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**Tank Waste Remediation System Milestone Report
Magnetic Separation of Tank Waste:
Surrogate System Separations Report**

Jan. 14, 1994

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Introduction

High-level radioactive waste (HLW) has been stored in large underground storage tanks (UST) at the U.S. Department of Energy's Hanford Site since 1944. More than 253,000 m³ of waste have been accumulated in 177 tanks. The waste consists of many different chemicals and are in the form of liquids, slurries, salt cakes and sludges. A magnetic separation effort at Los Alamos National Laboratory is funded through the Tank Waste Remediation System (TWRS) to explore the use of high-gradient magnetic separation (HGMS) for tank waste segregation. The concept is to concentrate into a low volume waste stream, all or most of the magnetic components, which include actinide compounds, most of the fission products and precious metals. As a first step in this process investigations were made on surrogate systems. This milestone report discusses the HGMS results on these systems.

Magnetic separation is a physical separation process that can be used to segregate materials in a mixture on the basis of magnetic susceptibility.¹ Because the technology relies on physical processes, little or no secondary waste is generated. Because all actinide compounds are paramagnetic, magnetic separation of actinide containing mixtures is feasible. Table 1 illustrates several species identified in tank waste that can be separated and concentrated with magnetic separation. Magnetic separation should provide a head-end separation and concentration of many radioactive components of UST waste. This will reduce the volume of tank waste that ultimately goes to the high level waste vitrification unit while reducing the chemical processing capacity

needed for other unit operations such as TRUEX.² With volume reduction a commensurate cost reduction should result. Magnetic separation can be made field deployable making on site operations practical.

The production of both high magnetic fields (>4 tesla) and large field gradients using superconducting magnet technology have helped make magnetic separation of small (<0.1 μm) paramagnetic particles achievable. The sludge components in the UST have been found to contain the majority of the radioactivity. The sludges consist of small particles and colloids in the form of hydrated metal oxides and hydroxides and is, therefore, ideally suited for the application of HGMS.³

The initial target waste for this study is neutralized cladding removal waste (NCRW). This waste form originates from the chemical decladding of Zircaloy-clad metallic uranium fuel. The mixture contains zirconium hydrous oxides in a basic salt medium with low levels of transuranic and fission components (~1000 nCi/g). The potential exists for HGMS to extract the actinides to non-TRU levels. Because preliminary studies of actual tank waste would make tests difficult and expensive, several nonradioactive waste simulates were used during this period to study the HGMS effectiveness on surrogate NCRW materials.

A calcined 101-SY synthetic tank waste product, obtained from Westinghouse Hanford Company (WHC), was also studied during this period.⁴ This material contains inorganic oxides and originated from a WHC November 1992 plasma arc calcination test. If the paramagnetic particles could be liberated as discrete particles, they could be separated and concentrated using HGMS.

In addition, an analytical model has been developed which provides guidance in selecting the appropriate bench scale experiments to perform and assists in analyzing the resulting data. A validated analytical model is needed to support prototype design and process scaleup. The majority of the model development work was performed under a cooperative research and development agreement (CRADA) with Lockheed Environmental Systems and Technologies.^{5,6}

Experimental

A typical HGMS experiment consisted of pumping a 200 ml slurry of the Hanford simulate through a 20 cm³ ferromagnetic filter element contained in a cylindrical matrix canister. The canister was positioned in the bore of a Cyromagnetics, Inc. superconducting magnet. The slurry was pumped through the matrix and a sample of the effluent was obtained for analysis. Two or three repetitive passes were made with sample collection from the effluent of each pass. After

testing was completed, the matrix canister was removed from the magnetic field and rinsed with distilled-deionized water to collect the paramagnetic particles that were trapped in the filter. The concentration of the paramagnetic components was determined by inductively coupled plasma-mass spectrometry (ICP-MS), atomic emission spectroscopy, electronic absorption spectrophotometry, or kinetic phosphorimetry.

High Gradient Magnetic Separation Analytical Model

The HGMS process involves at least 10 distinct variables that independently affect the magnetic separation process. The development of an analytical model for HGMS provides direction in selecting the appropriate bench scale experiments to perform and in analyzing the resulting data. Separation design variables are listed in Table 2. For convenience the list has been divided into material characteristics and separator parameters. In general, experiments were performed where only one or two parameters were varied and the remaining parameters were held constant.

