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Project Technical Information

Assessment of Commercially Available Ion Exchange Materials for Cesium Removal from Highly Alkaline Wastes

K. P. Brooks
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April 1996

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Richland, Washington 99352

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SUMMARY

Ion exchange is the leading candidate process for radioactive cesium removal from Hanford's alkaline supernates and dissolved salt cakes. Duolite™ CS-100 has been chosen as the baseline material for cesium ion exchange in the Initial Pretreatment Module (IPM) conceptual design. A final exchanger down-selection will occur in FY 96 before IPM Title I design. At that time, other cesium exchange materials will be considered to replace CS-100. This report presents the results of an evaluation of commercially available exchangers to determine which materials warrant further investigation. Only exchangers which are currently in production or which can be purchased by special order have been included in this study.

To identify candidate exchangers, representatives from major ion exchange manufacturers were consulted and literature from the DOE complex was reviewed. The exchangers which were evaluated are shown in Table S.1. These materials were compared based on the following criteria: (1) cesium distribution coefficient, (2) rate of cesium sorption, (3) elution characteristics, and (4) chemical and radiochemical stability. Each exchanger was compared to the baseline CS-100 resin. Resins with cesium distribution coefficients markedly lower than CS-100 were eliminated from consideration.

TABLE S1. List of Ion Exchange Materials Studied

Organic Resins	Organic Resins	Inorganic Zeolites
Duolite™ CS-100	Amberlite™ IRC-718	Durasil® 210
Resorcinol Formaldehyde	Amberlite™ IRC-50	Durasil® 230
Duolite™ C-3	Amberlite™ DP-1	Ionsiv™ IE-95
Lewatit™ TP-207	ResinTech SIR-300	Ionsiv™ IE-96

Very few ion exchange materials show strong cesium selectivity in highly alkaline solutions. Of the eight organic resins studied, only resorcinol-formaldehyde (R-F) and Duolite C-3 resins have distribution coefficients as high or higher than CS-100. All of the zeolite materials were also found to have cesium distribution coefficients of similar magnitude to CS-

100. A summary of how these materials compare in terms of the selection criteria is shown in Table S.2.

Although R-F resin has a significantly higher distribution coefficient than CS-100, the elutability and chemical and radiochemical stability of the resin may be a concern. Duolite™ C-3 has equilibrium behavior similar to CS-100, but information is lacking with regards to mass transfer rate and chemical stability. Furthermore, in the one elution test performed, C-3 showed poor elutability.

Zeolites have similar cesium sorption characteristics to CS-100. However, their poor chemical stability in both high caustic and acidic make loading in Hanford wastes and subsequent elution difficult. Furthermore, since no eluants for zeolites are now being considered, the loaded exchanger would be vitrified as high level waste. Studies have shown that excessive amounts of HLW glass would be produced if zeolites were used.

TABLE S2. Summary of Exchanger Properties Relative to CS-100

Property	CS-100	R-F	C-3	Zeolites
Distribution Coefficient	average	very high	average	average
Mass Transfer Rate	high	high	--	average
Elutability	high	average	low	very low
Chemical Stability	average	below average	--	low
Radiation Stability	average	below average	average	very high

Future research should focus on addressing the limitations of these exchangers. The chemical and radiochemical stability of R-F resin should be verified with further testing using the newly available BSC-210 batch of R-F resin. The resin's stability should be studied in the context of the full-scale ion exchange process to determine how significant these problems really are.

Duolite C-3 was originally eliminated from consideration because it had to be purchased by special order. Now that all organic resins require special order purchase, use of this resin should be considered as a viable alternative to CS-100. Future work should obtain the data required to compare C-3 to CS-100.

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1.0 INTRODUCTION

1.1 BACKGROUND

Approximately 61 million gallons of nuclear waste generated in plutonium production, radionuclide removal campaigns, and research and development activities is stored on the Department of Energy's Hanford Site, near Richland, Washington. The waste is stored in 177 underground storage tanks (USTs) as a mixture of sludge, salt cake, and alkaline supernatant. The sludge fraction of the waste consists of metal oxides and hydroxides and contains most of the radionuclides of concern (e.g. Sr, Pu, Am, U). The salt cake consists primarily of dried sodium salts, and the supernates are concentrated aqueous solutions of sodium salts. Radioactive cesium (^{137}Cs) is the primary water soluble radionuclide contained in the salt cake and supernatant solutions.

The disposal options for these wastes are either as high-level waste (HLW) glass for disposal in a repository or as low-level waste (LLW) glass for on-site disposal. To reduce disposal costs and comply with environmental regulations, waste pretreatment will separate the small quantities of radionuclides from the bulk non-radioactive chemicals. Although the pretreatment process and disposal requirements are still being defined, most pretreatment scenarios include removal of cesium from the aqueous streams. In many cases, after cesium is removed, the dissolved salt cakes and supernates can be disposed of as LLW. Ion exchange has been a leading candidate for this separation. Ion exchange systems have the advantage of simplicity of equipment and operation and provide many theoretical stages in a small space.

1.2 PURPOSE

The organic ion exchange material Duolite™ CS-100 has been selected as the baseline exchanger for conceptual design of the Initial Pretreatment Module (IPM) by the Westinghouse Hanford Company (WHC). Use of CS-100 was chosen because it is considered a conservative, technologically feasible approach. During FY 96, final resin down-selection will occur for IPM Title I design. Alternate ion exchange materials for cesium exchange will be considered at that time.

The purpose of this report is to conduct a search for commercially available ion exchange materials which could potentially replace CS-100. This report will provide where

possible a comparison of these resin in their ability to remove low concentrations of cesium from highly alkaline solutions. Materials which show promise can be studied further, while less encouraging resins can be eliminated from consideration.

1.3 SCOPE

This assessment will include only ion exchange materials which are currently in production or which are available by special order. Ion exchange materials which have been used in the past, but which are now not commercially available will be mentioned, but not included. There are several cesium selective resins which are now under development by EM-50 which are not commercially available. These materials are not considered in this report.

The supernate from the USTs varies widely in composition. For the purpose of this study, these exchangers were evaluated with Neutralized Current Acid Waste (NCAW), Double Shell Slurry Feed (DSSF), and West Valley Alkaline Supernate (WVAS) simulants. The compositions of the waste simulants are shown in Table 1.1. The NCAW simulant was modeled after the composition of Hanford tank 241-AZ-101 and represents a high sodium and cesium waste. The DSSF simulant was modeled after the composition of Hanford tank 241-AW-101 and represents a high sodium and potassium and low cesium waste (Kurath et al. 1994). The WVAS simulant is similar to NCAW in composition and was modeled after West Valley high-level waste tank 8D2 (Bray et al. 1984).

TABLE 1.1. Simulated Hanford Alkaline Waste Solutions

Species, Total	NCAW, M	DSSF-7, M	WVAS, M
Na	4.987	7.000	8.7
K	0.120	0.945	0.01
Rb	5.0E-05	--	--
Cs	5.0E-04	7.0E-05	7.8E-04
Al	0.430	0.721	--
SO_4	0.150	0.008	0.29
OH (Total)	3.400	4.634	--
OH (Free)	1.680	1.750	pH = 10
CO_3	0.230	0.147	0.5
NO_2	0.430	1.512	1.6
NO_3	1.669	3.521	3.1
F	0.089	-	
Cl	-	0.120	0.004
PO_4	0.025	0.014	0.06

1.4 APPROACH

Two approaches were taken to identify candidate materials which might be selective for cesium. First, technical and sales representatives from major manufacturers of ion exchangers were contacted and asked to suggest ion exchange materials which they considered as potentially selective for cesium in highly alkaline solutions. Samples of these materials were sent to Los Alamos National Laboratory (LANL) for determination of the batch distribution coefficient with NCAW and DSSF. Second, data was collected from past studies by PNL, WHC, and others which provided assessments of ion exchange materials. Only commercially available ion exchange materials identified in the literature search were included in this study.

The exchangers were compared in four categories: (1) cesium batch distribution coefficient, (2) rate of cesium sorption, (3) elution characteristics, and (4) chemical and radiochemical stability. The exchange materials were compared with the baseline CS-100 to facilitate the comparison. Exchangers which exhibited poor cesium distribution coefficients were eliminated from further study. Exchangers which had similar or higher cesium batch distribution coefficients than CS-100 were studied further in terms of the subsequent three categories where data was available.

2.0 ION EXCHANGE MATERIALS

This section provides a description of the ion exchange materials studied in this report. It delineates how the materials were identified and their properties.

2.1 RESULTS OF SEARCH

Table 2.1 presents the resins suggested by the manufacturer representatives. In many cases, the company did not have an exchanger which they believed was selective for cesium in highly alkaline solutions. In other cases, the company did not have materials available which were known to be selective cesium in alkaline solutions. When resins were suggested for these cases, their cesium selectivity was not known but the company representative believed that they could provide some cesium selectivity. These resins are indicated with a (U) in the table below. The resins known to be selective for cesium, at least to some extent are indicated with a (K).

A review of past literature was undertaken to find cesium selective exchangers. A variety of materials were found in these past reports. Bray, et al (1984) studied Duolite CS-100, Ionsiv IE-95, Duolite ARC-359[1], and Amberlite IRC-718 exchangers with West Valley Alkaline supernatant. Gallagher (1986) provided sorption and column data on CS-100, Zeolon 900, Duolite ARC-9359, and Durasil 210 contacted with NCAW simulant. The memos from Prignano (1989a and b) provided batch distribution information in NCAW and HNO_3 elution with Duolite CS-100, resorcinol formaldehyde (R-F), Duolite C-3, and ARC-359N in NCAW simulant. More recent work has focused on cesium sorption with IE-96, R-F, and CS-100 resins (Bray, et al. 1992; Kurath et al 1994). Marsh, et al. (1994a) has recently completed a comparison of resins in 101-SY simulant with CS-100, R-F, Ionsiv TIE-96 (IE-96 with titanium to improve Pu and Sr sorption), Durasil 230, and several other exchangers. In an electrochemical system developed in the UK, Lewatit DN-KR and R-F resins were tested for cesium removal from a NCAW simulant (Griffiths 1994).

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1 Duolite ARC-359, -9359, and -359N are all believed to be analytical grades of Duolite C-3. Rohm and Haas does not currently manufacture these analytical grade resins.

TABLE 2.1. Exchangers Suggested by Manufacturers

Resin Manufacture	Name of Contact	Suggested Resins
Rohm and Haas	Lloyd Brown	Amberlite IRC-718 (U) Amberlite DP-1 (U) Amberlite IRC-76 (U)
Resin Tech	Douglas Kellogg	RT-3972 (U)
Miles	Italious Chiari	Lewatit TP-207 (U)
UOP	Dennis Fennelly	Ionsiv IE-95 (K) Ionsiv IE-96 (K)
GTS Duratek	Regina Mowad	Durasil 190 (K) Durasil 230 (K)
Vydac	Yanbo Yang	Nothing selective for Cs
Pharmacia	Randy Lowe	Nothing selective for Cs
Purolite	Jim DeBenedictis	Nothing selective for Cs
Sybron	Dave Dally	Nothing as selective as CS-100
Dow Chemical	Phyllis Ferris	Nothing as selective as CS-100

2.2 ION EXCHANGER PROPERTIES AND HISTORY

Table 2.2 displays the properties of the ion exchangers studied here. Note that the list contains a variety of functionalities, purposes, and costs. The phenolic resins have been used successfully for cesium ion exchange, while other exchangers have not. The phenolics are granular in structure while the other exchangers are spherical and usually macroreticular (macroporous); the phenolic materials are made by a process which cannot produce spherical, macroporous beads. Furthermore, the commercially available phenolic resins (CS-100, R-F, and C-3) are not stock items and must be produced on a special order basis.

Most exchangers which were studied in the literature but are not commercially available have been eliminated from this list. Zeolon 900[2] and Duolite ARC-359[3] are two of the

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2 Zeolon 900 was originally produced by Norton Co. Worchester, MA. Philadelphia Quartz now owns the rights to its production, but does not produce this material. It produces similar but not identical mortenite materials: CBV10A-X16 and CP461.

exchangers which will not be studied here. Although Lewatit DN-KR[4] and Durasil 210 are not currently commercially available, because batch distributions for these exchangers were recently performed and it showed reasonable selectivity for cesium, they have been included in the evaluation.

The Rohm and Haas Duolite CS-100 resin has been used for several years as a full scale process to remove ^{137}Cs from alkaline low-level radioactive wastes at Oak Ridge National Laboratory (Chilton 1981). CS-100 was also considered for Hanford's B-plant for cesium removal from NCAW and CC wastes, but the process was never constructed. Currently, CS-100 is the IPM baseline for cesium ion exchange. Rohm and Haas will produce this resin on a special order basis only.

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3 This exchanger was originally produced by Diamond Shamrock, but when the ion exchange products were sold to Rohm and Haas, this product was discontinued.

4 Originally produced by Miles, Inc. this material had a batch distribution coefficient similar to CS-100. However, this resin's manufacture has been discontinued both in the US and Germany for approximately 5 years.

TABLE 2.2. Properties of the Resins

Resin; Manufacturer	Functionality; Capacity	Matrix	Primary Purpose	Commercial Availability	Approximate Cost/ft^3	Comments
CS-100; Rohm and Haas	Phenol, Carboxylic acid; > 2 meq/g	Phenol-formaldehyde	Cesium removal; amino acids	Special batches made 150-200 ft^3 minimum, 3 months lead time	$600	granular; used extensively at ORNL
R-F; Boulder Scientific	Phenol; 2.85 meq/g	Resorcinol-formaldehyde	Cesium removal	Special batches made 50-250 ft^3 runs	$1700	granular; used to remove Cs from 350,000gallons of waste
C-3; Rohm and Haas	Phenol, sulfonic acid; 2.8 meq/g	Phenol-formaldehyde	Cesium removal; amino acids	Special batches made 150-200 ft^3 minimum, 3 months lead time	$550	granular; it analytical grade used extensively at B-plant
Lewatit DN-KR; Bayer	Phenol, sulfonic acid; 1.3 meq/g	Poly-condensate	Cesium removal	Not available at this time	--	granular
IRC-718; Rohm and Haas	Iminodiacetic acid; 1.1 meq/mL	Styrene-divinylbenzene	Heavy metal removal	Available	$384	macroreticular spherical
IRC-76; Rohm and Haas	Carboxylic acid; 11 meq/g	Cross-linked Acrylic	Deionization; softening	Available	$190	macroreticular spherical
DP-1; Rohm and Haas	Carboxylic acid; 10 meq/g	Cross-linked Acrylic	Sodium recovery; acid neutralization	Available	$208	spherical
RT 3972 (SIR-300); Resintech	Phosphorous acid; 7.9 meq/g	Polystyrene	Heavy metal removal	Available	$350	spherical
TP-207; Miles	Iminodiacetic acid; 2.0 meq/g	Polystyrene	Heavy metal removal	Available	$310	macroreticular spherical
Durasil 210; GTS Duratek	Acidic;	Inorganic Zeolite	Cesium, cobalt, manganese specificity over sodium	Not available at this time	--	granular
Durasil 230; GTS Duratek	Acidic; 3.1 meq/g	Inorganic Zeolite	Cesium removal in radioactive environment	Available	$900	granular
IE-95; UOP	Acidic; 2-2.5 meq/g	Inorganic Zeolite	Recovery and Storage of Radionuclides from acid solutions	Available	$180	granular
IE-96 (TIE-96); UOP	Acidic; 2-2.5 meq/g	Inorganic Zeolite	Cesium removal in radioactive environment	Available	$396	TIE-96 is IE-96 with titanium added to remove Pu and Sr

The resorcinol formaldehyde resin was first developed by Savannah River Laboratory in the early 1980s. It has been produced on a semi-commercial scale for the last six years by Boulder Scientific Company on a special order basis. This resin has been used once one a large scale to remove 700 curies of cesium from 350,000 gallons of alkaline waste (pH = 11-12). This was an experimental test done by ECOTECH at a General Electric power plant.[5]

The Rohm and Haas Duolite C-3 resin has been used in its analytical form (ARC-359) at Hanford's B-plant to remove cesium from highly alkaline wastes. It was also considered for use in the more recent B-plant operations. However, because it had to be purchased on a special order basis only, it was eliminated from consideration. It appears to be similar in composition to Lewatit DN KR, which is no longer available. Duolite C-3 continues to be made by Rohm and Haas on a special order basis.

