# DURASIL$^{TM}$ ION EXCHANGERS:

## EXPERIENCE AT ARKANSAS NUCLEAR ONE

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## ABSTRACT

Durasil$^{TM}$[a] ion exchangers have been used for laboratory testing, an in-plant demonstration and in full-scale processing at the Arkansas Nuclear One Generating Station (ANO). The experience gained to date indicates that the Durasils$^{TM}$ should provide: (1) significant cost savings; (2) volume reductions on the order of at least a factor six over conventional organic resins; (3) reduced releases and; (4) reduced radiation exposure for personnel. These conclusions were borne out during the full-scale processing of very high conductivity waste at ANO.

## INTRODUCTION

The Arkansas Nuclear One (ANO) Generating Station is a twin unit approximately 850 Mwe (each) PWR operated by the Arkansas Power and Light Company located on the shores of Lake Dardanelle in Russellville, Arkansas. In normal operation, waste water is segregated into two streams: (1) reactor coolant water and; (2) floor drain and other miscellaneous waste. Each stream is processed separately, using permanent in-plant sluiceable ion exchange systems. The treated RCS water is recycled into the plant while the floor drain and miscellaneous waste stream is discharged into Lake Dardanelle after processing. The latter stream, which includes most of the high conductivity water generated in the plant, exhausts the major portion of the organic mixed bed resins used in the radwaste system.

Early in 1984 Duratek began laboratory testing of the Durasil$^{TM}$ ion exchange media with water samples drawn from the floor drain and miscellaneous waste stream at ANO. In April and May of 1984 these tests were followed by an in-plant comparison of Durasils$^{TM}$ and organic resins using the Durasil$^{TM}$ Demonstration System (DDS) provided by Duratek. In the in-plant demonstration the Durasil$^{TM}$ media exhibited capacities and decontamination factors (DFs) that were far superior to the organics. After a competitive bidding process, the Arkansas Power and Light Co. contracted with Duratek to process 54,000 gallons of ultra high conductivity water using Durasils$^{TM}$. This processing was carried out using Duratek's sluiceable Mobile Processing System in November 1984 and resulted in substantial cost savings, reduced burial volumes and reduced exposure when compared to processing using organics.

This paper is divided into two sections. The first details the laboratory and in-plant testing of the Durasils$^{TM}$. The second details the full-scale use of the Durasils$^{TM}$ for the clean-up of the ultra high conductivity water.

## LABORATORY TESTING AND IN-PLANT DEMONSTRATION

### Laboratory Testing

Four one liter samples drawn from the RCS water and floor drain streams at ANO were sent to Duratek in January of 1984. The samples contained levels of radioactive cesium (Cs), cobalt (Co) and iodine (I) in the $10^{-3}$ - $10^{-5}$ u Ci/cm range typical of many power plants. The samples were analyzed chemically at the Vitreous State Laboratory (VSL) of the Catholic University of America. The results of the analyses are given in Table I.

TABLE I

Analysis of ANO Samples

| Property | Sample | | |
|---|---|---|---|
| | RCS | Floor Drain 1 | Floor Drain 2 |
| pH | 5.78 | 7.47 | 7.63 |
| sp cond (umho) | 5.25 | 2080 | 1500 |
| B (ppm) | 1600 | 181 | 194 |
| Na | <.01 | 387 | 306 |
| K | <.01 | 5.64 | 3.60 |
| Ca | <.01 | 8.14 | 7.04 |
| Mg | 0.80 | 0.99 | 0.73 |
| Cl | <.01 | 425 | 253 |

As can be seen from the table the floor drain waste water is of very high conductivity and contains high levels of sodium (Na) and chloride (Cl). Although sulfate $(SO_4)$ levels were not determined analytically, rather high levels would be expected in the floor drain samples. Calculation of specific conductances

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[a] Durasil is a registered trademark of the Duratek Corporation.

using ionic conductances and consideration of the balancing of ionic charges lead to the conclusion that $SO_4$ levels could be as high as 516 ppm and 586 ppm for floor drain samples 1 and 2, respectively. The high concentrations of ions in the floor drain samples would lead to very rapid depletion of organic ion exchange resins. For example, the life expectancy of standard organic cation resin would be only 900 gal/ cu. ft. for floor drain sample 1 and 1150 gal/cu. ft. for floor drain sample 2.

