# DOWEX™ MONOSPHERE™ Ion Exchange Resins
## Nuclear Power Plant Improves Efficiency and Water Quality with DOWEX Resins

### Site Information
*Location*
Connecticut, USA
*Purpose*
- Reliable control of steam generator chemistry
- Reduce operating costs

*Comparative Performance*
- Mixed bed effluent quality <1 ppt
- Plant has maintained CPI value of 1.00 and reduced blowdown from 100 gpm (22.7 $m^3$/h) to 25 gpm (5.7 $m^3$/h).
- Blowdown reduction yields additional 1 MW of power.

*The Dominion Engineering Millstone Nuclear Power Station is located on a peninsula at the eastern end of Long Island Sound. (Photo courtesy of the Dominion Engineering Millstone Nuclear Power Station).*

*The Dominion Engineering Millstone Nuclear Power Station has undergone a significant performance improvement in water quality and operational efficiency of the deep-bed condensate polishers in Unit 2. The use of DOWEX™ MONOSPHERE™ 650C and 550A gel resins (now in service for more than 6 years) along with procedure modifications for regenerating and re-mixing resin has enabled the Millstone secondary cycle chemistry group to reliably maintain a Chemistry Performance Index (CPI) value of 1.00 and reduce blowdown by 75%.*

### Introduction

The Dominion Engineering Millstone Station is a PWR nuclear power plant in Connecticut that relies on their deep-bed condensate polishing systems to help control secondary cycle steam generator chemistry in Units 2 and 3.

In this application the mixed bed condensate polishers are designed to:
- Protect the steam generators in the event of a condenser tube failure
- Allow 100% power operation during periods of low level seawater ingress
- Filter corrosion products transported from the main condenser

The Millstone Station decided to use DOWEX MONOSPHERE resins in their full-flow condensate polishing systems to optimize water quality and operational efficiency.



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## Background

Prior to 1990, the Unit 2 steam generators experienced serious tube degradation by a variety of corrosion-related mechanisms. These mechanisms resulted in denting, pitting, intergranular attack (IGA), and intergranular stress corrosion cracking (IGSCC). This eventually necessitated the replacement of the steam generators in 1992 at an enormous cost to the station's utility owner.

To maintain the material integrity of the new steam generators and the balance of plant components, Millstone 2 implemented the following changes to the secondary cycle chemistry program:

- Replace ammonia with ethanolamine as the secondary cycle pH-control additive beginning on April 12, 1993
- Increase the hydrazine feed rate to attain an 8:1 concentration ratio of final feedwater hydrazine to condensate dissolved oxygen
- Operate with full-flow condensate polishing and only in the hydrogen cycle (terminate the service cycle at the amine break)

Ethanolamine reduces the potential for two-phase erosion-corrosion in the heater drains and other wetted steam areas of the plant. So the expectation of this new chemistry was to significantly reduce the amount of insoluble impurities in the final feedwater. Once the switch was made to ethanolamine, the impact on final feedwater iron for Millstone Unit 2 was an immediate step change improvement from a range of 8 to 10 ppb to a range of 2 to 3 ppb.

Operating with full-flow condensate polishing and limiting the service cycles to the amine break minimizes the leakage of contaminant ions at the polisher effluent and also maximizes the ability of the resins to prevent contaminant ions from entering the steam generators should a seawater leak occur.

The Millstone station installed DOWEX™ MONOSPHERE™ resins in the Unit 2 condensate polishing system in November 1995. This choice was based primarily on testimonials from other PWR stations with regard to the features and benefits of DOWEX MONOSPHERE resins (Table 1, Figure 1).

Table 1. Features and benefits of the DOWEX MONOSPHERE 650C and 550A resins for deep-bed condensate polishing

| Features | Benefits |
|---|---|
| Complete separation of the mixed resin | Improves effluent water quality |
| Small uniform bead size for the 650C cation resin | Longer service cycles, fewer regeneration cycles, fast rinse down |
| Small uniform bead size for the 550A anion resin | Excellent protection against condenser tube failures and in-leakage |
| Superior mechanical strength and oxidative stability | Less particle attrition and release of high MW (> 1000) TOC species from cation resin to minimize downstream sulfate excursions |
| Cation and anion beads with a distinguishable color difference | Easy-to-verify separation of the mixed resin following a backwash separation |

## Procedure Modifications

Millstone explored two changes to the resin handling and regeneration procedures to optimize the performance of the condensate polishers (CP) with respect to effluent water quality and service cycle run length:

- In-vessel mixing of the freshly regenerated mixed resin
- Extending the regeneration of the cation exchange resin

The in-vessel mixing uses compressed air to re-mix the condensate polisher resin in the service vessel immediately following the transfer from the mix and hold tank. This redistributes the cation resin equally throughout the vessel and consequently more of the cation resin settles in the usable portion (upper section) of the service vessel.