Zeolites have been used extensively in a variety of nuclear applications for the removal of cesium. They have higher temperature and radiation stability than organic exchangers. Furthermore, the once-through processing usually done with zeolites offers operational simplicity since the exchanger can be disposed of fully loaded with cesium. Their general limitations are their chemical instability in highly alkaline solutions and their impact of the volume of final waste form when used on a once-through basis. UOP's zeolite exchangers Ionsiv IE-95 and IE-96 have been studied extensively for cesium removal from alkaline wastes and TIE-96 are being used in the full-scale unit to remove cesium from the wastes at West Valley. Durasil 230 has also been used commercially for cesium removal from deionized waters to decontaminate streams containing 10^{-3} μCi/mL of cesium.

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5 Information is based on a discussion with John Birmingham, president of Boulder Scientific Company.

3.0 EVALUATION OF ION EXCHANGE MATERIALS

Ion order for the exchangers discussed above to be considered for cesium ion exchange at Hanford, certain criteria were developed. The exchangers were evaluated based on their distribution coefficient (Section 3.1), mass transfer rate (Section 3.2), elutability (Section 3.3), and chemical (Section 3.4) and radiochemical stability (Section 3.5).

3.1 COMPARISON OF DISTRIBUTION COEFFICIENT

The Hanford alkaline wastes have high concentrations of sodium and potassium, as well as other multivalent cations. In order to be effective, the exchanger must be capable of separating the cesium from these other competing cations. The ion exchange process must create a cesium depleted stream for LLW disposal and produce a cesium concentrate stream which does not impact the volume of HLW glass requiring disposal. If it cannot provide this degree of separation, there is no value added by the ion exchange process.

The distribution coefficient K_d is a measure of the effectiveness of a material to remove cesium from a liquid stream. It is defined as the ratio of cesium concentration in the solid to cesium concentration in the liquid. The K_d is generally determined with batch contacts between the exchanger and solution and is calculated according to the following formula:

$$K_d = \frac{(C_i - C_f)}{C_i} \frac{V_s}{m_e}$$

where C_i is the initial (before contact) and C_f is the final concentration of cesium in solution, m_e is the mass of exchanger used, and V_s is the volume of solution. The distribution coefficient is specific to the temperature and concentration of other ions in solution.

A common basis was sought in which to compare the ion exchange resins. Solution concentration, volume, temperature, and dilution as well as the water content of the resin all affect the distribution coefficient obtained. Fortunately, CS-100 resin has been included in all batch distribution coefficient studies conducted. Therefore, not only is it the baseline for Hanford ion exchange, it will also be used here as a common basis of comparison.

The distribution coefficients for the exchangers are presented for DSSF, NCAW, and WVAS simulant in Table 3.1. Based on the results of the table, only R-F resin consistently has a higher K_d than CS-100. Duolite C-3 is the only other organic exchanger that has a high distribution coefficient.

The ion exchange resins suggested by manufacturers had distribution coefficients which were significantly less than CS-100 using NCAW, DSSF, and WVAS. Based on these results, they would be unacceptable for cesium ion exchange. On further inspection, most of these exchangers are primarily used for chelating multivalent ions. Since cesium is a univalent cation, it does not form chelates. Therefore it is not surprising that these exchangers produced unacceptable behavior.

TABLE 3.1. Batch Distribution Coefficients for Resins Studied

	NCAW				DSSF		WVAS
	Marsh[1]	Prignano[2]	Gallagher[3]	Bray[4]	Marsh[5]	Bray[6]	Bray[7]
CS-100	96	120	30	45	50	70	14
R-F	666	1200	–	450	236	650	–
C-3	–	115	35	–	–	–	12
IRC-718	0.1	–	–	–	2.0	–	2
IRC-76	0.8	–	–	–	4.2	–	–
DP-1	0.5	–	–	–	3.4	–	< 1
RT-3972	0.6	–	–	–	6.6	–	–
TP-207	< 0.1	–	–	–	–	–	–
Durasil 210	–	–	16	–	–	–	–
Durasil 230	–	–	–	–	13	–	–
IE-95	–	–	–	–	–	–	39
(T)IE-96	45	–	–	42	12	–	–

1. Initial $[Cs^+] = 5x10^{-4}, [Na^+] = 5.0$, as received resin, ambient temperature. K_d values obtained after only 6 hours of contact. The slower sorbing exchangers may not have reached equilibrium.

2. Initial $[Cs^+] = 2.4x10^{-4}, [Na^+] = 1.8$, as received resin, irradiated to 10^7 rads. Slightly different NCAW simulant recipe than shown in Table 1.1.

3. Initial $[Cs^+] = 7.37x10^{-4}, [Na^+] = 1.94$, as received resin. Slightly different NCAW simulant recipe than shown in Table 1.1.

4. Final $[Cs^+] = 5x10^{-4}, [Na^+] = 5.0$, dried at 85C, experimental run at 25C.

5. Initial $[Cs^+] = 7x10^{-5}, [Na^+] = 7.0$, as received resin, ambient temperature. K_d values obtained after only 6 hours of contact. The slower sorbing exchangers may not have reached equilibrium.

6. Final $[Cs_+] = 7x10^{-5}, [Na^+] = 7.0$, dried at 85C, experiment run at 25C.

7. Initial $[Cs^+] = 7.4x10^{-4}, [Na^+] = 8.7$, dried at 105C, experimental run at ambient temperatures. These runs were performed at pH = 10 and 13. At pH = 13, IE-95 and CS-100 both have K_d values of 34.

The inorganic ion exchange resins Durasil 210 and 230 and IE-95 and -96 in most cases had distribution coefficients of the same order of magnitude as CS-100. CS-100 in general had better selectivity than these zeolite materials. This result may be in part because zeolites have slower cesium sorption and the K_d values for the Marsh data were allowed to equilibrate for only 6 hours. Thus the exchangers with slower kinetics have not reached equilibrium by the end of the test.

Batch distribution coefficients were measured with NCAW simulant and Lewatit DN-KR and R-F resins. Similar to the results of C-3 on Table 3.1, Lewatit DN-KR produced a K_d value of 76 mL/g. R-F produced a K_d value of 458 mL/g. Because no additional data exists for Lewatit DN-KR and it is not commercially available, it will not be discussed further in this report.

The following materials have acceptable cesium selectivity for continued investigation in this report: CS-100, R-F, C-3, and the zeolite materials.

3.2 COMPARISON OF MASS TRANSFER RATES

The rate of ion exchange is important in the design and operation of the ion exchange system. The exchange rate will impact the size of the ion exchange columns required and/or the its flow rate. Similar to the K_d, kinetics is affected by the specific exchanger, solution concentration, and temperature at which the exchanger is operated.

The mass transfer rate for many of these ion exchange materials has been measured in one of two ways. In the work done by Marsh, et al (1994(a) and 1994(b)), the cesium uptake was measured at 30 minutes, 2 hours, and 6 hours. Using the cesium sorption at each of these time periods, the particle diffusivity can be approximated based on the formula:

$$F = 1 - \frac{6}{\pi^2} \sum_{n=1}^{\infty} \frac{e^{\frac{-n^2\pi^2 Dt}{r^2}}}{n^2}$$

where F is the fraction of equilibrium attained, D is the ion exchange particle diffusivity, and r is the particle radius. This formula assumes (1) particle diffusion is rate controlling, and (2) infinite solution volume (concentration in the solution is constant). Assumption (1) is based on

the composition and extent of solution mixing and may or may not be true. Assumption (2) is not true under the conditions of study. Furthermore, Marsh only provides three data points to fit this equation. In cases where the mass transfer is very slow, the final distribution coefficient is not known. In order to determine the particle diffusivity, both the particle diffusivity and the final distribution coefficient are adjusted to minimize error between the model and the experimental values. Therefore, the diffusivities obtained from this approach may not be completely accurate. However, the results will provide a means of comparing the sorption rates of the resins.

A second method of determining the rate of mass transfer is through column breakthrough curves. Experimental breakthrough curves exist at a range of flow rates. A column ion exchange model was developed which regresses the mass transfer coefficient (Kurath et al. 1994). The particle diffusivity (assuming once again no film mass transfer resistance) can be calculated from the mass transfer coefficient based on the formula:

$$k_p a = \frac{60D}{d_p^2}$$

where $k_p a$ is the mass transfer coefficient assuming particle diffusion limited mass transfer, D is the particle diffusivity, and d_p is the resin particle diameter. Both these methods will be employed to compare ion exchange resin kinetics.

The particle diffusivity describes the rate of diffusion of cesium into a particle but does not necessarily describe the performance of the ion exchange column. The number of transfer units (N), provides a factor which is proportional to the slope of the ion exchange breakthrough curve (Perry and Chilton 1973):

$$N = \frac{60 K_d \rho_b D v}{d_p^2 F}$$

where ρ_b is the bed density, v is the bed volume, F is the volumetric flow rate, and d_p is the particle diameter. Both the particle diffusivity (D) and the number of transfer units (N) will be presented to compare the exchanger kinetics.

Using Marsh's data (1994b), the particle diffusivities and number of transfer units of CS-100, R-F, TIE-96, and Durasil 230 were calculated. These are shown in Table 3.2. Based on the data, CS-100 has the fastest kinetics; nearly an order of magnitude higher than the other exchangers shown. This also results in a larger number of transfer units for CS-100. R-F resin has very slow kinetics, especially in the case of DSSF, but because of its high K_d, it has a reasonable number of transfer units. Both the zeolites have similar diffusivities which fall between CS-100 and R-F resins. In the case of C-3 and the other zeolites, no mass transfer data is available.

TABLE 3.2. Particle-Phase Diffusivities and Number of Transfer Units from Batch Tests

Exchanger	NCAW		DSSF	
	D (cm^2/min)	N*	D (cm^2/min)	N*
CS-100	$7x10^{-6}$	93	$7x10^{-6}$	48
R-F	$1x10^{-7}$	40	$4x10^{-8}$	9.3
TIE-96	$6x10^{-7}$	21	$1x10^{-6}$	9.2
Durasil 230	--	--	$1.5x10^{-6}$	13

Based on data from Marsh 1994b
*Assuming 3 cv/hr flow rate.

Using the mass transfer coefficients from analysis of column run data, Kurath et al (1994), similar values are obtained (See Table 3.3). Although the method of obtaining this data is significantly different from that taken with the Marsh data, the result are very similar for R-F. The particle phase diffusivities of CS-100, however are lower than those obtained from the Marsh data, causing in turn a reduction in the number of mass transfer units. In this case, although R-F resin has a significantly lower cesium particle diffusivity than the other exchangers, it has more mass transfer units because of it high distribution coefficient. Therefore, the slope of the breakthrough curve will be acceptable for the R-F resin.

TABLE 3.3. Particle-Phase Diffusivities and Number of Transfer Units from Column Tests

Exchanger	NCAW		DSSF	
	D (cm^2/min)	N*	D (cm^2/min)	N*
CS-100	$1x10^{-6}$	12	$1x10^{-6}$	4.8
R-F	$2x10^{-7}$	39	$4x10^{-8}$	5.8

Based on data from Kurath 1994
*Assuming 3 cv/hr flow rate.

3.3 EXCHANGER ELUTABILITY

Once exchange material in a column operation is loaded to equilibrium with cesium, either the cesium or the exchanger itself must be removed from the column and disposed of. In the case of organic exchangers, the cesium is most often eluted from the column using an acidic solution. A resin which cannot be eluted effectively may require an unrealistic quantity of eluant or may have to be removed from the column and disposed of after each loading cycle.

In the work done by Prignano (1989a), CS-100, C-3, and R-F were investigated for their elution characteristics using 0.3M nitric acid. The samples were allowed to equilibrate in a constant quantity of the eluant for four hours. The percent eluted from an average of three runs per resin is shown in Table 3.4. In this study, C-3 did not elute easily, while CS-100 eluted very nearly 100% of the cesium from the column. R-F resin eluted reasonably well.

TABLE 3.4. Results of Batch Elution Tests

Exchanger	Percent Eluted
CS-100	100.1 $\pm$ 3
C-3	27.5 $\pm$ 0.3
R-F	89 $\pm$ 4

Data taken from Prignano (1989a)

In more recent studies, the elution of R-F resin was studied in a column arraignment (Kurath, et al. 1994). For these tests, it was difficult to remove the cesium down to a C/C_0 of

less than 0.1, even after passing 25 to 40 column volumes of acid through the column. The relatively poor elution behavior of the resin appears to be the result of resin agglomeration due to the ~35% volume shrinkage during elution. The shrinkage resulted in column channelling along the column walls. Recent runs with a newer batch of R-F (BSC-210) indicate much improved performance. Using BSC-210, the columns were eluted to a C/C_0 of of less than 0.01 in 11 cv. This is nearly the elution rates achieved with CS-100. The reason for this improved elution performance is still uncertain.

In general, zeolites have not eluted and are considered for once-through operation only. Because they are not reused after a loading cycle, other concerns must be addressed including: (1) their impact of the final waste form is more significant than eluted resins; and (2) the exchangers will be stored in the solid form, safety issues associated with their storage must be addressed.

Goheen and Kurath (1994) have shown that their use may be precluded due to the large increase in HLW glass logs produced as compared to an eluted exchanger. They found that in order to remove the cesium from a total blend of Hanford wastes using IE-96, 160,000 HLW canisters would be produced. For an eluted resin, only 26,000 HLW canisters would be produced in processing the same feed to similar cesium product levels.