It is important to note that this short bed life is determined by the high levels of non-radioactive species and has little or nothing to do with the levels of radioactive species. Since species such as Na, K, Ca, Mg, Cl and $SO_4$ could be safely released to the environment, their removal by the organic resin represents a great waste of capacity. Durasil$^{TM}$ ion exchangers are designed to have selectivity for the radioactive species such as Cs, Co and I that are typically found in power plant waste streams. This selectivity allows non-radioactive species such as those found in the ANO floor drain waters to pass through, thus using more of the available capacity for the radioactive species and allowing greatly extended bed life.

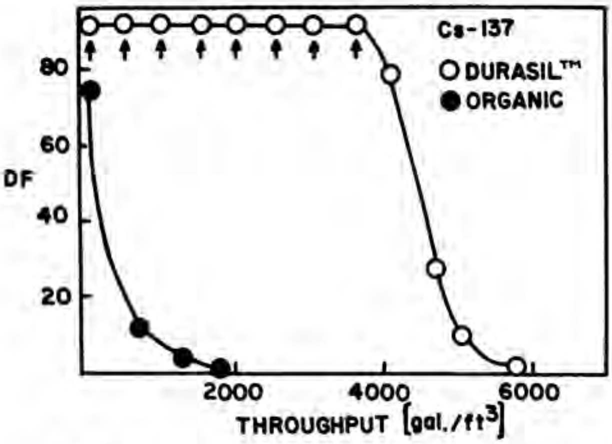

Fig. 1. Lab Results: DF vs. Throughput For Cs-137

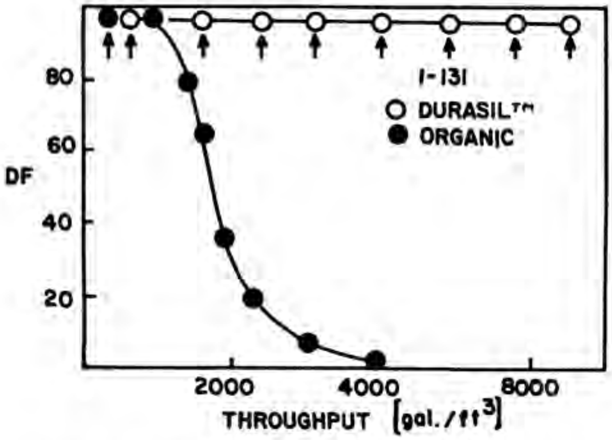

Fig. 2. Lab Results: DF vs. Throughput For I-131

Laboratory experiments to determine actual bedlife were conducted at the VSL. Glass columns of 0.6 cm ID and 1 cubic centimeter volume were fed by a constant flow parastaltic pump. The small column volume was necessitated by the limited volume of water available. All water was filtered through a 5 u filter prior to use to prevent clogging. The organic resin used was a 50/50 combination of strong acid cation and strong base anion resin employed at most nuclear power plants. The Durasil$^{TM}$ used was a mixture of Durasils$^{TM}$ 60, 10 and 70 in proportion 1:2:1. Durasils$^{TM}$ 60 and 70 are carbon based materials which are highly selective for I and Co, respectively. Durasil$^{TM}$ 10 is a glass based material which is selective for Cs, Co, Mn and some other polyvalent cations. It is virtually transparent to Na, K, Mg and Ca.

Figures 1-3 are plots of DF vs. through-put for the organic resins and Durasils$^{TM}$ found for the Floor Drain 2 sample. Maximum observable DFs for the experiments were approximately 100 due to the limits of counting statistics on the small volume samples generated. All three figures show the DF and capacity of the Durasils$^{TM}$ to be superior to the organics. The results of the test are summarized in Table II.

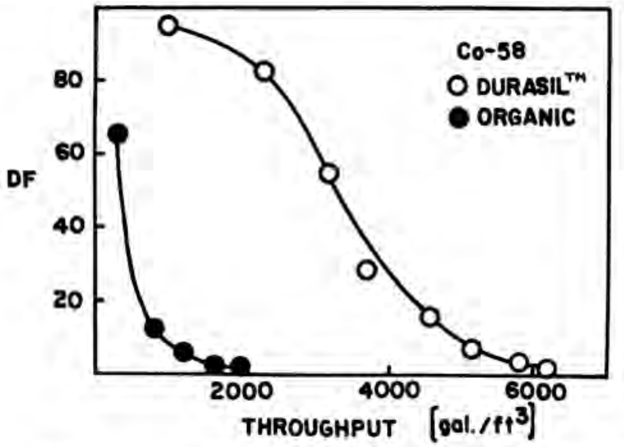

Fig. 3. Lab Results: DF vs. Throughput for Co-158

TABLE II

Capacity and DF For Organic Resins and Durasils$^{TM}$
Floor Drain Sample 2

| | Capacity (gal./cu. ft.) | | Maximum DF | |
|---|---|---|---|---|
| | Durasil | Organic | Durasil | Organic |
| Cs-137 | 5,600 | 1,250 | >100 | 72 |
| I-131 | >7,000 | 4,000 | >100 | >100 |
| Co-58 | 6,000 | 1,800 | >100 | 66 |

