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CHALK RIVER LABORATORIES DEMONSTRATION OF SLOWPOKE-2 FUEL FABRICATION FOR HEU CORE CONVERSIONS

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ABSTRACT – As part of the Global Threat Reduction Initiative, highly-enriched uranium-fuelled reactors located at civilian sites worldwide are being converted to use low-enriched uranium fuel. SLOWPOKE-2 research reactors were originally designed to use highly-enriched uranium fuel and some of the operating reactors have yet to be converted to low-enriched uranium fuel. The Chalk River Advanced Fuel Technology sections at Atomic Energy of Canada Ltd. have developed processes to fabricate low-enriched uranium cores for the SLOWPOKE-2 reactor. This paper briefly describes the development of pellet fabrication and element fabrication activities for low-enriched uranium SLOWPOKE-2 cores, and highlights AECL's capabilities in this field.

1. Introduction

The SLOWPOKE-2 is an Atomic Energy of Canada Ltd. (AECL) designed research reactor with a maximum thermal power of 20 kW. The reactors are mainly used for neutron activation analysis, neutron radiography (where equipped), and for nuclear education [1]. Of the seven SLOWPOKE-2 reactors built, five remain in operation [2]. The original cores for the reactors were fuelled with highly-enriched uranium (HEU) alloyed with, and clad in, aluminum. Two of the SLOWPOKE-2 reactors have since been converted to low-enriched uranium (LEU) cores consisting of uranium dioxide (UO_2) fuel pellets clad in Zircaloy-4, while the remainder of the reactor cores are of the original design [1].

The Government of Canada is a participant in the Global Threat Reduction Initiative (GTRI). One of the GTRI's goals is to convert civilian research reactor and isotope production facility fuels from HEU to LEU [3]. In anticipation of future HEU SLOWPOKE-2 core conversions, the Chalk River Advanced Fuel Technology (CRAFT) sections at AECL have developed the capability to fabricate SLOWPOKE-2 pellets and elements. The CRAFT Ceramics and Element and Bundle Assembly sections are well acquainted with fabricating CANDU type fuel on small and pilot scales. This paper describes how we have adapted our established processes to produce SLOWPOKE-2 fuel to specification.

2. SLOWPOKE-2 Pellet Fabrication

In lieu of using expensive LEU oxide powder to fabricate SLOWPOKE-2 pellets, natural UO_2 powder, which conforms to the SLOWPOKE-2 powder specification, was used for fabrication tests. Fabrication of the pellets followed the typical flow sheet for UO_2 as illustrated in Figure 1.

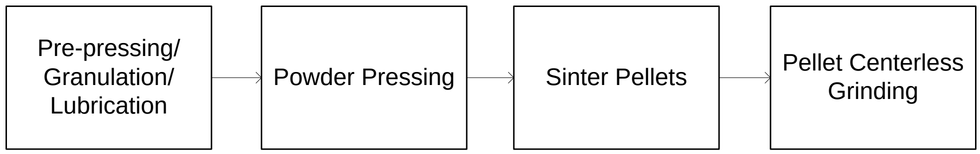
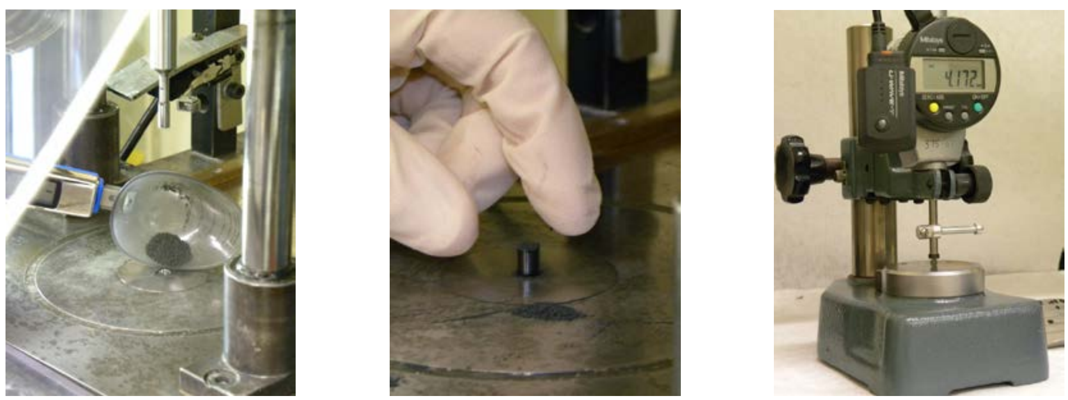


