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REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS

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LOW ENRICHED URANIUM-MOLYBDENUM COUPON FABRICATION AT THE Y-12 NATIONAL SECURITY COMPLEX

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ABSTRACT

The Y-12 National Security Complex (Y-12) is a participant in the NNSA NA-21 Convert Program, also known as RERTR, by performing development activities, supporting low enriched uranium (LEU)-molybdenum (Mo) research, and performing production activities in casting and machining. In 2012, Y-12 began fabrication of LEU-Mo coupons for the Limited Production Facility (LPF) campaign using a pre-alloyed depleted uranium (DU)-Mo feedstock to downblend with the highly enriched uranium (HEU). This campaign compares two different casting molds and two sources of DU-Mo alloy feedstock. The purpose of this report is to describe the experimental plan, update the audience on the progress made and define the activities planned for the next FY.

1. Introduction

The Reduced Enrichment for Research and Test Reactors (RERTR) Program was initiated by the U.S. Department of Energy (DOE) to develop the technical means for the conversion of high powered research reactors (HPRRs) from HEU to LEU. The RERTR program cooperates with the research reactor community to achieve this goal of HEU to LEU conversion while maintaining reactor reliability and performance. The Y-12 National Security Complex (Y-12) is a participant in the NNSA NA-21 Convert Program, also known as RERTR, by performing development activities, supporting low enriched uranium (LEU)-molybdenum (Mo) research, and performing production activities in casting and machining.

In previous years, LEU-Mo casting was performed in a two-step process, as depicted in *Figure 1: Two Step U-Mo Casting Process.* First, highly enriched uranium (HEU) was blended with a diluent and molybdenum in an initial cylindrical casting. The alloy was then broken and recast into a plate form. This process had a large molybdenum distribution range, typically from 8% to 12%, resulting in a higher than desired reject rate. One theory was that the two step process had too many process variables in a one unit operation to provide a repeatable and predictable casting. In 2011, Y-12 began experimenting with LEU-Mo casting using a pre-alloyed arc melted diluent feedstock, labeled as UMoF, as depicted in *Figure 2: Current Casting Process*.

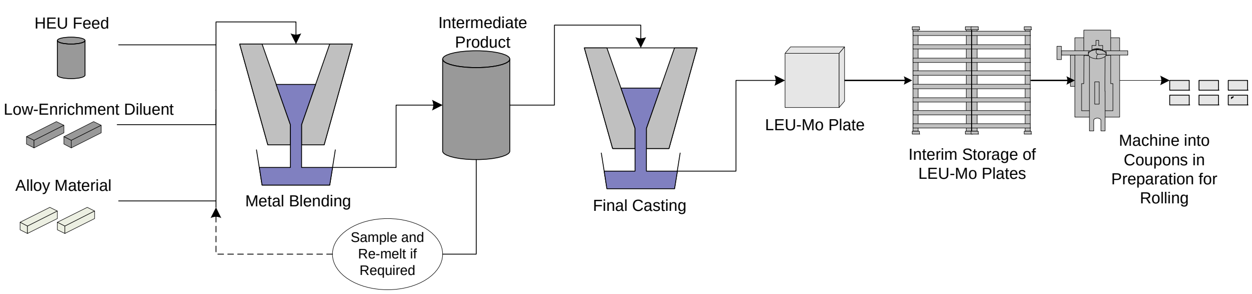
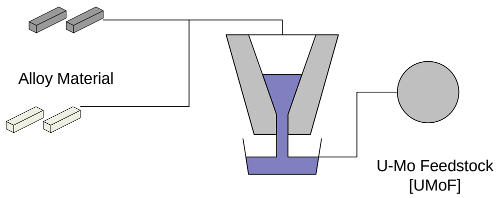


Figure 1: Two Step U-Mo Casting Process



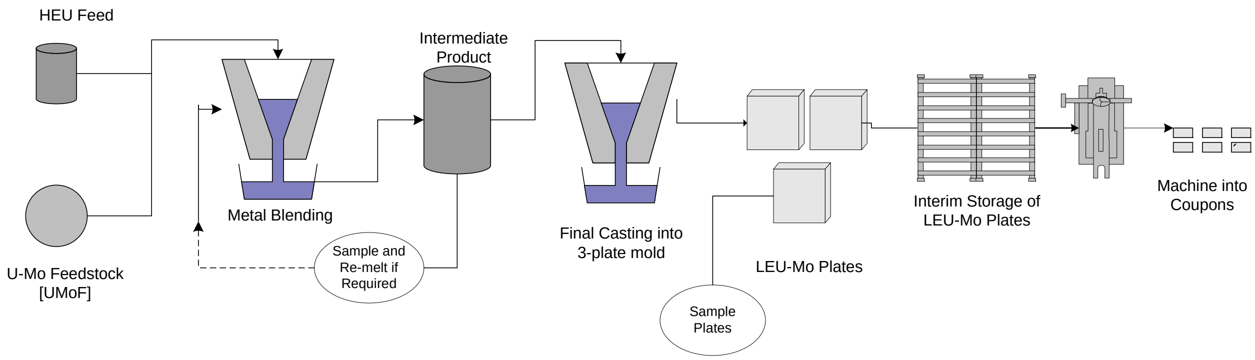


Figure 2: Current Casting Process

While data was limited, the new process indicated there was a greater control of process parameters by pre-alloying the diluent. The new process also indicated that the Mo and U235 distribution throughout the casting was more uniform. In response to these finding, participants in the Fuel Fabrication Capability developed an experimental plan to fabricate coupons with the new process. The intent is that the coupons would be fully characterized and then sent to the final fabricator for fuel fabrication. Then data from the foil fabrication process could be used to provide feedback on the front end process.

