This document was prepared in conjunction with work accomplished under Contract No. DE-DE-AC09-76SR00001 with the U.S. Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available for sale to the public, in paper, from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
phone: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/index.asp

Available electronically at http://www.osti.gov/bridge

phone: (865)576-8401
fax: (865)576-5728
email: reports@adonis.osti.gov
INTRODUCTION

This document describes a laboratory tracer facility which was used to show Duolite CS-100 resin's capability for removing cesium from supernate. The data presented is part of the High Level Waste Technology Section's effort to develop design information for the Reference Defense Waste Processing Facility (DWPF).
BACKGROUND

About 20 million gallons of high level radioactive waste, generated in the production of special nuclear materials during the last twenty-five years, are stored in large underground tanks at the Savannah River Plant in the form of a damp salt cake and a gelatinous sludge. A process was being developed to: (1) remove from supernate the hazardous radionuclides, (2) recombine radionuclides with sludge, and (3) combine sludge in leach resistant glass matrix suitable for long-term geologic storage. A step in this conceptual process is the use of an ion exchange resin to remove cesium from the supernate.

SUMMARY

A tracer facility (Figure 1,2) for testing ion exchange resins was built and used to test Duolite CS-100 resin's capability to remove cesium from synthetic supernate. Cesium-137 was used as a tracer. The variables, feed flow rate, and cesium concentration were plotted as functions of, % change of cesium concentration to column volumes passed (Appendix A). The resultant Kd's were then plotted as a function of cesium concentration (Figure 3). The Kd data was then extrapolated to other hydroxide cesium concentrations, (Appendix B).

At a DF of 10,000, the relationship of feed flow rate was correlated to column volumes passed and cesium concentration (Figure 4).

The physical properties of the resin are shown in Appendix C.

I/E TRACER LEVEL FACILITY (TLF) EQUIPMENT

The major goals of this equipment were to demonstrate the proposed DWPF flowsheet and to explore the I/E variables such as feed rate, elutriant composition, and regenerant composition.

The height of the cesium I/E resin column (92 inches) was near the expected DWPF column height. A three inch diameter column was chosen to meet the limits of radiation and maximum reasonable laboratory feed tank size (100 gal.). A schematic of the I/E test facility (ST5-22530), as installed in the laboratory (Room 139, Building 773-A), is shown in Figure 1. The facility includes: a glass I/E column, 100 gallon feed tank, receipt tank and automatic gamma counting sensors in column input and output streams.
Both columns were made of Corning beaded pressure pipe rated at 50 psig. The resin was supported by a perforated plate. A Johnson Profile wire screen (.007 inch slot) distributed the feed at the top of the column and prevented resin from entering the feed line during the backwash cycle.

A mix tank (30 gal. stainless steel) was used to make up elutriant and regenerant. Polyethylene carboys (50 liter) served as metering tanks for water, elutriant, and regenerant.

Two mRoy duplex positive displacement pumps (maximum flow 12.4 gph for load and 3.6 gph for elution and regeneration) supplied feeds to the column. Four Jabsco® self-priming impeller pumps (5.5 gpm at 10 ft. head) transferred liquids from drums, metering tanks, receipt tank, and floor pans.

Over-pressure protection was provided by 35 psig relief valves on the metering pumps and by 30 psig electrical pump overpressure interlocks that shut off the pumps, fed the tank agitator, and sent an alarm to Building Operations. The pumps were also shut off by level switch/alarms that were activated if a pump ran dry or liquid spilled into a secondary floor container pan. See STS-20550, 20552.

Because of the very low cesium-137 tracer concentration in the I/E effluent, automatic counting equipment and 3 inch sodium iodide detectors (in lead shielded counting chambers) were used. The I/E inlet feed chamber (44 ml) was made of a coiled 0.15 ID Teflon tube, and the effluent chamber (1000 ml) of teflon and polypropylene (SK 3620-I5). These plastics were used to reduce buildup of radionuclides on surfaces and thus reduce background levels and variations.

