAUTION—Acidic and basic regenerant solutions are corrosive and should be handled in a manner that will prevent eye and skin contact.

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.

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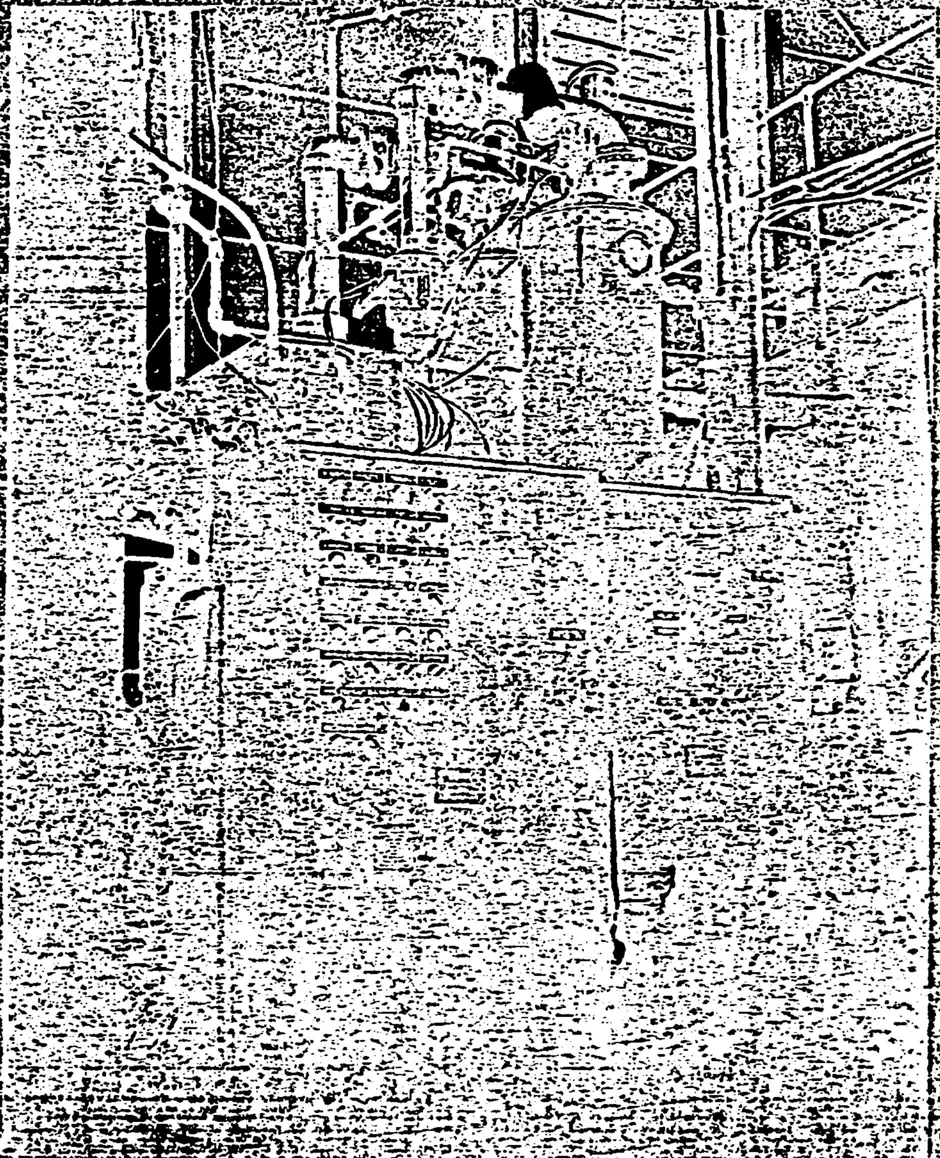
Lancy Sorption Filter Systems

Solutions Through Teamed Technologies



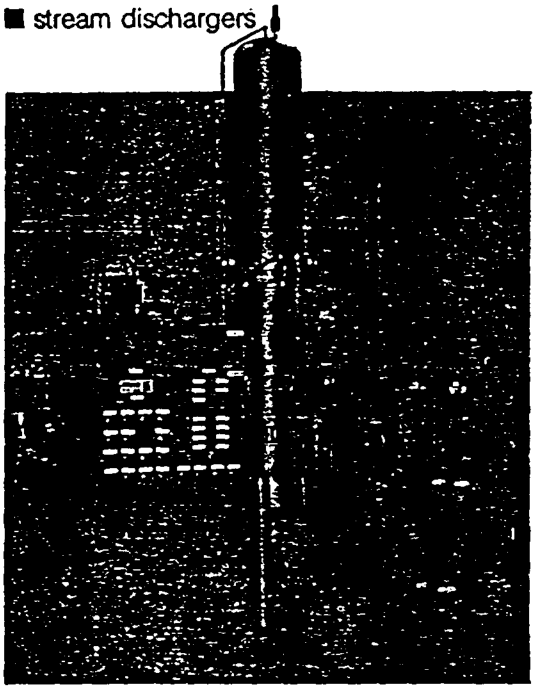
U.S. FILTER

UNITED STATES FILTER CORPORATION

Applications

The Lancy Sorption Filter is designed for treatment of segregated and non-segregated streams, stand alone treatment, polishing treatment, and retrofitting or upgrading of existing treatment systems. It consistently removes heavy metals to meet extremely low effluent levels for:

- contaminated groundwater applications
- electronics manufacturing (printed circuit board)
- metal finishing operations
- landfill leachate
- stream dischargers



Design Criteria

Lancy Sorption Filter units are designed to remove low levels of total suspended solids and heavy metals. Typical maximum incoming loadings are as follows:

Total heavy metals:
0-50 ppm total metals
>50 ppm, pre-treatment is required

Total suspended solids:
0-100 ppm
>100 ppm, pre-treatment is required

Total acidity:
Less than 100 ppm expressed as CaCO3

The influent should be essentially free of emulsified oil and grease which drastically increases media consumption. Typically less than 10 ppm oil and grease is tolerable. Separate equipment can be provided to pretreat such streams.

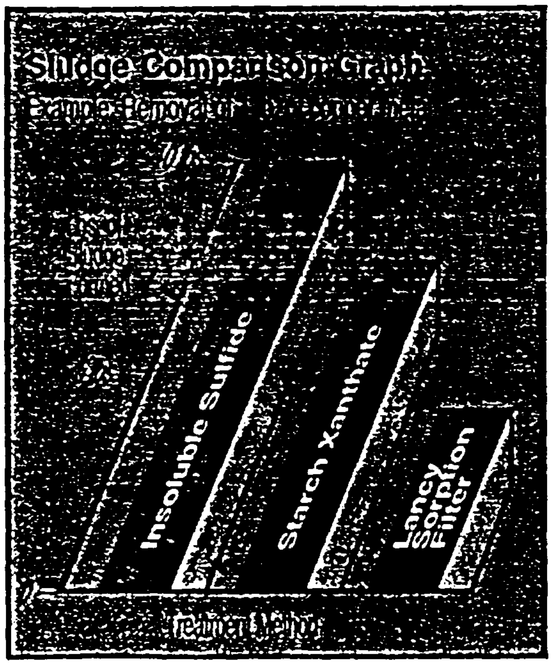
All chemical feed concentrations and chemical feed pump rates are based on these parameters. Consult the factory for alternatives if these loadings are exceeded.

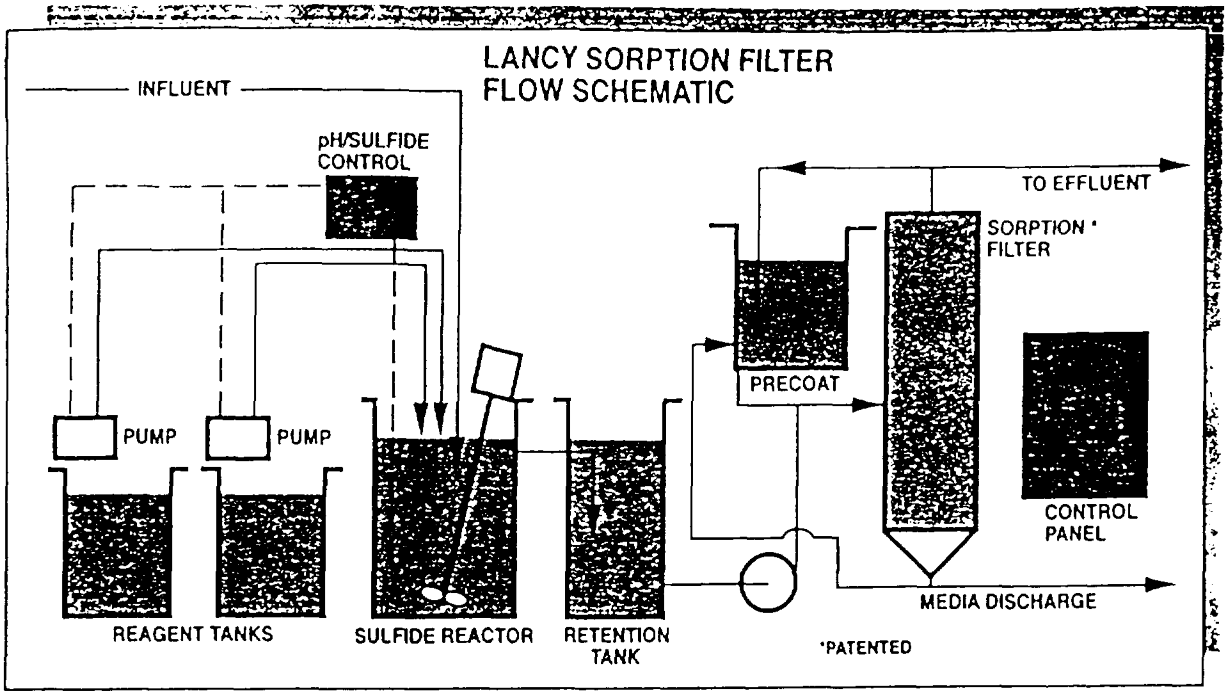
Features

- Removes chelated and non-chelated heavy metals from segregated or mixed waste streams
- Specialized proprietary filter media for removal of heavy metals and residual soluble sulfides
- Patented sulfide control
- Pre-piped and pre-wired skidded unit with built in chemical feed modules
- Fully automatic and continuous operation for four standardized sizes: 20, 80, 160, 240 gpm
- No internal moving parts
- PLC controlled operation
- Unique backwash system which utilizes compressed air to drive filtered water back through the filter tubes

Benefits

- Zinc, silver, copper, lead, cadmium can be reduced to < 0.05 ppm and other metals to < 0.1 ppm
- Mercury can be reduced to < 2.0 ppb
- Continuously recycles and reuses the media for maximum solids handling capacity
- Easy installation
- Minimal operator attention required
- Can be designed into new or existing treatment systems
- No additional solids are added to the waste stream to remove heavy metals
- Low sludge generation
- Capital and operating costs are typically lower than cross flow microfilters
- Process guarantees are provided based on treatability




LANCY SORPTION FILTER FLOW SCHEMATIC

Process Description

The Sorption Filter process uses sodium sulfide chemistry to precipitate heavy metals to meet very low effluent limits.

Wastewaters to be treated by the Lancy Sorption Filter are directed to the integral pH adjustment - sulfide reactor. Here the pH is raised automatically by caustic addition. Simultaneously, sodium sulfide is added via a patented sulfide sensing device to the wastewater. Safety interlocks are included to insure that the pH is a minimum of 9.5 before sulfide can be added.

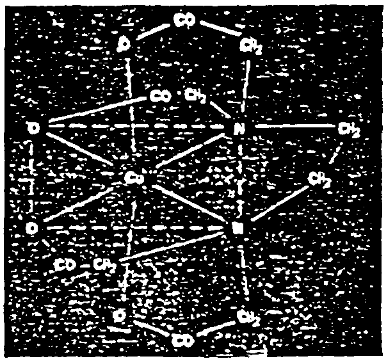
The wastewater then overflows to the retention tank, which serves as a pump down/holding vessel. From the retention tanks, the wastewater is pumped to the filter body where it is filtered through a proprietary reactive media which performs two functions. First, it filters out the fine, colloidal metal sulfide precipitate formed in the reaction module. Second, it absorbs any residual soluble metals and unreacted sulfides remaining in the solution.

Sizing Chart

Flow Rate (gpm)	Filter Area (sq ft)	Overall System (L x W x H)
20	40	11 x 8 x 12
80	160	8 x 8½ x 13
160	320	Multiple skids
240	480	Multiple skids

Equipment arrangement is flexible and can, if required, be supplied to fit other equivalent plan area dimensions.

As the liquid passes through the numerous filter tubes contained in the filter body, suspended solids and metals are deposited on the outside of the tubes. Filtrate passes up through the inside diameter of the tubes, into the filtrate headers and on to the main outlet.



At the end of the filter cycle, air trapped in the top of the filter cap is released causing the filter tubes to expand and "bump" the filter cake along the entire length of the tube. Filtered liquid is forced back through the tubes, carrying the accumulated solids and liquid to waste in a matter of seconds. At this time, the solution in the filter system is recycled back through a separate precoat tank until the media is recoated on the filter fingers, therby exposing new sites for filtration and adsorption.

While the filter precoats, the incoming waste is accumulated in the retention tank. After the precoat cycle is completed, the filter resumes processing of the accumulated wastewater.

Capabilities

Whether you are integrating a Lancy Sorption Filter into a new or existing treatment design, or depending on the sorption filter to consistently perform as a stand-alone treatment process, US Filter has the in-house capabilities to help.

