Studsvik

June 10, 2010

**MEMORANDUM**

**FROM:** Brad Mason, Chief Engineer, and Corey Myers, Engineer I

**TO:** Joseph DiCamillo, General Counsel

## RE: ISSUES WITH BLENDING OF DIFFERENT TYPES OF ION EXCHANGE RESIN

## INTRODUCTION

This document summarizes the results of testing that demonstrates that it is not technically feasible to blend certain types of ion exchange resins due to substantial particle size and density differences that result in rapid segregation of resin types in the disposal container.

Ion exchange resins are used in the cleaning of water in nuclear power plants. Depleted resins are produced in a wide variety of forms that vary in size, shape, density, and chemical composition. These variations significantly impact the settling time and resultant segregation of different resin types when otherwise well-mixed resins are transferred to the disposal container for final dewatering. When well-mixed resins are transferred into a large disposal container, the filling and dewatering operations occur over at least several hours to as much as several days to fully fill and dewater a large disposal container with resins. Table 1 in the Addenda provides a few examples of the different types of ion exchange resin and their general characteristics. Partially or fully depleted resins will have further density and particle size differences from the resin data provided in Table 1.

## BLENDING, RESIN MIXING, AND SEGREGATION

Blending of resins is based upon the mathematical averaging of small amounts of high activity Class B and/or C wastes with a large amount of lower activity Class A waste in such a way that the overall waste class of the combined mixture is still considered Class A. In order for blending to be viable, a relatively homogenous mix of high activity and low activity waste must be achieved. Otherwise, blending is nothing more than placing high activity waste next to low activity waste and calling both wastes low activity.

For resins, blending requires that two or more batches of resin be thoroughly mixed in an appropriate vessel and the resultant well-mixed resins be transferred to a disposal container for dewatering and ultimate shipment to a licensed disposal facility. It is not possible to mix the resins in the disposal container due to the presence of large banks, sheets and/or racks of dewatering filtration media that make it impossible to mix resins in the disposal container.

As is seen in nuclear power plants, the mixing and movement of resins requires copious amounts of water. However, testing has shown that as the water content of a resin slurry increases, the segregation of different resin types becomes faster and more distinct, see Addenda - Table 2, resin settling test data. As shown in Table 2, in all cases, the initially well-mixed resins segregate much more quickly than the 'mixture' can ever be dewatered, with substantial to complete segregation occurring in less than one minute. Consequently, the final product in the high activity waste can separate from the low activity waste producing a non-homogeneous final waste in the disposal container.

Resins segregate in a process called segregation or 'classification' based primarily on two factors: 1) particle size and 2) particle density. Classification is well-documented phenomenon, as described by the Department of Energy Handbook on Water Treatment Processes [1]:

*'Because of the different densities of anion and cation resins…lighter anion resin would gradually rise to the top by a process called classification, resulting in a layer of anion resin on top of the cation resin'*

The denser, larger cation resin beads settle quickly to the bottom of a container, while smaller and lighter bead resins, such as anion resins, are carried upward by rising water turbulence and eventually settle on top of the denser, larger cation beads. In the event that powdered resins are mixed with bead resins, the segregation phenomenon is significantly aggravated as the very fine powdered resins can remain fluidized until the last of the initially well-mixed powdered-bead resin mixture is added to the disposal container. This results in the bead resins being largely settled in the bottom of the disposal container while the powdered resins are still fluidized or only partially settling at best. While it is obvious that a homogeneous physical mixture cannot be achieved, the same concepts apply to radioactivity. The theoretical possibility of achieving homogeneity of radioactivity exists; the physical and technological challenges of achieving radiological homogeneity make such a goal virtually impossible to meet.

Six sets of photos are provided below that show the classification/segregation of different resin mixes at various water concentrations. Table 2 provides a discussion of the parameters for each test run with information on the resin mix ratios and the water content of the initially well-mixed resin/water slurries. In the photographs the settled resins segregate rapidly, in less than one minute, as recorded in Table 2.