2. Description of Experimental Plan

As part of the LPF campaign, Y-12 will fabricate ninety-six LEU-Mo coupons and ship to the foil fabricator as shown in *Figure 3: Limited Production Facility Experimental Plan*. These ninety six coupons will be split into two batches of forty eight coupons. One set of forty eight will be cast using an arc melted DU-Mo alloy prepared by Y-12. The second set of forty eight will be cast using a VIM melted DU-Mo alloy prepared by an outside vendor. Assuming that each log yields 2.5 plates, five logs are required for each alloy to obtain the forty eight coupons. From the five logs cast, twelve plates will be cast using the single plate mold and twelve plates will be cast using the three plate mold (i.e. 4 cast runs). This plan is expected to yield ninety-six coupons. This experimental plan assumes that there is no attrition for cast surface defects. The intent is to allow the final fabricator to process all of the coupons and provide feedback to determine the true defects of coupons that lead to foil failures during the fabrication process.

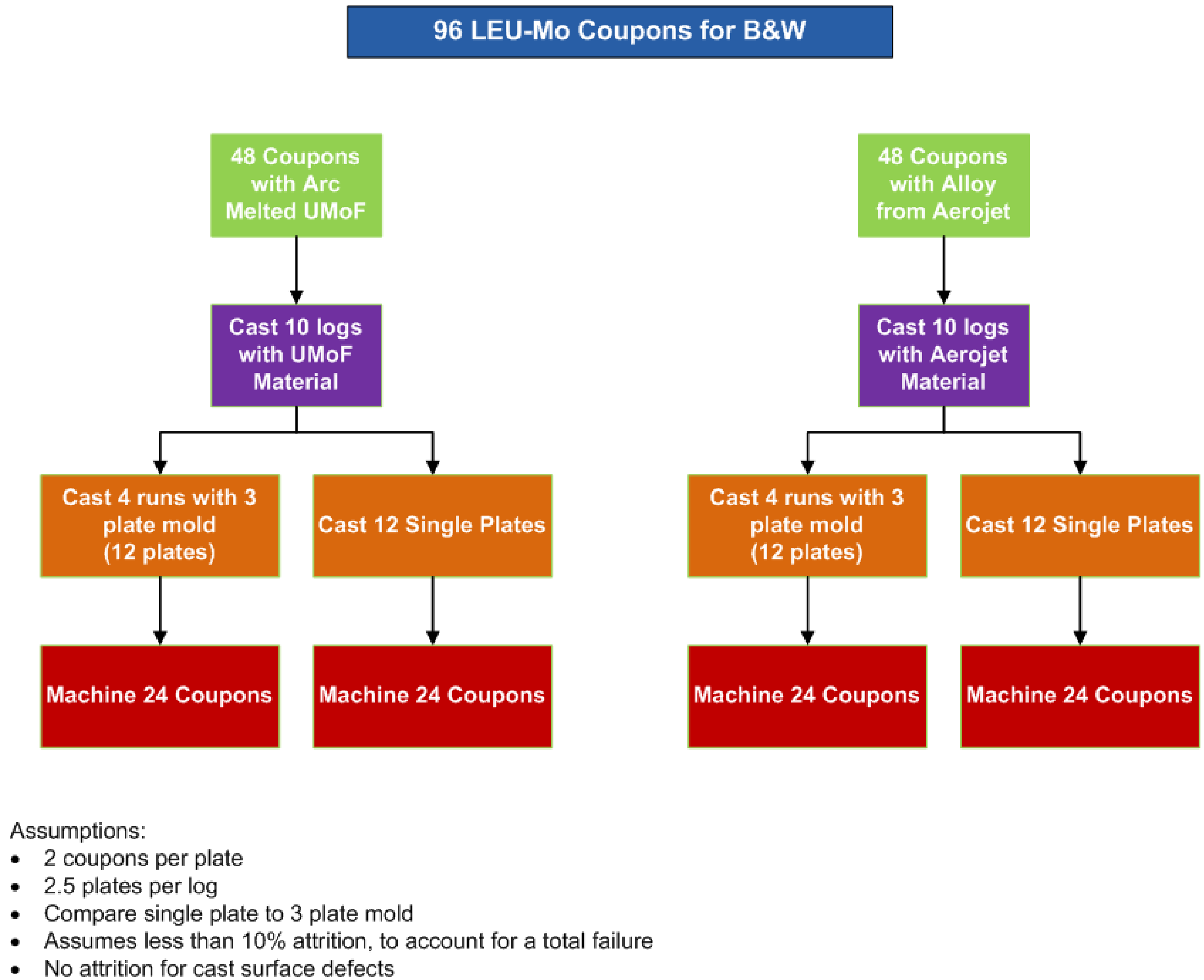


Figure 3: Limited Production Facility Experimental Plan

3. Progress of Experimental Plan

In 2012, Y-12 began fabrication of LEU-Mo coupons for the Limited Production Facility (LPF) campaign using a pre-alloyed uranium (U)-Mo feedstock to downblend with the highly enriched uranium (HEU). This campaign compares two different casting molds, a single plate mold and a multi-plate mold, and two sources of U-Mo alloy feedstock, an arc melted UMoF and a VIM cast vendor supplied UMoF.