## In-Plant Demonstration

The in-plant demonstration of Durasil$^{TM}$ ion exchangers was conducted at the Arkansas Power and Light Company's Arkansas Nuclear One (ANO) Generating Station in Russellville, Arkansas between April 25, 1984 and May 15, 1984. The demonstration compared the performance of the Durasil$^{TM}$ media with the organic resins currently in use at ANO under actual plant conditions using plant waste water.

The demonstration was carried out in the auxiliary building of Unit 2 using water from the floor drain and miscellaneous waste stream. Water for the Durasil$^{TM}$ Demonstration System was obtained from a connection located immediately prior to the in-plant filtering system. Analysis of plant water taken from this point shows that it contains large quantities of sodium and other ions (presumably from the service water taken from Lake Dardanelle) which are responsible for rapid depletion of the organic resins presently in use.

The Durasil$^{TM}$ Demonstration System was configured as shown in Figure 4. Waste water from the plant passed into a holding tank through a 5 u CUNO filter cartridge and was split into two streams. The first stream passed through two ion exchange columns each filled with 1210 cubic centimeters of 50/50 cation/anion, mixed bed, ion exchange resin. The second passed through a column of Durasil$^{TM}$ 60, followed by two Durasil$^{TM}$ 10 columns and one Durasil$^{TM}$ 70 column. Each of the Durasil$^{TM}$ columns held 131 cubic centimeters of Durasil$^{TM}$. The smaller columns were used on the Durasil$^{TM}$ side to limit radiation build up during the test. Residence times were maintained at 2.1 minutes per column on the Durasil$^{TM}$ side and 4.3 minutes per column on the organic side. Periodic samples of the influent and effluent from each column taken at the numbered sample points and were analyzed for radionuclides by the ANO counting laboratory. Additional samples of the influent were analyzed by ANO once daily for Na, pH and specific conductivity. Total flow and flow rates were also measured at each sampling. Initially, samples were taken every 4 hours. This was changed to every 8 hours after the first day and every 12 hours after the organic resins were expended.

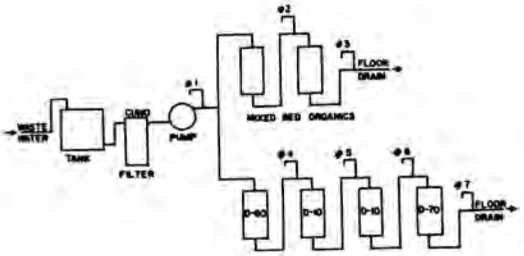

Fig. 4 Schematic: DURASIL$^{TM}$ Demonstration System

In order to allow comparison of the two trains and extrapolation to plant size systems, the unit column volume (CV) and equivalent column volume (ECV) are used to measure the amount of water passed through each train. A column volume or (bed volume) is the volume of ion exchange material in any processing vessel. Capacity in column volumes is constant regardless of vessel size. Equivalent column volumes (EQV) is simply the number of column volumes divided by the number of columns in the train. It allows fair comparison of the results from the 2 column organic train and the 4 column Durasil$^{TM}$ train.

$$\text{EQV} = \frac{\text{(Volume of Water Passed)}}{\text{(Volume of Column) (Number of Columns in Train)}}$$

This unit, in effect, gives the results that would be obtained if all the media in one train were placed in a single column. Influent levels to the DDS of the major isotopes are given in Table III.

TABLE III

Influent Levels of Major Isotopes For The DDS (uCi/cm)

| Isotope | Maximum | Minimum | Median |
|---|---|---|---|
| Cs-134 | 2.3 E-4 | 0.7 E-4 | 1.6 E-4 |
| Cs-137 | 6.4 E-4 | 1.9 E-4 | 4.4 E-4 |
| Co-58 | 2.6 E-4 | 0.3 E-4 | 1.0 E-4 |
| Co-60 | 1.1 E-4 | Non-Detectable | 1.3 E-5 |
| I-131 | 1.5 E-2 | 1.8 E-4 | 1.6 E-3 |

Results of the demonstration are given in Figures 5-9 and summarized in Table IV.