**TEST NO. 6: 86% BEAD RESIN, 14% POWDERED RESIN, 2:1 RESIN TO WATER RATIO**

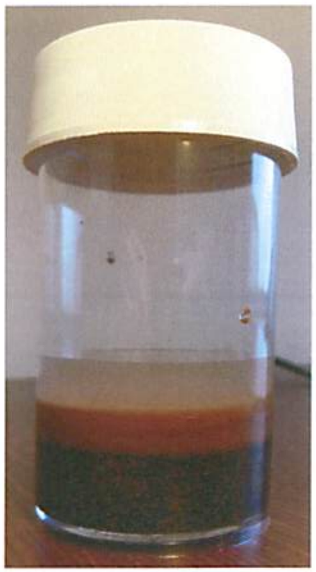
The bead resin used in this test comprises mixed resins with part anion (clear) and part cation (black). The powdered resin is tan or beige in color. As is evident in the first photo, the anion/cation beads will segregate with the lighter anion beads settling on top of the cation beads and the much smaller powdered resins mostly separated and settled on top of the clear anion resins. The lighter clear anion resins appear to have the same color as the powdered resins that have settled on top of the anion resins. There is some minor mixing of the powdered resins into the bottom cation layer and the middle anion layer. The second picture was taken immediately following the vigorous mixing and pouring of the combined resins from another container into the container shown in the second and subsequent photos. At this very early stage, second photo, resin classification is already occurring. In less than 15 seconds, the resin has re-segregated as shown in photos 3, 4 and 5, with cation beads on the bottom, anion beads in the middle, and powdered resin on top. Examination from above and below shows no beads are at the top of the 'mixture', and no powder is at the bottom; therefore, this cannot be called a homogeneous mixture, but shows strong segregation of each resin type.

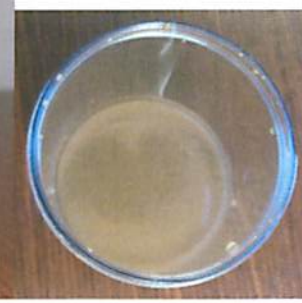




## TEST NO. 3: 86% BEAD RESIN, 14% POWDERED RESIN, 3:1 RESIN TO WATER RATIO

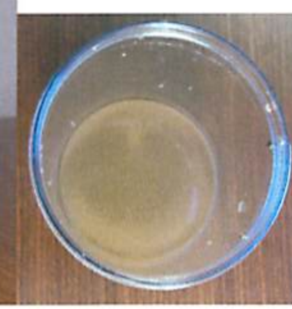
The same resins used in Test No. 6 were used in Test No. 3, but less water was used for Test No. 3. Classification again occurred in less than 15 seconds and significant segregation of the resins occurred.  Again, this cannot be called a homogeneous mixture, but shows strong segregation of each resin type.




### TEST NO. 1: 86% BEAD RESIN, 14% POWDERED RESIN, 4.5:1 RESIN TO WATER RATIO

The same resins used in Test No. 3 were used in Test No. 1, but less water was used for Test No. 1. The first photo illustrates the very small amount of excess water used in this test. Again, picture 2 represents the slurry immediately after mixing. The third picture was taken approximately 1 minute after mixing was stopped. It shows that the anion and cation beads are not substantially segregated. However, the powdered resins have largely segregated to the top of the bead mixture. Since the powdered resin is only 14% of the total resin volume it shows that most of the powdered resins have fully segregated from the bead resins. Examination of above and below shows the top is entirely powdered resin and the bottom has only cation beads with some anion beads. Classification occurred in approximately 30 seconds. Again, this does not represent a homogenous mixture, as the powdered resins show strong segregation from the bead resins.

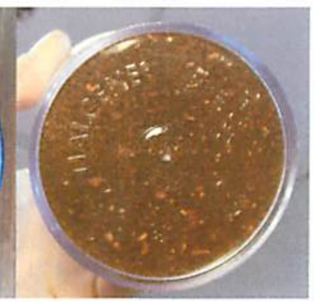


**TEST NO. 12: 14% BEAD RESIN, 86% POWDERED RESIN, 2:1 RESIN TO WATER RATIO**

The bead resin used in this test comprises mixed resins with part anion (clear) and part cation (black). The powdered resin is tan or beige in color. Due to the small volume of the mixed bead resins, the composition of the bead portions of the resin mix appears to be relatively homogenous. However, the bead resins are clearly segregated from the much smaller sized powdered resins that form a separate layer on top of the bead resins. The second picture was taken immediately following the vigorous mixing and pouring of resins from another container into the pictured container. At this very early stage, resin classification is already occurring with the much larger bead resins rapidly settling to the bottom of the container. In less than 15 seconds, the resin has re-segregated, with beads on the bottom and powdered resin on top. Examination from above and below shows no beads are at the top of the 'mixture', and no powder is at the bottom; therefore, this cannot be called a homogeneous mixture, but shows strong segregation of each resin by size.





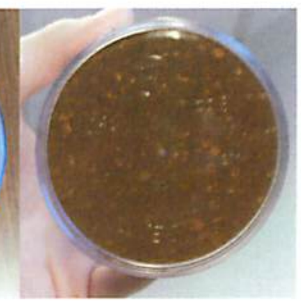


## TEST NO. 9: 14% BEAD RESIN, 86% POWDERED RESIN, 3:1 RESIN TO WATER RATIO

The same resins used in Test No. 12 were used in Test No. 9, but less water was used for Test No. 9. Classification of the bead resins from the powdered resins occurred in approximately 30 seconds. The third picture shows a solid layer of bead resins on the bottom, a secondary layer of low bead resin concentration in the middle, and an entirely powdered resin layer on top. This cannot be called a homogeneous mixture, but shows strong segregation of each resin by size.