This year, Y-12 focused on the arc melted UMoF portion of the study. Y-12 completed fabrication of the entire arc melted UMoF feed stock needed for this experimental plan. This method had a rejection rate of approximately two percent. Y-12 cast eight logs with the arc melted UMoF. At the date of this report, the chemical analysis was available on seven of these eight logs. Of the arc melted UMoF feedstock, the twelve single plate castings and subsequent twenty-four coupons are complete. At the date of this report, the chemical analysis was available on eleven plates.

Table 1: Process ID Chart for V0P8 and V0P9 and *Table 2: Process ID Chart for V1WP and V1WR* display the process flow charts for the twelve cast plates and the twenty four coupons. Two logs were blended to provide the feed material for six plates. Each plate yielded two coupons.

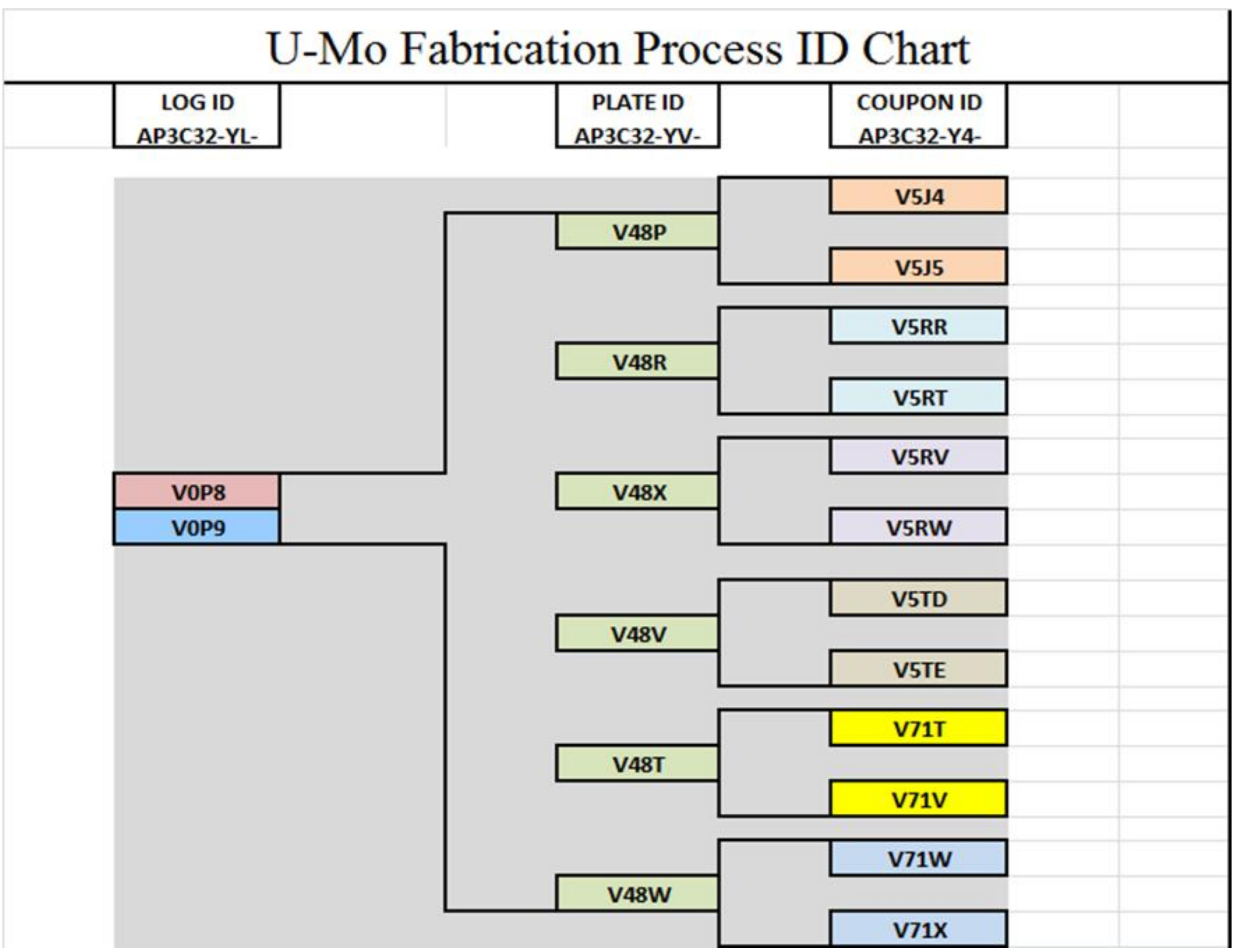


Table 1: Process ID Chart for V0P8 and V0P9

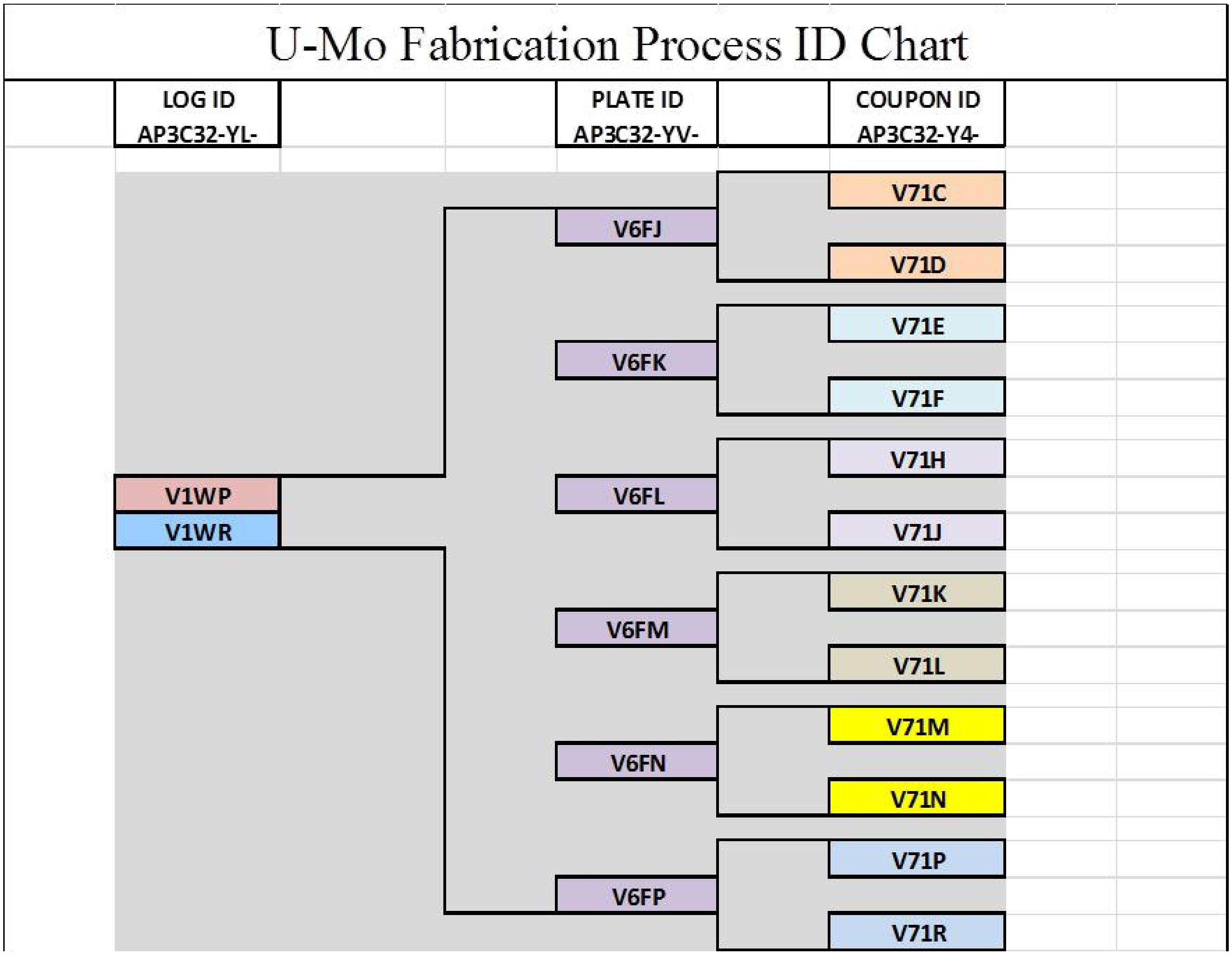


Table 2: Process ID Chart for V1WP and V1WR

Available chemical analyses results for the log casting with arc melted UMoF are shown in *Figure 4: Molybdenum Distribution in Log Casting*, *Figure 5: Uranium 235 Distribution in Log Casting*, and *Figure 6: Carbon Distribution in Log Casting*. Based on the available data, *Figure 4* indicated that the Mo distribution range is smaller with the arc melted UMoF than with the previous process. Similarly, the U235 distribution is more precise. However, THA9 was below the desired U235 level. This can be adjusted prior to the plate casting by blending two logs. Another