TABLE IV

In-Plant Demonstration Results Summary

| Capacity (ECV) | | Durasil | Organic Resin |
|---|---|---|---|
| | Cs-137 | 1260 | 260 |
| | Cs-134 | 1260 | 260 |
| | I-131 | >1900 | 120 |
| | Co-58 | >1900 | 455 |
| | Co-60 | 200 | 70 |
| Average DF | Cs-137 | 119 | 113 |
| | Cs-134 | 164 | 168 |
| | I-131 | 159 | 10 |
| | Co-58 | 8.4 | 6.1 |
| | Co-60 | 3.5 | 3.4 |
| Residence Time | | 2.1 min. | 4.3 min. |

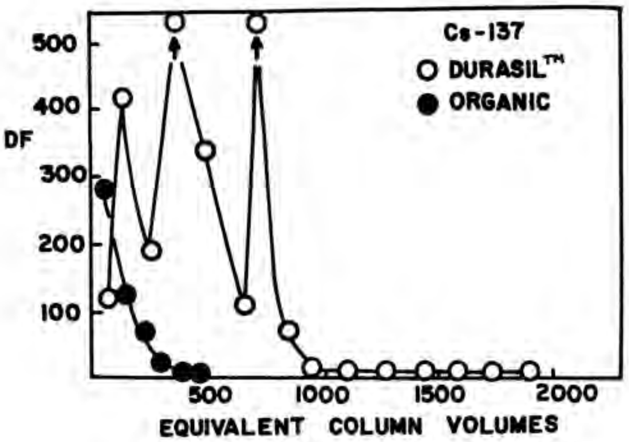

Fig. 5. In Plant Demonstration: DF vs. EQV For Cs-137

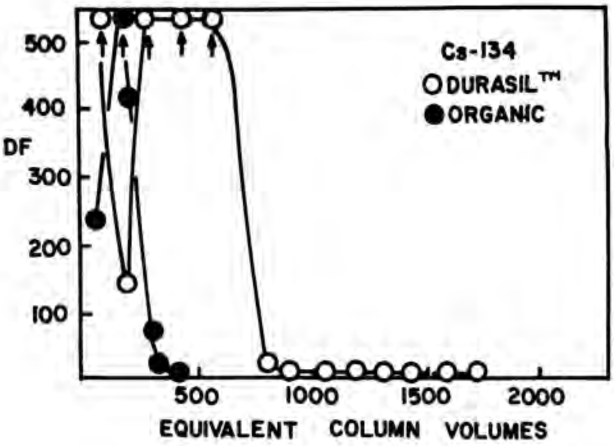

Fig. 6. In Plant Demonstration: DF vs. EQV For Cs-134

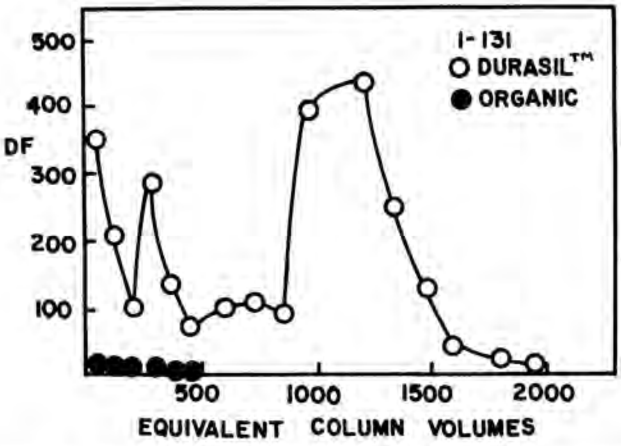

Fig. 7. In Plant Demonstration: DF vs. EQV For I-131

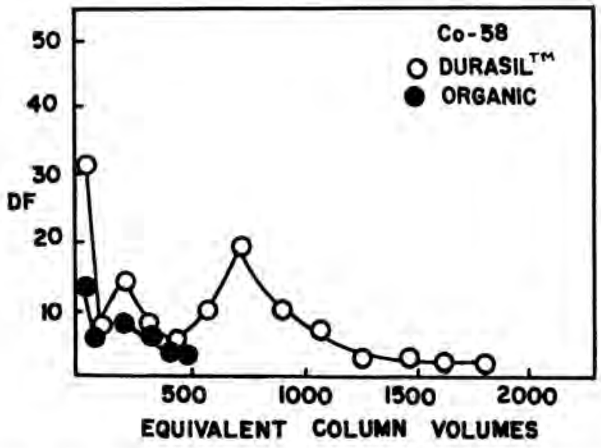

Fig. 8. In Plant Demonstration: DF vs. EQV For Co-58

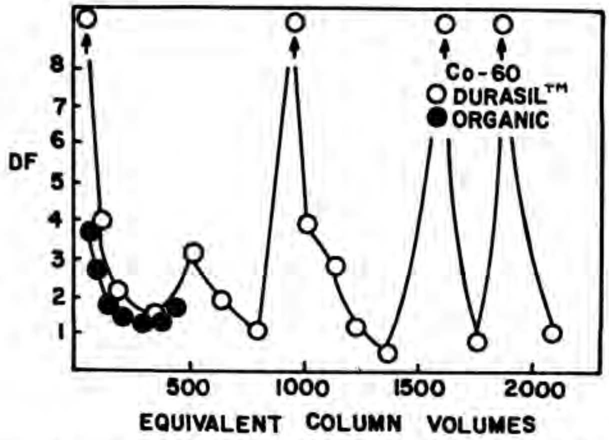

Fig. 9. In Plant Demonstration: DF vs. EQV For Co-60

As shown by Table IV the Durasil$^{TM}$ system outlasted the organics by a factor 5 for Cs, and more than 16 for I. Both systems removed Co-58 equally well for the duration of the demonstration. However, the test lasted 4 times longer for the Durasil$^{TM}$ than for the organics. The Durasil$^{TM}$ system lasted 3 times longer for Co-60 but neither system had very large DFs. This may be due in part to the extremely low levels of Co-60 present which were an order of magnitude lower than any other major isotope. The average DFs were similar for Durasil$^{TM}$ and organics except for the I-131 where the Durasil$^{TM}$ was a factor 16 better. Note that the process rate for Durasil$^{TM}$ was more than twice that of the organics.