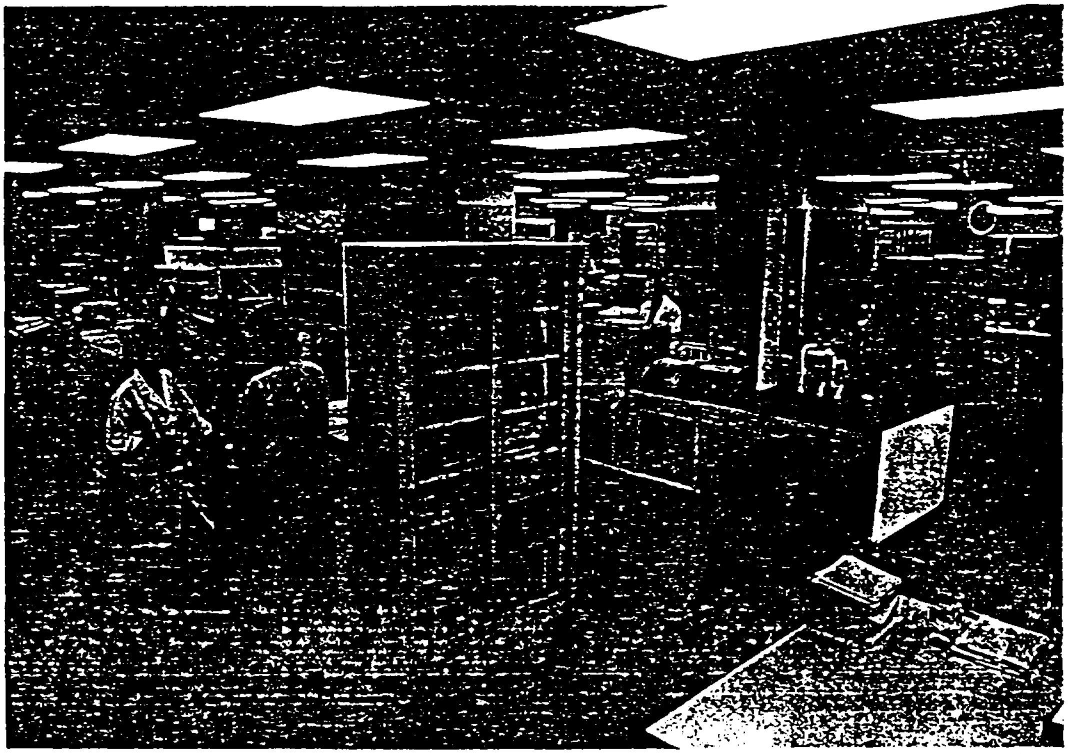
Based on conclusive laboratory treatability work as well as our experience with hundreds of applications, US Filter will provide in writing, a straight forward performance guarantee in addition to our mechanical warranty.

Once sizing is confirmed, you get equipment that performs reliably for years. The reliability starts with professional start-up assistance and continues with uninterrupted customer service. If you prefer, we can also install any of the equipment we supply. Our installation experience includes hundreds of turnkey and equipment supply projects. By choosing US Filter, you get more than a good piece of equipment, you get professional, experienced assistance with your treatment solution.

With environmental regulations continuing to become more stringent, the Lancy Sorption Filter effectively reduces heavy metals in a contaminated stream to the part per billion range. The Lancy Sorption Filter provides an exceptionally efficient method for the continuous removal of both chelated and non-chelated heavy metals using proven sulfide chemistry and specialized adsorption media.

Options

1. Stainless steel filter body
2. 3-channel chart recorder
3. Materials of construction for piping - PVC, CPVC
4. Alternate medias including diatomaceous earth and cellulose fiber
5. Sludge handling equipment
6. Pre-treatment equipment



U.S. FILTER
UNITED STATES FILTER CORPORATION

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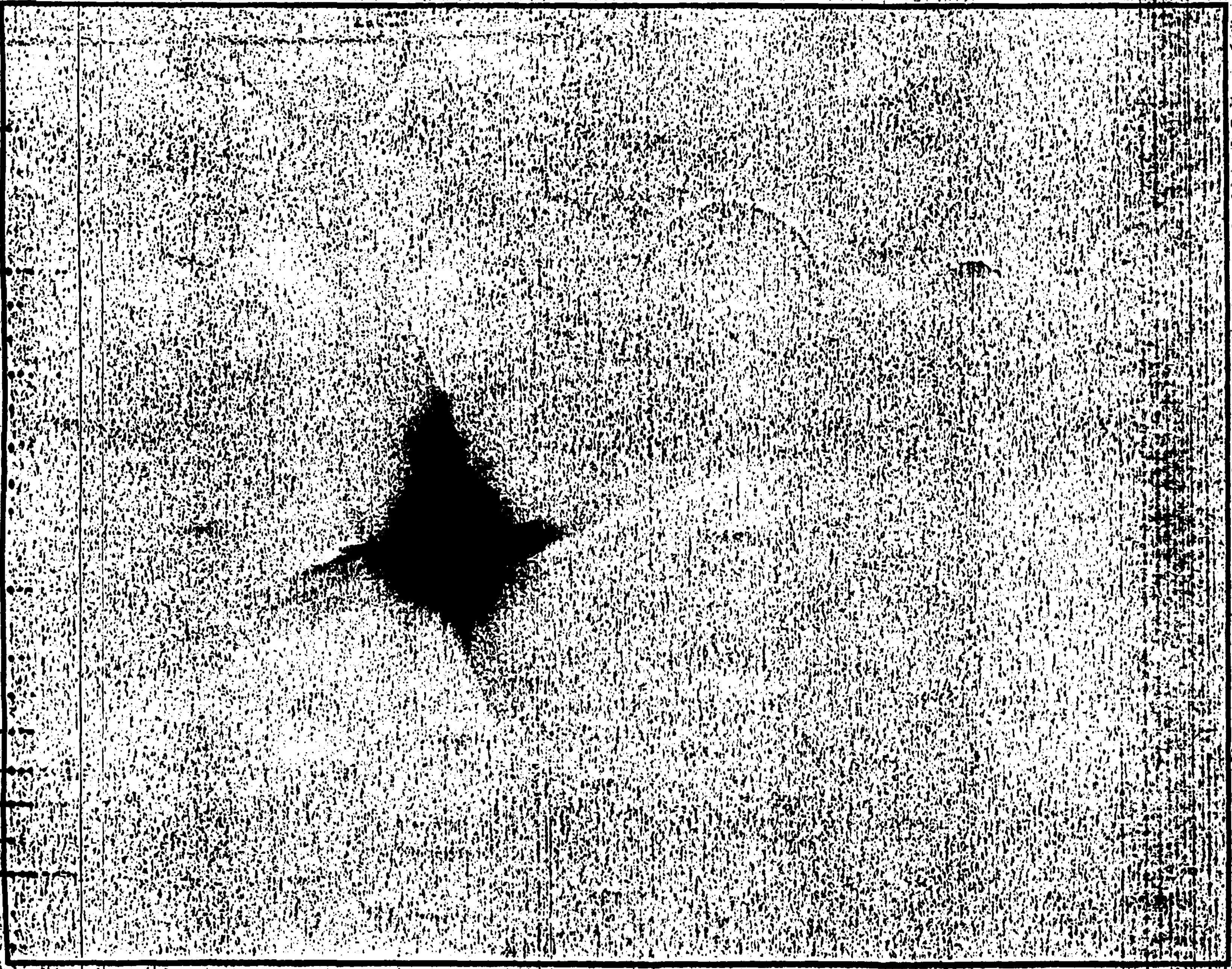
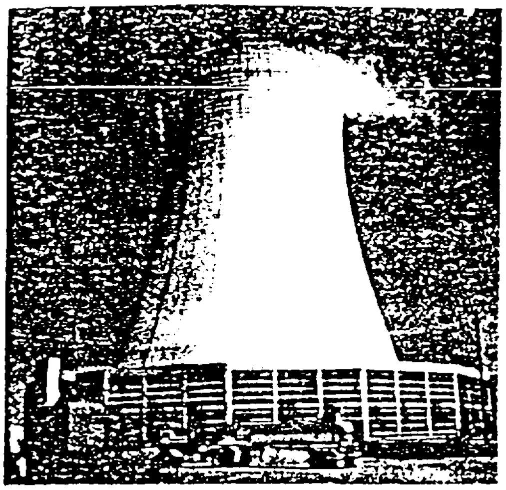
ION EXCHANGE RESINS AND SERVICES

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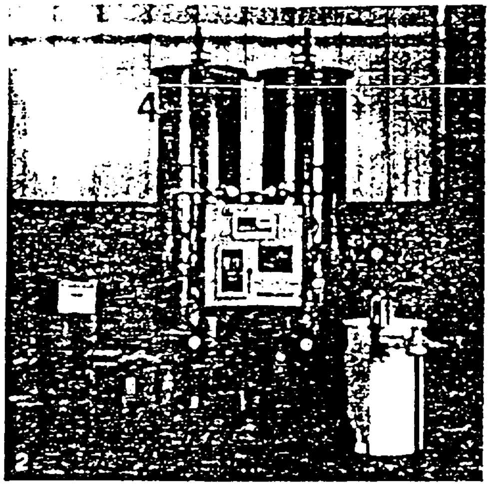
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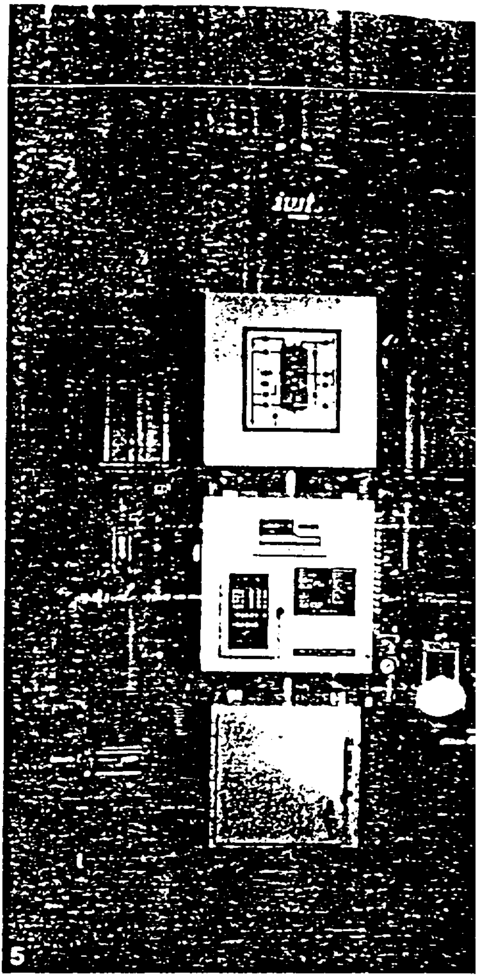
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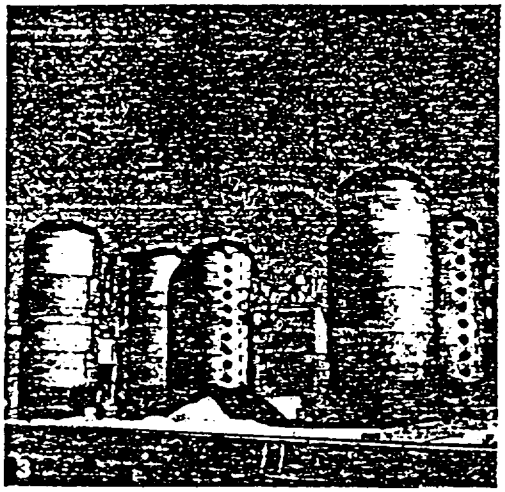
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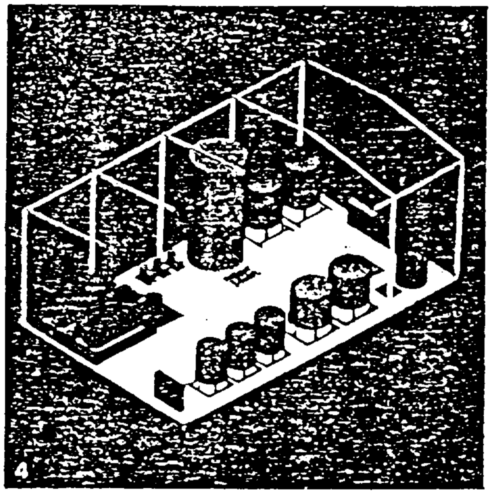
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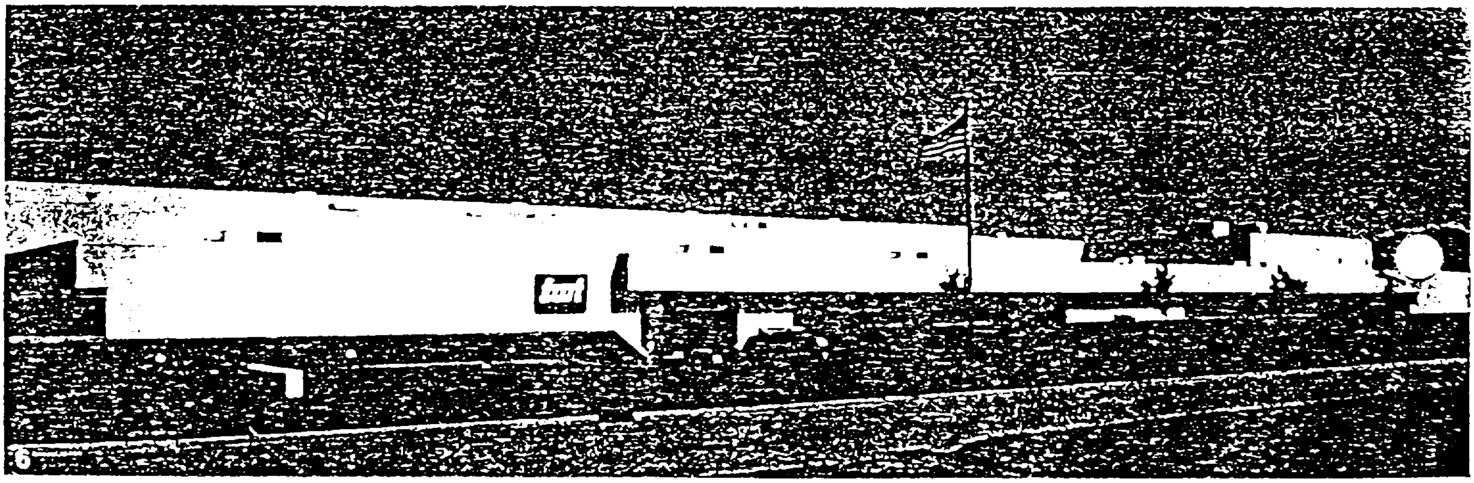
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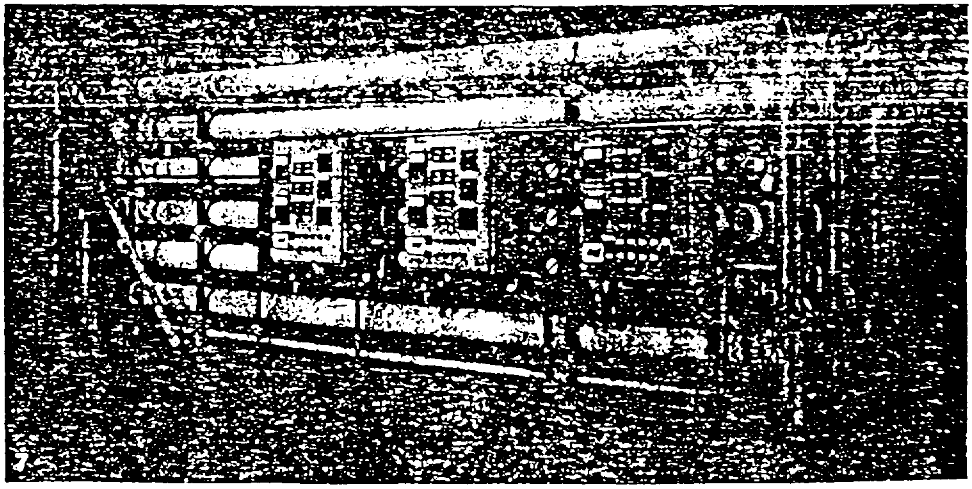
1. Resin processing and transport services
2. Pre-engineered two bed deionization systems
3. ADSEP systems for high purity separations
4. Complete turn-key plant capabilities
5. Pre-engineered mixed bed deionization systems
6. Plant administration, sales, engineering, R&D, and manufacturing
7. Reverse osmosis membrane systems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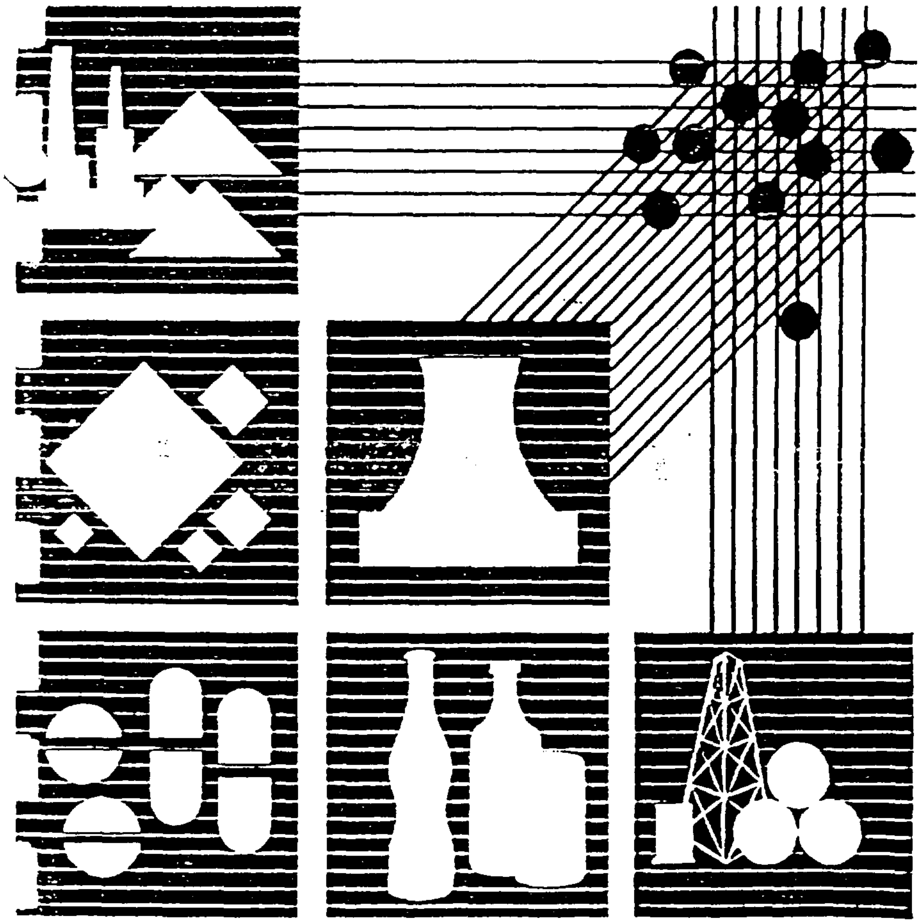
IWT ION EXCHANGE RESINS AND SERVICES