significant difference with the new levels is the lower carbon seen during the log casting. During the two step casting process previously used, carbon levels in the log casting would range from 500 to upwards of 700 ppm. *Figure 6* indicates that carbon levels are below 350 ppm.

Available chemical analyses results for the plate castings are shown in Figure 7*Figure 7: Molybdenum Distribution in Plate Casting*, *Figure 8: Uranium 235 Distribution in Plate Casting*, and *Figure 9: Carbon Distribution in Plate Casting*. These analyses depict samples that are taken immediately after the plate is cast and prior to machining. This analysis is used to determine if the success of the casting, meaning this sample could indicate non-mixing or an unsuccessful downblend. *Figure 7* indicates that the more precise Mo distribution continued into the plate casting. While V48X is still well within the tolerance, the value seems lower than the other five plates made with the same starting feedstock. The plate will be sampled after machining, which will provide additional data. *Figure 8* displays the U235 content for the drilled plate samples. Based on the group, V6FP seems to be an outlier. This could be due to a contaminated sample or a local region of inhomogeneity. The plate will be sampled after machining, which will provide additional data. Figure 9 displays the carbon distribution of the drilled plate samples. Most carbon levels analyzed lower than 500 ppm C. This is a significant improvement over the previous casting process, which yielded carbon levels in the 700 to upwards of 900 ppm.