Figure 1. Separation of DOWEX™ MONOSPHERE™ 650C/550A

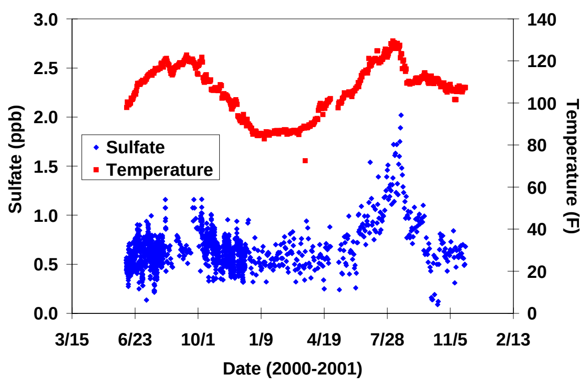
Extending the regeneration is a simple approach that involves regenerating the cation resin until 95% or more of the ethanolamine elutes from the cation resin bed. This requires the application of 8 wt % sulfuric acid for 120 min, which equates to a regenerant loading of 40 lb/ft$^3$ of resin (100% basis) (640 g/L).

When combined with other procedural changes Millstone implemented in previous years to reduce the leakage of contaminant sodium (skipping regeneration cycles for the anion resin, performing resin-on-resin regeneration), the performance of the condensate polishers has been exceptional.

## Steam Generator Quality

The water quality performance at Millstone Unit 2 is best illustrated by the data in Figure 2. This shows the steam generator sulfate profile over an 18-month period beginning in June 2000 along with the condensate temperature trend.

Figure 2. Steam generator $SO_4$ and condensate temperature trends at Millstone Station Unit 2

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Over this time period sulfate remains in the 0.5 to 1.0 ppb range and correlates with the trend in condensate temperature. A trend toward 1.5 ppb sulfate occurred in the early summer of 2001 due to fouling problems in the main condenser, which resulted in higher than normal condensate temperature. But overall, steam generator sulfate remains under very tight control and free from inexplicable excursions.

Chloride and sodium are also critical to steam generator integrity. Table 2 provides a snapshot of typical quality measured in Unit 2. What is most impressive about this steam generator quality is that the blowdown rate is only 25 gpm (5.7 $m^3/h$) (concentration factor of 465). With two steam generators operating in Unit 2, this saves over 1 MW of electricity when compared to the normal blowdown rate of 100 gpm (22.7 $m^3/h$).

Table 2. Typical water quality measurements at Millstone Unit 2

| Compound | CP Effluent (ppt) | Steam Generator (ppb) |
|---|---|---|
| Chloride | 0.7 | 0.4 |
| Sodium | 0.5 | 0.3 |
| Sulfate | 0.8 | 0.5-1.0 |

## Chemical Cost Efficiency

The condensate polishers reliably operate for 11-day service cycles processing 48 million gal per charge. This equates to a cation resin utilization that is approximately 85% of the total exchange capacity of the cation resins. This is noteworthy when you consider that in 1996 a survey report of 18 different PWR units in the United States showed cation resin utilization ranging between 45% and 65%.

Table 3 lists annual cost requirements for regeneration based on full-flow operation for 350 days excluding costs associated with waste disposal and rinse water. The bulk chemical costs are for 93 wt % sulfuric acid and 50 wt % sodium hydroxide.

Table 3. Chemical cost requirements for DOWEX™ MONOSPHERE™ resin regeneration at Millstone Unit 2

| Parameter | DOWEX MONOSPHERE 650C | DOWEX MONOSPHERE 550A |
|---|---|---|
| Volume per charge, $ft^3$ | 80 | 120 |
| $m^3$ | 2.3 | 3.4 |
| Regenerant loading, $lb/ft^3$ | 40 | 43.5 |
| g/L | 640 | 695 |
| Bulk chemical costs, $/lb | 0.052 | 0.127 |
| $/Kg | 0.114 | 0.279 |
| Regenerations per year | 24 | 3 |
| Costs | | |
| per $10^6$ gal condensate | $3.8 | $3.5 |
| per 1000 $m^3$ of condensate | $1.0 | $0.93 |
| Annual costs | | |
| per charge | $4,300 | $4,000 |
| Total for 8 charges | $34,350 | $32,000 |

## Conclusions

The Dominion Engineering Millstone Nuclear Power Station has undergone a significant performance improvement in water quality and operational efficiency of the deep-bed condensate polishers in Unit 2. The use of DOWEX™ MONOSPHERE™ 650C and 550A gel resins (now in service for more than 6 years) along with procedure modifications for regenerating and re-mixing resin has enabled the Millstone secondary cycle chemistry group to reliably maintain a CPI value of 1.00 and reduce blowdown from 100 gpm (22.7 $m^3/h$) to 25 gpm (5.7 $m^3/h$). The blowdown reduction alone yields an additional 1 MW of available power. Unit 3 is now benefiting from the same type of chemistry control program and procedure modifications with DOWEX MONOSPHERE gel resins that have been in service since June 1995.

**DOWEX Ion Exchange Resins**
For more information about DOWEX resins, call the Dow Liquid Separations business:

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