Increased volumes and higher purity levels of water and other liquids are the result of a continuous effort to achieve higher product quality and greater cost effectiveness in industry today.

Ion exchange is the primary process for producing high purity water and its use has grown dramatically. Its cost effectiveness has improved through equipment innovations, resin improvements, system selection and application, and maintenance services. The cost of ion exchange resins typically represents less than 10% of the total operating cost to produce high purity water and other liquids; whereas, the remaining 90% is consumed in chemicals, labor, water, power, sewer, and maintenance costs. Like any other service, the selection, application, and supplying of ion exchange resins must result in cost savings that make the service a good value. Many variables affect the ability of a resin to perform efficiently in any system. IWT, as a leader in the water and liquid treatment industry, combines equipment design and operating experience with resin evaluation expertise to assist customers in identifying these variables.

This publication describes the factors to be considered for the cost-effective selection and application of ion exchange resins. Information is also provided on the many support services available from IWT for optimizing your system's performance.



ION EXCHANGE—A VERSATILE TOOL

What is the significance of the number .0000000001? This number is the allowable fraction of sodium contamination in the feedwater to a utility nuclear steam generator. It is equivalent to 0.1 parts-per-billion. In terms of the proverbial needle in the haystack, if the needle were 1/32" in diameter and 2" in length, the haystack would have to be 20' in diameter and over 40' tall to achieve this concentration level. How is it possible to achieve this stringent sodium concentration level? It is accomplished through modern technological advancements and the phenomenal capabilities of a process called ion exchange.

This illustrates just one of hundreds of applications where ion exchange has been applied by IWT. In addition to removing ionized minerals to extremely low levels, the porosity and electro-chemical characteristics of the ion exchange copolymers have wide application for the separation and purification of various food products and organic chemicals including high fructose corn syrup, high purity dextrose, phenols, amino acids, vitamins, hormones, and various petroleum fractions. Ion exchangers can remove specific ionic species selectively, such as gold, platinum, and palladium, so that these valuable minerals can be recovered and recycled. Variations of ion exchange resins have also been used to adsorb toxic chemicals, such as herbicides, so that they can be concentrated and recycled within the production process.

Since the synthesis of ion exchange resins by Adams and Holmes in 1935, the list of applications has grown continuously for the highly versatile ion exchange resin in its many forms, even more rapidly today than in past years.

The selection of the optimum resin for a given application and geographical location requires expert consultation because of the expanding applications for ion exchange resin technology and the more than 100 commercially available resins being marketed today. IWT welcomes the opportunity to discuss your application requirements and how our Total System method can benefit you.

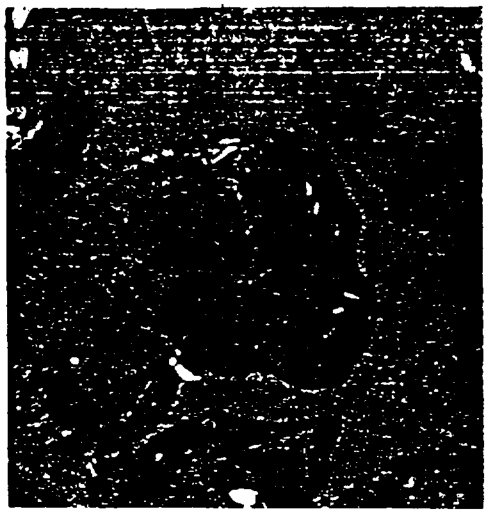
In the 1930's, Illinois Water Treatment Com- y was founded for the purpose of produc- chemicals and eventually evolved into a manufacturer of water treatment systems. In 1935, an innovative chemical development k place in England. It was demonstrated t cationic (positive) and anionic (negative) functional groups could be chemically nded onto synthetic polymers—termed ins. These materials were originally produced in granular forms; spherical resins were developed later. It was further demon- ated that through a combination of ion hange and sorption, nearly all of the dissolved salts contained in water could e removed by simply passing the water ough columns filled with ion exchange ins, thus, avoiding more expensive distillation processes. The ion exchange resins ld also be rejuvenated for continued after exhaustion by treatment with acids and alkalies.

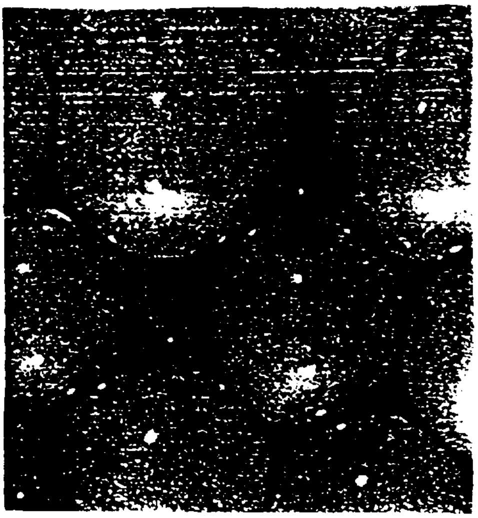
ecognizing the potential for this process, T developed the capability to design and nufacture the equipment needed to produce high quality water in commercial quan- s. As far as it is known, the first commercial onizing unit in the United States was built by IWT and installed in a plant in Rockford, Illinois. During World War II, many industries uired water of high quality and, as early as 1942, IWT already had installed over 50 deionizers throughout the United States. Over the years, many important contributions have been made to expand the application of the ion exchange process. Resin manufacturers have made available a wide variety of ion exchange materials in each of the four major classifications of strong acid, weak acid, strong base, and weak base resins. These resins have been used in various combinations and in numerous system configurations to economically achieve a given quality or characteristic of end product. Since the company's beginning, IWT has made significant contributions in the development of a number of techniques which have upgraded the quality of treated solutions and improved the operational efficiencies of the ion exchange process. Some of the major patents that have been issued to IWT that have greatly impacted the treatment of water and other liquids are:

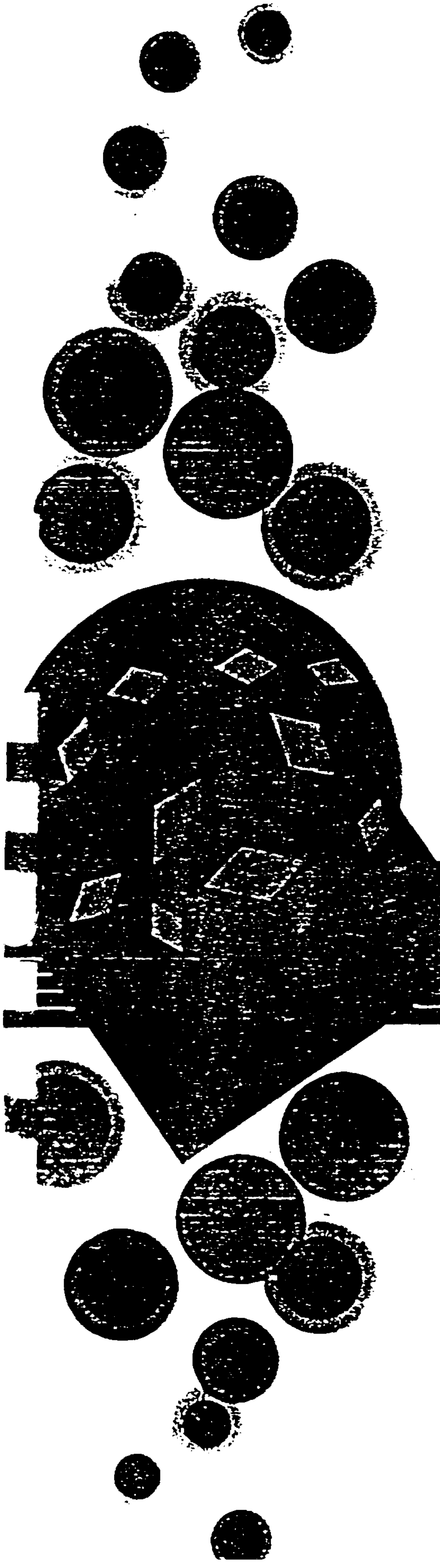
Patent #	Title
2,605,084	Method of Mixing Granular Materials (for mixed bed deionizers)
2,615,924	Method of Purifying Glycerin
2,771,424	Process for Regenerating Ion Exchange Material
2,891,007	Method of Regenerating Ion Exchangers
3,382,169	Process for Deionizing Aqueous Solutions
3,617,558	Layered Ion Exchange Process
4,193,817	Production of Bottler's Liquid Sugar
4,204,041	High Loading of Immobilized Enzymes on Activated Carbon Supports
4,316,802	Filter

To meet the expanding treatment requirements of industry, IWT's product line has grown over the years to include not only ion exchange systems, but clarification, filtration, ultrafiltration, reverse osmosis, adsorption, waste treatment, and pollution control systems, as well as systems for the recovery of valuable chemicals and precious metals from solutions.

