Resin Selection and Loading to Reduce Wet Radwaste Generation – 15153

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ABSTRACT

In the United States, high activity spent resin disposal has been constrained or very costly. This situation has driven operating nuclear power plants to consider up front wet waste pollution prevention or minimization in addition to back end volume reduction. Several plants have altered the resin load placed into system process vessels to reduce spent resin volume. The use of different types of resin can extend bed life to reduce radwaste generation. The use of marcro porous resins can remove particulate and reduce the quantity of radioactive mechanical cartridge filters. Loading cation resins into separate vessels from anion resin has extended resin life reducing radwaste generation. In addition, several plants have also found that loading less anion resin in "mixed" beds provides the same bed life with only 50% of the resin volume. These practices and the overall reduction of resin generation volume will be discussed in the paper. These successful practices indicate that new power plants should provide resin vessels of smaller overall size that are taller and thinner.

INTRODUCTION

This paper will discuss operational practices to reduce wet radwaste generation at Pressurized Water Reactors (PWR). These practices involve loading less ion exchange resin in plant vessels and using alternate resins to achieve the same bed life thereby reducing the generation of wet radwaste.

DESCRIPTION

Liquid radwaste treatment systems in the US have been changed or replaced by vendor skid mounted mobile (or modular) units to improve performance. The changes often involve the use of multiple vessels, each with a different ion exchange media to extend media life, reduce effluent activity and reduce wet solid waste generation- a triple play! Although these improvements had dramatic results, the reduction in waste disposal cost was not as dramatic. This is because spent resin from liquid radwaste systems is lower activity, typically qualifying as Class A low level radioactive waste. Higher activity Class B and C spent resin in the US can cost ten times as much for disposal as Class A waste.

To achieve cost reduction, application of several liquid radwaste system resin reductions practices have been conducted on Chemical Volume Control (CVCS) and Spent Fuel Pool (SFP) treatment systems at PWRs in the US.

DISCUSSION

High activity resin disposal is extremely expensive in the US under past and current burial rate schedules. Higher activity Class B and C spent resin costs about ten times as much as Class A spent resin.

Table 1 below show the history of spent resin generation at Diablo Canyon Power Plant from 2003 through 2013. Diabloc Canyon is a two unit Westinghouse 4 loop PWR. The volume of all radioactive resin and the volume of just the higher activity Class B and C resin is shown for each year. The steady reduction in Class B and C spent resin was no accident. It was achieved with out any physical modification to any plant piping or vessles. The only changes were to the amount and type of resin loaded into plant demin vessels in the CVCS and SFP systems. The reduction in spent resin volume by 2013 resulted in a saving in packaging, shielded transportation and burial fees of over $500,000 per year for Diablo Canyon Power Plant.

Table 1

Year	Volume m3 (ft3)	B/C Volume m3 (ft3)
2003	6.54 (231)	4.50 (159)
2004	11.4 (403)	4.05 (143)
2005	6.96 (246)	3.74 (132)
2006	8.07 (285)	3.59 (127)
2007	9.85 (348)	2.89 (102)
2008	5.26 (186)	2.18 (77)
2009	8.61 (304)	3.14 (111)
2010	6.71 (237)	2.18 (77)
2011	5.89 (208)	1.70 (60)
2012	5.41 (191)	2.23 (79)
2013	4.70 (166)	1.75 (62)

The remainder of the paper will discuss how this resin reduction was achieved.

The use of a mixed bed ion exchange vessel requires the replacement of both the cation and anoin resin even if only one component is exhaused. Spent anion resin in practice is low in activity and by itself would be lower cost to bury. Unfortunately, the entire volume of the spent mixed bed has a disposal fee based on the high activity cation resin.

The standard water treatmet mixed bed resin is a stochiometric bed which has an equal number of cation and anion removal sites. This results in twice as much anion resin by volume versus cation. Nuclear power plants have make up water systems that provide very pure water. In practice, spent resin from the CVCS and SFP systems exhauste on cation resin capacity first. Much of the anion resin in the vessel is not needed. Simply reducing the amount of anion resin loaded into vessels for mixed bed service is the key to reducing the volume of spent resin generation.

