November 11, 2014

Mr. Mark Shaffer
Director
Region IV – Division of Nuclear Materials Safety
1600 E. Lamar Blvd
Arlington, TX 76011-4511

RE: Completion of Root Cause Analysis – Honeywell Drum Incident of September 9, 2014

Dear Mr. Shaffer:

As you are aware, Uranium One retained Golder Associates ("Golder") to conduct a root cause analysis of the incident that occurred on September 9, 2014 at the Honeywell Metropolis Conversion Facility ("Honeywell") involving a drum (Drum #43, Lot 51) of yellowcake from Uranium One USA's Willow Creek project. A plan detailing the root cause analysis was presented to the NRC on September 29, 2014.

Golder has completed the root cause analysis and upon investigation it was found that the root cause of the September 9, 2014 drum incident at Honeywell was the decomposition of uranyl hydrates resulting in the generation of oxygen gas in the drum. The reason the gas generation occurred was likely the placement of the lid on the dried yellowcake drum in such a way that the venting of gases during the cool-down period after drum filling was not properly completed.

As outlined in the September 29, 2014 root cause analysis plan, Golder investigated a number of potential root causes related to the drum incident. The table below summarizes the items that were investigated and the associated findings for each.

What was investigated	Findings of investigation
Operations Records	Operations records and logs were reviewed to evaluate conformance with established Standard Operating Procedures during the processing and drying of yellowcake associated with Lot 51, and in particular Drum 43. All operational records and logs reviewed found no deviations from standard operating procedures had occurred.
Physical Conditions and Operating Procedures – Uranyl Peroxide precipitation	A review of these procedures concluded that operating procedures were followed and no unusual conditions were identified that could have contributed to the drum pressurization.
Dryer Operations	A dryer modification following the last maintenance shut down (i.e., burner and vent gas refurbishment) resulted in significantly improved burner operations and better temperature control enabling the dryer to operate more efficiently and to produce a higher degree of drying. Modifications to dryer operations are discussed in recommendation number 2 below.

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Dryer Temperature Profile	Two thermocouples were installed in the dryer discharge system to better understand the temperature profile of the yellowcake as it exits the dryer into the packaging drum.
Packaged Drum Temperature Profile	Temperature profiles were taken of the drummed yellowcake. These data were then utilized to gain a more comprehensive understanding of the time required for the drummed yellowcake to cool to near ambient conditions.
Packaged Drum Pressure Testing	Pressure readings were recorded by means of a 0-5 psi gauge(s) installed on drum lids placed on dried, cooled and vented (24 hr) drums. Pressure readings were monitored for at least 8 days. Additionally, a drum pressure test was performed on a drum that was cooled and vented using the old procedure of placing the lid loosely on the drum. No pressure was recorded from any of the drums tested.
Drum Venting and Cooling Procedures	The root cause analysis identified potential inconsistencies in the venting and cooling procedure. Some lids were off-set on the drum while others were placed directly on top of the drum during venting and cooling. Drum lids placed directly on top of the drum raised a potential concern that the lid placement may create a temporary sealing of the rubber gaskets to the drum, thus not allowing adequate venting during the cool-down period. Recommended corrective actions were implemented as a result of this finding and are discussed in recommendation number 1 below.
Drum Handling Procedure Prior to Shipment	Tests were conducted to determine if water could inadvertently be introduced (or would have been introduced) into a drum during the final wash down prior to shipment. It was determined that an aggressive wash-down with a pressure washer pointed directly at the drum closing mechanism could allow water to get in to the drum. Although water within Drum 43 was determined to be a highly unlikely cause of the incident, as a result of this information the final drum wash-down procedure was modified as presented in recommendation number 3 below.
Physical Evaluation of the Shipping Drums	Reconditioned empty drums used for yellowcake shipments were evaluated as a potential source for a chemical reaction that could lead to drum pressurization. It was determined that any foreign material within the reconditioned drums (if any were present at all) would not be responsible for a chemical reaction leading to drum pressurization. The drum lid gasket was also evaluated to determine if exposure to high temperature conditions could create a seal preventing the drum from properly venting prior to final closure of the drum lid. This scenario was eliminated as a result of the modified drum cooling and venting procedure discussed in recommendation number 1 below.

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Potential pressure changes due to environmental conditions	An evaluation (consisting of calculations) was performed to determine if environmental conditions (change in ambient temperature and elevation) could result in drum pressurization in the time between drum shipment from Willow Creek and processing at Honeywell. It was determined that no significant increase in the drum pressure would be expected as a result of a change in environmental conditions between the two sites.
Yellowcake samples	Findings are set out under the heading "XRD Analysis of Dried Uranyl Peroxide" below.

XRD Analysis of Dried Uranyl Peroxide

The chemical conversion of uranyl peroxide to uranium oxides at elevated temperatures was investigated to determine what crystalline structure could exist in the dried yellowcake. Samples (4) were sent to Evans Analytical Group for XRD analysis. Of the four samples sent to Evans Analytical, three samples were from the recent higher temperature (650°C) production run Lot 57 (WC57 Drum 28, WC57Drum 37 and WC57 Drum 39) and one sample from the drum involved in the Honeywell incident, Lot 51 Drum 43. Six samples were also sent to Dr. Peter Burns, Director, Energy Frontier Research Center, *Materials Science of Actinides* at Notre Dame University for analysis. Four of the six samples were composites of drums from Lots WC51, WC53, WC55 and WC56. One sample was from the recent production run WC57, Drum 42 and the final sample was from the pressurized drum Lot WC51, Drum 43.