IWT has applied ion exchange and related processes to the treatment of water supplies for power generation and the production of electronic components, chemicals, pharmaceuticals, cosmetics, and food products, to name a few. Today, ion exchange is the preferred method for treatment of water supplies for industries all over the world. By incorporating the specialized skills of chemists, biologists, engineers, and technologists, IWT can provide the expertise necessary to solve any liquid treatment problem.







Efficient, economical operation of ion exchange systems and auxiliary equipment has become an increasingly important consideration in the processing of various products. A significant cost associated with the operation of these systems is the chemical regeneration of the resin that is required to restore them to a service condition. This includes not only the cost of the regenerant chemical, but also the labor cost, neutralization cost, and sewer surcharges or waste treatment costs required to meet discharge limitations.

Proper selection and application of ion exchange resins can be a major contributor to the cost-effective operation of any ion exchange system. The cost of resin typically represents less than 10% of the total operating cost to produce high purity water and other liquids; whereas, the remaining 90% is comprised of chemicals, labor, water, power, sewer, and maintenance costs, etc. Many variables affect the ability of the resins to perform efficiently in any system. IWT combines equipment design and operating experience with resin evaluation expertise to help identify these variables and optimize equipment performance.

The overwhelming cost of chemicals, water, and labor as compared to the cost of ion exchange resin associated with the operation of a typical two bed boiler feedwater make-up demineralizer is illustrated in Chart 1. The cost of replacing the resin is small, but the savings of the other operating costs can be significant. You can get the most for your money by purchasing resins from a supplier with the expertise to address this important issue

Every ion exchange system has its unique "Optimum Replacement Point" (ORP). It is IWT's goal, as a leader in the replacement resin market, to help our customers prolong the useful life of their resin and move the *ORP (as illustrated in Graph A) as far to the right as economically feasible.

Proper resin selection will contribute to improving the *ORP by reducing:

- The frequency of regenerations
- Irreversible fouling
- Premature chemical degradation
- The effects of inadequate equipment design
- The effects of variations in feedwater and regenerant characteristics

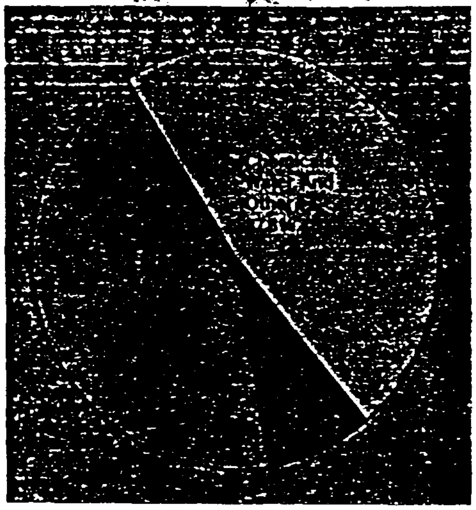
Other ways to reduce chemical, water, and labor consumption are by:

- Adding pretreatment equipment to protect the resin
- Optimizing regenerant quality
- Optimizing equipment design
- Improving operator knowledge

IWT can assist you in determining where the *ORP is for your system and can recommend steps which can be taken to optimize your system's performance.

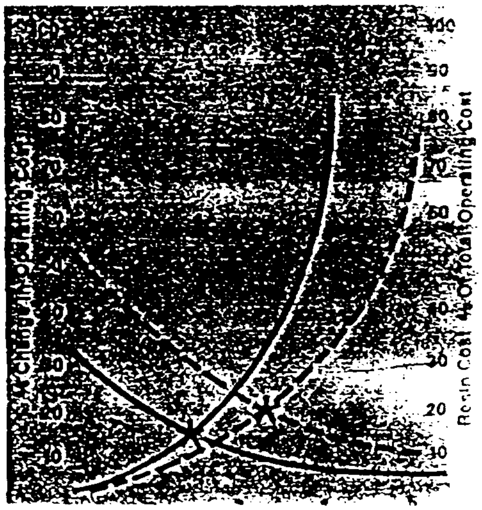
Chart 1
Operating Cost of a Typical Two Bed Boiler Feedwater Make-up Demineralizer

Even considering regional differences in the variables used to develop this chart, the cost of resin replacement is minor compared to the total system operating costs.



Graph A
Optimum Replacement Point (*ORP)

This graph illustrates the *ORP's for two demineralization systems. When the percent increase in operating costs becomes greater than the cost of the resin as a percent of operating cost, it is more economical to replace the resin



Responsiveness And Reliability

e of the largest inventories of ion exchange n in the United States and an experienced staff of chemists, chemical engineers, factory t ned service personnel, and local represen- ves allow IWT to provide customers with ast, dependable resin replacement service. IWT's extensive inventory of cation and anion n meets the needs of a wide variety of lustries and applications including:

- BWR Condensate Polishing
- onventional Condensate Polishing
- Radwaste
- Boiler Make-up
- oftening
- Pharmaceutical
- ugar Demineralization
- ator Cooling
- Metal Recovery
- ation Conductivity
- atalysts
- Dealkalization
- ectronics
- lp and Paper
- Deoxygenation

Resin Processing For Special Needs

High purity resins require special processing to ensure high degrees of conversion and low levels of impurities. Resins, as listed in Chart 2, are made in IWT's facility to meet stringent industry specifications, such as those recommended for nuclear units by General Electric and Westinghouse and the ultrapure water quality requirements of the electronics industry. IWT's facility is designed specifically for these high purity applications and many other customer requirements, such as:

- Cleaning and sterilizing fouled and contaminated resins
- Custom blending of resins
- Resizing and regenerating chromatographic resins
- Pick up and delivery of resins in a slurry
- Custom packaging of resins
- Cross regenerating of resins including resins for food and pharmaceutical applications

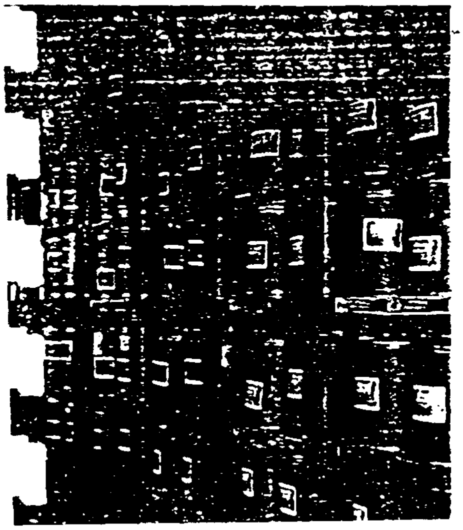
IWT has a resin reprocessing service for salvaging fouled and/or exhausted resin when it is not feasible or economical to do so at the jobsite. The resin can be transported to and from the jobsite in our tank trucks, 55 gallon steel drums, or standard fiber drums. Hydraulic transfer of the resin to and from our tank trucks minimizes field labor and downtime. This service has helped save some of our customers thousands of dollars worth of replacement resin and other associated costs.

Chart 2
Nuclear Grade, Semiconductor, and Specialty Resins

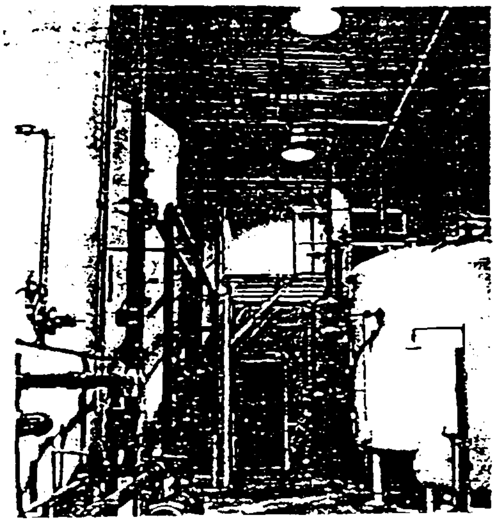
Name	Ionic Form	Description and Application
	Hydrogen	Nuclear grade gel type cation resin with a high degree of conversion and low levels of metallic impurities and sodium. Applications include condensate polishing, radwaste, and high purity systems
	Hydroxide	Nuclear grade gel type anion resin with a high degree of conversion and low levels of impurities. Applications include condensate polishing, radwaste, and high purity systems.
	Hydrogen/ Hydroxide	Nuclear grade mixed bed resin for use in condensate polishing, radwaste, and high purity systems.
	Hydroxide	Nuclear grade porous gel type anion resin with a high degree of conversion and low levels of impurities. Applications include condensate polishing, radwaste, and high purity systems.
	Hydrogen	Nuclear grade high crosslinked gel type cation resin with a high degree of conversion and low levels of metallic impurities and sodium. Applications include condensate polishing, radwaste, and high purity systems.
	Hydrogen	Self-indicating cation resin used in cartridge systems and for cation conductivity determination in the utility industry.
	Sulfite	High purity oxygen removal resin.
	Sulfate	High purity anion resin specially treated for taste and odor free food and pharmaceutical applications.
	Hydrogen/ Hydroxide	High purity mixed bed resin specially treated for taste and odor free food and pharmaceutical applications.

High purity semiconductor resins are specially tested to ensure the required effluent guarantee.

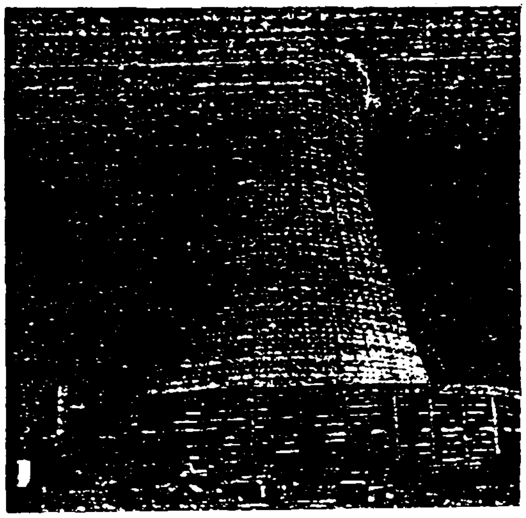
RESIN INVENTORY

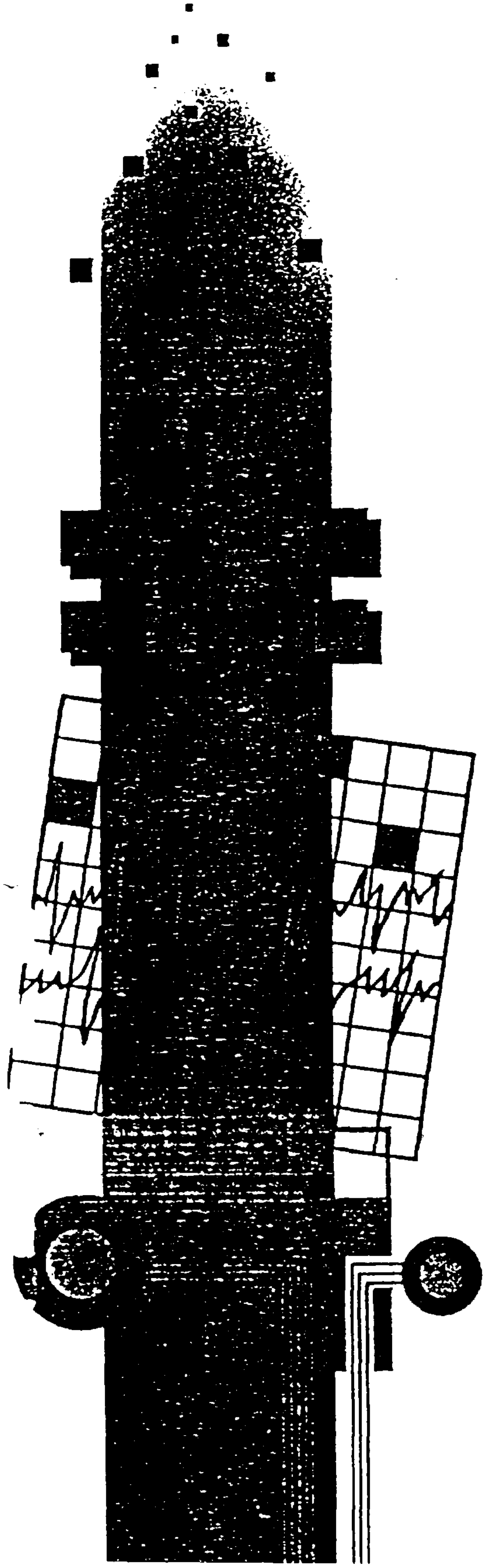


RESIN PROCESSING FACILITY



RESIN TRANSPORT SERVICE





Research And Development Support Services

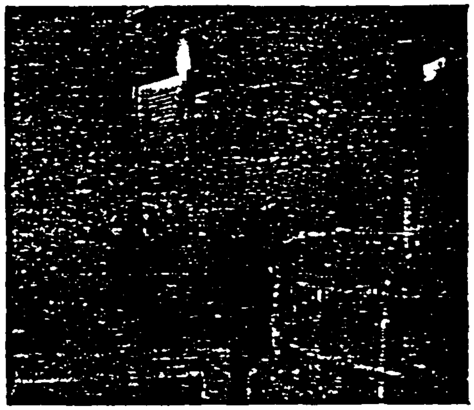
Achieving optimum performance from a demineralizer system is enhanced by periodic analysis of the ion exchange resin. IWT's extensive analytical capabilities are used by analysts and chemists in determining resin quality, as well as diagnosing unit operating problems and evaluating new ion exchange products for conventional and special liquid processing applications.