3.4 CHEMICAL STABILITY

Study of the R-F resin has shown that its chemical stability during storage, loading, and cycling may be a concern. Ion exchange studies were performed with the R-F resin in 1988. Similar experiments were performed with the same batch of resin in 1993 and the resin was shown to have degraded (Bibler 1994a). In some cases, the distribution coefficient decreased by more than an order of magnitude. The exact cause of the degradation was not clear. Freezing and oxidation were investigated but conclusions were not reached.

Resin degradation in caustic was studied with a 10M Na^+ DSSF simulant by Bibler (1994b). The results of this study consistently show > 50% decrease in cesium distribution coefficient after the resin is exposed to the caustic solution for 451 hours.

The Bibler study contradicts the earlier work by Bray (1990). Using SRL simulant, Bray loaded and eluted the same ion exchange column for seven cycles. He found that the

distribution coefficient decreased between the third and fifth cycle by approximately 20%. The distribution coefficient remained relatively constant between the fifth and seventh cycle. Over the course of these cycles, the resin was exposed to caustic for approximately 700 hours, while in Bibler's work, the resin was exposed for only 451 hours. Therefore, the stability of R-F resin must be studied further to address this difference.

The results of Bray's work (1990) are very similar to those seen by Chilton (1981) with CS-100. Chilton cycled the resin between the acid and sodium form for 30 cycles. He found that the distribution coefficient of CS-100 decreased by approximately 2-3% after each cycle. Therefore, the resin degradation for both CS-100 and R-F during cycling appears to be fairly comparable.

Zeolites are not chemically compatible with highly alkaline wastes such as DSSF and NCAW and tend to degrade with time. Zeolites are contain significant quantities of aluminum. In high alkaline solutions, the caustic dissolves the aluminum as aluminate ion which in turn reduces the cesium K_d and/or capacity. Therefore, the hydroxide concentration must be considered before zeolites can be used. The operational range of Durasil 230, for example, is specified as between a pH of 3 and 10.

3.5 RADIATION STABILITY

Zeolite materials, being inorganic, are virtually immune to radiation damage. Organic materials, however, degrade with accumulated radiation dose. Several static radiation studies have been performed to quantify its effect (Bibler et. al. 1990; Bibler 1994b; Bryan 1993). These results are shown in Figure 3.1. Bibler's work measured the distribution coefficient of R-F resin. For both cases, the distribution coefficient did not decrease from its original value of 3000 mL/g until the resin had been exposed to $> 10^7$ rads. Above these dose levels, the resin distribution coefficient quickly becomes unacceptable. By 10^8 rads accumulated dose, the distribution coefficient drops to 900 and 100 mL/g for the 1994 and 1987 tests, respectively. CS-100 was studied in NCAW simulant and shows only a 20% reduction in the K_d over a similar range as R-F (exposed to 10^8 rads). It should be noted that even after the significant decrease due to a radiation exposure of 10^8 rads, R-F still has a higher Kd than CS-100.

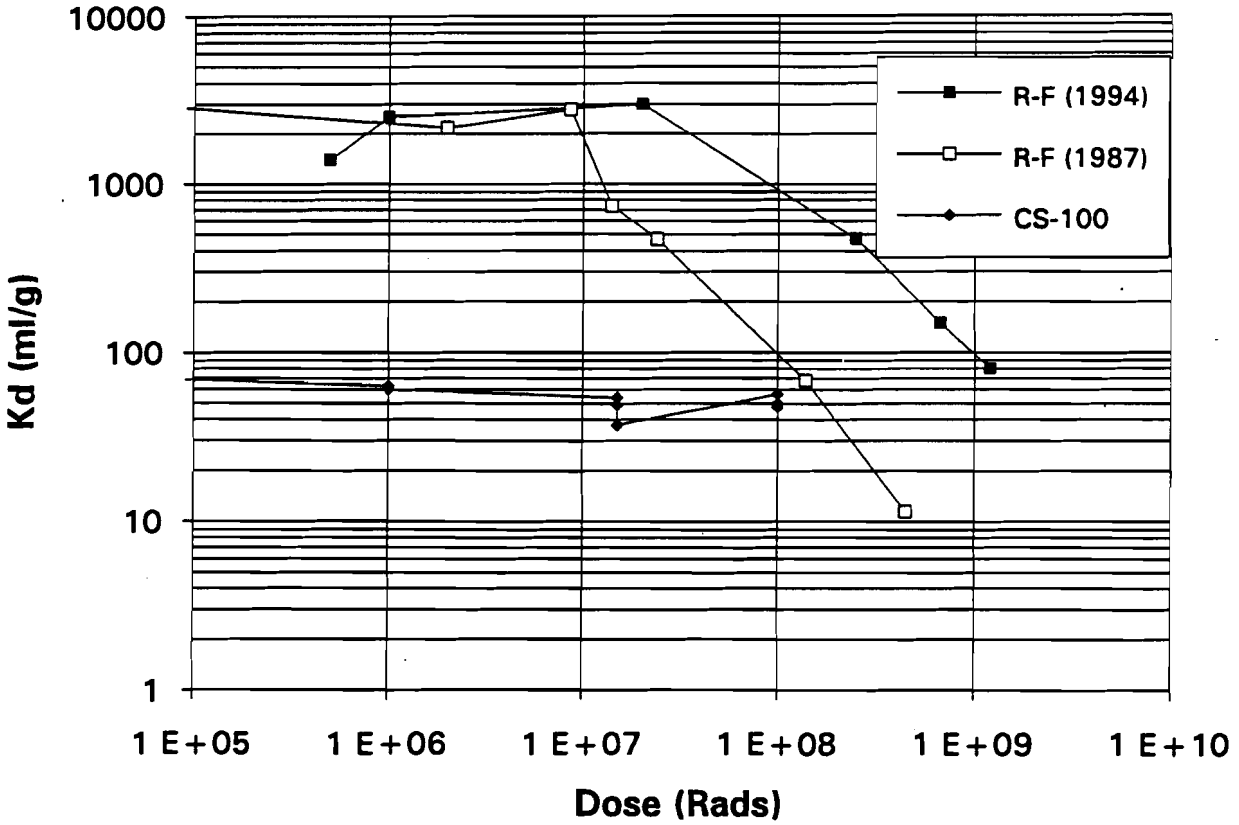

FIGURE 3.1. Cesium Batch Kd for CS-100 and R-F as a Function of Gamma Dose. Kd Taken with NCAW for CS-100 and a 6M Na^+, 1.5M OH, $2x10^{-4}$M Cs Solution for R-F Runs.

4.0 CONCLUSIONS AND RECOMMENDATIONS

There are very few commercially available ion exchange materials which are suited for cesium removal from alkaline supernates. Among those studied, CS-100, R-F, C-3, and zeolites may be acceptable, but these materials are not without their limitations. R-F resin has reasonable ion exchange performance, but concerns remain with respect to its elutability in a column, and chemical and radiolytic stability. C-3 has reasonable ion exchange performance, but showed poor elution behavior. The zeolites have K_d values as high as CS-100, but appear to be unstable in the highly alkaline solutions which comprise most of Hanford's supernates and saltcakes. Furthermore, if the zeolites are used once-through, they may produce unacceptable quantities of HLW glass.

Work should be done to address the limitations of these exchangers. The chemical and radiochemical stability of R-F should be verified with the new batch of R-F resin (BSC-210). The channelling during elution may not be a significant concern in the larger columns during actual operation. Furthermore, the levels of chemical and radiochemical degradation which are seen with R-F may be acceptable from a processing standpoint.

Only limited data is available on C-3 resin. It was eliminated for consideration for B-plant because it was available only by special order. Since all of the promising organic resins are only available by special order, it should be considered as a viable alternative to CS-100. Although it does not appear much better than CS-100 in terms of its cesium distribution coefficient, further study may show it has other advantages over CS-100. If this resin is investigated, laboratory work should be done to confirm earlier batch distribution and elution results, and the kinetics and chemical compatibility of the C-3 resin should be tested.

Although zeolites degrade in acid eluant, the cesium may be effectively eluted and the zeolites disposed of a LLW glass. This would reduce their impact to HLW glass. This option as well as other similar elution strategies should be considered.

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APPENDIX A

ION EXCHANGER MANUFACTURER INFORMATION

APPENDIX A

ION EXCHANGER MANUFACTURER INFORMATION

- Amberlite is a registered trademark of Rohm and Haas, Philadelphia, PA, (215) 592-3000.
- Duolite is a registered trademark of Rohm and Haas, Philadelphia, PA, (215) 592-3000.
- Durasil is a registered trademark of GTS Duratek, Columbia, MD, (410) 312-5100.
- Lewatit is a registered trademark of Miles, Inc., Pittsburgh, PA, (412) 777-2000.
- Ionsiv is a registered trademark of UOP, Mt. Laurel, NJ, (609) 727-9400.
- Boulder Scientific Company, Mead, CO, (303) 535-4494.
- ResinTech, Inc., Cherry Hill, NJ, (609) 354-1152.
- Vydac, The Separations Group, Inc., Hesperia, CA, (619) 244-6107.
- Pharmacia Biotech, Piscataway, NJ, (800) 526-3593.
- Purolite Company, Bala Cynwyd, PA, (215) 668-9090.
- Sybron Chemicals, Birmingham, NJ, (609) 893-1100.
- Dow Chemical Company, Midland, MI, (517) 636-1000.

APPENDIX B

ION EXCHANGER TECHNICAL DATA SHEETS

Duolite International, Inc.
Diamond Shamrock Corporation
1100 Superior Avenue
Cleveland, Ohio 44114
216/694-6080

Duolite CS-100

Diamond Shamrock

Weak Acid Cation Exchange Resin

Technical Sheet

1923

Product Description

Duolite CS-100 is a granular weak-acid cation exchange resin containing both carboxylic acid and phenolic hydroxyl groups. Because of its unusually high selectivity for cesium and multivalent cations, this resin is particularly effective for the treatment of alkaline low level radioactive waste solutions. This high degree of selectivity may suggest other uses for this unique resin.

Duolite CS-100 has a rigid macroporous structure which is unusually resistant to attrition. Because it swells much less than most weak-acid cation exchangers, very little resin breakdown is encountered in acid-base cycling. Phenolic resins are more resistant to radiation than polystyrene exchangers. Duolite CS-100 is easily and completely converted to the hydrogen form with little more than stoichiometric quantities of mineral acids.

Table 1.
Physical and Chemical Characteristics of Duolite CS-100

Resin matrix	Phenol-formaldehyde condensate
Functional groups	Carboxylic and phenolic
Ionic form, as shipped	Hydrogen (other forms on request)
Physical form	Porous granules
Particle size (moist)	0.3-1.3 mm. (16-50 mesh, U.S. standard sieves)
Bulk density, H form	600-700 grams (moist)/liter B.S.&D. (38-45 lbs/cu. ft.)
Moisture retention capacity	48-58% (H form)
Void Volume	40% (0.4 1/1 or 3 gal/cu. ft.)
Maximum reversible swelling, H to Na form	20-25% (e.g., 1.0 → 1.23)
Total ion-exchange capacity	Minimum 1.0 eq/1 (22 Kgr/cu. ft., as $CaCO_3$)
Operating pH range	6-14
Suggested temperature limitation	Up to 80°C (about 175°F)
Chemical stability:	
Resistance to most acids	excellent
Resistance to alkalies	good
Maximum chlorine concentration	0.1 ppm
Maximum HNO_3 concentration	1.0 M (at 25°C)

Low-Level Radioactive Waste Treatment

The presence of the phenolic hydroxyl group increases the selectivity of this resin for cesium by a factor of 10 to 100. This very weakly acidic group is activated at pH values above 9. For this reason, Duolite CS-100 has been particularly useful in the selective removal of Cs-137 (and Sr-90) from alkaline low-level radioactive wastes. This process, developed originally at the Oak Ridge National Laboratory (1), consists of precipitation with alkali to remove suspended solids and hardness, sludge removal, then filtration through a column of Duolite CS-100 to remove residual radionuclides. The resin is effectively regenerated with dilute solutions of nitric, hydrochloric or sulfuric acids. Based on the published reports, this scavenging-precipitation ion-exchange process removes more than 99.9% of the cesium and strontium to levels well below the maximum permissible concentration (MPC) of these radionuclides.

(1) ORNL-3036, ORNL-TM-5, ORNL-3322, ORNL-3349, ORNL-3863.

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:echnical Sheet

he decontamination factors for cesium and strontium with Duolite CS-100 have been in the range of 10^3 to 10^4. Capacity is influenced by the presence of other multivalent cations since they compete for the exchange sites. Thus the overall performance of the above system depends considerably on the efficiency of the flocculation and filtration. Any hardness ions present will reduce the ion-exchange capacity for cesium and strontium. If this problem occurs, residual hardness can be removed by using a column of Duolite C-464 prior to the Duolite CS-100. Duolite C-464 in the primary position will selectively remove the divalent cations (including strontium); Duolite CS-100 will then selectively remove cesium. Both resins are effectively regenerated (in series) with dilute HNO_3 or HCl. Some operating conditions for low level waste treatment with Duolite CS-100 are given in Table 2.

Table 2.
Operating Conditions for Duolite CS-100 in the Treatment of Low Level Radioactive Waste

Bed depth:	Minimum 90 cm (36 inches)
Height to depth ratio:	2:1 to 10:1
Service flow rate:	12 to 20 liters/liter/hr (1.5 to 2.5 gpm/cu. ft.)
Solution pH:	11.2 to 12.0
Volume throughput:	1500 to 6000 bed volumes (11,000 to 45,000 gals/cu. ft.)
Regeneration:	0.5 N HNO_3, 10 to 15 bed volumes (Dilute HCl and H_2SO_4 have also been used)
Rinse:	One bed volume soft water
Conversion to sodium form:	20 bed volumes of 0.1 N NaOH

Adsorption of Organic Compounds

The unique properties of Duolite CS-100 suggest its use in the isolation or chromatographic separation of organic compounds such as the basic amino acids (arginine, histidine and lysine), alkaloids (nicotine and quinine), vitamins (thiamine, nicotinamide, adenine, folic acid and B_{12}) and enzymes. These substances can be adsorbed by either the hydrogen or sodium form of the resin and are eluted by near stoichiometric amounts of dilute acid (or alkali). In general, the hydrogen form is suggested for adsorption of compounds in the free-base form whereas the sodium form is more effective in the adsorption of acidic salts.

In an interesting application (2), coenzyme A was adsorbed by Duolite CS-100 from an acidic solution, the impurities stripped off with 0.2 N HCl, and the coenzyme eluted off with water.

(2) J. Am. Chem. Soc. 74,854 (1952).

Our information, recommendations and suggestions appearing in this bulletin concerning the use of our products are based upon tests and data believed to be reliable. However, it is the user's responsibility to determine the suitability for his own use of the products described herein. Since the actual use by others is beyond our control, no guarantee, expressed or implied, is made by Duolite International, Inc. as to the effects of such use or the results to be obtained, nor does Duolite International, Inc. assume any liability arising out of use, by others, of the products referred to herein. Nor is the information herein to be construed as absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein contained is to be construed as permission or as a recommendation to infringe any patent.