EXPERIMENTAL RESULTS

Duolite CS-100 resin (Lot 316-300-OE; 40-60 mesh U. S. standard) in the hydrogen form was loaded in the column and then converted to the sodium form with 0.5 molar NaOH. Spiked supernate was passed through the column (Table I, II, III and Appendix A) and the results tabulated (Table III, IV) and plotted (Figures 3,4). The results were then extrapolated (Appendix B) to other cesium and hydroxide levels (Figure 5).

The feed and first rinse cycles were downflow, and the elution and regeneration cycles upflow. After loading the resin in the column, it was treated with elutriant and regenerant. Gamma counting of the process streams was used to calculate the
decontamination factor (DF) and the elution frequency. The down-flow feed rate tested was varied from 0.43 to 3.0 gpm/ft$^2$, and the upflow elution-regeneration rate tested was 0.54 gpm/ft$^2$. Elution of cesium was with .5 molar formic acid$^3$ and regeneration with 0.5 molar NaOH.

The supernate pressure drop through resin is shown by Figure 19 in Appendix C.

LLK:pmc
Att
Disc 1
FIG 1

STRONTIUM TRACER LEVEL ION EXCHANGE FACILITY
Cs/Sr ION EXCHANGE TRACER FACILITY

FIG 2

Neutralizer
Down Pump

Cs #1

Cs #2

Sr

Backwash Column
To Drain

Water

HNO₃

Neutralizer

Delay

Counter

HL

LL

Delay

Counter
## TABLE I

**Synthetic Supernate Feed to Duolite CS-100 Ion Exchange Column**

<table>
<thead>
<tr>
<th>Ion</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALO₂</td>
<td>0.423</td>
</tr>
<tr>
<td>NO₃</td>
<td>2.2</td>
</tr>
<tr>
<td>NO₂</td>
<td>0.95</td>
</tr>
<tr>
<td>OH</td>
<td>1.62</td>
</tr>
<tr>
<td>CO₃</td>
<td>0.48</td>
</tr>
<tr>
<td>SO₄</td>
<td>0.24</td>
</tr>
<tr>
<td>Na</td>
<td>5.3</td>
</tr>
</tbody>
</table>

SpGr = 1.29

Dissolved Solids = 33%
TABLE II
CS-100 Experimental Range Attempted

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Test No.</th>
<th>Range</th>
<th>Expected Cs</th>
<th>Cs (M)</th>
<th>CV's/Hr</th>
<th>gpm/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4C</td>
<td>100</td>
<td>2.5E-4</td>
<td>1.7</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5C</td>
<td>100</td>
<td>2.5E-4</td>
<td>3.8</td>
<td>2.97</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6C</td>
<td>100</td>
<td>2.5E-4</td>
<td>.84</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7C</td>
<td>50</td>
<td>2.5E-3</td>
<td>1.7</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8C</td>
<td>50</td>
<td>2.5E-3</td>
<td>3.8</td>
<td>2.97</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>9C</td>
<td>50</td>
<td>2.5E-3</td>
<td>.84</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>10C</td>
<td>200</td>
<td>2.5E-5</td>
<td>1.7</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>11C</td>
<td>200</td>
<td>2.5E-5</td>
<td>3.8</td>
<td>2.97</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>12C</td>
<td>200</td>
<td>2.5E-5</td>
<td>.84</td>
<td>0.66</td>
<td></td>
</tr>
</tbody>
</table>
TABLE III