Instrumentation such as the HIAC particle counter used to measure particle size and distribution of ion exchange resin beads and an AVC-80 microwave moisture analyzer used in the determination of solids content of resin beads are two examples of the state-of-the-art equipment available for accurate evaluation of ion exchange resin characteristics. Other instruments include two Perkin-Elmer atomic absorption spectrophotometers, two Hewlett-Packard gas chromatographs, a Dohrmann Envirotech total organic carbon analyzer, a Waters Associates liquid chromatograph, and a Dionex ion chromatograph. These instruments and their uses are described in the "IWT Research And Development" bulletin.

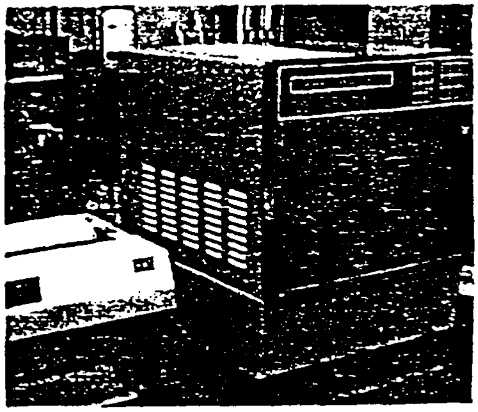
Tests measuring the capacity, percent conversion, moisture content, particle size distribution, bead strength, impurities, extractables, and kinetics are used in varying degrees to evaluate the suitability of new and used ion exchange resins for specific applications. Test results of field resin samples are compared with the original manufacturing specifications with the aid of a computer program, resulting in a detailed report that can be used as a valuable trouble-shooting tool.

Presently, over 100 ion exchange resins are commercially available; many have unique features for specialized applications. Modifications in bead size and uniformity, better resistance to osmotic shock, and the development of the inert resin system are some of the most recent advancements in the industry. IWT's pilot plant coupled with extensive analytical capabilities is used in its Resin Evaluation Program to evaluate new and improved products. IWT is qualified to recommend and provide the resins and services that will help achieve the most cost-effective operation of your demineralizer system.

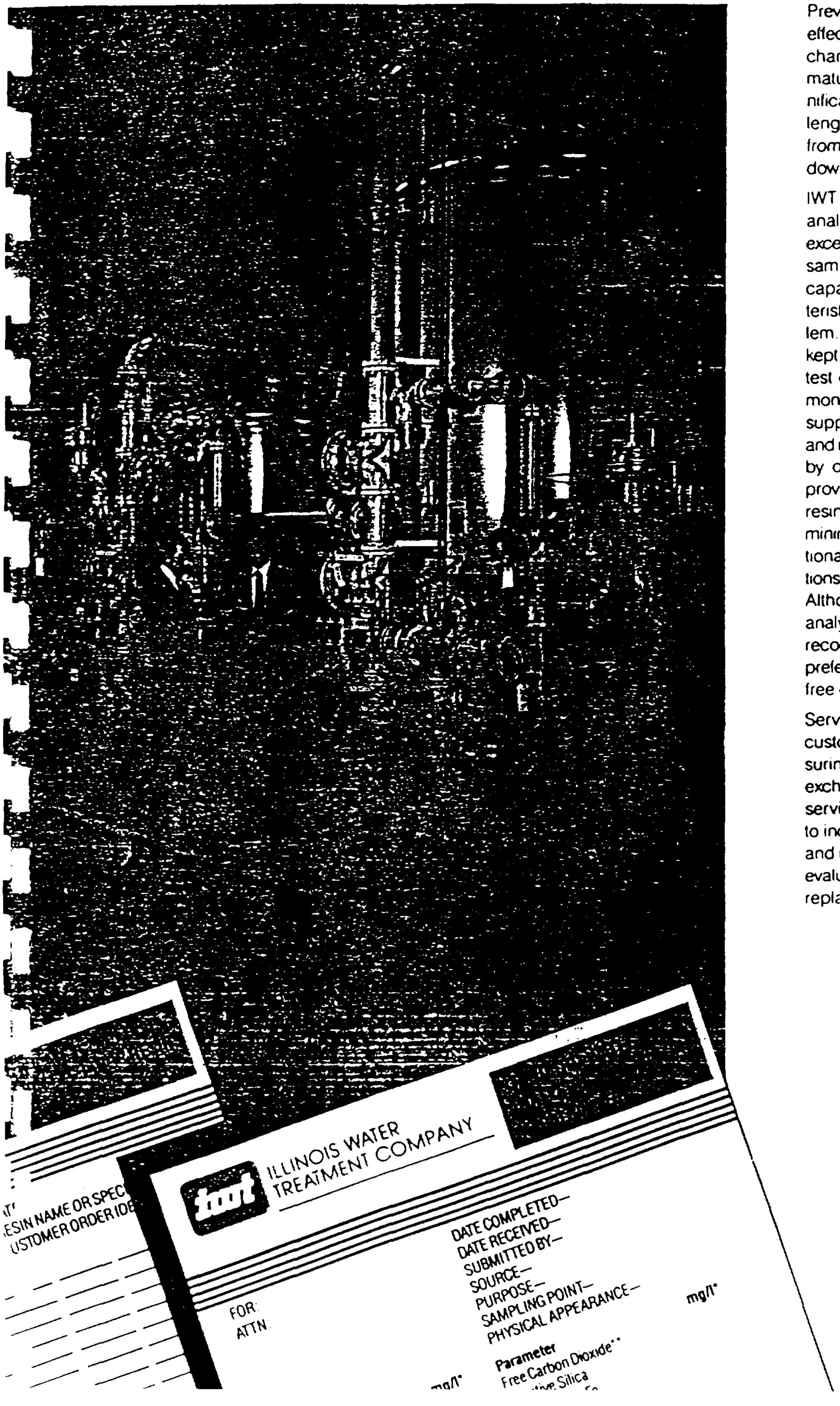
ATOMIC ABSORPTION SPECTROPHOTOMETER



MICROWAVE MOISTURE ANALYZER



VT LIQUID TREATMENT SYSTEM



ILLINOIS WATER
TREATMENT COMPANY

ESIN NAME OR SPEC
USTOMER ORDER IDE

DATE COMPLETED—
DATE RECEIVED—
SUBMITTED BY—
SOURCE—
PURPOSE—
SAMPLING POINT—
PHYSICAL APPEARANCE—

FOR:
ATTN:

mg/l*

Parameter
Free Carbon Dioxide**
…tive Silica

mg/l*

Preventative maintenance is essential to cost-effective and reliable operation of ion exchange systems. Resins can become prematurely fouled or oxidized having a significant effect on effluent quality and run length. It is also possible that by-products from oxidized resin can foul other resins downstream.

IWT recommends frequent sampling and analysis of resins to identify premature or excessive degradation. Analyses of your resin samples will report any significant losses in capacity or changes in other resin characteristics that could indicate a potential problem. A trend analysis of resin characteristics kept by the customer from accumulated resin test data can also be used to more closely monitor performance. Resin analyses can be supplemented with feedwater, product water and regenerant chemical analyses if indicated by operating experience. In addition, IWT provides recommendations for restoring the resin through special cleanup procedures, minimizing further deterioration through additional pretreatment or operational modifications, and resin replacement when necessary. Although the optimum frequency of resin analysis varies with operating conditions, IWT recommends a minimum of once a year and preferably every six months to assure trouble-free operation.

Service contracts are available to provide customers with a cost-effective way of assuring reliable performance of their ion exchange and auxiliary equipment. IWT service contracts can be custom designed to include operation records analysis, water and resin analyses, equipment maintenance evaluations, operator training, and resin replacement

WT's liquid treatment capabilities are the result of forty-seven years of experience in providing service and equipment to clients in all major industries.

hrough the years, a wide variety of products and processes has been developed and improved by IWT experts. Now, the company is applying its extensive knowledge in this specialized technology to major research, engineering, technical service, and manufacturing programs aimed at developing lower cost, higher performance systems.

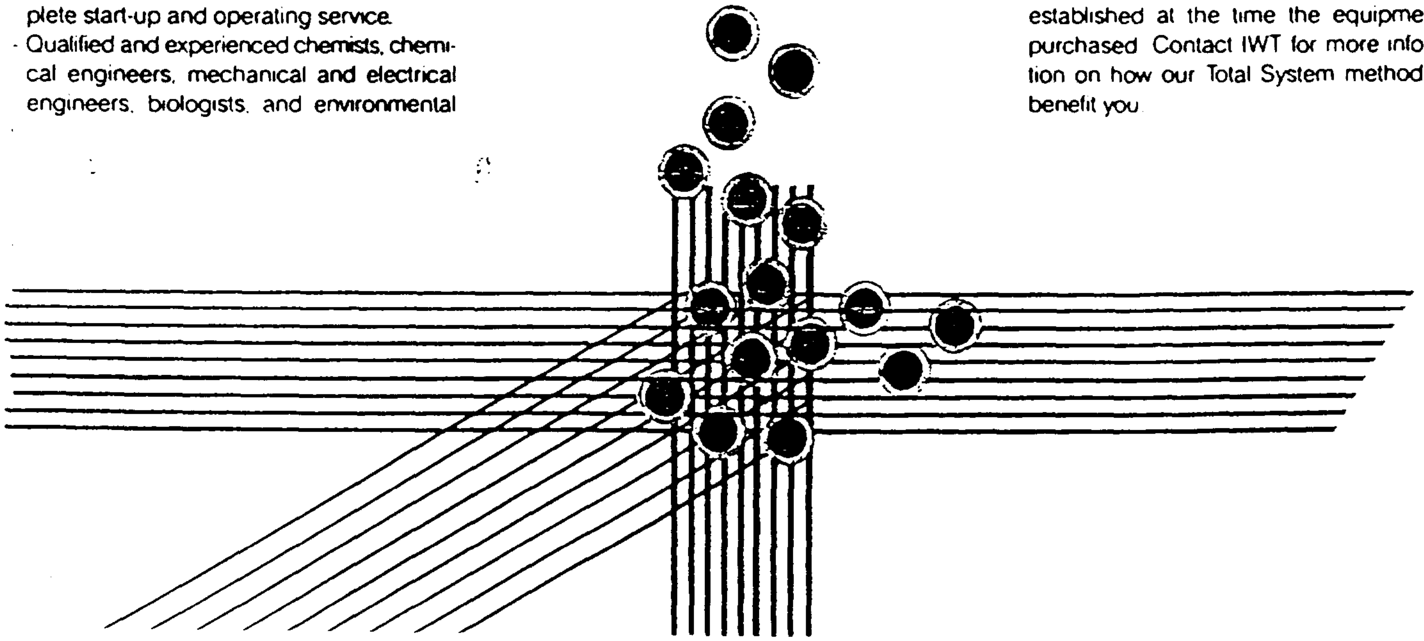
Key liquid treatment related services

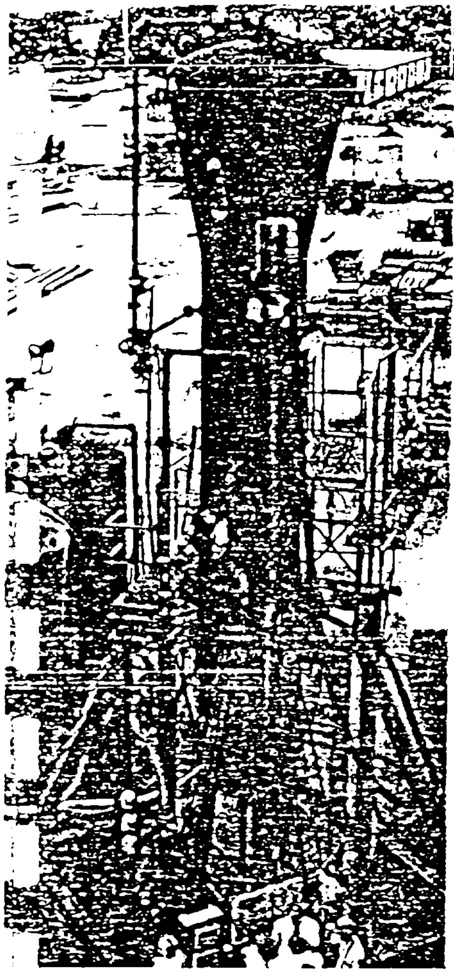
- State-of-the-art analytical and pilot plant capabilities are available for process feasibility testing, laboratory simulations, and pilot test programs.
- Equipment design, evaluation, and operation training can be conducted for engineers and operators. Custom designed training programs can also be held at the customer's jobsite.
- IWT can provide assistance in specification preparation for both ion exchange resins and equipment. Many of these specifications are modularized on IWT's computer.
- Market test samples of various purified products, such as sugar solutions, fruit juices, bottled water, pharmaceutical grade water, and other solutions, can be produced in IWT's semi-works facility and shipped in drums or tank car quantities for user evaluation.
- Equipment designed for specific customer applications is available for lease. Complete operating systems can be provided on a lease, option to purchase, or rental basis.
- Field pilot plants are available for optimizing process parameters and can include complete start-up and operating service.
- Qualified and experienced chemists, chemical engineers, mechanical and electrical engineers, biologists, and environmental engineers can assist customers with consulting services. These services include structural analysis, control panel layout, control software design, process and instrument diagrams, and detailed mechanical and electrical drawings.
- Replacement distribution, sight strainers, conductivity instrumentation, support beds, and membranes are a few of the more critical spare and replacement items that can be readily supplied by IWT.
- IWT can contract turn-key installations for entire liquid treatment plants including all auxiliary and waste treating equipment. This service provides unified responsibility and avoids contractor-supplier conflicts.