The model was derived from a multi-component force balance, which governs the physical separation of discrete particles involved in the HGMS process.⁵ If the particles are physically liberated from the host material and are not electrically charged, the principal forces governing their behavior are magnetic, viscous, and gravitational, Figure 1. When the feed stream is passed through a high magnetic field, interlaced with high field gradients, the magnetic forces on the particles are proportional to the applied magnetic field, the resulting field gradient, and the relative magnetic susceptibility between the particles and the bulk slurry. Particle motion within the separator is governed by inertial, frictional, and gravitational forces. Also, attractive or repulsive interparticle forces become significant as particle size decreases. The separation efficiency predicted by the analytical model is proportional to this force balance. The model assumes that if the magnetic capture forces are greater than the competing viscous drag and gravity forces, the particle is captured and removed from the flow stream. These forces combine to act differently for each particle system or feed material treated.

Neutralized Cladding Removal Waste Results

Four generations of NCRW tank waste were prepared. The reagents and products are listed in Table 3. Surrogate I consisted of a simple precipitated metal hydrous oxide. A nonradioactive NCRW surrogate was prepared where the final products contain precipitated zirconium and iron (as the radioactive surrogate) hydrous oxide solids. Surrogate II was generated by this approach. Yet, after review of the PUREX Technical Manuals,⁷ more realistic surrogates were prepared following the chemistry behind the fuel pin decladding process. This generated the remaining

surrogates where iron serves as the radioactive component in Surrogate III, and uranium serves as the radioactive component in Surrogates IV and V.

Model Calculations on NCRW Tank Waste

The analytical model was utilized for feasibility studies and HGMS performance tests. Model calculations were done on a zirconium based slurry that contained varied uranium particulate components. The results are illustrated in Figure 2. The graph shows the HGMS effectiveness versus the paramagnetic particle size for four different uranium compounds each with a different magnetic susceptibility. The calculated results show that even a particle with a very low magnetic susceptibility can be extracted at 8 tesla. More than 80% of UO_3 particles can be extracted if the particle size range is between 8 and 200 microns. This is a significant result indicating that HGMS will be effective for very weakly paramagnetic liberated particles.

A further calculation was done on the effect of magnetic field strength and the HGMS performance. The results, Figure 3, show that magnetite (Fe_3O_4) is easily extracted at very low applied magnetic fields (<0.5 tesla). Yet for very weakly paramagnetic particles, such as UO_3 , higher magnetic fields, offered by superconducting technology, are required. The results also indicate that it may be possible to separate ferromagnetic components from weakly paramagnetic particles.

Surrogate I and II Results

Surrogate I was prepared by dissolving iron ($\text{Fe}(\text{NO}_3)_3$) in dilute acid followed by precipitation of the hydrous oxides with sodium hydroxide. Surrogate II was prepared analogously with addition of zirconium chloride salts (ZrCl_4), Table 3. The resulting pure and mixed slurries were characterized for particle size, magnetic susceptibility and HGMS test performance.

Hydrous oxide particles of iron and zirconium were measured and found to be in the two to four micron range. The magnetic susceptibilities of the iron samples have been measured both as aged and unaged isolated powders. The susceptibilities for the aged and the fresh powders were similar: $\chi_g = 1.48 \times 10^{-6}$ and 1.11×10^{-6} (m^3/kg), respectively. These values are larger than copper oxide by a factor of ~ 4 . These isolated ferric hydrous oxide powders approached ferromagnetism. The magnetic susceptibility of the precipitated $\text{Zr}(\text{IV})/\text{Fe}(\text{III})$ solid from Surrogate II was $\chi_g = 1.55 \times 10^{-9}$ (m^3/kg); the zirconium hydrous oxide powders were diamagnetic ($\chi_g = -2.75 \times 10^{-9}$ (m^3/kg)).

HGMS tests were conducted at a field of one tesla in the superconducting magnet. Initial tests with a steel wool matrix and a zirconium hydroxide slurry, plugged the matrix. The matrix element was

changed to expanded metal (EXMET) for subsequent tests. The results, shown in Figure 4, indicate that 98% of the ferric hydrous oxide iron can be captured from a slurry after treatment with ultrasound.

The HGMS performance was poor with the Zr(IV)/Fe(III) mixture. Sonication was used to disperse the particles in the slurry, and to liberate the zirconium particles from the iron particles in the Zr(IV)/Fe(III) slurry. It is possible that the iron and zirconium are co-precipitated, which apparently leads to an iron containing precipitate with low overall magnetic susceptibility. Aging of such a slurry, as occurs in the tanks, might generate an iron compound with either a much higher magnetic susceptibility or more discrete crystalline particles in the sludge.