Distribution Coefficient (Kd) Measured at 60% Column Breakthrough

<table>
<thead>
<tr>
<th>Test No.</th>
<th>CV's/Hr</th>
<th>Cs M</th>
<th>CV's @ 60% Breakthru</th>
<th>(1.1) CV's @ 60%</th>
<th>Kd See Below</th>
</tr>
</thead>
<tbody>
<tr>
<td>1C</td>
<td>1.58</td>
<td>2.4E-4</td>
<td>35</td>
<td>38</td>
<td>89.3</td>
</tr>
<tr>
<td>2C</td>
<td>1.61</td>
<td>&quot;</td>
<td>37</td>
<td>40.7</td>
<td>94.4</td>
</tr>
<tr>
<td>4C</td>
<td>1.66</td>
<td>&quot;</td>
<td>32</td>
<td>35.2</td>
<td>81.7</td>
</tr>
<tr>
<td>5C</td>
<td>3.8</td>
<td>&quot;</td>
<td>28</td>
<td>30.8</td>
<td>71.5</td>
</tr>
<tr>
<td>6C</td>
<td>.57</td>
<td>&quot;</td>
<td>32</td>
<td>35.2</td>
<td>81.7</td>
</tr>
<tr>
<td>7C</td>
<td>1.55</td>
<td>2.5E-3</td>
<td>14</td>
<td>15.4</td>
<td>35.7</td>
</tr>
<tr>
<td>8C</td>
<td>2.13</td>
<td>&quot;</td>
<td>14</td>
<td>15.4</td>
<td>35.7</td>
</tr>
<tr>
<td>9C</td>
<td>.51</td>
<td>&quot;</td>
<td>14</td>
<td>15.4</td>
<td>35.7</td>
</tr>
<tr>
<td>10C</td>
<td>1.5</td>
<td>2.5E-5</td>
<td>40</td>
<td>44</td>
<td>102</td>
</tr>
<tr>
<td>11C</td>
<td>2.0</td>
<td>&quot;</td>
<td>55</td>
<td>60.5</td>
<td>140</td>
</tr>
<tr>
<td>12C</td>
<td>.55</td>
<td>&quot;</td>
<td>57</td>
<td>62.7</td>
<td>145</td>
</tr>
</tbody>
</table>

K_d = \frac{(1.1)(CV's @ 60\%)}{(0.431)} \times \left\{(-22.45 \ln Cs) - 103\right\}; (Figure 3)

\rho_B = 0.431 \text{ gms resin in Na form/ml resin in Na form in 1M NaOH.}
DISTRIBUTION COEFFICIENT ($K_D$) 
FOR DUOLITE CS - 00 (40-60 MESH) 
VS CESIUM CONCENTRATION 
IN SUPERNATE

**Figure 3**

<table>
<thead>
<tr>
<th>ION</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH^-</td>
<td>1.62</td>
</tr>
<tr>
<td>NO_3</td>
<td>2.2</td>
</tr>
<tr>
<td>NO_2</td>
<td>.95</td>
</tr>
<tr>
<td>AIO_2-</td>
<td>.423</td>
</tr>
<tr>
<td>CO_3</td>
<td>.48</td>
</tr>
<tr>
<td>SO_4</td>
<td>.24</td>
</tr>
<tr>
<td>K</td>
<td>.0095</td>
</tr>
<tr>
<td>Na</td>
<td>5.3</td>
</tr>
</tbody>
</table>

$K_D = \frac{(1.1)(Cv/60\text{%} \text{BREATHRU})}{C}$

$K_D = -22.45 \ln C_S = 103$

$C =$ wt. oven-dried Na form 
$Cv =$ volume in 1M NaOH 
$K_D =$ DISTRIBUTION COEFFICIENT
TABLE IV
At DF = 10,000 Supernate Flow Rate vs. Column Volumns Fed At Various Cesium Concentrations