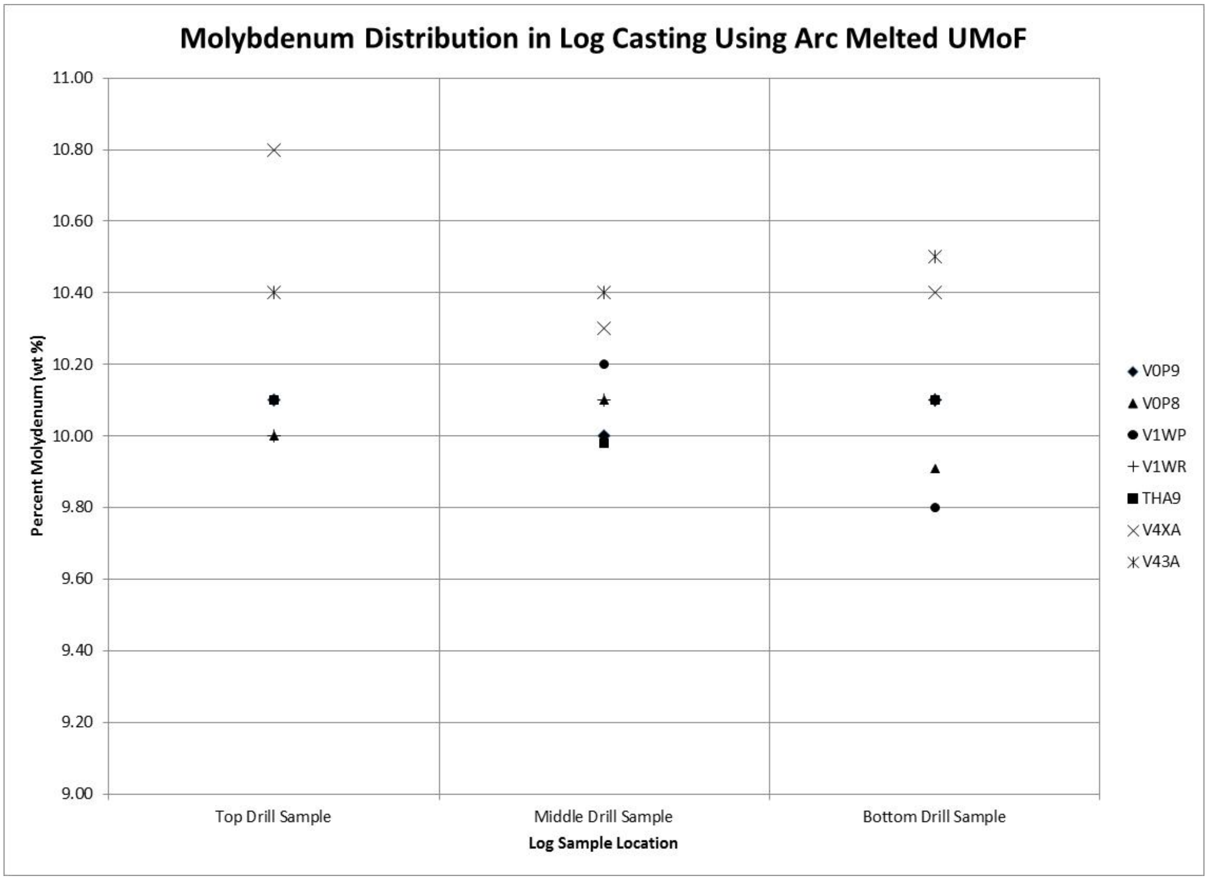


Figure 4: Molybdenum Distribution in Log Casting

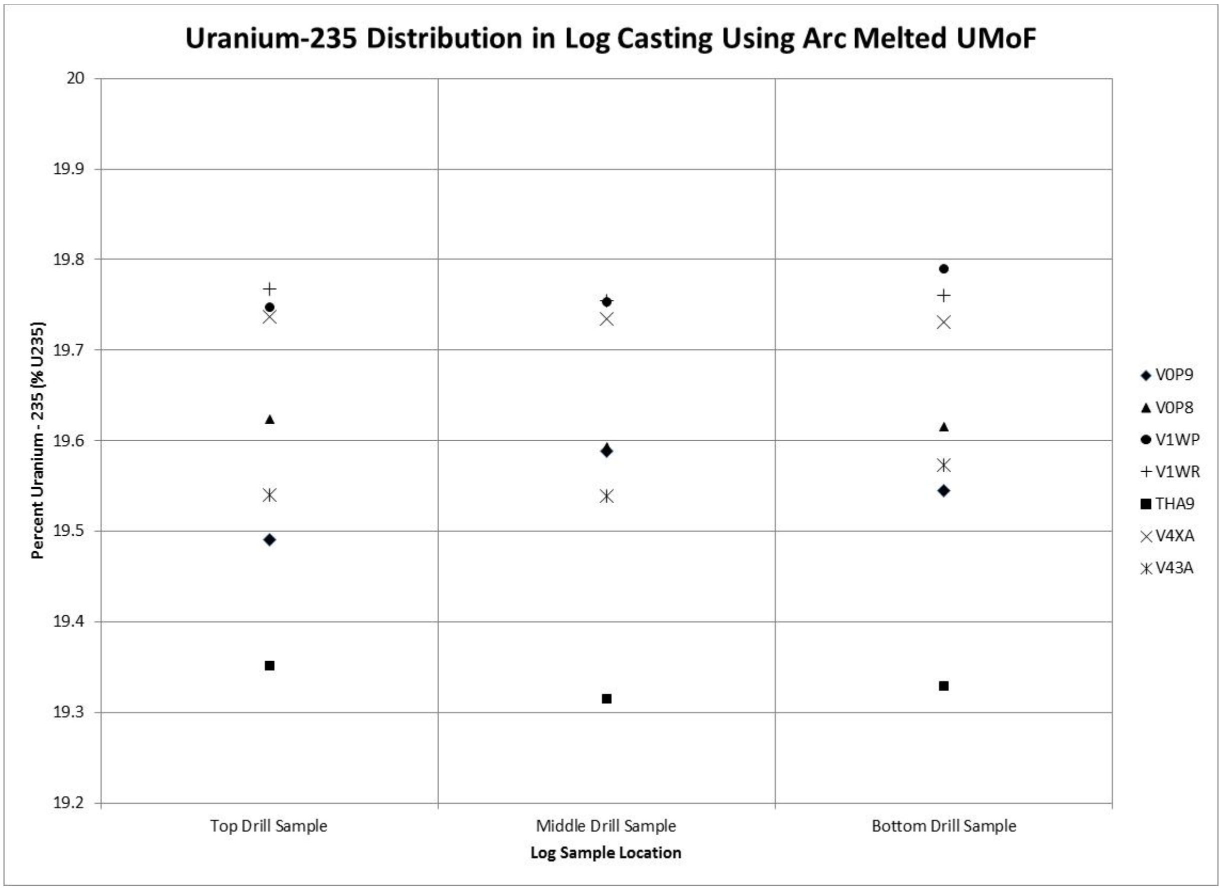


Figure 5: Uranium 235 Distribution in Log Casting

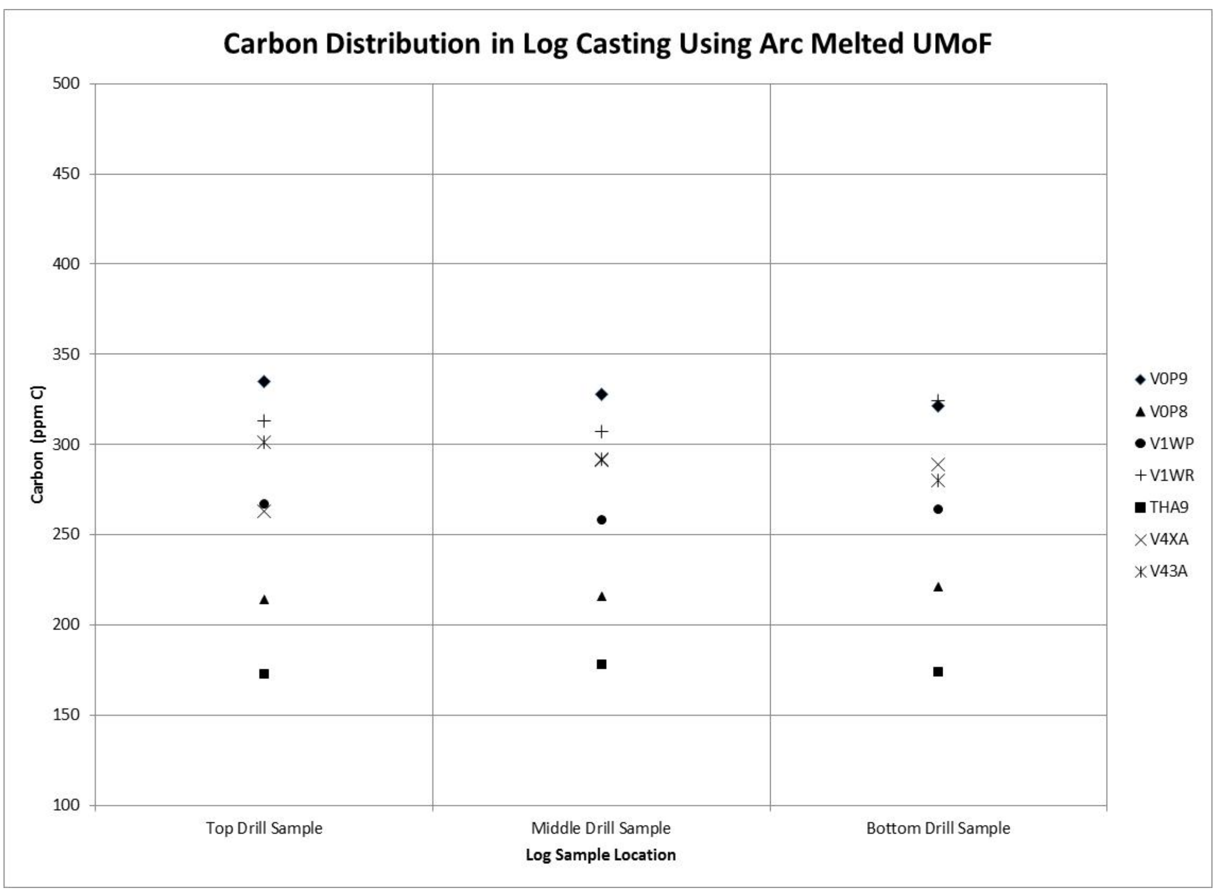