Figure 1 Pellet Fabrication Flow Sheet.

Powder was pre-pressed into slugs and granulated by pushing the slugs through a sieve. Zinc stearate lubricant was then added to the granules in the amount of 0.2 wt.%. The lubricated granules serve as the feed for final pressing. Green pellets were pressed to roughly half of the theoretical density of UO_2 using a hydraulically-compensated mechanical press and a custom made punch and die set. The green pellets were then sintered in a hydrogen atmosphere at ~1600°C for two hours. The sintered pellets were ground to final diameter using a centerless grinder. Pictures depicting various stages of pellet fabrication are provided in Figure 2. The average density of the fabricated pellets was 10.61±0.09 g/cm^3 and the length to diameter ratio was 1.3.



a) **b)** **c)**

Figure 2 Pellet Fabrication Pictures: a) Granule feed for final pressing b) Green pellet after final pressing c) Sintered pellet after grinding

3. SLOWPOKE-2 Element Fabrication

AECL has recently developed the necessary processes for complete fabrication of SLOWPOKE-2 LEU fuel elements. A high level flowchart of activities is presented in Figure 3. The basic process is to procure and inspect supplies (pellets, sheaths, and endcaps), and then prepare them for element fabrication. Pellets are formed into stacks of a pre-calculated length, and their length and weight recorded. The sheaths are cut to length to ensure the completed element meets the design requirements, and the sheath ends are prepared for welding using a computer numerically controlled (CNC) lathe. The final sheath length must consider the axial gap, pellet stack length, endcap heights, and account for weld upset during the welding process. All inspection measurements performed before, during, and after fabrication are performed using wireless data acquisition systems and stored electronically.