<table>
<thead>
<tr>
<th>Test*</th>
<th>CsM</th>
<th>CV's</th>
<th>CV's/Hr</th>
<th>gpm/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>8C</td>
<td>2.5E-3</td>
<td>21</td>
<td>2.13</td>
<td>1.66</td>
</tr>
<tr>
<td>7C</td>
<td>2.5E-3</td>
<td>23</td>
<td>1.55</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>2.5E-3</td>
<td>41</td>
<td>.51</td>
<td>0.40</td>
</tr>
<tr>
<td>5C(2)</td>
<td>2.5E-4</td>
<td>10</td>
<td>3.8</td>
<td>2.97</td>
</tr>
<tr>
<td>4C</td>
<td>2.5E-4</td>
<td>18</td>
<td>1.66</td>
<td>1.30</td>
</tr>
<tr>
<td>2C</td>
<td>2.5E-4</td>
<td>19</td>
<td>1.61</td>
<td>2.56</td>
</tr>
<tr>
<td>1C</td>
<td>2.5E-4</td>
<td>21</td>
<td>1.58</td>
<td>1.32</td>
</tr>
<tr>
<td>6C</td>
<td>2.5E-4</td>
<td>26.5</td>
<td>.57</td>
<td>0.445</td>
</tr>
<tr>
<td>11C</td>
<td>2.5E-5</td>
<td>21</td>
<td>2.0</td>
<td>1.56</td>
</tr>
<tr>
<td>10C</td>
<td>2.5E-5</td>
<td>23</td>
<td>1.5</td>
<td>1.17</td>
</tr>
<tr>
<td>12C</td>
<td>2.5E-5</td>
<td>41</td>
<td>.55</td>
<td>0.43</td>
</tr>
</tbody>
</table>

*See Appendix A.
FOR DE=10,000

SUPERNATE FLOW RATE VS
COLUMN VOLUMES FOR
VARIOUS CESIUM CONCENTRATIONS
FOR DUOLITE CS-100 (40-60 MESH)

FIGURE 4

\[
\begin{array}{c|c}
\text{ION} & F_a \\
\hline
\text{AlO}_2 & 0.423 \\
\text{NO}_3 & 2.2 \\
\text{NO}_2 & 1.95 \\
\text{OH} & 1.62 \\
\text{CO}_3 & 0.98 \\
\text{SO}_4 & 0.24 \\
\text{Na} & 5.3 \\
\end{array}
\]

\[
\text{SpGr} = 1.29 \\
\% \text{SALT} = 33
\]

\[
Q/\text{s/HR} = a e^{b(cvs)}
\]

\[
\begin{array}{c|c|c|c}
\text{Cv} & a & b \\
\hline
2.5E-3 & 7.33 & 0.0732 \\
2.5E-4 & 12.38 & 1.000 \\
2.5E-5 & 9.84 & 0.0732 \\
\end{array}
\]
DISTRIBUTION COEFFICIENT (Kd) FOR DUOLITE CS-102 VS CESIUM CONCENTRATION IN SUPERNATE

EXTENDED TO OTHER CS-1 CONCENTRATIONS (SEE APPENDIX B FIG 5)

* Kd = -12.8 log [Cesium] + 6.5 (FIG 5)

DISTRIBUTION COEFFICIENT = Kd
Experimental data plots are shown in the following figures. The reasoning for plotting the experimental data is shown in Figure 6. The data plots are shown in Figures 7 to 18. A tabulation of the experiments run is shown in Table III.
**EXPERIMENTAL NOMENCLATURE**

\[
CV's = \frac{V}{V_C} = K_d [\rho (1-\phi)] + \phi = K_d \rho_B + \phi
\]

- \(\phi\) = volume fraction, liquid/bed volume
- \(\rho\) = density resin wet
- \(CV\) = volume of column
- \(CV's\) = volume of feed
- \(\rho (1-\phi)\) = bulk density of resin wet

Let \(\rho_B\) = bulk density = \(\frac{\text{wt dried form}}{\text{volume in liquid}}\)

\(K_d = \frac{q}{q'_{eq}} = \frac{\text{volume bed}}{\text{volume feed}}\)

- \(q\) = solid concentration, gm equal/ml bed volume
- \(q'_{eq}\) = liquid concentration, (g-equiv)/ml

In Practice: \(\rho_B\) \(K_d \approx 1.1\) [(CV)'s at 60% breakthrough]
TEST IC

CESIUM ION EXCHANGE

DUOLITE CS 100 (40-60 MESH)