DUOLITE C3

Cation Exchanger

Technical Sheet

Duolite International SA, a Unit of Rohm and Haas Company

PRODUCT DESCRIPTION

DUOLITE C 3 is a highly porous strongly acidic cation exchange resin based on crosslinked phenol-formaldehyde polycondensate, in granular form. The configuration of this resin differs significantly from that of a polystyrene cation exchanger: the functional groups of Duolite C 3 are methylene sulphonic rather than benzene sulphonic. This has a favourable influence on the regeneration efficiency, the selectivity and the adsorptivity. The highly porous matrix of DUOLITE C 3 combined with its sorptive properties makes it particularly useful where a combination of cation exchange and adsorption is necessary.

PROPERTIES

Resin matrix	Crosslinked phenol-formaldehyde polycondensate
Functional groups	Methylene sulphonic
Appearance	Dark red granules (wet)
Specific gravity	1.24 (H form)
Bulk density	700 to 770 g/litre (fully hydrated)
Particle size	0.3 to 1.4 mm (fully hydrated)
Ionic form as shipped	Hydrogen
Moisture retention capacity	45 to 65 % (fully hydrated H form)
Total exchange capacity	1.0 eq/litre (wet) 2.8 eq/kg (dry)
Reversible swelling	Approx. 3 % (from sodium to hydrogen form)
Pressure drop per metre of bed depth	Approx. 2 kPa per m/h linear flow rate (water, 20°C)
Hydraulic expansion	Approx. 50 % at 15 m/h (water, 20°C)

FROM ROHM AND HAAS IER 09.09.1994 16:03 P. 2

APPLICATIONS

The principal uses of DUOLITE C 3 are in the nuclear, starch hydrolysates and pharmaceutical industries.

Nuclear Power Stations:

Caesium removal.

Starch Hydrolysates Industries:

Taste and odour removal, refining, HMF removal.

Pharmaceutical Industries:

Chromatographic separation of amino acids and alkaloids.

Food Processing Applications:

DUOLITE C 3 complies compositionally with the US regulation FDA 21 CFR 173.25. As governmental regulations vary from country to country, it is recommended that potential users of resins for food processing applications contact their Duolite representative to assess the best choice of resin and optimum operating conditions.

SUGGESTED OPERATING CONDITIONS

pH range:	0 to 13
Temperature limitation:	max 60°C
Minimum bed depth:	700 mm
Service flow rate:	
• When treating high viscosity liquors or high levels of impurities:	up to 8 BV/h
• With low viscosity liquors or low levels of impurities:	8 to 24 BV/h

Regeneration:

Regenerants	H_2SO_4	HCl
Regeneration level g/litre resin	50 to 100	40 to 80
Concentration w/v	2 to 4%	2 to 6 %
Flow rate	2 to 8 BV/h	
Minimum contact time	30 minutes	
Rinse flow rate	16 BV/h (2 BV displacement at regeneration flow rate)	

Remarks

1. In special cases, in order to reactivate totally the surface adsorption properties of DUOLITE C 3, a periodic dilute caustic rinse before the acid regeneration is recommended.

2. Combinations of factors such as strong oxidizing agents, high pH and elevated temperature can produce undesirable effects on the life time of the resin.

3. Volume delivered is measured in the fully hydrated form, after being exhausted with dilute NaOH solution, regenerated (see above), backwashed extensively, settled and drained.

Safe Handling Information :
A Material Safety Data Sheet is available for each product upon request.

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.

All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable ; however, it is the user's responsibility to determine the suitability for this own use of the products described herein. Since the actual use by others is beyond our control, no guarantee, expressed or implied, is made by Rohm and Haas Company or its subsidiaries as to the effects of such use or the results to be obtained, nor does Rohm and Haas assume any liability arising out of use, by others, of the products referred to herein. Nor is the information herein to be construed as absolutely complete since additional information may be necessary or desirable when particular conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein contained is to be construed as a permission or recommendation to infringe any patent.

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Lewatit DN KR

Bestell-Nr.
5-3020

Produktinformationen

Gelförmiger Kationenaustauscher mit gemischt sauren Gruppen auf Basis eines Polykondensationsharzes, gereinigt und ausgewaschen entsprechend den Spezifikationen der Kerntechnik, für den Einsatz in

Einzelbett-Filtern zur **selektiven Cäsiumbindung aus** Lösungen mit großen Mengen an Alkali-Ionen

Dekontaminierung von Kreisläufen in kerntechnischen Anlagen

bei Filtrationsgeschwindigkeiten bis 40 m/h und Betriebstemperaturen bis 50 °C.

Ziel der Anwendung von Lewatit® DN KR ist es, das Cäsium an eine Festsubstanz zu binden und bis zum teilweisen Abklingen der Radioaktivität sicher zu lagern. Es ist daher im allgemeinen keine Regeneration des Austauschers vorgesehen.

Die Beständigkeit des Lewatit DN KR nimmt mit steigendem pH-Wert ab. Dies zeigt sich an einer zunehmenden Peptisation, die bei pH-Werten über 11 zur deutlichen Verfärbung des aufbereiteten Wassers führt.

Wichtige Produktdaten und Empfehlungen zum Betrieb von Lewatit DN KR sind auf der Rückseite dieses Blattes zusammengestellt.

Spezifikation für den Einsatz in kerntechnischen Anlagen:

Gehalt an Chlorid und organisch gebundenem Chlor	max. 300 mg/l
Strahlenbeständigkeit Matrix	$10^8 - 10^9$ rad
Strahlenbeständigkeit Funktionelle Gruppen	$10^6 - 10^7$ rad

Die Leistung der KH-Harze wird wesentlich auch von der Konstruktion der Apparaturen, der Verfahrenstechnik und den Anforderungen an das aufbereitete Wasser im Verhältnis zu den Zulaufwerten beeinflußt.

Bayer

23-SEP-94 13:23 FROM: AEA TECHNOLOGY ID: 0235 432278 PAGE 2

Lewatit DN KR

Produktdaten	Lieferform DELIVERED AS Na FORM		Na
	Kornform BEADS		Kugeln
	Farbe LOWER: BLACK		schwarz
	Grundgerüst STRUCTURE – POLYCONDENSATE		Polykondensationsharz
	Ankergruppe PHENOL-SULFONATE		Phenol/Sulfonsäure
	Korngrößenbereich* (min. 90%) SIZE RANGE	mm	0,315–1,6
	Effektive Korngröße (+ 0,03) MEAN	mm	0,45
	Gleichheitskoeffizient	max.	2,1
	Schüttgewicht PACKING DENSITY	g/l	800–900
	Dichte DENSITY	ca. g/ml	1,21
	Feuchtigkeitsgehalt* MOISTURE CONTENT	Gew. %	50–55
	Totale Kapazität* in Austauscheinheiten CAP.	min. mol/l	1,1
	STABILITY Beständig bei Temperaturen	°C	+ 1 bis + 50
	im pH Bereich		0–11
	Lagerfähig in Originalverpackung bei Temperaturen	°C	+ 1 bis + 40
		min. Jahre	5
	Standardverpackung		200-l-Fibretrommel
Empfohlene Betriebsdaten zur Wasseraufbereitung	Nutzbare Kapazität in Austauscheinheiten	max. mol/l	–
	Schichthöhe	min. mm	1000
	Volumenänderung Na ⟶ pH 7	ca. %	– 5
	Druckverlustfaktor je m Schicht u. m/h bei 15°C	ca.	0,009
	Betriebstemperatur	max. + °C	50
	pH-Arbeitsbereich		5–11
	Lineare Geschwindigkeit bei Beladen	max. m/h	40
	Regenerieren	ca. m/h	–
	Auswaschen	m/h	–
	Rückspülen (beladenes Harz)	m/h	–
	Rückspülraum (bezogen auf das Harzvolumen)	%	70
	Bettausdehnung (bei Rückspülen)	max. % je m/h	5
	Regenerermittel Produkt		–
	Konzentration	%	–
	Menge (100%ige Ware)	ca. g/l Harz	–
	Waschwasserbedarf	ca. l/l Harz	–
	Spezif. organ. Belastung je Zyklus	max. g $KMnO_4$/l Harz	–
	Zulässiger Druckverlust	max. bar	1,5
	Empfohlene Beladungsformen bei längeren Betriebspausen		Na, betriebsbedingte Beladungsformen

Alle Angaben beziehen sich auf die Lieferform * = Daten nach DIN ermittelt

Achtung: Allgemeine für Chemikalien empfohlene Vorsichtsmaßnahmen einhalten. Starke Oxidationsmittel, z.B. Salpetersäure, können in Kontakt mit Ionenaustauscherharz sehr heftige Reaktionen verursachen.

Entsorgung: In der Wasseraufbereitung verwendete Ionenaustauscherharze können in der Bundesrepublik Deutschland unter dem Abfallnummernschlüssel 57125 entsorgt werden. Bei eventuellen Beladungsstellen kann die Unterbringung auf einer Sondermülldeponie erforderlich sein. Möglich ist auch die Vernichtung in einer Verbrennungsanlage mit Rauchgaswäsche.

Kein gefährliches Transportgut

Unsere anwendungstechnische Beratung in Wort, Schrift und durch Versuche erfolgt nach bestem Wissen, gilt jedoch nur als unverbindliche Hinweise, auch in Bezug auf etwaige Schutzrechte Dritter, und befreit Sie nicht von der eigenen Prüfung der von uns gelieferten Produkte auf ihre Eignung für die beabsichtigten Verfahren und Zwecke. Anwendung, Verwendung und Verarbeitung der Produkte erfolgen außerhalb unserer Kontrollmöglichkeiten und liegen daher ausschließlich in Ihrem Verantwortungsbereich.

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Ausgabe: Januar 1986
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Bayer

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AMBERLITE® IRC-718

AMBERLITE IRC-718 chelating cation exchange resin has a high affinity for heavy metal cations over alkali or alkaline earth metals, such as sodium, potassium, calcium and magnesium. Selectivity is achieved by an iminodiacetic acid functionality chemically bonded to a macroreticular resin matrix. The functional group coordinates heavy metal ions with several active sites, binding the ions very tightly.

The selective nature of AMBERLITE IRC-718 resin may dramatically decrease the cost of waste treatment. When small amounts of toxic metals are in solution with larger amounts of alkali or alkaline earth cations, AMBERLITE IRC-718 resin will prefer the toxic metals over the other cations. This allows removal of the undesirable metal contaminant without the need to completely deionize the waste stream. Regenerant costs and, in some cases, capital costs can be reduced, since a smaller system can be used.

The macroreticular structure of AMBERLITE IRC-718 resin provides a number of advantages over traditional gel resins. It is highly resistant to osmotic shock, providing greater resin life than gel resins used under the same conditions. Due to the short ion diffusion path, the high porosity of AMBERLITE IRC-718 resin improves the kinetics of ion exchange.

AMBERLITE IRC-718 resin is ideal for use in non-aqueous media, such as chemical process streams, because of its macroreticular structure. The resin is based on a very stable styrene-divinyl benzene matrix. Typical physical properties are given in Table 1.

Selectivity

The apparent selectivity of any ion exchange resin for a given metal depends upon concentration, the presence of other species, and pH. This makes absolute selectivities very difficult to determine, especially for waste treatment applications. Because of this, laboratory testing is essential when a resin is required to remove one or more types of metal ions selectively. Selectivities have been measured under various conditions to give starting points for choosing a resin for selective metal removal.

TABLE 1

Typical Physical Properties
(These do not constitute specifications)

Appearance	Hydrated, opaque beads
Shipping Weight	42 lbs./ft.^{3} (Na form)
Screen Grading (wet)	16 to 50 mesh (U.S. Standard Screen)
Moisture Content	62 to 68% (Na form)
Swelling	40% H → Na
Cation Exchange Capacity	1.1 meq/ml wet resin

1) pH = 2 Metal Ion	K^M_{Ca}
Fe^{+++}	325,000
Cu^{++}	130,000
Hg^{++}	> 43,000
Au^{+++}	> 8,100
Ag^{+}	4,600
Ni^{++}	3,200
Cd^{++}	620
Fe^{++}	190
Mn^{++}	120
Zn^{++}	120
Al^{+++}	50
Mg^{++}	20
Ca^{++}	1.0

2) pH = 4 Metal ion	K^M_{Ca}
Hg^{++}	2,800
Cu^{++}	2,300
Pb^{++}	1,200
Ni^{++}	57
Zn^{++}	17
Cd^{++}	15
Co^{++}	6.7
Fe^{++}	4.0
Mn^{++}	1.2
Ca^{++}	1.0

3) pH = 9, very high ammonium background ($200g/L(NH_4)_2SO_4$). Metal ion	K^M_{Ca}
Ni^{++}	30
Cd^{++}	14
Cu^{++}	10
Zn^{++}	3
Ca^{++}	1.0

These data provide a guideline of relative selectivities; no table can provide selectivities under all conditions. Using these starting points, the affinity of the resin for a given metal can be increased or decreased by adjusting pH.

Operating Conditions

AMBERLITE IRC-718 resin is widely used in waste treatment, chemical processing, and hydrometallurgical applications where there is high variability in feed streams and competition from other species present in solution. Changes in pH, concentration, and background composition (especially complexing ions such as EDTA) may change sorption characteristics. The suggested conditions listed in Table 2 should, therefore, be considered a starting point; laboratory experiments should be done to determine the effectiveness of any ion exchange process for a desired application.

Operating Capacity

The total exchange capacity of AMBERLITE IRC-718 resin in the sodium form is 1.1 meg/ml wet resin. In normal use, however, the resin bed is usually not completely exhausted during operation, and economic considerations may dictate less than 100 percent regeneration. Actual operating capacity will be less than the total exchange capacity and should be determined by specific applications testing.

Backwashing

Many feed streams contain particulate matter which can clog an ion exchange bed. Backwashing is necessary at regular intervals to remove this material. When there are large amounts of suspended matter, backwashing may be necessary at each regeneration cycle. The backwash should be at a sufficient rate to give at least 50 percent bed expansion. The proper flow rate can be found in Figures 3 and 4.