Surrogate III Results

After completion of the Zr(IV)/Fe(III) tests (Surrogate I-II), the PUREX Technical Manuals were reviewed to determine the chemistry and proportions of chemicals that the PUREX plant used during NCRW generation.⁷ The simulant (Surrogate III) was prepared by neutralization of a dissolved solution of $(\text{NH}_4)_2\text{ZrF}_6$, NH_4 , NH_4NO_3 , and $\text{Fe}(\text{NO}_3)_3$, Table 3. The iron served as the paramagnetic component for separation. The resulting brown slurry of zirconium and iron hydrous oxides was divided and unaged and aged (48 hours at 90°C) solutions were prepared for HGMS testing. The differences between Surrogate II and III include the initial zirconium salt (ZrCl_4 versus $(\text{NH}_4)_2\text{ZrF}_6$) and the much higher ionic strength present in Surrogate III.

SEM photos indicated that the 5% solids slurry was composed of particles in a range of 2 to 15 microns in size. The magnetic susceptibility of a dried isolated sample was positive ($\chi_g = 3.31 \times 10^{-8} \text{ m}^3/\text{kg}$) and was 22 times higher than the susceptibility of the surrogate materials prepared from $\text{Fe}(\text{NO}_3)_3$ and ZrCl_4 .

HGMS tests of aged and unaged slurries were conducted at a 0.5 and 6.0 tesla field in the superconducting magnet at Los Alamos. The matrix element for these tests was EXMET due to the high performance of prior HGMS tests with hydrous oxides. The results, Figure 5, indicate that up to 86% of the aged ferric hydrous oxides can be captured from a slurry. The performance is much higher than previously observed for surrogate II where Zr(IV) and Fe(III) were coprecipitated (see Figure 4). There is also little difference in the capture efficiencies of the aged materials at low and high applied magnetic fields. These results are encouraging because aging occurs in actual tank waste. The aging process apparently produces a highly magnetic form of iron or the crystallization of larger magnetic particles. During the tank aging process, the iron is also

anticipated to adsorb or collect uranium and other actinides. This would be beneficial for the HGMS process.

Surrogate IV Results

Surrogate IV represents the start of the first radioactive simulates that were tested for the TWRS program. Surrogate IV was generated from reagents used in NCRW production from the PUREX process. A small amount of uranyl nitrate ($\text{UO}_2(\text{NO}_3)_2$) instead of iron, was added to the solution before adjusting the pH to basic conditions, Table 3. This solution simulates fuel pin dissolution and precipitation. Unaged and aged (48 hours at 90°C) solutions were prepared.

In conjunction with the first radioactive tests, an HGMS test on a UO_3 / water mixture was performed. The purpose of this test was to demonstrate the effectiveness of HGMS on very weakly paramagnetic particles in a simple system. This form of uranium (U^{VI}) might be found in NCRW. The volume magnetic susceptibility of UO_3 was measured at 19.2×10^{-6} (SI units). The results are shown in Figure 6. Significantly, UO_3 particles are more than 81% extracted at a two tesla field strength. This also agreed with the HGMS model predictions.

HGMS tests were done at 2 and 6.5 tesla on the Surrogate IV aged slurry. The results are shown in Figure 7. HGMS showed no effectiveness in uranium extraction. The probable explanations are that (a) the uranium (VI) hydroxide species that forms is very weakly paramagnetic and thus difficult to extract with the addition of zirconium solids using the EXMET matrix material, or (b) the uranium is co-precipitated with the zirconium. Magnetic susceptibility measurements will be performed on the uranium hydroxide product.

Surrogate V Results

The addition of iron and its effect on uranium extraction was investigated in the fifth generation slurries. The attraction of rare earth ions or complexes to iron oxides is well known. The idea is that weakly paramagnetic uranium species will become attached to highly magnetic iron particles. Two forms of iron were studied. One batch had iron nitrate co-precipitated with the uranyl nitrate / zirconium fluoride solution (Surrogate V-A). In the second batch, (Surrogate V-B), magnetite was added to the precipitated uranium and zirconium hydrous oxides immediately preceding the HGMS test.