TRACER LEVEL FACILITY

EXPANDED BED VOLUME 9.73 L

1 KG DRY = Expand bed = 1 KG WET RESIN SYNTHETIC SUPERNATE 1.27 SPGR

CONCENTRATIONS

FIGURE 7

ION

Cs
Sr
Oxalate
Ba
Pb
Hg
Yb
OH
NO₃
NO₂
AlO₂
CO₃
SO₄

CONCENTRATION (M)

2.5 x 10⁻⁴
5.0 x 10⁻⁴
3.3 x 10⁻³
2.0 x 10⁻⁷
2.0 x 10⁻⁶
5.0 x 10⁻⁵
1.65 x 10⁻⁵
1.68
2.7
1.0
.40
.56
.26

% BREAKTHROUGH

C/C₀ x 100

COLUMN VOLUMES
TESTIC
ELUTION CYCLE
TRACER LEVEL FACILITY

\[ \Sigma \% \]

\[ \Sigma \% \]

\[ CV' s \]

\[ 100 \]
\[ 99.5 \]
\[ 99.0 \]
\[ 95.0 \]

\[ 6.0 \]
\[ 4.5 \]
\[ 4.2 \]
\[ 3.6 \]

\[ \% \]

\[ \% \]

\[ COLUMN VOLUMES \]
Cesium ion exchange test

DUOLITE CS-100 (40-60 mesh)

TRACER LEVEL FACILITY

EXPANDED BED VOLUME 9.73 L

1 KG DRY = DEXPBED KG WET

SYNTHETIC SUPERNATE 1.293 SPEC

Figure 9

Concentrations

ION

M

Cs
2.5E-4

S
5.0E-7

Oxalate
3.3E-3

Ba
2.0E-7

Pb
2.0E-6

Hg
5.0E-6

Yb
1.65E-5

OH
1.43

NO3
2.2

NO2
1.0

PO4
1.45

CO3
1.9

SO4
1.9

* Lot 316-300 CE
TEST 4C
CESIUM ION EXCHANGE
DUOLITE *CS100 (40-60 mesh)
TRACER LEVEL FACILITY
EXPANDED BED VOLUME 8.752
SYNTHETIC SUPERNATE 129 m3
FIGURE 10

CONCENTRATIONS
ION
Cs = 2.5E-4
Sr = 5.0E-7
OH = 1.62
NO3 = 2.2
NO2 = 0.95
AlO2 = 1.42
CO3 = 0.78
SO4 = 0.24

% BREAKTHROUGH
C/Co x 100

COLUMN VOLUMES
2 3 4 5 6 7 8 9 10 15 20 30 40 50 60 70 80 90 100 150 200 300 400 500 600 700 800

R. B. FERGUSON
DPST-82-677
19 JULY 6, 1982

19
TEST 5C (2)
CESIUM ION EXCHANGE
DUOLITE * CS 100 (40-60 MESH)
TRACER LEVEL FACILITY
EXPANDED BED VOLUME 8.75-
SYNTHETIC SUPERNATE 1.2856

FIGURE II
CONCENTRATIONS

ION \( \bar{N} \)

<table>
<thead>
<tr>
<th>Ion</th>
<th>( \bar{N} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs</td>
<td>( 2.5 \times 10^{-4} )</td>
</tr>
<tr>
<td>Sr</td>
<td>( 5.0 \times 10^{-7} )</td>
</tr>
<tr>
<td>Oxalate</td>
<td>0</td>
</tr>
<tr>
<td>Ba</td>
<td>0</td>
</tr>
<tr>
<td>Pb</td>
<td>0</td>
</tr>
<tr>
<td>Hg</td>
<td>0</td>
</tr>
<tr>
<td>Yb</td>
<td>0</td>
</tr>
<tr>
<td>CH</td>
<td>1.62</td>
</tr>
<tr>
<td>NO₃</td>
<td>2.2</td>
</tr>
<tr>
<td>NO₂</td>
<td>1.95</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.42</td>
</tr>
<tr>
<td>CO₃</td>
<td>1.48</td>
</tr>
<tr>
<td>SO₄</td>
<td>1.24</td>
</tr>
</tbody>
</table>