Figure 6: Carbon Distribution in Log Casting

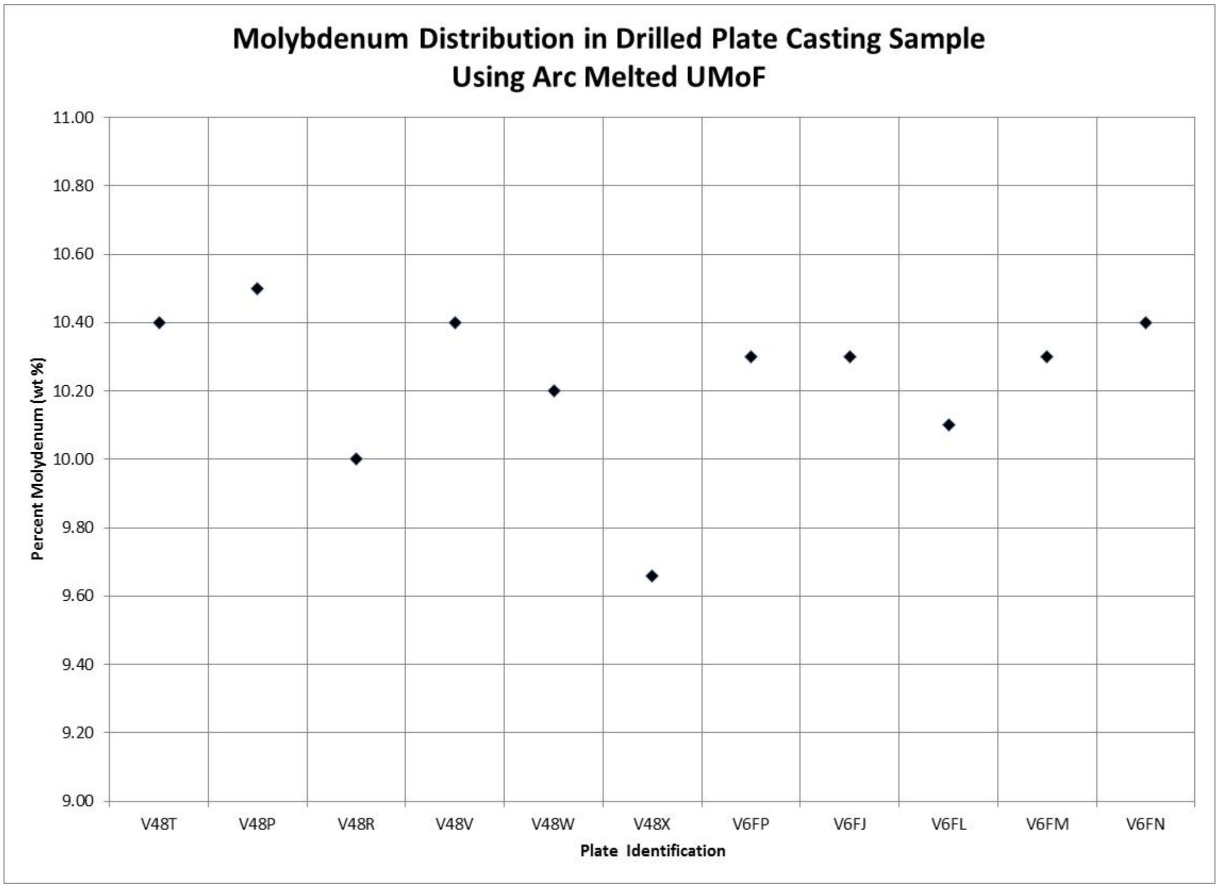


Figure 7: Molybdenum Distribution in Plate Casting

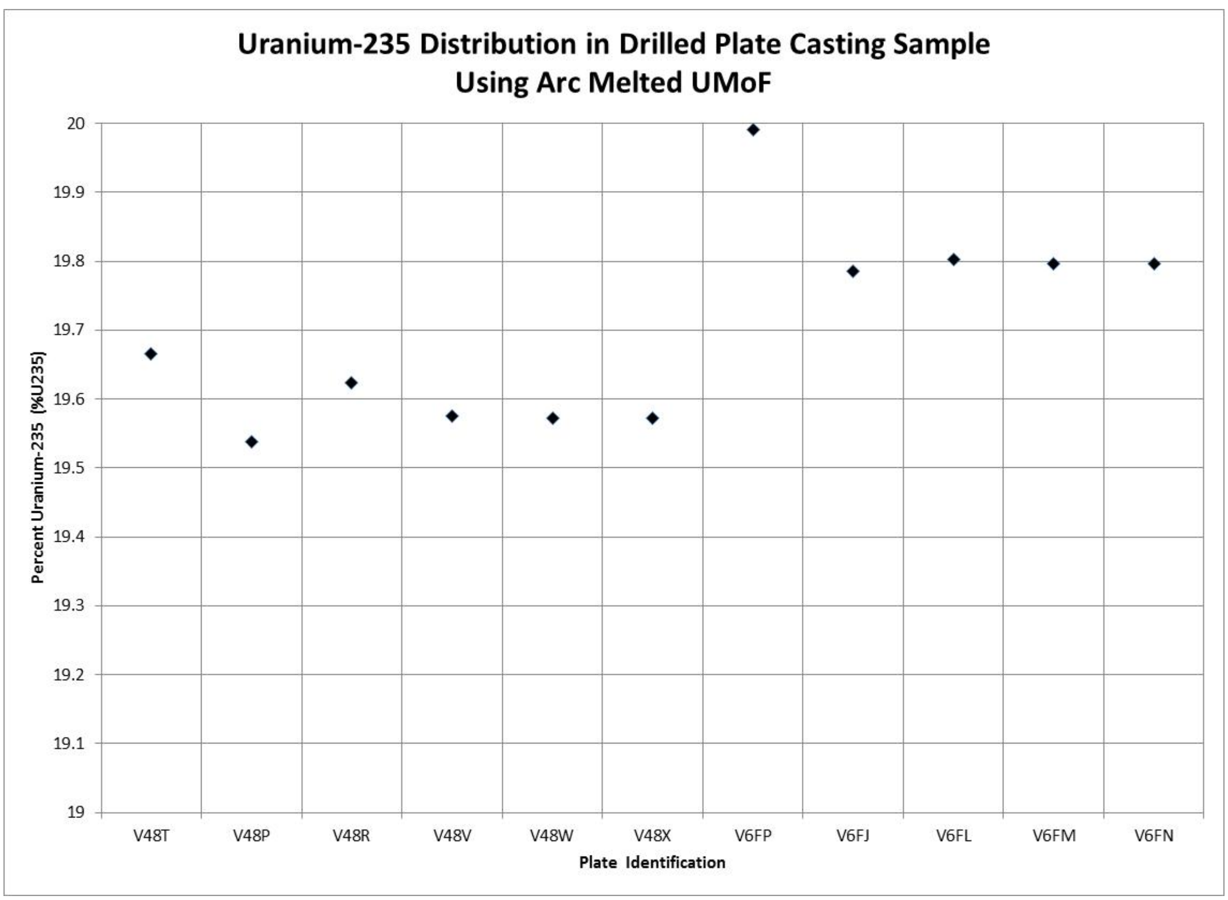


Figure 8: Uranium 235 Distribution in Plate Casting