The best separation was observed with the slurry that had co-precipitated iron, Figure 7. The HGMS effectiveness was 38% at 6.5 tesla. The addition of magnetite yielded only a 12% HGMS effectiveness on the uranium extraction. It appears that the addition of iron does make a positive

effect, yet the extraction results are low. Further tests are planned on uranium (IV) hydrous oxides where the magnetic susceptibility is two orders of magnitude higher.

Westinghouse Hanford Company NCRW Surrogate

Blair Emory at Westinghouse Hanford Company (WHC) has prepared a batch of NCRW simulant from unirradiated fuel elements. The material was generated from the PUREX procedure by dissolution of the fuel pin cladding and neutralization of the resulting solution. NCRW was generated containing traces of uranium without the fission products. The slurry contains ~300 pCi/g of depleted uranium. HGMS tests at a two tesla field were conducted on this slurry at WHC. Analysis of the resulting solutions are underway. Some of this slurry will be sent to Los Alamos for high field testing.

Calcined Synthetic Tank Sludge

Tests were done on a synthetic 101-SY tank sludge received from WHC. The material contains inorganic oxides, and the elemental analysis of the original material is given in Table 4. The sample was characterized by water solubility, particle size, and HGMS performance. Pretreatment tests were minimized: a small amount of calcined solid was added to water (1:9 ratio) and stirred; 25% of the solid remained undissolved, 75% of the solid dissolved. Table 4 includes the elements that dissolved in the water. The particle size was 1-8 microns for the undissolved solid.

A 10 weight % solid slurry was prepared for HGMS testing. This was done by addition of water to the original solid. After stirring, the undissolved solid was isolated and re-suspended as a slurry for HGMS testing. The slurry was passed through the magnetic field at 0.5 tesla followed by a 6.0 tesla pass. The initial low field pass serves as a ferromagnetic scalping pass. Results (Table 5) indicate that 31 - 47% of the inorganic paramagnetic species were removed. The majority of the material was extracted at 6.0 tesla.

A second series of HGMS tests was performed to study the effect of the addition of surfactant and presonation of the slurry. A sonication step could deagglomerate paramagnetic particles from host material. Three slurries (10 weight % solids) were prepared for HGMS testing. This was done as described above. Prior to HGMS testing, surfactants (sodium hexametaphosphate, sodium silicate) were added to two slurries followed by sonication for 10 minutes for all three slurries. The results are shown in Table 6. It is clear from the poor HGMS performance that a presonation step breaks particles down to a submicron regime which is too small for the EXMET matrix material to be effective.

The results from both sets of experiments suggest that calcination of the tank sludge must fuse paramagnetic and diamagnetic particles together. Even pretreatment with surfactant for particle liberation showed minimal effect for improved separation. The final conclusion is that for this specific form of calcined tank waste, HGMS is not the most efficient separation method.

Summary / Future Plans

A variety of surrogates were processed through superconducting magnetic separators at Los Alamos with different degrees of success.

From tests with NCRW Surrogate I and II, magnetic particles were found to be easily captured from fluids, yet the addition of extraneous zirconium hydrous oxides complicated the system. These complications may be attributed to the zirconium solids acting as a coprecipitant, by absorbing the precipitating iron particles, or by modifying the slurry properties. As a result of difficulties passing the zirconium hydrous oxide containing slurry through the steel wool matrix, the remainder of the HGMS tests utilized an expanded metal matrix.

NCRW Surrogate systems III - V used chemistry closely resembling the PUREX chemistry that generated the NCRW. In Surrogates IV and V, uranium (VI) was exclusively used for the HGMS testing. Results were somewhat disappointing with 40% or less of the uranium extracted. However, there is evidence that the uranium present in the tanks is in the IV oxidation state. This is an important difference because the magnetic susceptibility and the ability of HGMS to extract the uranium increases by one to two orders of magnitude. Particle morphology in the NCRW is another important unknown factor.

Tests with the simulated calcined material supplied by Hanford gave poor results. This is likely due to particle agglomeration or fusing of elements with differing magnetic properties into small particles.

All the tests supplied important information for the analytical model. Late in the test series, analytical results closely matched the model predictions.

In the future, samples of the simulant prepared by Blair Emory as well as actual NCRW samples must be obtained. While much has been learned from the surrogate work, it is the properties of the real system that will dictate success or failure of this HGMS application.

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Table 1. Volume magnetic susceptibility of selected UST elements and compounds. Positive values are paramagnetic susceptibilities and negative values are diamagnetic susceptibilities.