CVCS Shutdown Beds

Many PWRs make use of a CVCS shutdown clean up bed. A vessel in the CVCS is loaded with a mixed bed and dedicated to reactor water cleanup of the shutdown crud burst only. These beds can remove large amounts of activity in less than a week's time. The ratio of cation to anion resin has been inverted at Diablo Canyon to two parts by volume cation to one part anion resin. With a 0.8 m^3 (30 ft^3) vessel, Diablo Canyon was able to load 0.56 m^3 (20 ft^3) of cation resin and 0.28 m^3 (10 ft^3) of anion resin to support a shut down clean up.

The type of resin used has also been changed. Originally the plant used standard Rhom and Haas IRN-77 cation and IRN-78 anion resin. The cation resin was changed to the macro porous DOW C-75 NG for improved colbalt removal.[1] Purolite NRW 160 cation resin has also been used in this service with equivalent results. The anion resin component has also been changed. Use of marco porous Purolite 501P was conducted for several outages to increase the removal of particulate activity. This also reduced the generation of CVCS letdown filters during shut down clean up. This resin had to be loaded as a 1/3 m (1 ft) high top layer to prevent the beads from fracturing and generating resin fines and fouling the down stream letdown filter.

Source term reduction reduction actions at Diablo Canyon have greatly reduced the peak shutdown reactor coolant crud burst peak activity from 370 kBq/cc (10 uCi/cc) in the early 1990's down to 3.7 kBq/cc (0.3 uCi/cc) in 2013. These action include replacement of steam generators, replacement of reactor vessel heads and the addition of depleated zinc to the reactor coolant. With the reduced peak crud burst activity, the volume of cation resin loaded into the shutdown vessels has also been reduced. A stronger macro porous anion resin Purolite 5070 is now being used. It does not need to be loaded as a top layer.

The current shut down vessel load at Diablo Canyon is a 0.56 m^3 (20 ft^3) bed with 0.28 m^3 (10ft^3) of cation resin, 0.14 m^3 (5 ft^3) of 5070 and 0.14m^3 (5 ft^3) of IRN-78. This bed size can support two shutdown cleanups. So only 0.28 m^3 (10 ft^3) of spent resin is now generated per cycle for this shutdown clean up service.

Several plants in the US have adopted similar "short loading" practices for shutdown beds. Some of these plants had CVCS vessels much larger than 0.8 m^3 (30 ft^3). Even if a plant did not pursue source term reduction actions, a shutdown bed need not be larger than 0.8 m^3.

Spent Fuel Pool Beds

Diablo Canyon also has a 0.8 m^3 (30 ft^3) SFP demineralizer vessels. The original load for this vessel was a stocheometric mixed bed using Rhom & Hass IRN-77 cation and IRN-78 anion. After the first bed in each unit exhausted on cation capacity, the re-load ratio of cation tio anion resin was invered to two parts cation to one part anon. These beds lasted for over two years through the mid 1990's.

By the mid 1990's, our SFP beds started eluting resin fines after about 1 year of service (that plugged down stream resin trap filters) and later sulfates. A peer check with several other plants revealed that the nuetron flux in the SFP creates hydrogen peroxide in the SFP liquid. This peroxide cleaves the cation resin releasing resin fines and ultimately sulfates.

To reduce peroxide attack and extend resin life, several plants in the US have ceased operation of SFP beds 24/7. Instead they only align the SFP bed prior to work in the fuel handling buildings. Diablo Canyon began reducing the cation component volume in each subsequent bed reload by 0.14m^3 (5 ft^3). It was determined that the bed still eluted resin fines from only 0.14m^3 (5 ft^3) of cation resin after about 1 year of service before exhausting on Cobalt 60. No further reduction in the volume of cation resin was pursued for fear of channeling the bed.