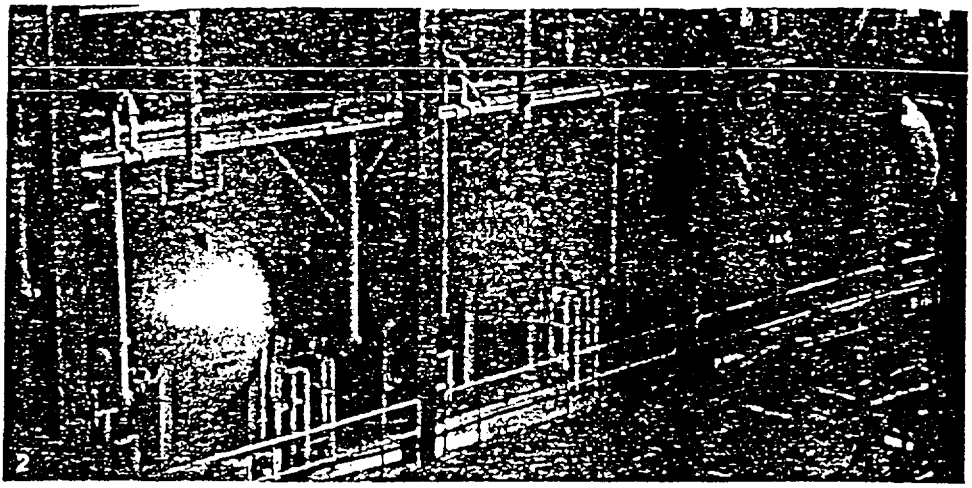
The Total Cost

The development of an optimum liquid treatment system is a team effort that requires both the intimate knowledge of the owner-user's unique operating methods and conditions, as well as the broad knowledge which is provided by a quality equipment supplier.

The total cost of a liquid treatment plant is made up of many cost factors—including the cost of reliability, chemicals, waste water treatment, maintenance, operating labor, power, ion exchange resin and other media replacements, initial equipment capital, etc. It has been demonstrated that the operating, maintenance, and reliability costs associated with a liquid treatment plant usually exceed the initial cost of the plant over its useful life by two to one or three to one; and yet these cost factors do not always receive a proportionate amount of attention and investment. To ensure cost effectiveness, a program of operator training, maintenance, and performance monitoring should be established at the time the equipment is purchased. Contact IWT for more information on how our Total System method can benefit you.







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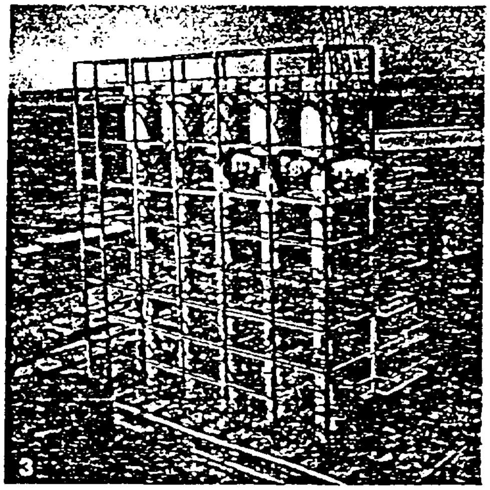

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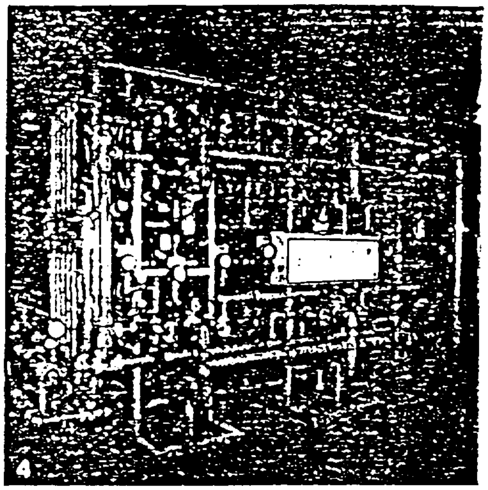

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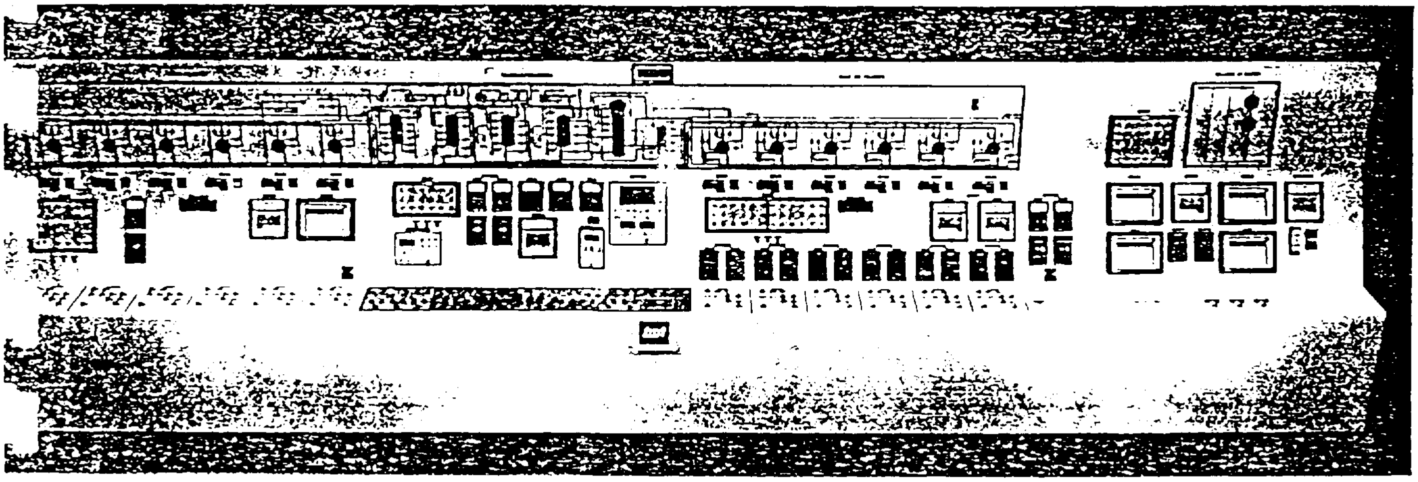
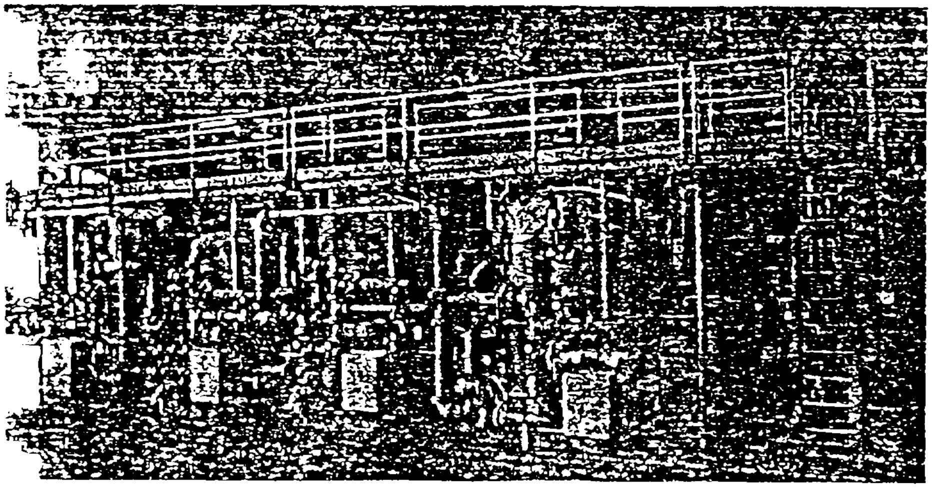
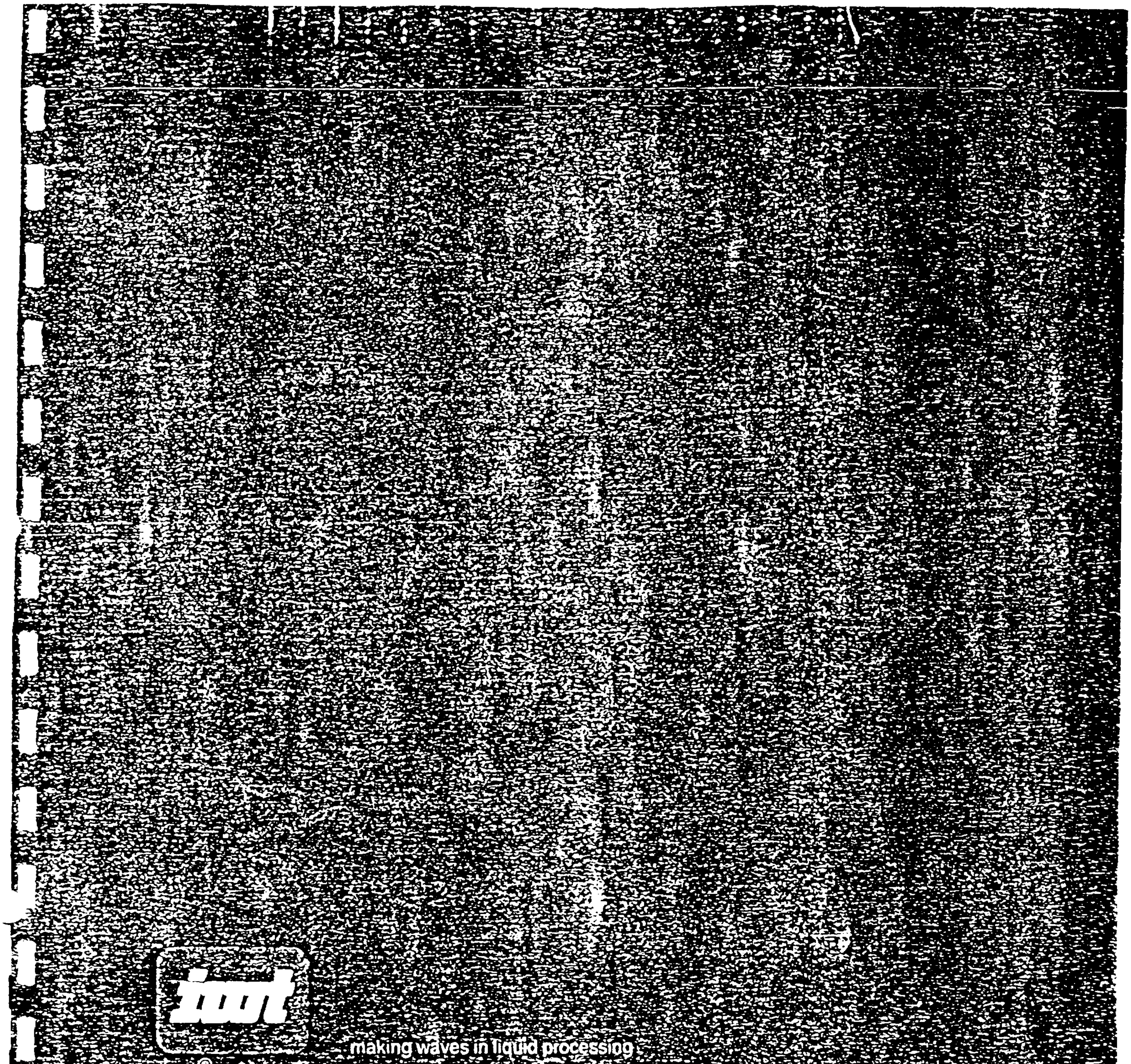




1. [illegible] separators for condensate systems
2. Condensate polishing systems for power generation
3. IWT-Himsley continuous fluidized bed systems
4. Ultrafiltration membrane systems
5. Custom engineered and fabricated control systems
6. Complete makeup water treatment systems



making waves in liquid processing

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amber-hi-lites

ION EXCHANGE IN HEAVY METALS REMOVAL AND RECOVERY

William H. Waitz, Jr.

Editor's Note

Amber-hi-Lites has now completed 30 years of continuous publication. This milestone is a tribute to the efforts of Dr. Robert Kunin, who wrote the first issue and nearly every one since, and continues to be the principal contributor. We want publicly to acknowledge our debt to him for his guidance and hard work Dr. Kunin joined the Research Division of Rohm and Haas Company in 1946 and was employed there until 1970 when he became a member of the marketing staff. In this new capacity he served as technical consultant to the company's ion exchange sales and marketing personnel throughout the world. He retired from Rohm and Haas in 1976 and established a private consulting practice. Throughout his association with Amber-hi-Lites, his fertile imagination, his encyclopedic knowledge of the chemical industry and his prolific pen have enabled this publication to grow and develop. We are grateful to him, and look forward to his future contributions.

The first issue of Amber-hi-Lites was dated April, 1949, and differed considerably from our current issue. There were several short items on the front page, covering various news items of interest to the ion exchange "industry." The second and third pages contained three short articles on *Protein Purification, Silica Sorption and Bacteria Binding* as well as several abstracts of articles on ion exchange taken from the current literature The back page was devoted to an advertisement for two new ion exchange resins, Amberlite IRC-50 and Amberlite IRA-400.

There was a short note on the bottom of the front page which read:

"Every publication must have a motive, a plan, a reason for existence And Amber-hi-Lites is no exception It will report all the news of ion exchange that it can hold, so that you who now employ adsorption techniques, and you who search for efficient process short-cuts, and you who have only an academic interest in ion exchange phenomena may run and read and file to read again."

This statement of objective is as valid today as it was then. The technology of ion exchange has increased in scope and complexity, and the length and depth of Amber-hi-Lites have both increased accordingly. Short items have given way in this publication to longer, more involved treatises on a single phase or use of ion exchange. Amber-hi-Lites has provided a forum for presentation of new ideas, new products and new concepts, and it has occasionally been the starting point for spirited discussions on various aspects of the art and science of ion exchange between people whose views might differ from those expressed in these pages.