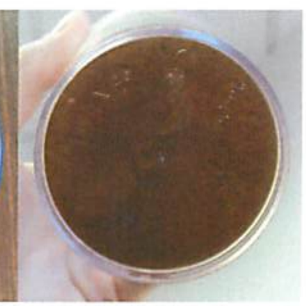


## TEST NO. 7: 14% BEAD RESIN, 86% POWDERED RESIN, 4.5:1 RESIN TO WATER RATIO

The same resins used in Test No. 9 were used in Test No. 7, but less water was used for Test No. 7. The first photo demonstrates the very small amount of excess water used in this test. Picture 2 represents the slurry immediately after mixing. The third picture was taken approximately 1 minute after mixing. It shows a completely segregated layer of powdered resins on top of a variable layer of bead and powdered resins in a non-uniform mixture. However, the side view misrepresents the location of most of the bead resins. This occurs because the walls of the container increase the drag force on the bead resin, slowing their descent. This becomes evident when the beaker is examined from below. The bottom of the beaker shows uniform bead content of a higher concentration than is seen from the side of the container. Examination from above confirms the top layer is entirely powdered resin. Classification occurred in less than one minute. Again, this does not represent a homogeneous mixture, but shows strong segregation of each resin by size.







## VIDEO

A video recording of the testing was taken to demonstrate the classification of resins in real time.

Video available upon request.

## SUMMARY

Blending is not an appropriate technique for the disposal of ion exchange resins that have widely different activity levels and different particle sizes or densities, as the heavier bead resins with one level of activity will mostly settle to the bottom of the disposal container, while the lighter bead resins or much smaller powdered resins will mostly accumulate near the top of the disposal container, producing a final dewatered disposal container that is highly segregated by resin type, density, particle size and/or by relative activity.

If resin blending is to be authorized, only resins of similar particle size and density should be mixed together to prevent substantial segregation in the disposal container, as it is not technically feasible to provide mixing in the disposal container where there are numerous banks or racks of dewatering filter media. Of special concern is that powdered resins of one Class should not be mixed with bead resins of a different Class, or large variations in activity will certainly result as demonstrated by the testing document in this paper.

**ADDENDA**

TABLE 1: EXAMPLES OF UNSPENT RESIN CHARACTERISTICS

| Brand - Model | Size (microns) | Shape | Bulk Density | Moisture Retention | Type |
|---|---|---|---|---|---|
| Purolite – NRW 5010 | 650 – 950 | Spherical Beads | 36.9 $lb/ft^3$ | 80-90% | Strong Base Anion |
| Rohm Haas – IRN99 | 300 – 850 | Spherical Beads | 52.4 $lb/ft^3$ | 37-43% | Strong Acid Cation |
| DOW – DOWEX SBR-C | 350 – 1200 | Bead | 42 $lb/ft^3$ | 43-48% | Strong Base Anion |
| Graver – POWDEX PAO | <200 | Powder | 44 $lb/ft^3$ | 50-60% | Strong Base Anion |
| Graver – POWDEX PCN | <200 | Powder | 45 $lb/ft^3$ | 40-60% | Strong Acid Cation |

TABLE 2: RESULTS OF BLENDING OF POWDERED RESINS WITH ANION AND CATION BEAD RESINS – SEGREGATION

| Test No. | Bead : Powder | Resin : Water | Degree of Classification / Segregation | Settling Time (sec) |
|---|---|---|---|---|
| 1 | 6 : 1 | 4.5 : 1 | Powder/Bead Classification Present | 27 |
| 2 | 6 : 1 | 3.6 : 1 | Complete Powder/Bead Classification | 24 |
| 3 | 6 : 1 | 3.0 : 1 | Anion/Cation Bead Classification | 13 |
| 4 | 6 : 1 | 2.6 : 1 | Rapid Classification | 9 |
| 5 | 6 : 1 | 2.25 : 1 | Immediate Classification | 7 |
| 6 | 6 : 1 | 2.0 : 1 | Tightly Packed Classification | 7 |
| 7 | 1 : 6 | 4.5 : 1 | Concentration Gradient with all Powder on top | 41 |
| 8 | 1 : 6 | 3.6 : 1 | Powder/Bead Classification Present | 33 |
| 9 | 1 : 6 | 3.0 : 1 | Powder/Bead Classification | 32 |
| 10 | 1 : 6 | 2.6 : 1 | Complete Classification | 16 |
| 11 | 1 : 6 | 2.25 : 1 | Rapid Classification | 8 |
| 12 | 1 : 6 | 2.0 : 1 | Tightly Packed Classification | 4 |

**REFERENCES**

[1] U.S. Department of Energy. DOE Fundamentals Handbook, Chemistry, DOE-HDBK-1015/2-93. Vol. 2. Washington, 1993.