Exhaustion Flow Rate

Chelating ion exchange resins may have slightly poorer kinetic characteristics than conventional (strong electrolyte) ion exchangers. Flow rates,

TABLE 2

Suggested Operating Conditions for AMBERLITE IRC-718

pH (minimum pH depends on application)	1.5 to 14.0
Maximum Temperature	190°F. (90°C) (Na) 160°F. (70°C) (H)
Service Flow Rate	1.0 to 4.0 gpm/ft.^{3} (8.0 to 32.0 BV/hr.)
Regeneration	5 to 15% HCl or H_2SO_4 0.25 to 0.50 gpm/ft.^{3} (2.0 to 4.0 BV/hr.) 6 to 12 lbs. acid/ft.^{3}
Neutralization (if necessary)	1 to 3% sodium hydroxide or ammonium hydroxide 0.25 to 0.50 gpm/ft.^{3} (2.0 to 4.0 BV/hr.) 2 to 4 lbs./ft.^{3}
Pressure Drop	See Figures 1 and 2
Hydraulic Expansion During Backwash	See Figures 3 and 4

Figure 1. AMBERLITE IRC-718
SODIUM FORM HMS—0.55

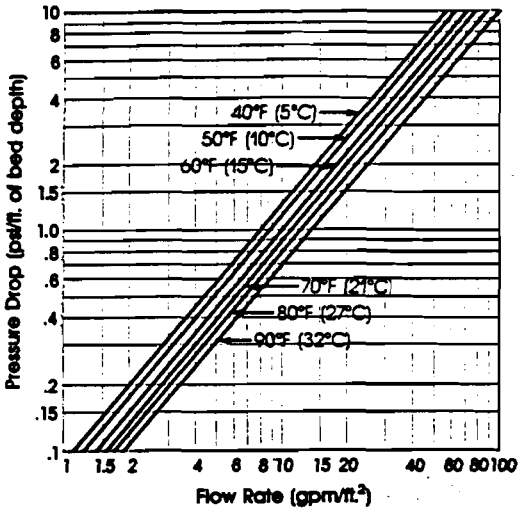
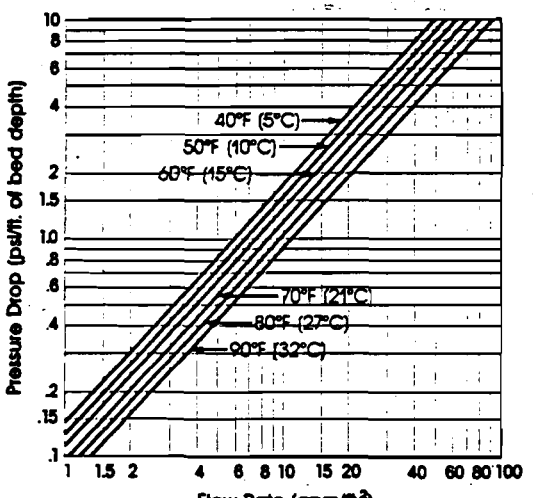


Figure 2. AMBERLITE IRC-718
HYDROGEN FORM HMS—0.54



Metric Conversion
gpm/ft.² to M/hr. = gpm/ft.² x 2.45
psi/ft. to MH_2O/M resin = psi/ft. x 2.30

Figure 3. HYDRAULIC EXPANSION OF THE
SODIUM FORM OF AMBERLITE IRC-718

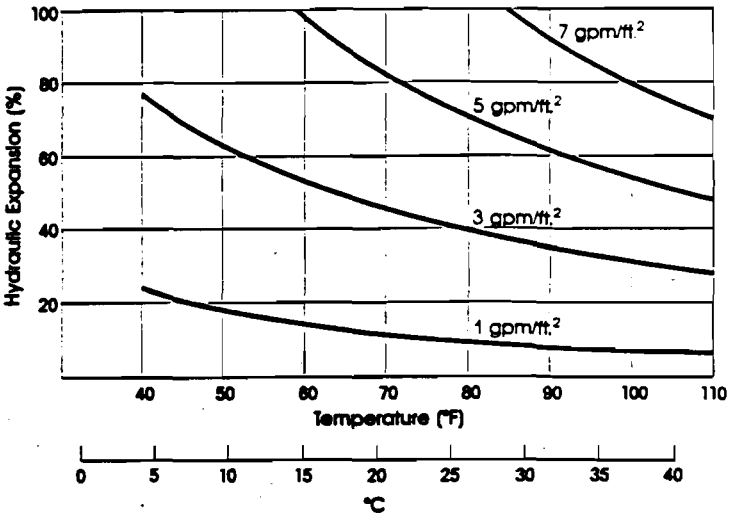
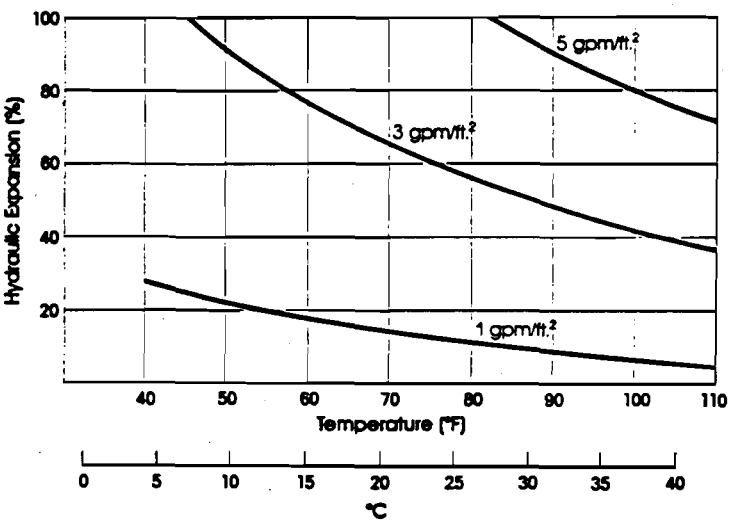


Figure 4. HYDRAULIC EXPANSION OF THE
HYDROGEN FORM OF AMBERLITE IRC-718



Metric Conversion
gpm/ft.² to M/hr. = gpm/ft.² x 2.45

therefore, may need to be somewhat slower than would be typical for water treatment resins. Flow rates of 1.0 to 4.0 gpm/ft.^{3} (8.0 to 32.0 BV/hr.) should be acceptable for less demanding applications but should be reduced when high flow rates prevent efficient removal of the heavy metal ions.

Regeneration

Because AMBERLITE IRC-718 resin has an extremely high affinity for metal ions, the amount of acid required is higher than that required for conventional weakly acidic ion exchange resins. A regeneration level of 6 to 10 lbs. HCl/ft.^{3} may be

sufficient for metals with moderate selectivity, but this should be increased slightly for tightly held metals. Flow rates of 0.25 to 0.5 gpm/ft.^{3} (2.0 to 4.0 BV/hr.) provide the best results. Acid concentration should be 5 to 15 percent, with higher concentrations needed for more tightly bound species.

Neutralization

Because it is a weakly acidic chelating resin, AMBERLITE IRC-718 resin may require neutralization after acid regeneration. The resin should be rinsed after acid regeneration with several bed volumes of water, then treated with 2 to 4 lbs./ft.^{3} of 1 to 3 percent sodium hydroxide or ammonium hydroxide. Neutralization may not be necessary for tightly bound ions or when the pH of the influent is high. Laboratory tests on individual influent compositions will indicate whether neutralization is needed.

Commissioning New Resin

AMBERLITE IRC-718 resin is supplied in the sodium form and can, therefore, be used immediately after rinsing with several bed volumes of water.

Suggested Applications

Chlor-alkali Industry. AMBERLITE IRC-718 resin effectively removes hardness to less than 50 ppb from brine that is fed to chlor-alkali electrolysis cells, although an aminophosphonic resin (such as DUOLITE® C-467) should be used for maximum performance.

Purification of Process Streams Containing Trace Heavy Metals. Objectionable levels of metals may be present in process streams due to their use as catalysts and their presence in raw materials. The high surface area and good selectivity of AMBERLITE IRC-718 resin, as well as its ability to remove metals over a wide pH range, make it a good choice for this application.

Electroplating Industry. The high selectivity of AMBERLITE IRC-718 resin for heavy metals is useful in the removal and recovery of metal ions from plating baths and rinse waters common to the plating industry. The macroreticular structure of this resin ensures its stability in the aggressive solutions of plating baths.

Recovery of Heavy Metals from Hydrometallurgical Leach Streams. Because of the ability of AMBERLITE IRC-718 resin to function over a wide pH range, it can be used to recover heavy metal cations that have been leached from ores by acids or bases. Elution of metals from this resin is extremely efficient, yielding a concentrated solution of the desired metal ion.

Safe Handling Information

A Material Safety Data Sheet is available for AMBERLITE IRC-718. 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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ROHM AND HAAS
PHILADELPHIA, PA 19105

SEPARATION TECHNOLOGIES

AMBERLITE® IRC-76

CATION EXCHANGE RESIN

Amberlite IRC-76 resin is a high capacity, weakly acidic, macroreticular cation exchange resin. It has carboxylic acid functional exchange sites within a crosslinked acrylic matrix. Amberlite IRC-76 resin is supplied as white spherical particles in the hydrogen form. As a weakly acidic resin, Amberlite IRC-76 can split alkaline salts of multivalent cations such as calcium and magnesium, and also alkaline salts of sodium. Amberlite IRC-76 resin combines a very high capacity with lower swelling than is exhibited by conventional carboxylic resins. Amberlite IRC-76 resin offers high regeneration efficiency, excellent chemical stability, and high resistance to physical breakdown due to osmotic or mechanical stress.

IMPORTANT FEATURES

High Capacity

Amberlite IRC-76 resin has an exchange capacity of 4 equivalents per liter.

Excellent Stability

Amberlite IRC-76 resin has excellent resistance to attrition from osmotic or mechanical stresses.

Stable Over a Wide pH Range.

High Regeneration Efficiency

Because it is a weakly acidic resin, Amberlite IRC-76 resin can be easily regenerated with slightly more than stoichiometric amounts of dilute solutions of mineral acids. The result is a process which is very chemically efficient.

PHYSICAL CHARACTERISTICS

Physical Form – Opaque spherical beads, shipped in the hydrogen form. Typical physical properties for Amberlite IRC-76 resin are listed in Table 1.

TABLE 1

TYPICAL PHYSICAL PROPERTIES OF AMBERLITE IRC-76 RESIN

Type	Weakly acidic, carboxylate cation exchanger
Moisture Content, %	54 to 58
Bulk Density, lb/ft^3	48[1]
Specific Gravity	1.14
Screen Grading (wet)	16 to 50 mesh (U.S. Standard screen)
% Swelling	
H^+ to Ca^+ form	15[1] (full conversion)
H^+ to Na^+ form	60[1] (full conversion)
Total Exchange Capacity,	
meq/g (dry),	11
meq/ml (wet)	4

[1]approximately

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TABLE 2

SUGGESTED OPERATING CONDITIONS*

Service Cycle pH	5 to 14
Maximum Temperature	250°F (120°C)
Minimum Bed Depth	24 inches (0.61 m)
Backwash Flow Rate	See Figure 1
Service Flow Rate	0.5 to 8 gpm/ft³ (4 to 64 l/hr/l)
Regeneration Concentration	2 to 5% (HCl), 0.5 to 4% (H_2SO_4)
Regeneration Flow Rate	0.25 to 1.0 gpm/ft³ (2.0 to 8.0 l/hr/l)
Rinse Water Requirements	
Slow Rinse	2 BV at regeneration flow rate
Fast Rinse	4 to 8 BV at service flow rate

*These suggestions cover the majority of conditions encountered in operating units. Some situations may require operation outside these parameters (e.g. regenerant flow rate). Recommendations concerning operations of this nature should be sought from the equipment supplier, a knowledgeable consultant or your local Rohm and Haas technical representative.

APPLICATIONS

Dealkalization

In the hydrogen form Amberlite IRC-76 resin is very effective in removing ions associated with carbonate and bicarbonate alkalinity. This can be accomplished by using Amberlite IRC-76 alone in the hydrogen form or before a strongly acidic cation exchanger operating in the sodium form. A degasifier is placed after the weak acid resin bed to remove carbon dioxide.

Deionization

Amberlite IRC-76 may be used as the primary cation exchanger in a separate bed, followed by a bed of strong acid resin such as Amberlite IR-120 Plus. This type of operation can provide extremely efficient removal of cations.

An alternate system using a layered resin bed in a single cation vessel will also achieve excellent cation removal. This system uses Stratabed® 76 resin with Stratabed 122, a strong acid resin. These two Stratabed cation exchange resins are specially sized for layered bed operation.

Softening

In the sodium form, Amberlite IRC-76 is extremely effective in removing hardness well below the ppm leakage level even in the presence of high levels of common salt. Regeneration is accomplished with an acid strip followed by a caustic treatment step.

Amberlite IRC-76 can be used directly as a softener, or as a polishing softener following beds of strong acid cation resin such as Amberlite IR-120 Plus.

HYDRAULIC CHARACTERISTICS

Backwash Characteristics

To insure proper cleaning and hydraulic classification of Amberlite IRC-76 resin, the resin bed should be backwashed with water after every operating cycle. Backwash should be continued for about 10 minutes at a flow rate sufficient to expand the bed volume by 50 to 75 percent. Figure 1 shows typical hydraulic expansion curves for Amberlite IRC-76 resin at various flow rates and temperatures.

Pressure Drop

Figure 2 shows the expected clean bed pressure drop per foot of bed depth in normal downflow operation at various flow rates as a function of temperature. The total pressure drop can be estimated by multiplying the pressure drop determined from Figure 2 at the design flow rate by the bed depth in feet.

FIGURE 1

Hydraulic Expansion of Amberlite IRC-76 Resin Hydrogen Form

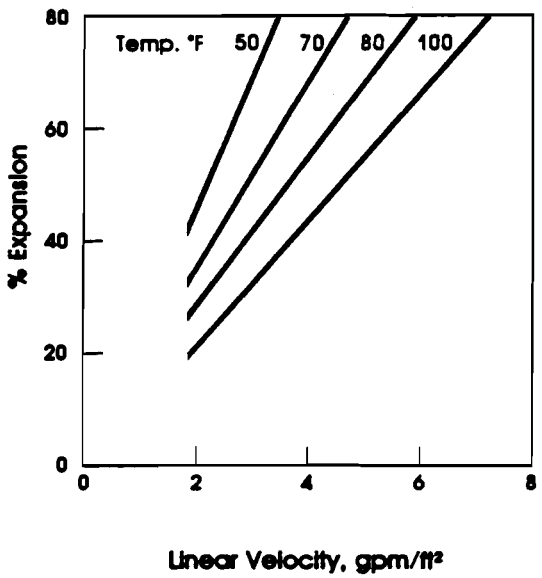
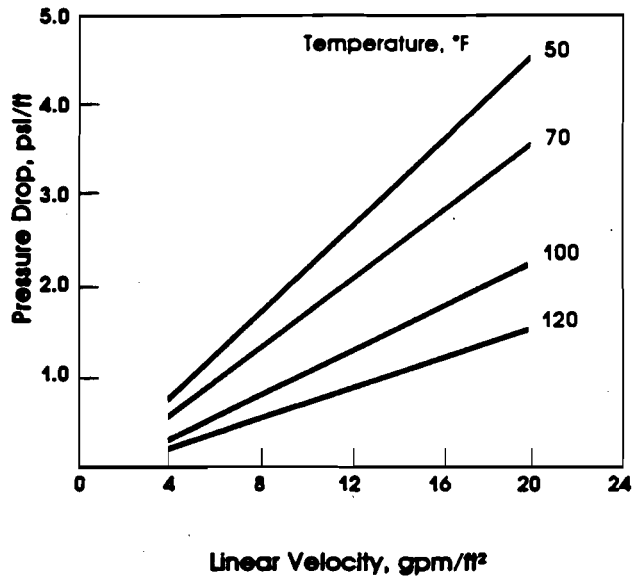


FIGURE 2

Approximate Pressure Drop of Amberlite IRC-76 Resin Hydrogen Form



MATERIAL SAFETY DATA SHEETS

Material Safety Data Sheets (MSDS) are available for all Amberlite ion exchange resins. To obtain a copy for a particular resin we suggest you contact your local Rohm and Haas technical representative or the Rohm and Haas Company.