Compound or Element	Susceptibility x 10 ⁶ (SI)
FeO	7178.0
CoO	5300.0
Fe ₂ O ₃	1479.0
Ce	1463.0
UO ₂	1204.0
Cr ₂ O ₃	844.0
Pd	805.0
NiO	740.0
Am	707.0
Pu	636.0
U	411.0
PuO ₂	384.0
CuO	242.0
RuO ₂	107.0
UO ₃	41.0
MoO ₃	26.0
Al	21.0
Ca	19.0
Si	-0.3
CaO	-1.0
ZrO ₂	-7.8
MgO	-11.0
KCl	-13.0
CaCl ₂	-13.0
NaCl	-14.0
SiO ₂	-14.0
Al ₂ O ₃	-18.0
BiPO ₄	-20.1

Table 2. Distinct variables that independently sffect the magnetic separation process.

Material Characteristics	Separator Parameters
Particle Size	Matrix Element Size
Impurity Concentration	Matrix Element Spacing
Solids Concentration	Magnetic Field Strength
Magnetic Susceptibility	Matrix Material
Surfactant Concentration	Residence Time
Slurry	Superficial Velocity

Table 3. Reagents and products in five varied surrogates for NCRW tank waste.

Surrogate	Reagents	<u>Products</u> ¹	
		Product A	Product B
I	Fe(NO ₃) ₃ (0.004M) HNO ₃ (10 ⁻³ M)	Fe(OH) _x NaOH	NA ²
II	ZrCl ₄ (0.15M) Fe(NO ₃) ₃ (0.004M) HNO ₃ (10 ⁻³ M)	Zr(OH) _x Fe(OH) _x NaOH	NA
III ³	(NH ₄) ₂ ZrF ₆ (0.15M) Fe(NO ₃) ₃ (0.004M) NH ₄ F (1.0M) NH ₄ NO ₃ (0.02M) HNO ₃ (10 ⁻³ M)	Zr(OH) _x Fe(OH) _x NaF NaNO ₃ NaOH	NA
IV ⁴	(NH ₄) ₂ ZrF ₆ (0.15M) UO ₂ (NO ₃) ₂ (0.002M) NH ₄ F (1.0M) NH ₄ NO ₃ (0.02M) HNO ₃ (10 ⁻³ M)	Zr(OH) _x UO ₂ (OH) ₂ NaF NaNO ₃ NaOH	NA
V-A ⁴	(NH ₄) ₂ ZrF ₆ (0.15M) UO ₂ (NO ₃) ₂ (0.002M) Fe(NO ₃) ₃ (0.004M) NH ₄ F (1.0M) NH ₄ NO ₃ (0.02M) HNO ₃ (10 ⁻³ M)	Zr(OH) _x UO ₂ (OH) ₂ Fe(OH) _x NaF NaNO ₃ NaOH	NA
V-B ^{4,5}	(NH ₄) ₂ ZrF ₆ (0.15M) UO ₂ (NO ₃) ₂ (0.002M) NH ₄ F (1.0M) NH ₄ NO ₃ (0.02M) HNO ₃ (10 ⁻³ M)	Zr(OH) _x UO ₂ (OH) ₂ NaF NaNO ₃ NaOH	Zr(OH) _x UO ₂ (OH) ₂ Fe ₃ O ₄ NaF NaNO ₃ NaOH

(1) Products were generated by addition of excess NaOH to the reagents. (2) Not Applicable. (3) Unaged and aged (48 hours at 90°C) slurries were prepared. (4) Aged slurries (48 hours at 90°C) were prepared. (5) After the precipitation step, magnetite (Fe₃O₄) was added to generate Product B.

Table 4. Analysis of calcined 101-SY synthetic tank waste before and after sample dissolution in water. Highlighted components are the paramagnetic species tracked during the HGMS experiments.

Element	Original Calcined Sample (ug/g)	Calcined Solid After H ₂ O Dissolution ¹ (ug/g)	Calcined Supernate After H ₂ O Dissolution ¹ (ug/ml)
Al	6290.2	5773.9	516.3
B	63730.	63730.0	
Ca	371.5	369.5	2.1
Co	5.9	5.2	0.7
Cr	573.9	110.3	463.6
Cu	226.3	224.9	1.4
Fe	5028.2	5022.7	5.4
K	590.6	115.7	474.8
Mg	20.5	19.8	0.6
Mn	231.2	228.5	2.7
Mo	38.4	17.5	20.9
Na	120708.1	88027.2	32680.9
Ni	418.3	415.8	2.5
P	2121.3	1560.6	560.7
Pb	74.1	68.3	5.7
Si	91121.2	90912.8	208.4
Sr	9.98	9.95	0.03
Ta	21.9	20.5	1.4
Ti	6759.0	6728.0	31.0
W	95.3	88.80	6.51
Zn	777.7	745.0	32.6
Zr	166.0	165.4	0.5

(1) Calcined solid was added to water (1:9 ratio) and stirred; 25% of the solid remained undissolved, 75% of the solid dissolved.