The currrent SFP vessel load at Diablo Canyon is a 0.42 m^3(15 ft^3) bed. Only 0.14m^3 (5 ft^3) of cation resin is loaded. A stronger cation bead resin, Purolite 1180, is being used. A bottom layer of 0.14m^3 (5 ft^3) of ResinTech BSM-50 is being loaded to remove Sb-125. The source of the SB-125 is legacy Westinghosue Vantage V fuel. This fuel, and Areva M-5, has tin in the cladding that becomes Sb125 when activated. Removing Sb-125 in the SFP is important to reduce liquid rad effluent activity. The remaining resin load is 0.14 m^3 of macro porous anion Purolite 5070 to enhance particulate activity removal.

This practice has reduced SFP resin generation to 0.42 m3 (15 ft3) per year per unit at Diablo Canyon. Several other PWRs in the US have operated with reduced resin loads in their SFP vessels.

CVCS On-line Mixed Beds

Diablo Canyon has 0.8 m^3 (30 ft^3) CVCS mixed bed vessels. The original load for this vessel specified by Westinghouse was Rhom & Haas IRN-217. This is a stocheometric mixed bed resin with the IRN-77 cation component lithiated. The volume of lithiated cation resin in this bed is 0.28 m^3 (10 ft^3).

Diablo Canyon has never exhausted a lithiated mixed bed on anion capacity. To reduce the volume of anion resin loaded in the vessel, the plant had to obtain lithiated cation resin seperately. Rhom & Hass has a high capactiy cation resin, IRN-99. They offer this resin in lithated form as IRN-318. Diablo Canyon changed the load for this vessel to 0.48 m3 (17 ft3) where 0.28 m^3 (10 ft^3) of IRN-318 and reduced the IRN-78 anion volume to 0.19 m^3 (7 ft^3).

Diablo Canyon has reduced the load to 0.42 m^3 (15 ft^3) using only 0.14 m^3 (5 ft^3) of anion resin. The litiated cation resin has been changed to either Purolite NRW-160 Li or Graver GR-7-16 NG. Both Graver and Purolite are now offering pre-lithiated mixed bed resin with a 2:1 cation to anion ratio-Purolite NRW 3562 or Graver GR4-2-NG.

The short loaded lithated mixed beds at Diablo Canyon have served in extended fuel cycles from 19 to 21 months with zinc addition. Other PWRs should be able to adopt this practice.

Roll Out to Industry

Altering the volume and type of ion exchange resin loaded into CVCS and SFP vessels cannot be implemented by the radwaste group at operating US power pants. Plant Chemistry Sections typically specify and control the resin loads and use of these beds. At Diablo Canyon the Radwaste Engineer work with the Primary Chemist over several years to implement the resin reduction program. Although a few peer plants have adopted resin short loading practices, all PWRs can achieve similar results.

Diablo Canyon has worked with the Electric Power Research Institute on several Class B/C waste reduction reports.[2] The technical Report 1023017 from 2011 is specifically targeted to Chemisrty managers to address their program concerns.[3]

The dramatic reduction of size of resin beds operating PWRs are using should also be reviewed by NSSS vendors to incorporate in future designs. Smaller, tall narrow vessels should be considered to achieve the same flow rate and bed life as larger vessels currently being provided.

CONCLUSION

Reducing the waste generation volume of high activity spent resin by 50% or more at PWRs can be achieved without any piping or vessel modifications. Reducing the amount of anion resin loaded into CVCS and SFP vessels can be done with no ill effect on liquid clean up or bed life. The use of alternate resin products can improve cleanup with reduced waste volume.

Reducing high activity Class B/C resin volume in the US can results in annual cost savings for PWRs of $500,000 per year. The reduction in waste volume can also cut the number of high activity resin packaging and cask transportations tasks in half.

NSSS vendors should incorporate this operating experience into future designs. Smaller, tall narrow vessels should be considered to achieve the same flow rate and bed life as larger vessels currently being provided.

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