SAFE HANDLING

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

Nitric acid and other strong oxidizing agents can cause explosive reactions when mixed with ion exchange resins. Processing equipment designed to prevent rapid buildup of pressure is necessary when an oxidizing agent such as nitric acid is utilized. Before placing strong oxidizing agents in contact with ion exchange resins, consult sources knowledgeable in the handling of these materials.

AMBERLITE® IRC-50

IMPORTANT NOTICE

The fundamental data contained in this technical bulletin may not be applicable to all field situations without some modification. An engineering company or equipment manufacturer who will give consideration to the specific conditions of operation should be consulted before any attempt is made to use these data in the design of a commercial scale operation.

Introduction

Amberlite IRC-50 is a synthetic cation exchange resin produced in the form of white, opaque beads. Its unusually high exchange capacity is derived from carboxylic acid groups.

Supplied in the hydrogen or "free-acid" form, Amberlite IRC-50 can be converted readily to the sodium salt by treatment with a solution of sodium hydroxide. In the sodium form, the resin undergoes reactions typical of the salt of a weak acid and strong base.

Because of its selectivity for the hydrogen ion, any absorbed cation can be desorbed easily with a regeneration efficiency approaching 100 percent by treatment with dilute mineral acid.

The carboxylic functionality and exchange selectivities of Amberlite IRC-50 lead to immediate consideration of this ion exchange resin in a variety of applications such as the neutralization of strong bases; the recovery of metallic ions; the isolation and concentration of antibiotics, basic amino acids, enzymes, and peptides.

Summary

Table 1 suggests general operating conditions for Amberlite IRC-50.

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TABLE 1

Suggested Operating Conditions

pH Limitation	None
Maximum Temperature	212°F (100°C)
Minimum Bed Depth	24 inches
Backwash Flow Rate	2 to 3 gal/ft^2/min
Regenerant Concentration	1 to 5 percent HCl or 1 to 5 percent H_2SO_4
Buffering Concentration	See Text
Regenerant Flow Rate	0.25 to 1.0 gal/ft^3/min
Regeneration Level	See Text
Rinse Flow Rate	Same as regeneration flow rate initially, then 1.5 gal/ft^3/min
Rinse Water Requirements	25 to 50 gal/ft^3
Service Flow Rate	1 to 2 gal/ft^3/min
Exchange Capacity	See Text

Physical and Chemical Characteristics

Amberlite IRC-50 is furnished in the form of white, opaque spherical particles. It is shipped in the hydrogen (H+) form (free acid) in a wet, swollen condition.

Density *(hydrogen form, as shipped):* Approximately 43 pounds per cubic foot *in place* (backwashed and drained bed volume).

Swelling: Maximum of 100 percent upon complete conversion from hydrogen form to sodium form.

Screen Grading *(wet):* 16 to 50 mesh (U.S. Standard Screens)

Effective Size: 0.33 to 0.50 millimeters

Moisture Content: 43 to 53 percent

Uniformity Coefficient: 2.0 maximum

Total Exchange Capacity:

(a) Volumetric . . .3.5 meq/ml, minimum
(b) Weight . . . 10.0 meq/g dry, minimum

Physical Stability

1. Swelling: Amberlite IRC-50 swells approximately 40 percent on transformation from the hydrogen to the calcium and magnesium form as shown in Table 2. This swelling is reversible and does not cause any apparent damage to the bead structure. When the exchanger is converted from the hydrogen to the sodium form, particle swelling varies linearly with increasing pH; at a pH of about 10, the resin expansion reaches a maximum of 100 percent.

2. Effect of Temperature: Exchange rate and equilibria of Amberlite IRC-50 are more affected by temperatures than are the physical characteristics of the resin. The rate of exchange and the affinity for hydrogen (H+) increase as operating temperatures are elevated.

3. Attrition: Extended field experience has shown that Amberlite IRC-50 has excellent attrition resistance.

Chemical Stability

Amberlite IRC-50 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 disintegration of the exchanger beads has been observed.

Operational Characteristics

Pressure Drop

The approximate drop in pressure to be expected for each foot of bed depth of Amberlite IRC-50 in normal downflow operation at various flow rates and temperatures is indicated by the data in Table 3.

Hydraulic Expansion

To insure proper cleaning and hydraulic classification of Amberlite IRC-50 after each operational cycle, the bed of resin should be backwashed with water for about ten minutes at a flow rate sufficient to effect a minimum of 50 percent expansion in bed volume.

The hydraulic expansion of the bed during backwashing operations is reported as a function of the flow rate at various temperatures in Table 4. Values for the calcium and sodium forms are used in the table.

TABLE 2

Percentage Swelling of AMBERLITE IRC-50 as a Function of Defense of Conversion from Hydrogen Form

Percent Converted	Sodium	Calcium and Magnesium
0	0	0
25	25	10
50	50	20
75	75	30
100	100	40

TABLE 3

Pressure Drop of AMBERLITE IRC-50 Beds as a Function of Flow Rate

(Calcium Form – Effective Size – 0.4 mm, Uniformity Coefficient – 1.6) Pressure Drop, lbs/in²/ft of Bed Depth

Flow, gpm/ft²	35°F	45°F	55°F	75°F
2	0.30	0.25	0.22	0.16
4	0.66	0.55	0.48	0.35
6	1.02	0.85	0.74	0.55
10	1.74	1.45	1.27	0.93
15	2.70	2.25	1.96	1.45
20	3.60	3.00	2.62	1.93
30	6.00	5.00	4.40	3.21

Swelling

Amberlite IRC-50 has swelling properties similar to those of all weakly acidic and weakly basic ion exchange materials. In the hydrogen form, the exchanger is at its smallest volume. When completely converted to the sodium form, the exchanger will have swollen to approximately double its volume in the hydrogen form. The calcium and magnesium forms are approximately 40 percent larger than the original hydrogen form.

The amount of swelling as a function of degree of conversion is given in Table 4. Values are based on a capacity of 3.5 milliequivalents per milliliter for the sodium form and 2.1 milliequivalents per milliliter for the calcium and magnesium forms. The value of 3.5 milliequivalents per milliliter for conversion to the sodium form is of interest only for cases where sodium hydroxide is being removed. This will apply usually only to special cases, for example, in polishing units where conversion to the sodium form will be quite high. The capacity value of 2.1 milliequivalents per milliliter for the calcium and magnesium forms was selected as an average value to be used for the exchange of calcium and magnesium salts from their bicarbonate salts.

Titration Characteristics

The potentialities of Amberlite IRC-50 in ion exchange processes can be determined conveniently by comparing it with one of the well-known sulfonic-acid type cation exchangers, Amberlite IR-120. The following equations, illustrating the reaction of each resin with sodium chloride and sodium bicarbonate, point to the fundamental differences in "reactivity" of the two exchangers:

Amberlite IR-120

1. $Rz\text{-}SO_3H + NaCl \rightleftharpoons RzSO_3Na + HCl$
2. $Rz\text{-}SO_3H + NaHCO_3 \rightleftharpoons RzSO_3Na + CO_2 + H_2O$

Amberlite IRC-50

3. $Rz\text{-}COOH + NaCl \rightleftharpoons Rz\text{-}COONa + HCl$
4. $Rz\text{-}COOH + NaHCO_3 \rightleftharpoons Rz\text{-}COONa + CO_2 + H_2O$

These reactions clearly illustrate that Amberlite IR-120 and Amberlite IRC-50 differ fundamentally in their relative affinities for the hydrogen ion. Amberlite IR-120, containing strongly acidic sulfonic-acid groups, is highly ionized and shows little affinity for hydrogen ion. In contrast, Amberlite IRC-50, containing slightly ionized carboxylic acid groups, shows tremendous affinity for hydrogen ions. As shown by

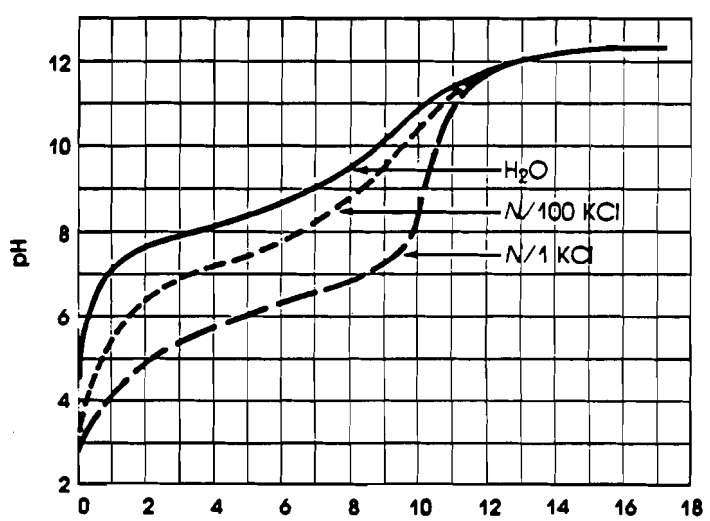
TABLE 4

Hydraulic Expansion of AMBERLITE IRC-50 (Ca or Na) as a Function of Backwash Flow Rate—Percent Expansion

	35°F		45°F		75°F	
Flow, gpm/ft²	A	B	A	B	A	B
1	11	5	8	0	0	0
2	39	22	31	16	13	5
3	66	39	54	31	28	1
4	93	57	77	46	44	24
5	121	74	101	61	59	34
6	148	91	125	77	75	44

A. Effective size 0.36 mm. Uniformity Coefficient—1.56
B. Effective size 0.44 mm. Uniformity Coefficient—1.65

Figure 1. TITRATION CURVES OF AMBERLITE IRC-50



equation (1), sodium easily displaces the hydrogen in Amberlite IR-120 with the resulting formation of hydrochloric acid. As shown by equation (3), sodium displaces with great difficulty the hydrogen in Amberlite IRC-50 since hydrochloric acid, a strong acid, is one of the reaction products. Thus, the equilibrium is shifted far to the left. As shown in equations (2) and (4), both Amberlite IRC-50 and Amberlite IR-120 react easily with the salt of a weak acid. In these reactions, Amberlite IRC-50 is active because few free hydrogen ions result from the exchange.

The hydrogen ions of both exchangers can be removed readily by simple neutralization with alkalies as shown in the following reaction between the carboxylic-acid exchanger and sodium hydroxide:

$$Rz\text{-}COOH + NaOH \rightleftharpoons Rz\text{-}COONa + H_2O$$

Here, Amberlite IRC-50 functions because only a low concentration of free hydrogen ion is formed during the neutralization reaction.

The product obtained on neutralization of Amberlite IRC-50 is the salt of a weak acid; and some hydrolysis will occur, therefore, as the salt form remains in contact with water. The extent of this reaction will depend upon the valence of the cation involved. Whereas the hydrolysis of the resin salts of polyvalent (di-, tri-, etc.) cations is negligible, the hydrolysis of the alkali metal derivatives of Amberlite IRC-50 occurs to a slight, but measurable, degree.

The relative affinity of Amberlite IRC-50 for various cations has been checked carefully. With the exception of hydrogen, the exchange potentials of all metal ions are in the same range for both carboxylic and sulfonic exchangers. Exchange potential series for Amberlite IRC-50 and Amberlite IR-120 are shown for comparison:

Amberlite IRC-50[a]

$$H^+ > CA^{++} > Mg^{++} > Na^+$$

Amberlite IR-120[a]

$$Fe^{+++} > Al^{+++} > Ca^{++} > Mg^{++} > Na^+ > H^+$$

[a]Each series represents *decreasing* exchange potentials, reading from left to right.

Exchange Capacity

The total exchange capacity of Amberlite IRC-50 is attainable only at high pH values. In strongly alkaline media, it is possible to utilize all of the carboxylic acid groups calculated to be present in the resin matrix. Amberlite IRC-50 exhibits a minimum weight capacity of *10.0 milliequivalents per dry gram,* and a volume capacity of approximately *3.5 milliequivalents per milliliter,* when all capacity measurements are based on the density of the hydrogen form of the exchanger.

Since Amberlite IRC-50 possesses great affinity for hydrogen ions, the exchange capacity will be affected considerably by the pH of the solution being treated. Above the neutral point (pH 7.0), almost all of the carboxylic acid groups participate in exchange reactions, while below pH 7.0, the resin rapidly reverts to the hydrogen form and shows progressively less capacity for metallic ion exchange. At a pH of about 3.5, Amberlite IRC-50 exists primarily as the free acid and does not exchange appreciably with other cations.

At the point of neutrality (pH 7.0), Amberlite IRC-50 possesses a weight capacity that can be as high as *8.0 milliequivalents per dry gram* and a volume capacity as high as *2.8 milliequivalents per milliliter,* depending on the ionic strength of the solution being treated.

Regeneration

Dilute hydrochloric or sulfuric acid can be employed to regenerate Amberlite IRC-50. Concentrations from one to ten percent may be used, however, care must be observed when using sulfuric acid not to precipitate calcium sulfate. Amberlite IRC-50 can be completely regenerated by treating with an amount of acid equivalent to 110 percent of the amount of cations removed. For example, if 3.0 equivalents per liter are utilized in the cation uptake, one would use approximately 3.3 equivalents of acid per liter of Amberlite IRC-50 for regeneration. For appropriate rates of flow during regeneration, see Column evaluation section 3.

Determination of Exchange Capacity

To facilitate evaluation of Amberlite IRC-50 in various applications, standard techniques for obtaining total exchange capacity and capacity at pH 7.0 are described:

Total exchange capacity: The maximum capacity of Amberlite IRC-50 can be determined conveniently by equilibrating a representative sample in the hydrogen form with an excess of 0.1 *N* sodium hydroxide. The resin should remain in contact with the excess caustic for 24 to 48 hours. The amount of sodium hydroxide neutralized is considered

equivalent to the maximum capacity of the exchanger.

Capacity at pH 7.0: The maximum capacity available at pH 7.0 is determined by first saturating Amberlite IRC-50 with a normal solution of sodium chloride which is 0.1 *N* with respect to sodium hydroxide. The exchanger is next rinsed with a pH 7.0 buffer (sodium acetate-acetic acid) until the rinsings maintain a constant pH of 7.0. After the sample has been washed several times with distilled or deionized water, it is placed in an excess of 0.1 *N* hydrochloric acid. The decrease in amount of acid is considered equivalent to the exchange capacity at pH 7.0.