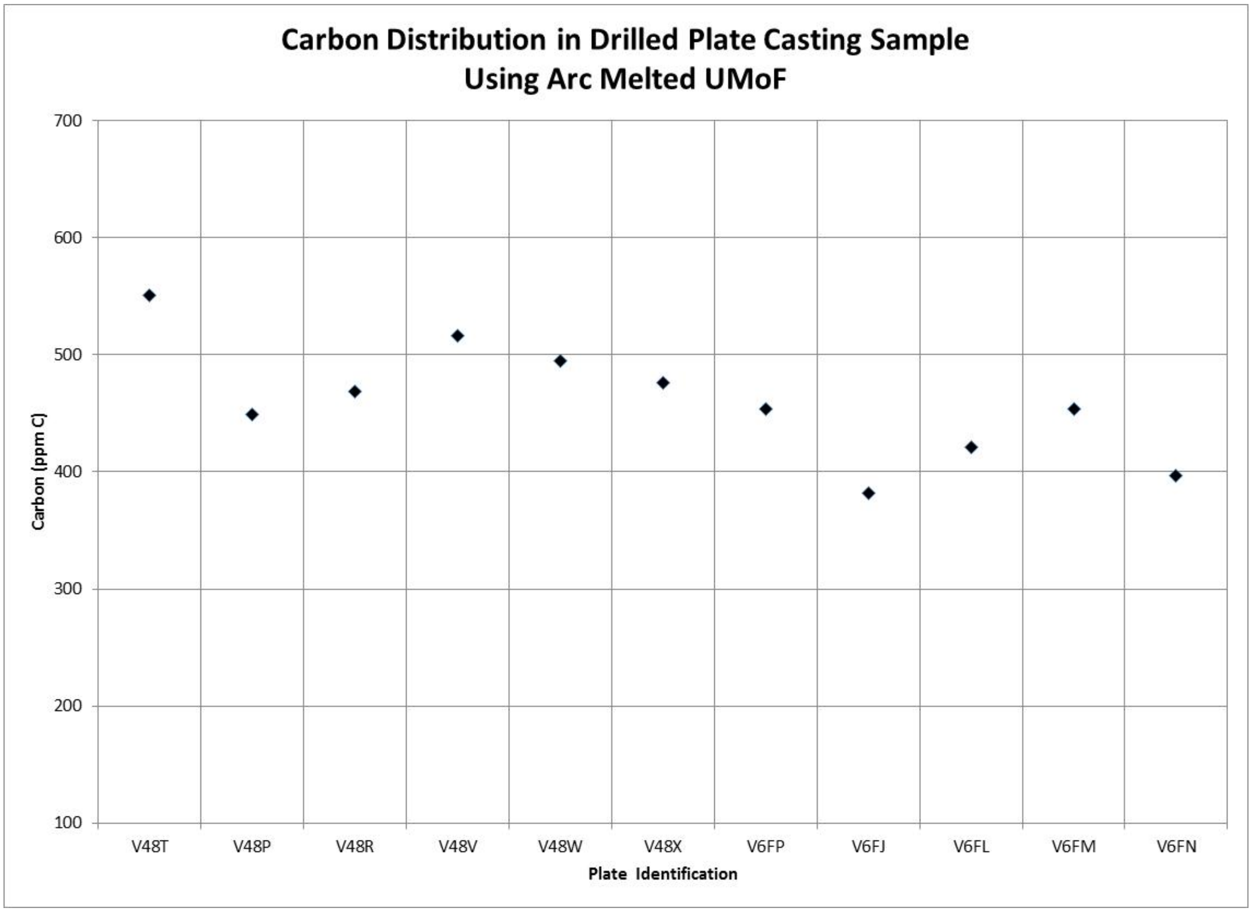


Figure 9: Carbon Distribution in Plate Casting

4. Summary

In 2012, Y-12 began fabrication of the LPF coupons using a pre-alloy diluent feedstock. Based on preliminary results, the new process appears promising in process control and optimization. In 2013, Y-12 will continue the fabrication and compare the two pre-alloyed diluents feedstock in processing, such as cycle time, and in costs impacts.