% BREAKTHROUGH

COLUMN VOLUMES

\[ \text{C / C_0 x 100} \]

\[ \text{2 3 4 5 6 7 8 9 10 15 20 30 40 50 60 70 80 90 100 150 200 300 400 500 600 700 800} \]
Figure 13

Concentrations

<table>
<thead>
<tr>
<th>Ion</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs</td>
<td>2.5E-3</td>
</tr>
<tr>
<td>Sr</td>
<td>5.0E-7</td>
</tr>
<tr>
<td>OH</td>
<td>1.62</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>2.2</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>1.95</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>1.42</td>
</tr>
<tr>
<td>CO₃⁻</td>
<td>1.48</td>
</tr>
<tr>
<td>SO₄⁻</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Test 7C
Duolite® CS100 (40-60 mesh)
Tracer Level Facility
Expanded Bed Volume 8.75 ft³
Synthetic Supernate 1.295 g/L

Column Volumes
Figure 14

Concentrations:

<table>
<thead>
<tr>
<th>Ion</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>2.5E-3</td>
</tr>
<tr>
<td>Sr</td>
<td>5.0E-7</td>
</tr>
<tr>
<td>OH</td>
<td>1.62</td>
</tr>
<tr>
<td>NO₃</td>
<td>2.2</td>
</tr>
<tr>
<td>NO₂</td>
<td>1.95</td>
</tr>
<tr>
<td>AlO₂</td>
<td>0.42</td>
</tr>
<tr>
<td>CO₃</td>
<td>0.48</td>
</tr>
<tr>
<td>SO₄</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Test BC

Duolite® CS100 (40-60 mesh)
Tracer level facility
Expanded bed volume 8.75 E
Synthetic supernate 1.295 g

% Breakthrough

Column volumes
TEST 11C

DUOLITE® CS100 (40-60 MESH)

TRACER LEVEL FACILITY

EXPANDED BED VOLUMES 8.758

SYNTHETIC SUPERNATE 1.295 g/L

FIGURE 17

CONCENTRATIONS

ION     M
CS— — — 2.5E-5
Sr— — — 5.0E-7
OH— — — 1.62
NO₃— — — 2.2
NO₂— — — 1.95
AlO₂— — — 0.42
CO₃— — — 0.48
SO₄— — — 2.4
DUOLITE CS100 40-60 MESH
TRACER LEVEL FACILITY
EXPANDED BED VOLUME 8.75x
SYNTHETIC SUPERNATE 1.295 gr

CONCENTRATIONS

ION          M
CS-          2.5E-5
Sr-          5.0E-7
OH-          1.62
NO3-         2.2
NO2-         1.95
Al2O3         4.2
CO3-         4.8
SO4-         2.4

% BREAKTHROUGH, C/C₀ x 100

COLUMN VOLUMES
APPENDIX B

Data relating the effect of cesium and hydroxyl concentration on the $K_d$ of Duolite CS-100 was measured by Eber and is shown on Table VII. This data was fit to the following equation:

$$\log K'_d = \left[ \frac{0.805 \log Cs + 0.263 + 0.15(OH)}{0.161 \log Cs - 1} \right]$$ (1)

The $K_d$ values measured in the Tracer Level Facility (Table IV and Figure 3) were fit to the following equation:

$$K_d \text{obs} = (-22.45 \ln(Cs)) - 103$$ (2)

The following equations were used to predict the $K_d$ value at other cesium and hydroxide conditions:

$$K_d \text{new} = \left[ K_d \text{obs} \right] \left[ \frac{K_d \text{new}}{K_d \text{cal}} \right]$$ (3)

Substituting 1 and 2 in 3, gives:

$$K_d \text{new} = -\left[ 12.83 \ln(Cs) + 58.9 \right] \left[ 10^{0.15(OH)} \right]$$ (4)

which was used to plot Figure 5.