This issue of Amber-hi-Lites features an article on adsorption of heavy metals, written by William H. Waitz, Jr Mr. Waitz is Market Planning Manager for Industrial Chemicals-North America, located in Rohm and Haas Company's Home Office in Philadelphia. He has had extensive marketing experience, most recently in the field of waste control and sugar processing applications of ion exchange resins

Gerald D. Button
Editor

INTRODUCTION

Interest in the removal and/or recovery of heavy metals from industrial waste streams continues to increase as discharge limitations become more restrictive Pre-treatment of wastes prior to discharge to municipal sewage treatment plants is now a reality In the past, it has frequently been possible to comply with the limitations through the use of precipitation systems However, as permissible discharge limits are lowered, precipitation will not meet these lower limits. In addition, when working at the usual low concentrations encountered in industrial waste streams, excessive amounts of chemicals are required to effect precipitation and large lagoons are necessary to settle out the resulting sludge. As inflation increases the value of metals, recovery begins to look more attractive. Consequently, there is increasing interest in ion exchange as a part of industrial waste treatment systems.

Ion exchange has been used widely for a number of years in the recovery of gold from plating wastes and for the rejuvenation of chrome plating baths by the removal of Fe^{+3} and Cr^{+3}. The chrome plating installations also use anion exchange resins to recover CrO_4^{-2} ions from the rinse water for return to the plating baths.[1] Recovery of Na_2CrO_4 from cooling tower blowdown for return to the system is another application being used in several large scale operations.[2]

In designing an ion exchange system to remove objectionable ions from waste streams, one must, of course, consider the selectivity of the resins for various ions. Fortunately, the natural selectivity of ion exchange resins favors the larger ions with higher valence. At low concentrations, therefore, both weakly and strongly acidic cation exchange resins will exchange ions of alkali metals and alkaline earths for heavy metal ions. The weakly and strongly basic anion exchange resins have an affinity for the large heavy metal anion complexes such as $Fe(CN)_6^{-4}$.[3]

The major exceptions to this preference for larger ions with higher valence are that weakly acidic cation exchange resins prefer to be in the acid (hydrogen ion) form and weakly basic anion exchange resins prefer to be in the free base form rather than a salt form. As a result, weakly acidic cation exchangers prefer hydrogen ions to all other cations and weakly basic anion exchange resins will shift preferentially to the free base form in the presence of hydroxide ions.

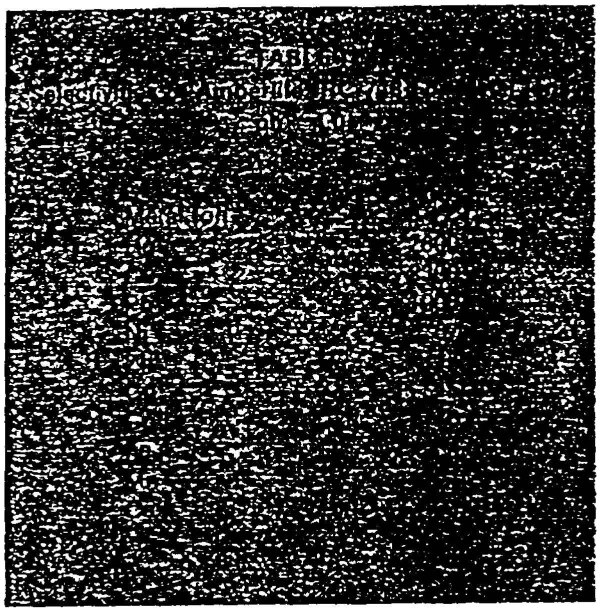
The resin choice in designing an ion exchange system for heavy metals removal or recovery is, of course, dependent upon the goal of the installation. If the removal of a single species is required, then a resin that is primarily selective for that ion, such as a "chelating resin," is called for. If, on the other hand, a variety of heavy metals must be removed, this can often be accomplished with a weakly acidic resin in the sodium form which will replace all the heavy metal ions with sodium ions. Where deionizing and recycling of waste water is of interest, a strongly acidic cation exchange resin in the hydrogen form must be used since it will release hydrogen ions to replace all other cations in the stream.

If one or more of the heavy metals to be removed is present as an anionic complex, an anion exchange resin, usually in the salt form, is selected. This resin will adsorb only those metals which are present as anions; all others present as cations will pass through the resin bed totally unadsorbed.

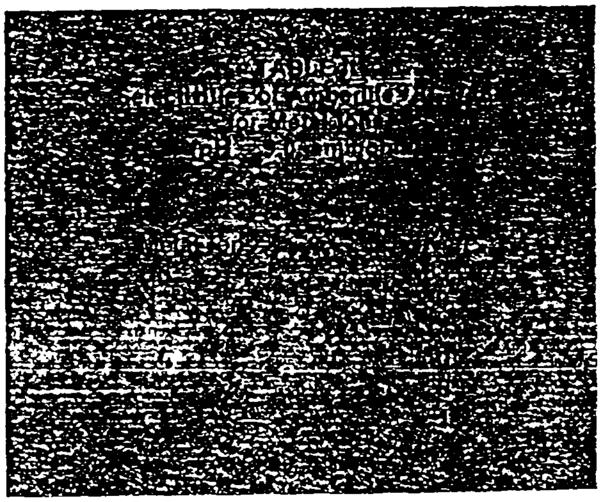
CHELATING RESIN

Amberlite IRC-718 is a macroreticular chelating resin specifically designed for the removal of certain heavy metals. For most applications, it must be operated in the sodium form and, therefore, cannot be used in total deionization. However, because of its high affinity for Cu^{+2} and Fe^{+3}, it can be operated in the hydrogen form when being used to remove these ions.

The selectivity, relative to calcium, of Amberlite IRC-718 for various cations at pH 4, determined in column experiments under laboratory conditions, is shown in Table I (as below). These values will, of course, be affected by both the concentration of metals and the pH of the stream being treated, as well as by changes in electrolyte and background metal concentrations. Note the resin's much greater selectivity for heavy metals than for calcium.



The selectivity of Amberlite IRC-718 was also investigated in an ammoniacal stream (pH=9) containing 200 g/l $(NH_4)_2SO_4$. The results are given in Table II.



Amberlite IRC-718 can be regenerated efficiently with a 4 to 10% solution of a strong acid. Capacities for various heavy metals under a variety of conditions are given in Table III.

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[1] Kunin, R. Amber-hi-lites #104, March 1968

[2] Kunin, R. Amber-hi-lites #151, May 1976

[3] Avery, N.L. and Waitz, W.H. Amber-hi-lites #155, summer 1977

[illegible]

Metal	Resin Form	[illegible]
[illegible]	Na	[illegible]
[illegible]	[illegible]	[illegible]
Nickel	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible]

Table IV and *Figure I compare the effectiveness of* the hydrogen and sodium forms of Amberlite IRC-718 for removing copper from a stream containing 50 ppm of Cu^{+2} and 1,000 ppm $CaCl_2$ at pH 4

[illegible]

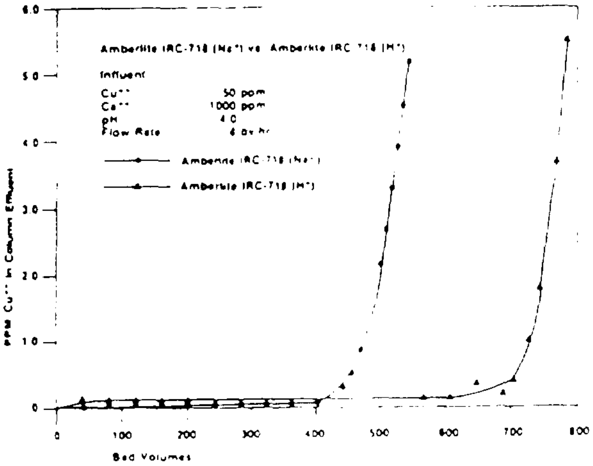

FIGURE I

EFFECT OF pH ON CAPACITY

The effect of pH on the capacity of Amberlite IRC-718 is dramatic. Because of its affinity for hydrogen ions, the resin's capacity for most other ions falls off sharply below pH 4. Figure II compares the capacity of Amberlite IRC-718 when used to remove nickel in the presence of calcium chloride from process streams at pH 2 and pH 4. The data show that good removal is realized for 200 bed volumes (1,500 gallons/cubic foot of resin) when treating the stream at pH 4 whereas early leakage occurred at pH 2, with the curve breaking sharply in less than 50 bed volumes.

Cupric and ferric ions are the exceptions to the above rule. These ions can be removed effectively by Amberlite IRC-718 at pH 2.

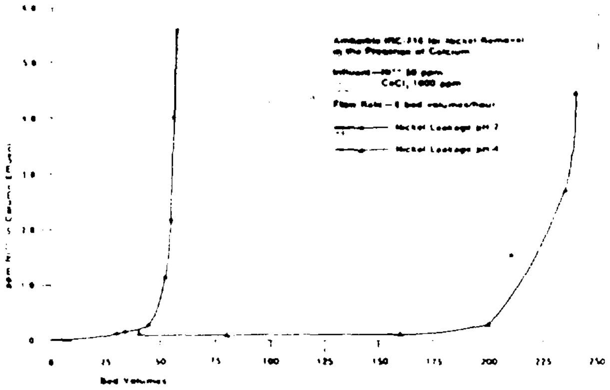

FIGURE II

CHELATING RESIN VERSUS WEAKLY ACIDIC CATION EXCHANGE RESIN

Although Amberlite IRC-718 is often required to achieve efficient heavy metals removal, Amberlite DP-1, a weakly acidic cation exchange resin in the sodium form, sometimes exhibits equal or superior capacity and regeneration efficiency when treating waste streams containing heavy metals. In addition, this resin is less costly than Amberlite IRC-718. Table V and Figure III compare Amberlite DP-1 with Amberlite IRC-718, both in the sodium form, for the removal of zinc from a solution containing 50 ppm of Zn^{+2} and 1,000 ppm of $CaCl_2$ at a pH of 7.0. The flow rate was 8 bed volumes per hour or 1 gpm/ft^3 and removal was essentially the same for both resins except that Amberlite IRC-718 showed a sharper break in the leakage curve after 250 bed volumes.

[illegible]

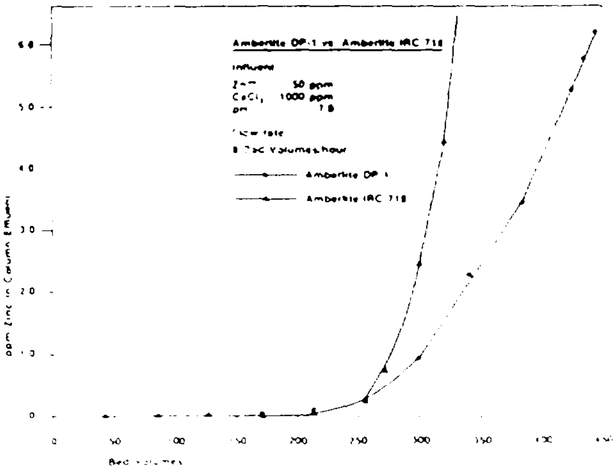

FIGURE III

Table VI and Figure IV illustrate the elution curves for zinc from Amberlite IRC-718 and Amberlite DP-1 with a 10% HCl regenerant at a flow rate of 8 bed volumes per hour or 1 gpm/ft^3. It can be seen that Amberlite DP-1 gives a sharper elution curve and is, therefore, the better choice under these particular circumstances.

[illegible]

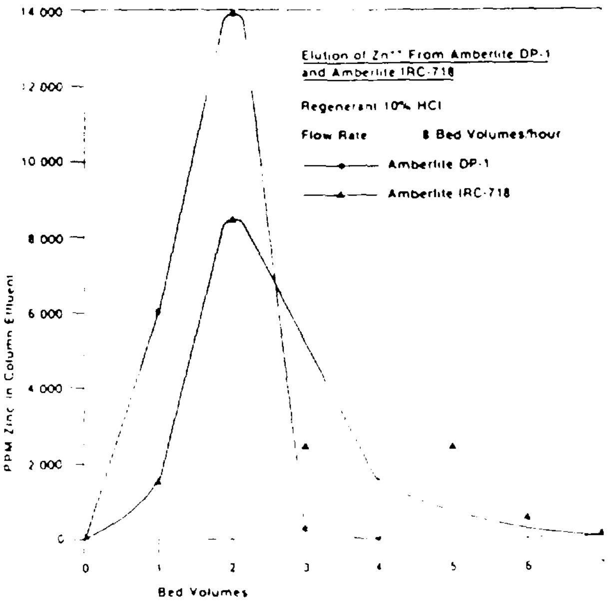

FIGURE IV

In Table VII and Figure V Amberlite IRC-718 and Amberlite DP-1 are compared for Pb^{+2} removal. In this waste stream the concentration of Pb^{+2} was 50 ppm in the presence of 1,000 ppm of $CaCl_2$ and at a pH of 4.0. The flow rate through the resin was 8 bed volumes per hour or 1 gpm/ft^3. The data show the significant advantage of Amberlite DP-1 over Amberlite IRC-718 in this application.

[illegible]

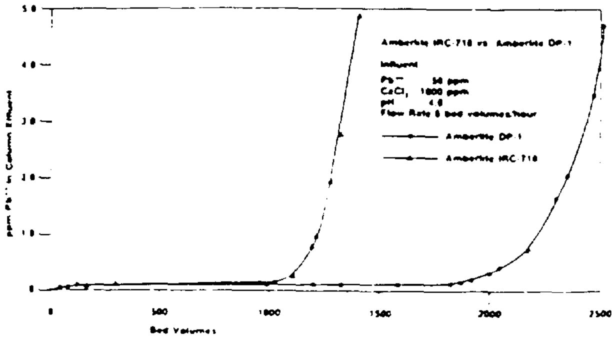

FIGURE V

Elution of lead from both resins is shown in Figure VI. 10% nitric acid was used at a flow rate of 8 bed volumes per hour or 1 gpm/ft³. Both resins readily released the lead but the Amberlite DP-1 gave the higher concentration of lead nitrate since it had removed more lead in the loading cycle. Amberlite DP-1 is the better choice for a waste stream of this type. *Extreme care should be exercised when contacting resins with nitric acid.* Oxidation of the resin may occur with gas evolution and potential pressure build up. The reader is referred to Amber-hi-Lites #153 Fall/Winter 1976.