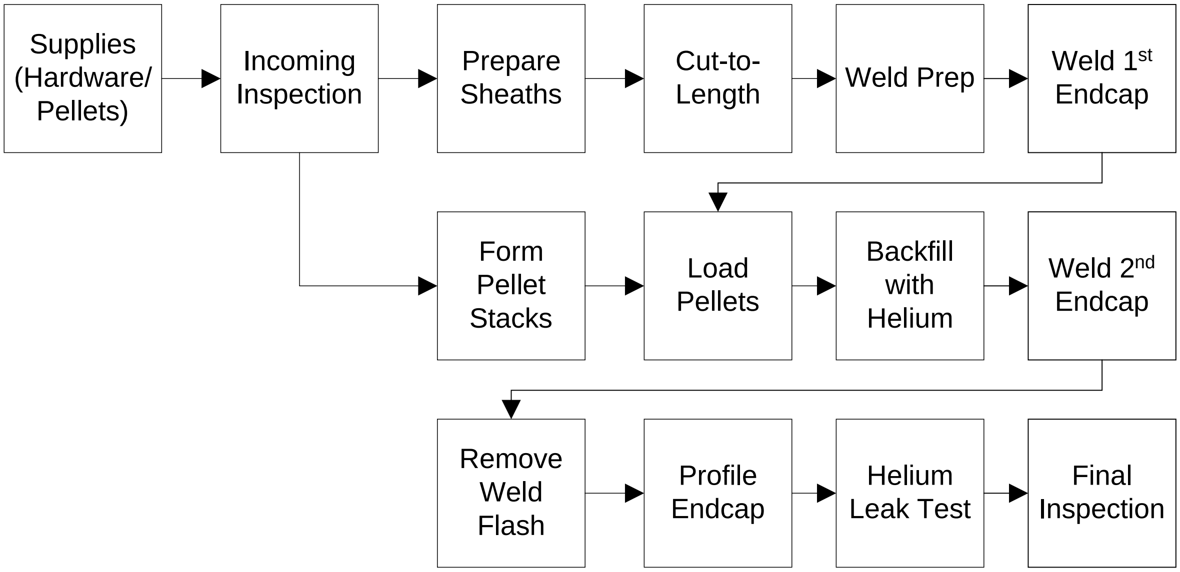


Figure 3 Simplified Element Fabrication Flowchart

Resistance welding of the endcaps to the sheath is a challenging process step with a high level of quality control and monitoring [4]. The weld is performed on a resistance welder that was built for CANDU fuel fabrication, but then recently modified to accommodate the smaller SLOWPOKE-2 diameter elements (~ 5 mm), compared to standard and experimental CANDU fuel (~ 11.5 – 20 mm). Several welding parameters were varied (including number of weld cycles, heat input, sheath stick-out, sheath preparation, and weld upset) until a weld was produced that met all design requirements. An acceptable weld must be stronger than the original sheath and various non-destructive (helium leak check and visual inspection) and destructive (tensile test, peel test, gas puncture, and metallography) examinations were performed to test the weld quality. Figure 4 is a metallographic cross-section of one side of the endcap to sheath weld; in the welded area, notice the absence of large discontinuities, and the transverse weld thickness is larger than the sheath thickness.

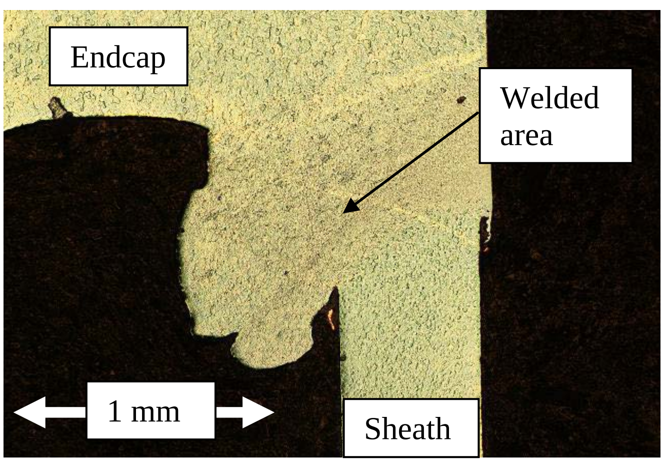


Figure 4 Typical Metallographic Cross-Section of the Endcap to Sheath Weld

The endcap to sheath weld is known as a “special process”; once the weld is performed there is no simple non-destructive method of completely determining the weld quality. Therefore, once repeatable acceptable welds were obtained, these optimized welding parameters can be qualified. Weld qualification involves performing a pre-determined number of welds and destructive weld examinations. Statistical analysis is then performed to provide confidence that welds performed using the qualified process always meet all technical requirements [5]. Furthermore, when actual elements are fabricated, process checks will be performed before and after each day of welding to confirm acceptable machine performance. Weld parameters are also recorded and trended electronically to monitor for inconsistencies.

4. Conclusions

The CRAFT labs have many years of experience manufacturing experimental CANDU fuel with various element designs, pellet sizes, and compositions. This expertise has recently been applied to the development and qualification of processes specific to the fabrication of SLOWPOKE-2 LEU fuel elements. This capability ensures AECL maintains its expertise and skills in anticipation of future HEU SLOWPOKE-2 core conversions as part of the Global Threat Reduction Initiative, and for re-fuelling of LEU cores as required.

5. References

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