A general case equation for extrapolating from any observed $K_d$ to a $K_d$ at any new cesium or hydroxyl level was developed from equations 1 and 3.
\[ K_{d_{\text{new}}} = \frac{.805 \log C_s_{\text{new}} + .263}{.161 \log C_s_{\text{new}} - 1} + .15 \frac{\log C_{\text{new}}}{.161 \log C_s_{\text{obs}} - 1} \]

\hspace{100pt} \text{predicted value of } K_d \text{ based on new } C_s \& OH

\[ K_{d_{\text{obs}}} = \text{observed } K_d \text{ at } C_s \text{ and } OH \text{ given} \]

\[ C_s_{\text{new}} = C_s \text{ molarity at predicted } K_d \]

\[ OH_{\text{new}} = \text{hydroxide molarity at predicted } K_d \]

\[ C_s_{\text{obs}} = C_s \text{ molarity at observed } K_d \]

\[ OH_{\text{obs}} = \text{hydroxide molarity at observed } K_d \]
TABLE V
(Ref 4)

Kd', for Duolite CS-100 at Various Cs and OH Concentrations and 6M Total Sodium

<table>
<thead>
<tr>
<th>OH^-</th>
<th>C_orig.</th>
<th>C_eq</th>
<th>(K_d')*</th>
</tr>
</thead>
<tbody>
<tr>
<td>4M</td>
<td>1 x 10^{-1}</td>
<td>8.49 x 10^{-2}</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-2}</td>
<td>6.00 x 10^{-3}</td>
<td>49.8</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-3}</td>
<td>3.59 x 10^{-4}</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-4}</td>
<td>2.94 x 10^{-5}</td>
<td>179</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-5}</td>
<td>1.16 x 10^{-6}</td>
<td>568</td>
</tr>
<tr>
<td>2M</td>
<td>1 x 10^{-1}</td>
<td>8.89 x 10^{-2}</td>
<td>9.37</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-2}</td>
<td>6.83 x 10^{-3}</td>
<td>34.4</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-3}</td>
<td>4.92 x 10^{-4}</td>
<td>77.1</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-4}</td>
<td>2.57 x 10^{-5}</td>
<td>216</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-5}</td>
<td>1.33 x 10^{-6}</td>
<td>486</td>
</tr>
<tr>
<td>1M</td>
<td>1 x 10^{-1}</td>
<td>9.53 x 10^{-2}</td>
<td>3.72</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-2}</td>
<td>8.02 x 10^{-3}</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-3}</td>
<td>5.54 x 10^{-4}</td>
<td>60.1</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-4}</td>
<td>3.39 x 10^{-5}</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-5}</td>
<td>1.94 x 10^{-6}</td>
<td>312</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-6}</td>
<td>1.32 x 10^{-7}</td>
<td>492</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-7}</td>
<td>1.04 x 10^{-8}</td>
<td>643</td>
</tr>
<tr>
<td>0.1M</td>
<td>1 x 10^{-1}</td>
<td>9.62 x 10^{-2}</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-2}</td>
<td>8.56 x 10^{-3}</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-3}</td>
<td>6.66 x 10^{-4}</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-4}</td>
<td>4.88 x 10^{-5}</td>
<td>78.4</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-5}</td>
<td>3.48 x 10^{-6}</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>1 x 10^{-6}</td>
<td>3.16 x 10^{-7}</td>
<td>500</td>
</tr>
</tbody>
</table>