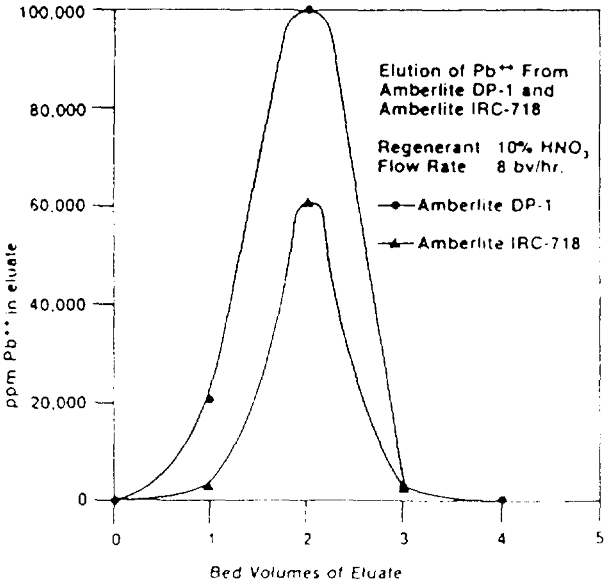

FIGURE VI

Amberlite IRC-718, on the other hand, was found to be the preferred resin when treating a stream containing copper with an ammonium sulfate background. Table VIII and Figure VII show the advantages of Amberlite IRC-718 over Amberlite DP-1 for removing copper in the presence of a *high concentration* of ammonium sulfate. As the table shows, at lower concentrations of ammonium sulfate, the performance of the Amberlite DP-1 is greatly improved, but Amberlite IRC-718 still out performs it.

[illegible]

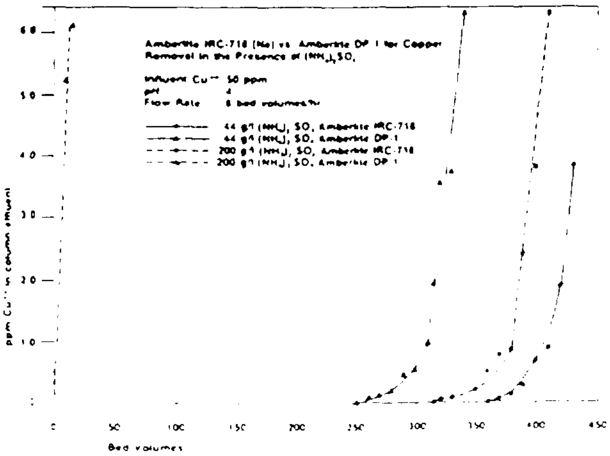

FIGURE VII

EFFECT OF pH ON CAPACITY

Figure VIII illustrates the effect of pH on the capacity of Amberlite DP-1 and Amberlite IRC-718 when these resins are used for removal of cadmium at pH 2.1 and pH 8.0. In this work, Cd^{+2} was present at a concentration of 50 ppm with 1,000 ppm of calcium chloride. At a flow rate of 8 bed volmes per hour (1 gpm/ft³), both resins showed sharp leakage curves with end points at less than 100 bed volumes at pH 2.1. At pH 8.0 and the

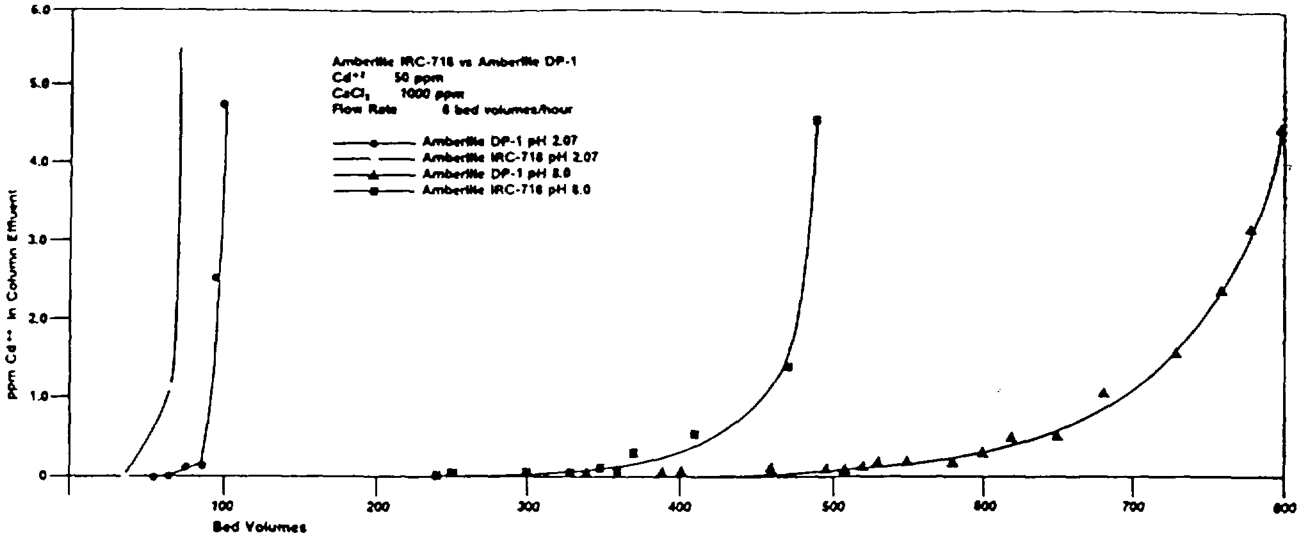

FIGURE VIII

same flow rate, however, Amberlite IRC-718 showed less than 0.1 ppm leakage for 350 bed volumes while leakage from the Amberlite DP-1 remained under 0.1 ppm for 520 bed volumes.

EFFECT OF FLOW RATE ON CAPACITY

Flow rate also has a major effect on the capacity of both Amberlite IRC-718 and Amberlite DP-1. Figure IX shows a comparison of these resins removing cadmium at flow rates of 8 bed volumes per hour and 16 bed volumes per hour or 1 and 2 gpm/ft³. The stream being treated contained 50 ppm of Cd^{+2} and 1,000 ppm of calcium chloride. Both resins showed greater capacity at 8 bed volumes per hour with the capacity of Amberlite DP-1 affected more by an increase in flow rate than the capacity of Amberlite IRC-718.

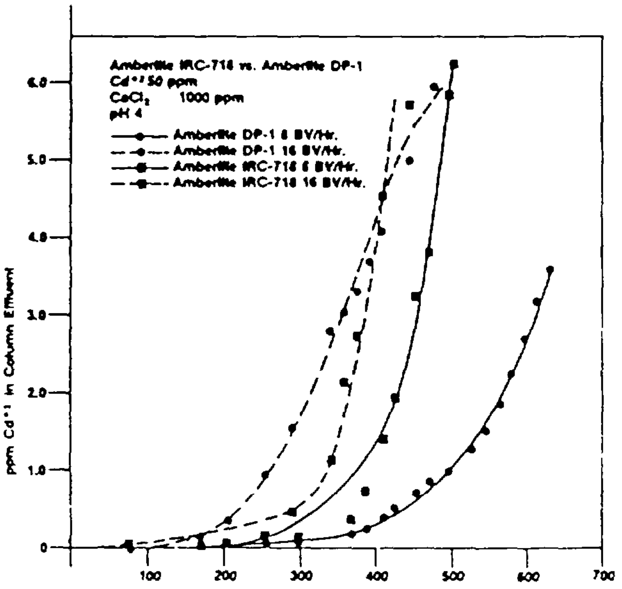

FIGURE IX

RECOVERY OF CHROMIUM FROM COOLING TOWER BLOWDOWN

In ion exchange systems that recover chromate from cooling tower blowdown, Amberlite IRA-94 is used to recover CrO_4^{-2} for recycling. This process is described in Amber-hi-Lites #151.[2] To meet most present NPDES permits, it is also necessary to remove Cr^{+3} from the blowdown. Again, this can be accomplished using either Amberlite IRC-718 or Amberlite DP-1, but Amberlite DP-1 shows twice the capacity and is the recommended resin. Figure X represents a comparison of Amberlite DP-1 and Amberlite IRC-718 in the treatment of a stream containing 50 ppm of Cr^{+3} and 1,000 ppm $CaCl_2$ at a pH 4. At a flow rate of 8 bed volumes per hour (1 gpm/ft³). Amberlite IRC-718 reaches breakthrough at 100 bed volumes while Amberlite DP-1 curve breaks at about 200 bed volumes.

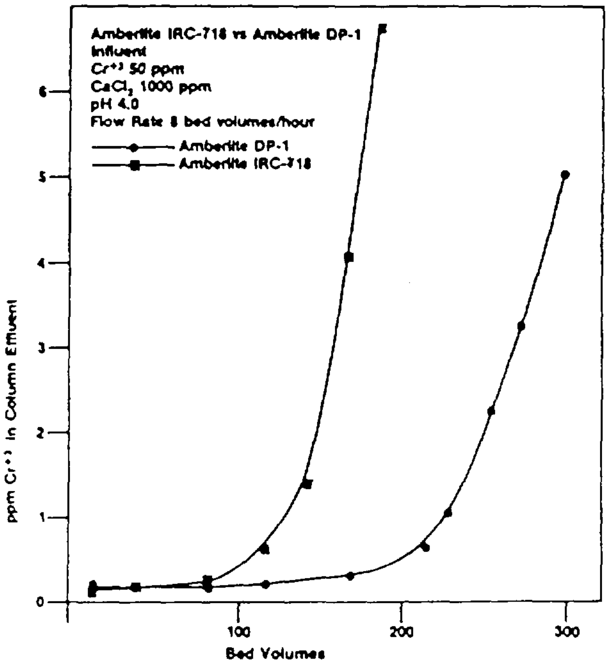

FIGURE X

A CASE HISTORY

There have been several interesting commercial applications of metal recovery technology using ion exchange. In one case Amberlite DP-1 was used to treat a waste water lagoon from an abandoned plating operation containing a variety of heavy metals.

This lagoon held one million gallons of acidic waste water with the following composition:

[illegible]

[illegible]

The principal anion was sulfate, although quantities of chloride and bicarbonate were also present. Total dissolved solids were 3550 ppm and the pH was 4.7. During rainstorms this lagoon would overflow into a local stream and the owner of the land was ordered to take action to abate water pollution.

Deionization in a situation like this, is of course, economically impractical. Therefore, tests were run treating the lagoon water with Amberlite DP-1 which would exchange sodium ions for the polyvalent ions present in the water, thereby making it suitable for use in spray irrigation.

Laboratory column experiments demonstrated that it was possible, through the use of Amberlite DP-1, to remove the heavy metals such as zinc and cadmium without removing the alkaline earths such as calcium. Early in the column run, calcium was exchanged for sodium by the resin. However, this calcium was then displaced by the heavy metals so that after 100 bed volumes of throughput calcium leakage had reached the concentration of the calcium in the influent. Leakage data for this laboratory experiment are presented in Table X.

A composite of the effluent of the first 175 bed volume from this run gave the following analysis:

[illegible]

Regeneration of the loaded Amberlite DP-1 with hydrochloric acid is shown in Table XII. Bed volumes 1 through 4 were 1N HCl. Bed volumes 5 through 8 were deionized water.

[illegible]

After pilot work was completed, twenty-eight cubic feet of Amberlite DP-1 were installed. Each cycle consisted of 125 bed volumes of 26,000 gallons. Consequently, 38 cycles were needed to treat the entire 1 million gallon lagoon. This required 40 days. The acid waste regenerant was treated with lime to precipitate the heavy metals as insoluble hydroxides and oxides. In this case the lime dosage had to be sufficient to reach a pH of greater than 10 to effect the maximum precipitation of zinc and cadmium. The supernatant liquid from the precipitation step was recycled to the waste lagoon since the zinc concentration exceeded 0.5 ppm. The sludge was buried in a suitable landfill.

Ion exchange resin and equipment costs for this operation were less than $3,000. Regenerant requirements were 200 pounds of acid per cycle with 225 pounds of sodium hydroxide per cycle required to return the resin to the sodium form.

The entire operation was carried out without incident at a cost that was less than $10,000 in 1975 exclusive of labor. This included equipment start-up costs and the required analytical work.

CONCLUSION

The proper choice of an ion exchange process for treating any stream containing heavy metals must begin with a careful analysis of the stream so that a judgment can be made as to the ionic state of the metals to be removed and the probable effect of background electrolytes. This knowledge will lead to a decision as to whether anion or cation exchange is more likely to be suitable and whether a strong or weak electrolyte exchanger, or a chelating structure, is indicated. Laboratory experiments are then essential in order to define operating conditions, leakage values and capacities under the conditions as they exist and under conditions which have been altered within economic limits. Comparisions of two or more resin types may be necessary where the exact nature of the various solutes is not known.

The data presented in this issue of Amber-hi-Lites indicate what can be accomplished under the conditions as described here. The circumstances of each stream are unique, and operating performance in any specific situation cannot usually be predicted with precision unless laboratory effort, as described above, is carried out.

The results presented here, and a steadily growing number of commercial installations, point to an expanding use of ion exchange resins to solve difficult separations in the field of waste control, particularly those involving heavy metals.

CREDITS

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