Column Evaluations

When Amberlite IRC-50 is employed in column studies, several precautions should be observed.

1. It should be recalled that the exchanger swells approximately 100 percent on conversion from the hydrogen to the sodium form. In small tube evaluations, extreme care is necessary to prevent column packing, bed channeling, or improper hydraulic classification resulting from this volume change. A two-inch column instead of the standard one-inch tube is recommended for laboratory work.

2. Exhaustion flow rates must be adjusted to the resin form. If Amberlite IRC-50 is being employed in the free acid (H+) form for adsorption, the exchange rate is slow and a very low rate of flow is advisable (0.134 milliliters per minute per milliliter of resin). On the contrary, if the sodium salt of Amberlite IRC-50 is used for the adsorption cycle, rapid exchange occurs, and a much higher flow rate (0.268 milliliters per minute per milliliter) can be employed.

3. The exchanger form also determines regeneration flow rates. If it is desired to convert Amberlite IRC-50 from the free acid (H+) to a salt by regeneration with sodium hydroxide, potassium hydroxide, ammonium hydroxide, etc., a flow rate up to (0.670 milliliters per minute per milliliter of resin) can be employed. To regenerate an exhausted salt form of the exchanger with acid, flow rates of 0.134 milliliters per minute per milliliter should be used.

Applications

The foregoing sections of this bulletin, describing the fundamental characteristics of Amberlite IRC-50, have shown that the usefulness of this resin in exchange processes stems from the exchange selectivity of the carboxylic acid groups. These functional groups impart three basic properties to Amberlite IRC-50, all of which depend upon the exchanger's affinity for the hydrogen ion.

Non-reactivity toward neutral salts: Since Amberlite IRC-50 shows only slight activity below pH 3.5, neutral salts can not be split effectively. This point was illustrated in an earlier section of this bulletin (see Titration Characteristics).

Buffering capacity: Amberlite IRC-50 can be buffered easily because of its weak-acid characteristics. Almost any ratio of salt to free acid (H+) groups can be obtained by treating the resin with appropriate buffer systems. Thus, adsorption can be performed at controlled pH values—operations almost impossible to achieve with a strong-acid type cation exchanger such as Amberlite IR-120.

Acid regeneration efficiency: Because of the affinity of Amberlite IRC-50 for hydrogen ion, dilute acids can be employed to regenerate the exchanger with efficiencies approaching 100 percent. Previously, where sulfonic-acid type exchangers have been applied to certain processes, the adsorbed ions are held so strongly that very large volumes of acid are required to recover the desired materials from the resin. In fact, the efficiency of acid (H–) as a regenerant for sulfonate exchangers is so low that many ion exchanger applications have been found impractical for large-scale operations. Amberlite IRC-50 eliminates these difficulties.

Organic Compounds

The buffering capacity and acid-elution efficiency of Amberlite IRC-50 have been demonstrated by applying the exchanger to the absorption and recovery of several classes of organic compounds. The compounds investigated included the following: basic amino acids (arginine, histidine and lysine); alkaloids (nicotine and quinine); vitamins (thiamine); and miscellaneous bases such as adenine, pyridine, hydrazine and ammonia.

Basic amino acid separations with Amberlite IRC-50: Considerable information has been collected by investigators on the use of a synthetic sulfonic-acid type cation exchanger to concentrate and separate the basic

amino acids (arginine, histidine and lysine) from a protein hydrolysate. Present processes involve treating a protein hydrolysate with the hydrogen form of a sulfonic exchanger. The arginine, histidine and lysine are adsorbed preferentially, because their basicity is greater than that of the neutral and acidic amino acids. But difficulties are experienced in eluting the adsorbed amino acids from the exchanger. The resin-basic amino acid combination is so stable that large volumes of acid or base are required for desorption. The ultimate necessity for separating the eluting reagent from the desorbed amino acids poses a serious problem, and because of these elution difficulties, the development ion exchange process has been restricted.

With Amberlite IRC-50, the difficulties in the ion exchange process for basic amino acid separation can be eliminated. Treatment of the carboxylic acid exchanger with an appropriate buffer (sodium acetate-acetic acid) converts the resin to a combined salt-acid form so that cation exchange occurs at a controlled pH. If the ratio of sodium (salt form) to hydrogen (free-acid form) in the exchanger is adjusted to give pH below the isoelectric points of arginine, histidine and lysine, but above the isoelectric points of the neutral and acidic amino acids, only the basic amino will exist as cations in solution and will be adsorbed by Amberlite IRC-50, while the other amino acids will pass through the resin bed unaffected.

The results in Table 5, were obtained using the column technique and an exhaustion flow rate of 0.268 milliliters per minute per milliliter of resin. The effluent characteristics were ascertained with a ninhydrin spot test, sensitive to a microgram of amino acid per milliliter of solution. The influent amino acid concentrations were approximately 1 milligram per milliliter of solution. In preparing the resin column for adsorption of the amino acids, a buffer consisting of a mixture of 1 *N* sodium acetate and acetic acid was employed. The treatment involved first putting the resin in the sodium form by treatment with sodium hydroxide and then passing the buffer (three volumes per volume of resin) through the exchanger at a low rate of flow. The last portion of the buffer was allowed to remain in contact with the resin bed for fifteen minutes. The exchanger column was rinsed free from residual buffer with deionized or distilled water.

The results indicate that resin pre-treatment with a pH 4.70 buffer is necessary for the adsorption of all of the basic amino acids. Only lysine and arginine are adsorbed by Amberlite IRC-50 when the exchanger is treated with a pH 7.0 buffer. This leads to a method for separating histidine from arginine and lysine.

A remarkable feature of Amberlite IRC-50 in the process is the small volume of dilute acid required for complete elution of the adsorbed amino acids. Two milliequivalents of 0.1 *N* hydrochloric acid per milliliter of resin effect complete displacement of the arginine, histidine, and lysine. In contrast, over thirty volumes of 6 N hydrochloric acid per unit volume of resin are required to remove the basic amino acids from sulfonic-acid type cation exchangers. Moreover, a certain fraction of the basic amino acids appears to be held very tenaciously by the sulfonic resins and recycling of the acid elutrient is necessary to effect complete recovery of the adsorbed material. Only one elution is necessary with Amberlite IRC-50.

Recovery of miscellaneous substances with Amberlite IRC-50: The unique properties of Amberlite IRC-50 have been exploited further by determining the adsorption-elution characteristics of the resin in the recovery of many ionic substances, including quinine, nicotine, thiamine, adenine, pyridine, hydrazine, ammonia, and sodium hydroxide. Both the hydrogen and sodium forms were studied in aqueous and alcohol solutions. The results of these investigations are reported in Table 6.

These results bear out the selective function of the carboxylic acid group in exchange reactions. The choice of the sodium (salt form) or hydrogen (free acid form) derivative of Amberlite IRC-50 for the adsorption cycle will vary with the nature of the substance to be recovered. If the compounds selected for study are in the salt form, the sodium derivative of the exchanger should be used, whereas the hydrogen form of the resin should be employed in the isolation of compounds in the "free base" form, especially where the materials to be adsorbed are weak bases.

If Amberlite IRC-50 is used as the hydrogen derivative, the acidity generated during the exchange reaction must be removed in some manner before the resin will exhibit appreciable adsorption capacity. Thus, if a "free base" is being adsorbed, exchange occurs because the displaced hydrogen ion from the exchanger combines with the hy-

TABLE 5

Basic Amino Acid Adsorption on AMBERLITE IRC-50

Amino Acid	Column Pre-Treatment	Leakage Percent	Capacity mg/ml	Capacity g/ft³
Histidine	H–resin	25	very low	
Lysine	H–resin	25	very low	
Arginine	H–resin	25	very low	
Histidine	Column buffered—pH 5.75	25	very low	
Histidine	Column buffered—pH 5.30	10	very low	
Histidine	Column buffered—pH 5.0	5–10	18	510
Histidine	Column buffered—pH 4.7	2–10	35	980
Lysine	Column buffered—pH 7.0	0–3	120	3400
Lysine	Na-resin	Ca–100	very low	
Arginine	Column buffered—pH 7.0	0–2	150	4248
Arginine	Na–resin	30	—	—
Leucine	pH 4.70 buffer	100	nil	nil
Glutamic Acid	pH 4.70 buffer	100	nil	nil

TABLE 6

Recovery of Miscellaneous Substances with AMBERLITE IRC-50

Substance Recovered	Form of AMBERLITE IRC-50	Solvent	Leakage Percent	Capacity mg/ml	Capacity g/ft³
Quinine sulfate	Na	H_2O	2	1,320	37,400
Nicotine	Na	H_2O	100	—	—
Nicotine	H	H_2O	0-2	385	10,950
Thiamine hydrochloride	Na	H_2O	5-8	53.5	1,510
Thiamine hydrochloride	Na	C_2H_5OH	25	—	—
Adenine sulfate	Na	H_2O	100	—	—
Adenine	H	H_2O	100	—	—
Pyridine	H	H_2O	0	14	396
Hydrazine	H	H_2O	0-2	51.2	1,450
Ammonia	H	H_2O	0	78	2,210
Sodium hydroxide	H	C_2H_5OH	0	13	369

droxide ion of the "free base", as in neutralization. For very weak bases (pKB > 10), adsorption will be negligible with either the salt or acid form of Amberlite IRC-50.

Another significant feature of the Amberlite IRC-50 is the exchanger's reactivity in organic solvents. From the data reported in Table VI, it can be seen that both organic and inorganic ions are adsorbed by the resin from alcohol solutions. The ability of Amberlite IRC-50 to swell in such solvents as water, ethanol, dioxane, ethylene glycol, acetone, and isopropanol indicates the exchanger may exhibit appreciable capacity in all of these solvents.

Suggested uses for Amberlite IRC-50: The foregoing discussion describes the varied uses for this carboxylic-acid type cation exchanger. Amberlite IRC-50 has been shown to effect considerable improvement in certain exchange reactions previously accomplished with sulfonate resins, but this resin is designed to supplement the available cation exchangers such as Amberlite IR-120.

Amberlite IRC-50 deserves consideration in the treatment of sugar solutions, amino acids, enzymes, hormones, milk and milk by-products, alkaloids, viruses, antibiotics, citrus derivations, fermentation products, water supplies and industrial wastes. The exchanger should offer interesting possibilities in catalysis, ore dressing, pharmaceutical compounding, plant nutrition, and recovery of rare metals. In every field of chemistry, Amberlite IRC-50 presents new opportunities for application of ion exchange processes.

Food and Drug Uses

When employing Amberlite IRC-50 in the processing or production of any food material which is to be consumed by human beings or animals, precautions must be taken to avoid contamination which may result from extractables, bacterial action or introduction of extraneous poisonous materials. For example, low molecular weight acrylic polymers may be present in fresh unconditioned resins and they may be extracted by the process stream unless removed by proper preconditioning treatment.

In one successful preconditioning treatment, the bed of Amberlite IRC-50 was subjected to at least three cycles of exhaustion and regeneration. The resin was exhausted with a 0.5 percent solution of sodium hydroxide. Following each of the three preconditioning exhaustion steps, the resin was regenerated with five percent sulfuric acid at a level of ten pounds H_2SO_4/cubic foot of resin. Experience has shown that this treatment reduces the extractables to levels complying with *F.D.A. Food Additive Regulation #173.25 (Formerly #121.1148)*.

When resins are in continuous use, no further special treatment is necessary. When use is intermittent, however, resins should be stored under water in the regenerated form and in the absence of materials which would nourish bacterial growth. When resins have been so stored for extended periods of time, it may be necessary that the conditioning procedure described above be employed before returning the Amberlite IRC-50 to service.

Since Amberlite IRC-50 has the capacity of adsorbing and releasing metal cations, care should be taken to avoid contacting the resins at any time with poisonous metallic salts which might subsequently be released to food or drug products. Also, regenerant chemicals should be chosen so as not to contain trace quantities of poisonous metal salts.

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ROHM AND HAAS
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ResinTech™
INNOVATIONS IN ION EXCHANGE

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ResinTech™ SIR-300
CATION EXCHANGE RESIN IMINODIACETATE

ResinTech SIR-300 is a macroporous cation exchange resin based on the Iminodiacetate acid functional group which has chelating properties for heavy metal ions even against high concentrations of Calcium; It is intended for use in polishing heavy metal ions from near neutral industrial wastes and process streams, and recovery of precious metals. **ResinTech SIR-300** is supplied in the sodium form as moist, tough, uniform spherical beads.

FEATURES & BENEFITS

* **ABLE TO CHELATE HEAVY METAL IONS EVEN AGAINST HIGH CALCIUM CONCENTRATIONS** - This gives high capacity for removing traces of heavy metals from waste waters that have been treated by conventional hydroxide precipitation.

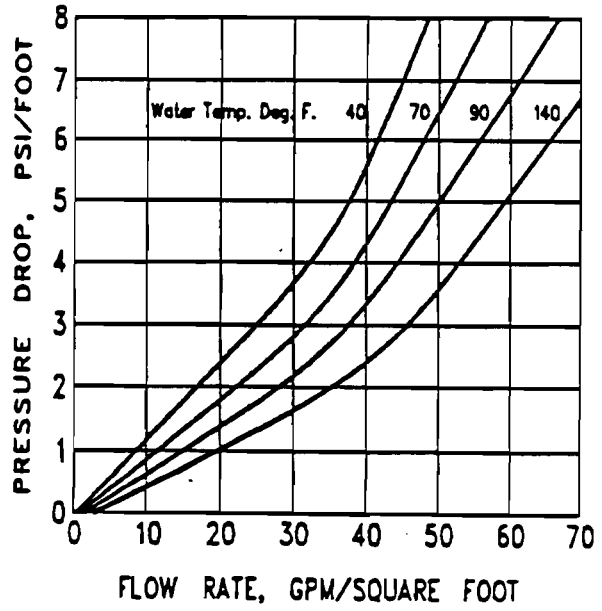
* **ABLE TO CHELATE HEAVY METALS IN THE PRESENCE OF COMPLEXING AGENTS** - Like complexing amines and carboxylic acids, including organic acids such as citric, tartaric, oxalic, and gluconic, phosphates etc.

* **UNIFORM PARTICLE SIZE** - 98% of all beads are in the minus 16 to plus 40 mesh range; giving a **LOWER PRESSURE DROP** while maintaining the **SUPERIOR KINETICS** of standard mesh size products.