Once the uranyl peroxide tetrahydrate (studtite) is formed it will decompose to lower forms of the uranyl hydrate –metastudtite, metaschoepite and lower oxides of UO_3 and U_3O_8. It is important to note that only two of these compounds, studtite and metastudtite, contain peroxide oxygen and all others compounds are non-peroxide containing compounds (non-oxygen forming).

Drying temperature plays a significant role in the uranyl peroxide progression of phases. Below are the progression phases of uranyl peroxide decomposition to lower forms of uranyl hydrates and uranium oxides and associated temperatures:

Studtite	⇨	Metastudtite	⇨	Metaschoepite	⇨	UO_3/U_3O_8
0°C – 80°C		80°C - 220°C		220°C - 525°C		525°C - 750°C+

XRD analysis from Evans Analytical and Notre Dame indicate similar results for all the samples that were analyzed. Both sets of XRD analysis for Drum 43 showed the highest level of metastudtite indicating a potentially lower drying temperature. Composite samples from Lots 53, 55 and 56 showed much lower levels of metastudtite indicating a higher degree of drying and a larger percentage of metaschoepite compound. Samples from Lot WC57 (dried at a higher temperature of 650°C after the dryer refurbishment) showed negligible levels of metastudtite confirming an even higher degree of drying. As a result of the dryer refurbishment the yellowcake product now produced is a lower oxide compound of UO_3 or U_3O_8, with little to no metastudtite. The lower oxide compounds (UO_3 and U_3O_8), as well as metaschoepite, are non-peroxide containing compounds – thus non-oxygen forming, presenting a low to near-zero potential to generate pressurized drums.

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Root Cause Analysis Recommendations

Three (3) recommendations have been identified as a result of the root cause analysis which should prevent future pressurization of dried yellowcake drums. Uranium One has implemented the three recommendations listed and discussed below:

1. Improve Packaged Drum Venting and Cooling Procedures

Uranium One implemented a revised venting procedure post drum fill as of September 18, 2014 utilizing a screen mesh instead of the actual drum lid, so that the venting process can be carried out without inadvertent premature closure of the lid, in a consistent manner by all operations personnel. This screen mesh procedure has been incorporated into Irigaray Procedure IR12. SOP IR12 has also been modified to require that all drums will be allowed to cool and vent for a minimum of 48 hours, or cool to a temperature of approximately 90°F, prior to lidding the drums. Since WC Lot 57 was packaged prior to implementing the drum venting changes, Uranium One has opened each drum in this lot prior to shipment to ensure no pressure exists and no build-up has occurred in any drum.

2. Overhaul of the Dryer Control System to Optimize Heating and Drying of the Uranyl Peroxide Yellowcake

In August and September 2014, the Irigaray site completed a dryer refurbishment or dryer optimization program which included upgrading of the burner system and improvements to the system controls. This comprehensive dryer upgrade resulted in significantly improved burner operations and better temperature control of the dryer system. The upgrade enabled the Irigaray dryer to operate more efficiently and to produce a product which has a higher degree of drying, thus producing a non-peroxide uranium compound.

XRD analysis has been performed on the composite of WC Lot 57 with samples collected from Drum 28 (prior to completion of all dryer modifications), and Drums 37, 39 and 42 after dryer modifications were completed. All samples from WC 57 show negligible amounts of metastudtite, indicating that all the uranium oxides are stable and should not produce oxygen gas. Each drum from Lot 57 was opened prior to shipment to ensure absence of pressure.

3. Revision to the Packaging Drum Handling Procedure

A revised drum washing procedure has been developed to ensure that no water can enter a closed drum during decontamination (wash-down) of the drum exterior prior to shipment. The present procedure involves the use of a high-pressure wash to remove any residual dust from the exterior of the drum. Irigaray has introduced an alternative washing procedure which will reduce the likelihood of water being introduced into a drum while still removing any uranium dust from the exterior to meet the surface contamination shipping requirements. Uranium One has instructed operations personnel performing drum decontamination to keep a distance of approximately one foot from the drum surface to minimize the potential of water entering the sealed drum. These instructions have been incorporated into Irigaray SOP IR12.

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Conclusion

The root cause analysis identified that the inadvertent sealing of rubber gaskets to Drum 43 due to the placement of the lid directly on top of the drum (instead of offset) likely created the condition in which oxygen gas was generated after the lid was secured prior to shipment. It is believed that the predominance of metastudtite mineral in Drum 43 combined with the inadvertent sealing of the lid could have created the presence of oxygen gas in the drum.

As identified from the XRD analysis, proper cooling and venting would eliminate the potential of oxygen gas generation if metastudtite was present in the dried yellowcake. Also, Uranium One expects that the refurbishments made to the dryer will allow production of a non-peroxide, non-gas producing yellowcake. These refurbishments, combined with the revised cooling and venting procedures, should serve to significantly reduce the probability of another pressurized drum occurrence.

Uranium One has implemented the recommendations and completed a SERP documenting the recommended actions. As the root cause analysis has been completed and recommendations have been implemented, shipments of Willow Creek yellowcake to the Honeywell conversion facility resumed on November 5, 2014.

If you have any questions please do not hesitate contact me at jon.winter@uranium1.com or 307-315-2638.

Sincerely,

Jon Winter
Director Health, Safety and Environment
Uranium One Americas

CC: Donna Wichers – Uranium One USA, Inc.
Ron Linton – NRC Project Manager Willow Creek Project
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