* Based on bulk density = .413 = ρ_B

ρ_B = wt of oven dried Na form

vol of Na form in 1M NaOH
APPENDIX C

TABLE VI

Chemical & Physical Properties of Duolite CS-100

<table>
<thead>
<tr>
<th>Property</th>
<th>Weight Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&lt;sub&gt;1&lt;/sub&gt; air dried H&lt;sup&gt;+&lt;/sup&gt; form/wet H&lt;sup&gt;+&lt;/sup&gt; form (1)</td>
</tr>
<tr>
<td></td>
<td>R&lt;sub&gt;2&lt;/sub&gt; wet Na&lt;sup&gt;+&lt;/sup&gt; form/wet H&lt;sup&gt;+&lt;/sup&gt; form (1)</td>
</tr>
<tr>
<td></td>
<td>R&lt;sub&gt;3&lt;/sub&gt; dry Na&lt;sup&gt;+&lt;/sup&gt; form/wet H&lt;sup&gt;+&lt;/sup&gt; form (1)</td>
</tr>
<tr>
<td></td>
<td>R&lt;sub&gt;4&lt;/sub&gt; oven dried H&lt;sup&gt;+&lt;/sup&gt; form/air dried H&lt;sup&gt;+&lt;/sup&gt; form</td>
</tr>
</tbody>
</table>

| Bulk Densities, g/ml                          |                                                                            |
| B<sub>H</sub> H<sup>+</sup> form (2)            | 0.694                                                                   |
| B<sub>Na</sub> Na<sup>+</sup> form (3)           | 0.515                                                                   |
| C<sub>B</sub> Na<sup>+</sup> form (4)            | 0.413                                                                   |

| Capacity                                      |                                                                            |
| C(g) meq/g (5)                                | 3.65                                                                    |
| C(V) meq/ml (6)                                | 1.71                                                                    |

Lot No. of resin 316-300-0E

(1) H<sup>+</sup> form as received from vendor.
(2) Weight of wet H<sup>+</sup> form (1)/volume of H<sup>+</sup> form in water.
(3) Weight of wet H<sup>+</sup> form (1)/volume of Na<sup>+</sup> form in 1M NaOH.
(4) Weight of oven dried Na form/volume of Na<sup>+</sup> form in 1M NaOH.
(5) Meq/g of dry Na<sup>+</sup> form.
(6) Meq/ml of Na<sup>+</sup> form in 1M NaOH.
DUOLITE CS-100
40-60 MESH
PRESSURE DROP VS FLOW
AND TEMPERATURE
OF SUPERNATE
(33% SALT)

FIGURE 19

\[
\frac{\text{PSI}}{\text{Ft}} = 0.2023 \left(\frac{\text{GPM}}{\text{Ft}^2}\right)^{2.412} \left(e^{-0.0358% \cdot 0.456^\circ C}\right)
\]
TABLE VII

Pressure Drop vs Flow Rate of Supernate (33% Salt) at 25°C
(Load Cycle - 3" Diameter Column)

\[
\text{psi/ft} = 0.4518 \left( \frac{\text{gpm}}{2 \text{ft}} \right)^{1.2412}
\]

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Pressure Drop lb/in²</th>
<th>Height Column Inches</th>
<th>Flow Rate CV's/hr</th>
<th>Flow Rate gpm/ft²</th>
<th>psi/ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>4C</td>
<td>3.67</td>
<td>77.5</td>
<td>1.65</td>
<td>1.33</td>
<td>.568</td>
</tr>
<tr>
<td></td>
<td>3.96</td>
<td>76.5</td>
<td>1.65</td>
<td>1.31</td>
<td>.621</td>
</tr>
<tr>
<td>5C(2)</td>
<td>9.4</td>
<td>72.0</td>
<td>3.8</td>
<td>2.85</td>
<td>1.567</td>
</tr>
<tr>
<td>6C</td>
<td>1.0</td>
<td>74.0</td>
<td>0.57</td>
<td>.439</td>
<td>.162</td>
</tr>
<tr>
<td>10C</td>
<td>3.3</td>
<td>73.0</td>
<td>1.5</td>
<td>1.14</td>
<td>.542</td>
</tr>
<tr>
<td>11C</td>
<td>5.1</td>
<td>74.0</td>
<td>1.9</td>
<td>1.46</td>
<td>.827</td>
</tr>
<tr>
<td>X</td>
<td>9.6</td>
<td>81.3</td>
<td>2.87</td>
<td>2.42</td>
<td>1.42</td>
</tr>
</tbody>
</table>
REFERENCES

1. L. L. Kilpatrick, "Strontium Removal from Synthetic Supernate Using Amberlite IRC 718".