The implications of the demonstration for use of Durasils$^{TM}$ at ANO are as follows:

1. Resin Usage: Last year ANO used approximately 1400 cu. ft. of mixed bed resin (50/50 cation/anion) on the floor drain waste water. Assuming the Durasil$^{TM}$ 60 will last 20 times longer for I-131 removal than the organics, that the Durasil$^{TM}$ 10 lasts 4.5 times longer for Cs and that the Durasil$^{TM}$ 70 which removes Co lasts as long as the 60, we find the Durasil Durasil$^{TM}$ usage for the year would be 155 cu. ft. of Durasil$^{TM}$ 10, and 35 cu. ft. each of Durasil$^{TM}$ 60 and 70 for a total volume of 225 cu. ft.
2. The use of Durasil$^{TM}$ ion exchange media would reduce the amount of radioactive iodine released to the environment by a factor of 16. Releases of Cs and Co would remain similar to present levels.
3. Radiation Exposure: The longer life of the Durasil$^{TM}$ columns would reduce the number of transfer/sluicing operations which should reduce man-rems. The major savings would be from the I-131 where over 90% of the isotope would decay on the column while in use due to the long life of the Durasil$^{TM}$.
4. Burial and Transport/On Site Storage: Much smaller volumes of Durasil$^{TM}$ would have to be dealt with. The small volume of I-131 material (35 cu. ft./yr.) would make it possible to store the material until I-131 decays away.

## FULL SCALE PLANT USE FOR CLEAN-UP OF THE ULTRA HIGH CONDUCTIVITY WATER

Arkansas Power and Light contracted with Duratek to process water from the Clean Waste Receiver Tank, T-12A, at Arkansas Nuclear One. This tank contained 54,000 gallons of water with the chemical and isotopic composition given in Tables V and VI.