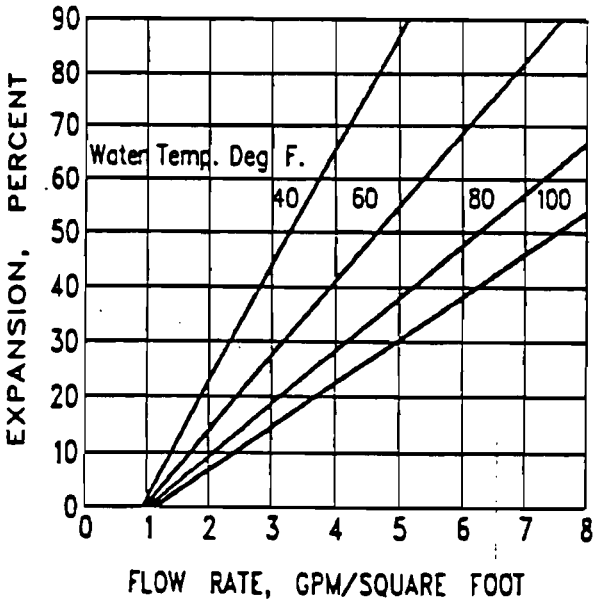
* **SUPERIOR PHYSICAL STABILITY** - 95% sphericity combined with a macroporous polymer structure, high crush strengths and uniform particle size distribution gives **ResinTech SIR-300** greater resistance to bead breakage and osmotic shock. This results in longer resin life and lower pressure drop, especially in frequently regenerated systems.

HYDRAULIC PROPERTIES

PRESSURE DROP - The graph below shows the expected pressure loss per foot of bed depth as a function of flow rate, at various water temperatures.



BACKWASH - After each cycle the resin bed should be backwashed at a rate that expands the bed 50 to 75 percent. This will remove any foreign matter and reclassify the bed.



TYPICAL PROPERTIES

Polymer Structure	Macroporous Styrene with DVB
Functional Group	$R\text{-}CH_2\text{-}N(COOH)_2$
Ionic Form, as shipped	Sodium
Physical Form	Tough, Spherical Beads
Screen Size Distribution	16-45 Nominal
+ 16 mesh (U.S. Std)	Less than 5 Percent
- 40 mesh " "	Less than 2 Percent
- 50 mesh " "	Less than 1 Percent
pH Range	1.5 - 14
Water Retention	
Sodium Form	50 to 60 Percent
Solubility	Insoluble
Approximate Shipping Weight	
Sodium Form	45 lbs. per cubic foot
Swelling H^+ to Na^+ Form	40 Percent
Total Capacity	>2.4 meq / mL Hydrogen form
Sphericity	> 95 Percent

SUGGESTED OPERATING CONDITIONS

Maximum Temperature	
Salt form	90 °C
Hydrogen form	60 °C
Maximum Free Chlorine	NONE
Minimum Bed Depth	36 inches
Backwash Rate	50 to 75 % Bed Expansion
Acid Regenerant Conc.*	4 - 10%
Regenerant Flow Rate	0.25 to .5 gpm / ft^3
Regenerant Contact Time	At least 30 Minutes
Regenerant Level / ft^3	8.7 (HCl), or 12.5 (H_2SO_4) pounds
Displacement Rinse Rate	Same as Regenerant Flow Rate
Displacement Rinse Volume	10 to 20 Gallons / ft^3
Fast Rinse Rate	Same as Service Flow Rate
Fast Rinse Volume	35 to 60 gal. / ft^3
Caustic Neutralization Conc.*	4 - 10%
Caustic Solution Flow Rate	0.25 to .5 gpm / ft^3
Caustic Contact Time	At least 30 Minutes
Caustic Dose Level	2.5 to 6.0 pounds / ft^3
Displacement Rinse Rate	Same as Regenerant Flow Rate
Displacement Rinse Volume	10 to 20 Gallons / ft^3
Fast Rinse Rate	Same as Service Flow Rate
Fast Rinse Volume	35 to 60 gal. / ft^3
Service Flow Rate	1 to 2 gpm / ft^3

***CAUTION: DO NOT MIX ION EXCHANGE RESINS WITH STRONG OXIDIZING AGENTS. Nitric acid and other strong oxidizing agents can cause explosive reactions when mixed with organic materials, such as ion exchange resins.**

OPERATING CAPACITY

The relative affinity of ResinTech SIR-300 for heavy metals in near neutral solutions is in accordance with the following sequence.

$H^{+1} >> Cu^{+2} > V^{+2} >> (UO_2)^{+2} > Pb^{+2} > Ni^{+2} > Zn^{+2} > Co^{+2} > Cd^{+2} > Fe^{+2} > Be^{+2} > Mn^{+2} > Mg^{+2}, Ca^{+2} > Sr^{+2} > Ba^{+2} >> Na^{+1}$

High concentrations of Chlorides or Sulfates, or the presence of cheating or complexing agents can alter this sequence and likewise will affect the operating capacity. ResinTech SIR-300 has similar chelating charecteristics to EDTA and NTA. Therefore it is effective when these agents are present.

As the pH decreases so does the capacity. For each particular metal ion, there is a critical or minimum pH below which ResinTech SIR-300 cannot remove significant amounts of that ion. These pH values are as follows.

Manganese	4.0
Iron	3.0
Zinc, Cobalt	2.7
Nickel	2.5
Copper	1.5

SELECTIVITY SEQUENCE IN HIGH CHLORIDE SOLUTIONS

$Cu^{+2} > Ni^{+2} > Co^{+2} > Zn^{+2} > Cd^{+2} > Fe^{+2}$

SELECTIVITY SEQUENCE IN HIGH SULFATE SOLUTIONS

$Cu^{+2} > Ni^{+2} > Cd^{+2} > Zn^{+2} > Co^{+2} > Fe^{+2}$

Applications include Waste Treatment, Chemical Processing and Resource Recovery - ResinTech SIR-300 can be used to remove heavy metal multivalent ions from a variety of industrial effluents like oil refineries, plating shops, mine drainage, battery manufacturing, cooling towers etc. Consult your ResinTech technical representative for recommendations for specific applications.

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These suggestions and data are based on information we believe to be reliable. They are offered in good faith. However we do not make any guarantee or warrantee. We caution against using these products in an unsafe manner or in violation of any patents; further we assume no liability for the consequences of any such actions.

MILES

Organic Products Division

Organic Chemicals

Product Information

Lewatit TP 207

Product Information 310

Lewatit TP 207 is a weakly acidic, macroporous cation exchange resin with chelating iminodiacetate groups for the selective extraction of heavy metal cations from weakly acidic to weakly basic solutions. Divalent cations are removed from neutralized waters in the following order:

copper > vanadium (VO) > uranium (UO_2) > lead > nickel > zinc > cadmium > iron (divalent) > beryllium > manganese > calcium > magnesium > strontium > barium > sodium.

Lewatit TP 207 is of standard bead size distribution. Its good chemical and mechanical stability make it specially suitable for use in the following applications:

- selective removal of heavy metals traces from effluents after their normal precipitation by hydroxides, even in the presence of high calcium contents
- recovery of precious metals from electroplating rinse waters
- concentration and extraction of heavy metals from hydrometallurgical solutions
- recovery of precious metals from pickling baths.

The selective extraction is achieved even in the presence of the following complexing agents:

- nitrogen compounds, e.g. ammonia, aliphatic, and aromatic amines
- multivalent carboxylic acids, e.g. citric acid, gluconic acid, glucuronic acid, oxalic acid, tartaric acid
- phosphates, e.g. tetrasodium diphosphate, sodium polyphosphate.

Lewatit TP 207 does not remove heavy metals from solutions containing EDTA or NTA respectively. Only cadmium is removed from solutions containing cyanides.

For the extraction of those heavy metals which follow the uranyl oxide ion in the selectivity sequence as shown above, Lewatit TP 207 has to be conditioned with caustic soda solution after every regeneration cycle/before every exhaustion cycle. After the conditioning it is partially in a salt-form, e.g. mono-sodium-form.

Before commissioning a Lewatit TP 207 unit, see our Technical Information OC/I 20343e for laboratory tests.

General Description — **Lewatit TP 207** — 310

Ionic form, as delivered	Na^+
Functional group	iminodiacetic acid
Matrix	crosslinked polystyrene
Structure	macroporous
Appearance	beige, opaque

Physical and Chemical Properties

Bead size* (U.S. Standard)	min. 90% mesh	16 - 40
Effective size*	mm	0.55 (± 0.05)
Uniformity coefficient*	max.	1.7
Bulk weight (± 5 %)	lbs/ft^3	50
Density	approx. g/ml	1.18
Water retention	% wt.	50 - 55
Total capacity* (H^+-form)	min. eq/L	2.4
Volume change Na^+ ---> H^+	approx. %	-30
Stability	temperature range °F	-4 up to 176
	pH range	0 - 14
Storability	of the product min. years	2
	temperature range °F	-4 up to 104

Recommended Operating Conditions**

Operating temperature		max. °F	176
Operating pH range			1.5 - 9
Bed depth		min. ft	3.3
Pressure drop (59 °F) per gpm/ft^2 approx. psi/ft			0.12
Pressure drop		max. psi	36
Flow velocity	service	gpm/ft^2	16
	backwash(68 °F) approx.	gpm/ft^2	4
Regenerant	type		HCl / H_2SO_4
Co-Current	level approx.	lbs/ft^3	8.7 / 12.5
	concentration	%	4 - 10 / 5 - 15
Flow velocity	regeneration approx.	gpm/ft^2	2
	rinsing min.	gpm/ft^2	2
Conditioning with			NaOH
Co-Current	level(form as shipped)	lbs/ft^3	Mono-Na: 2.5-3 Di-Na: 5-6
	concentration	%	4
Flow velocity	regeneration approx.	gpm/ft^2	2
	rinsing min.	gpm/ft^2	2
Rinse water requirement	approx.	gal/ft^3 resin	37
Bed expansion	per gpm/ft^2 (68 °F)	approx. %	10
Freeboard	(as % of resin volume)	approx.	80

Miles Inc.

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DURATEK

TECHNICAL BULLETIN

DURASIL® 230 Ion Exchange Media

Description

DURASIL® 230 media is an inorganic oxide based cation exchanger with a high specificity for radioactive cesium (Cs) and a low specificity for such nonradioactive species as sodium (Na) and lithium (Li).

Application

DURASIL® 230 media was designed to selectively remove Cs radioisotopes from radwaste streams, and has been used at commercial nuclear power plants and DOE sites. It is sluiceable, bridges retention screens, and can be used in systems designed for organic resins.

Characteristics

DURASIL® 230 media has the following characteristics:

- High capacity for Cs
- Excellent mechanical stability
- Invulnerable to attack by oxidants such as chromates and nitrates
- Non-flammable
- Does not shrink or swell
- Resists oil fouling
- Virtually immune to radiation damage and biological decay
- No effect on pH of waste stream
- Low pressure drop

Properties

Base Material	Inorganic Oxide
Bulk Density (dry)	40 lbs/cu.ft. (0.65 g/ml)
Maximum Swelling (%)	0
Particle Size	20-50 mesh (840µ-290µ)
Ion Exchange Mechanism	Sodium Exchange
Functional Group	Acidic
Ionic Form Shipped	Sodium
Exchange Capacity	2.0 meq/ml (3.1 meq/g)
pH Range	3 - 10
Operating Temperature	32-140°F (0-60° C)
Storage Temperature	32-140°F (0-60° C)
Shipped	Wet

Operating Performance

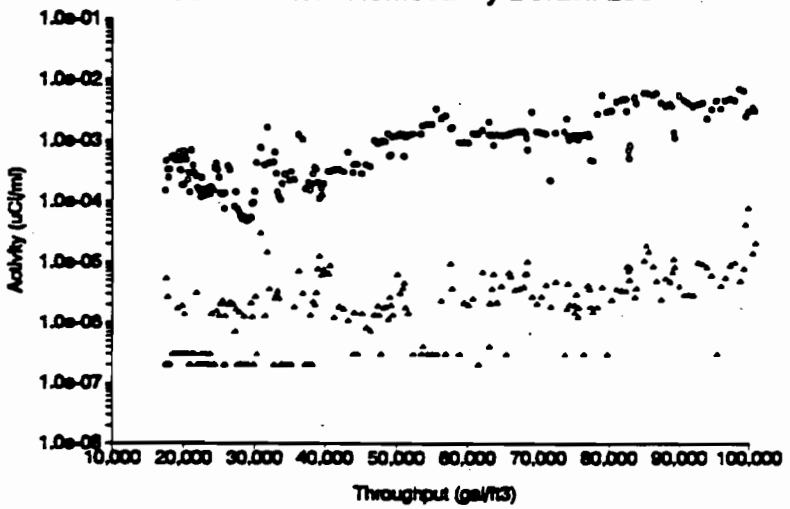
The selectivity of **DURASIL® 230** media results in high media capacity and large DFs for Cs. The graph below shows actual operating performance of **DURASIL® 230** media in the treatment of a radioactive wastewater stream. The total volume radwaste processed was 2,120,100 gallons with an average conductivity of 163 µmho/cm. Other chemistry data is presented below.

Average Cs Influent Activity
O 1.9E-03 µCi/ml

Average Cs Effluent Activity
Δ 7.7E-06 µCi/ml

Average
Decontamination Factor = 247

Actual Plant Data
Total Cesium Removal by Durasil 230



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DURATEK

Adsorbents

UOP

PRODUCT INFORMATION

MOLSIV® ADSORBENTS
a product of UOP

IE-95 ION EXCHANGER

Description

UOP IE-95 Ion Exchanger is an alkali metal alumino silicate primarily of the chabazite structure type supplied in the mixed ionic (Na^+, Mg^{++}, Ca^{++}) form.

Chemical Formula

$(Na_2O, MgO, CaO) \cdot Al_2O_3 \cdot 4\text{-}6\ SiO_2 \cdot H_2O$

Shipping Information

IE-95 Ion Exchanger is available in 20×50 mesh form. Samples may be obtained on request.

Regeneration

Typically, regeneration may be accomplished by the use of NaCl solution of the regenerant fluid.

Typical Properties

Partical Size	Mesh (20×50)
Pore Openings	3.7×4.2 Å and 2.6 Å
Bulk Density	
As shipped	40 lbs/cu.ft. 640 kg/cu.m.
Hydrated, packed	46 lbs/cu.ft. 740 kg/cu.m.
BS&D Density (hydrated)	38 lbs/cu.m. 610 kg/cu.m.
H_2O Content	
As shipped	1–10 wt.%
Hydrated	12–17 wt.%
Ion Exchange Capacity	2.0–2.5 meq/gm (anhydrous)

Typical Application Areas

UOP IE-95 Ion Exchanger products have been found to be effective for recovery and storage of radio-nuclides and for cation exchange from acid solutions.

Additional Information

Bulletins discussing additional applications of UOP Molecular Sieves are available. Call or write your nearest UOP Molecular Sieve Sales Office.

Sales Offices

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Typical Properties
IONSIV IE-96

Property	Typical Value
Bulk Density	55 LBS/FT3
Particle Size	20 X 50 Mesh
Ion Exchange Capacity	2.0-2.5 meq/gm (anhydrous)
Pore Openings	3.7 X 4.2 Å and 2.6 Å
H_2O Content	10-15 wt%
Chemical Formula	$(Na_2O, MgO, CaO) \cdot Al_2O_3 \cdot 4\text{-}6\ SiO_2 \cdot H_2O$