Table 5. HGMS effectiveness of the paramagnetic components in the calcined synthetic tank sludge. Testing parameters were: EXMET matrix; pretreatment by simple water dissolution and isolation of the solid for the feed material; 10% solids in slurry.

Element	Feed¹ (ppm)	Pass 1² 0.5 tesla (ppm)	Pass 2³ 6.0 tesla (ppm)	Total Effectiveness (%)
Co	1.0	0.9	0.7	31.0
Cr	369.1	363.2	237.5	35.7
Cu	6.3	7.9	4.2	33.3
Fe	288.1	277.2	151.9	47.3
Mn	10.6	9.7	5.6	47.5
Mo	20.2	18.7	13.3	34.0
Ni	13.4	12.7	7.2	46.3

(1) Analysis of solid feed material prior to HGMS experiment. (2) Analysis of solid material after one pass through the magnetic separator at 0.5 tesla. (3) Analysis of solid material after the second pass through the magnetic separator at 6.0 tesla

Table 6. HGMS effectiveness of the paramagnetic components in the calcined synthetic tank sludge with addition of surfactant and presonication. Testing parameters were: EXMET matrix; 10% solids in slurry; Presonication for 10 min.

Element	Surfactant	Feed ¹ (ppm)	Pass 1 ² 0.5 tesla (ppm)	Pass 2 ³ 6.0 tesla (ppm)	Total Effectiveness (%)
Slurry 1					
Cr	none	73.8	70.9	65.9	11
Cu	"	212.6	213.6	212	0
Fe	"	14027	14547	14674	-4
Mn	"	300	295	301	-0.4
Ni	"	485.1	465.5	439.1	10
Ti	"	859.0	815.2	810.0	6
Slurry 2					
Cr	0.2% (NaPCl ₃) ₆	301	327	296	1.6
Cu	"	200	208	180	10
Fe	"	14990	15119	13003	13
Mn	"	198.6	212.9	193.3	2.7
Ni	"	482.3	487.1	407.6	16
Ti	"	761.6	783.7	685.2	10
Slurry 3					
Cr	0.2% Na ₂ SiO ₃	70	73.6	69.8	0.3
Cu	"	182.7	181.5	177.6	2.8
Fe	"	12757	13083	12187	4.5
Mn	"	261.6	276.4	254.8	2.6
Ni	"	422.6	417.6	371.1	12.2
Ti	"	726.7	724.8	684.8	5.8

(1) Analysis of solid feed material prior to HGMS experiment. (2) Analysis of solid material after one pass through the magnetic separator at 0.5 tesla. (3) Analysis of solid material after the second pass through the magnetic separator at 6.0 tesla.

Figure 1. Force balance on a paramagnetic particle in the vicinity of a matrix element.

Figure 2. HGMS extraction of selected uranium compounds from an NCRW slurry.
Parameters include: Applied magnetic field of 8 tesla and EXMET matrix.

Figure 4. HGMS of metal hydrous oxides made from the precipitation of iron (III) and zirconium (IV) chloride salts (Surrogates I and II).

Figure 5. HGMS of metal hydrous oxides from precipitation of iron (III) and zirconium (IV) fluoride salts (Surrogate III).

Figure 6. HGMS Extraction of UO_3 from water. The measured UO_3 susceptibility was 19.2×10^{-6} (X_{volSI}). The HGMS test conditions were: Field Strength = 2.0 tesla; UO_3 Particle Size = 2-5 microns.

Figure 7. HGMS extraction of uranium hydrous oxides from zirconium / uranium hydrous oxide slurries (Surrogates IV, V-A, V-B). Slurries were aged at 90°C for 5 days. Surrogate V-A and V-B were pretreated with iron. The HGMS test conditions were: pH = 10, Pass 1 at 2.0 tesla; Pass 2 at 6.5 tesla; Matrix - EXMET.

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