TABLE V

Chemical Composition of High Conductivity Waste

| | |
|---|---|
| conductivity | 12,000 umho |
| suspended solids | 7.5 ppm |
| sodium | 1150 ppm |
| nitrites | 660 ppm |
| pH | 11.68 |
| chlorides | 5.5 ppm |
| fluorides | 0.1 ppm |
| lithium | 1.3 ppm |
| boron | 237 ppm |

TABLE VI

Isotopic Composition of High Conductivity Water

| | |
|---|---|
| Be-7 | 1.2E-3 uCi/cc |
| Co-58 | 1.2E-3 uCi/cc |
| Co-60 | 2.5E-3 uCi/cc |
| Sb-122 | 2.3E-5 uCi/cc |
| Sb-125 | 1.6E-4 uCi/cc |
| Cs-134 | 7.3E-3 uCi/cc |
| Cs-137 | 2.5E-2 uCi/cc |

A compact, two vessel version of the Duratek Sluiceable Mobile Processing System, was assembled on site and lowered into place in 5 hours. The first vessel was filled with 22 cu. ft. of Durasil$^{TM}$ 10, and the second with 25 cu. ft. of Durasil$^{TM}$ 70.

Processing was accomplished by transferring approximately 14,000 gallons to the Treated Waste Monitoring Tank, T-16A, neutralizing it with sulfuric acid, and processing it through the Duratek system to Treated Waste Monitoring Tank, T-16B. The water was then monitored, verified to be within release limits, and released to Lake Dardanelle.

Radioactivity analysis was performed on the influent and effluent streams of the System during processing. Initial DFs were excellent (Table VII) and far exceeded those experienced with organic resin beds. Initial DFs at ANO for organic resin beds are typically 10 for Co-58 and Co-60 and approximately 20 for Cs-137.

TABLE VII

MPS System Initial DFs

| Radionuclide | DF |
|---|---|
| Mn-54 | 100 |
| Co-58 | 862 |
| Co-60 | 918 |
| Sb-122 | 57 |
| Cs-134 | 1342 |
| Cs-137 | 1375 |

The DFs began to decrease rapidly towards the end of the second process batch, falling to 50 for Co-58 and 100 for Cs-137. Five cubic feet of additional Durasil$^{TM}$ 70 was added to the bed as a booster and processing continued.

At completion of processing Tanks T-12A, T-16A and T-16B were rinsed using radioactive water from another T-12. The rinse water was processed through the System and continued higher concentrations of radioactivity than the process water. This water was chosen as rinse water as it needed processing for release, and AP&L achieved maximum use of the Durasil$^{TM}$ material. Final DFs for the System are given in Table VIII.

TABLE VIII

System Final DFs

| Radionuclides | DF |
|---|---|
| Mn-54 | 23 |
| Co-58 | 46 |
| Co-60 | 18 |
| Sb-122 | 33 |
| Cs-134 | 268 |
| Cs-137 | 189 |

It should be noted that these are higher than those typically obtained at ANO for fresh organic resin.

At the conclusion of processing the Durasil$^{TM}$ was sluiced out of the processing vessels into the ANO resin hold-up tanks for eventual dewatering and burial in a High Integrity Container.

The Mobile Processing System was empited, disassembled, and stored for shipment in less than 8 hours. Total exposure for the project was lower than predicted. Actual processing resulted in less than 25 person millirem while the entire job required less than 200 person millirem.

In all, 63,426 gallons of water were processed through 55 cubic feet of Durasil$^{TM}$ ion exchange media. This is a tremendous volume reduction over the use of organic resin, because the chemical composition of this water would have rapidly depleted organic resin. ANO had expected to use 200-300 cubic feet of organic resin.

The use of the Mobile Processing System and Durasil$^{TM}$ ion exchange media resulted in the following advantages over conventional ion exchange systems and media.

1. Reduced burial volumes: 55 cu. ft. of Durasil$^{TM}$ vs. 200-300 cu. ft. of conventional resins and more than 500 cu. ft. of volume if disposable ion exchange vessels are used.
2. Reduced exposure: Duratek employees received less than 25 mrem during processing and less than 200 mrem for the whole job. ANO personnel exposure was nil. Use of conventional resins would have resulted in much higher exposures due to the large number of vessels and amount of resins handled.
3. Reduced use of plant personnel: Outside of routine coverage, plant personnel were required for only a few hours while the Mobile Processing System was assembled and disaasembled.
4. Reduced use of plant equipment: The use of cranes, forklifts and other equipment was minimized.

## SUMMARY

Laboratory testing and an in-plant demonstration of Durasil$^{TM}$ ion exchangers have pointed to significant cost savings and waste volume reductions at the Arkansas Nuclear One Generating Station. These predictions have been confirmed during full-scale of Durasils$^{TM}$ at ANO in a mobile sluiceable ion exchange processing system.