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LMFBR Plutonium Fuel Development and Fabrication

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Summary

This technical paper summarizes the history, development and fabrication of Fast Flux Test Reactor driver fuel pins at The Babcock and Wilcox Company's Parks Township Fabrication Facility in Western Pennsylvania. The basic process steps are described with emphasis placed on the development efforts which led to the specific production practices used today. Typical conventional production equipment is shown to highlight the standardization which has taken place. Years of continuous production operation have enabled testing and refinement of techniques and equipment systems to the extent that manufacture of LMFBR fuel is now performed routinely within the constraints of all regulatory safety and safeguards criteria, including ALARA (As Low As Reasonably Achievable) control philosophy.

History

The Babcock and Wilcox Company maintains its FFTF fuels fabrication plant at Parks Township in Western Pennsylvania.

(SLIDE 1)

Since 1972, more than two core loadings of driver fuel have been fabricated for use in the Fast Flux Test Facility being built at Richland, Washington as part of the U.S. LMFBR program. Babcock and Wilcox began actual participation in the FFTF LMFBR fuels procurement program with the manufacture of 500 qualification fuel pins from November 1972 through March 1973. This qualification was followed by a production order release in March of 1973 from our customer, Westinghouse Hanford Company.

In November 1975, the contract for the first FFTF core was completed with delivery of over 20,000 fuel pins. In January 1976, a second contract was received from Westinghouse Hanford for the manufacture of 35,500 fuel pins for FFTF Cores 3 and 4. Approximately two-thirds of this second production contract has now been completed.

The Babcock and Wilcox plutonium fuel fabrication plant presently has the capability of producing and certifying 1000 FFTF fuel pins per month. The facility consists of a 5600 ft^2 powder and pellet fabrication area, a 4400 ft^2 assembly and inspection area, plus support areas for conversion, scrap recovery, and laboratories.

Development of Standard Fabrication Processes

1. Plutonium Oxide Preparation

   Upon receipt, government-furnished plutonium oxide is sampled by Nuclear Materials Control to determine any shipper-receiver difference and by Quality Control to verify the plutonium assay, isotopic analysis and the impurity levels. The material is then released to the Manufacturing Department for mixed oxide blending.

   One of the most important process improvements was realized at this step. Prior to mixed oxide blending, PuO_2 was conventionally calcined, ballmilled, and screened to remove halogen impurities and to improve powder activity for pressing. These preparatory steps were costly due to the man-hours involved and relatively high losses. A significant percentage of total personnel radiation exposure was attributed to the handling of unmixed PuO_2 during these process steps. Through cooperative efforts with PuO_2 suppliers, the halogen impurities were removed by improved calcining prior to receipt at our facility. Subsequently, after a thorough evaluation and qualification program, approved by our customer, we were permitted to eliminate the initial PuO_2 preparation step.

2. Mixed Oxide Preparation

   At this stage, PuO_2, depleted uranium oxide powder (UO_2), and recycle mixed oxide powder are mixed in a V-shell blender. (Sub-lot size is nominally 28 kilograms.) The UO_2 powder is received from the Babcock and Wilcox Low Enriched Uranium Facility in Apollo, Pennsylvania. Recycle powder comprises up to 50% of the final batch mix.

   After brief sublot mixing, the PuO_2-UO_2 recycle powder is jetmilled to reduce particle size and thoroughly blend the oxides. Powders of different origin which have different physical characteristics can be reconstituted at this step to a powder mixture of uniform physical characteristics.

The jetmill operation is another important process improvement which overcame labor-intensive and sometimes unreliable ballmilling steps to achieve required homogeneity.

(SLIDES 2 & 3) By closely controlling the inert gas pressure and feed rates, it was shown that microhomogeneity comparable to co-precipitated mixed oxide could be achieved, and, at the same time, throughput rates could be improved. (SLIDES 4 & 5) Powder throughput rates greater than five kilograms per hour are maintained during the operation. This important improvement is readily adaptable to remote operation.

Mixed oxide powder that has been jetmilled can be sieved to break up any plutonium enriched zones that may occur. However, due to the recent advanced developments in the jetmilling process, this step is now optional. Homogeneity after jetmilling is now comparable to powder that has been jetmilled and screened.

In-process control samples are taken at this point from each 50-60 kg lot to verify plutonium assay and impurities.

3. <u>Ceramic Processing</u>

The first step in ceramic processing is the addition of organic material for control of density and oxygen-to-metal ratio (O/M). Due to a third process improvement, the operation consists of adding the organic material by mechanically blending batches in a Turbula blender (SLIDES 6 & 7). Conventional blending using V-shell or other rotary blenders did not adequately mix the light weight, small percentage organic additions with the heavy mixed oxide. It was found after months of development that the unique motions of the Turbula provided an excellent mixture of the hetrogeneous materials. Turbula-mixed batches are recombined in a V-shell blender to re-establish lot identity.

The mixed oxide powder is then slugged to approximately 50% of theoretical density, granulated and sieved in order to improve feed characteristics to the pellet press dies.

Following these process steps, additional organic is added to the mixed oxide as a die lubricant. Press feed batches of up to twenty-eight kilograms are then mixed in a V-shell blender. The granular mixed oxide is fed into a Hydromet hydraulic press and fuel pellets formed (SLIDES 8 & 9). Pellets are pressed at approximately 2.5 tons/square inch to approximately 75% of theoretical density. Here is where the fourth process improvement was realized. The small cross-sectional size of the FFTF pellets requires relatively low hydraulic press pressure to achieve density. Consequently, the highest press precision is needed at the low range of the dual acting press. Precision low-pressure loop modifications provided by Hydromet enable us to meet the stringent density control limits reliably.

The unfired (green) pellets are charged to a pre-sintering furnace under an argon-hydrogen atmosphere to remove the organic binder and die lubricant.

Final pellet sintering is accomplished in a continuous push-type furnace. Pellets are loaded into molybdenum boats and are pushed through the furnace which is heated to a temperature of greater than 1500°C. The final sinter furnace atmosphere is also an argon-hydrogen mixture.

In addition to increasing the pellet density, the sintering process is controlled to meet sub-stoichiometric O/M ratio and pellet size specifications.

In fact, temperature, stoking rate, gas mixture, and gas flow rate are all closely controlled to meet final pellet attributes. In-process control samples are pulled as the boats are discharged from the furnace.

Once the entire mixed oxide pellet lot is sintered, Quality Assurance takes certification samples for plutonium assay, uranium assay plutonium isotopic analysis and homogeneity.

Pellets are then "dry-ground" using a Royal Master centerless grinder (SLIDES 10 & 11). Here another important process improvement took place. Conventional wet grinding creates a sludge that must be wet processed chemically prior to recycling. Recently developed dry grinding using dust collectors enable direct recycle of all grinder dust. After grinding, pellets are checked by Quality Assurance for impurities, dimensions, density and visual appearance.

4. Pin Loading and Welding

Upon completion of all tests, Quality Control must issue a formal release of pellet lots for pin loading.

The pellets are loaded into the previously prepared and inspected cladding tubes which are inserted into a sphincter aperature mounted on the glovebox. Inside the glovebox, fuel pellets are weighed and then placed onto a loading fixture where the length of the fuel column is measured. Uranium oxide insulatory pellets are added to both ends of the fuel column, and then the fuel stack is inserted in the tube, through the sphincter.

During loading of a pellet lot, Quality Assurance takes lot certification samples for O/M, Total Gas Release (TGR), and Moisture measurements.

Prior to welding the second end cap to the cladding, the end of the cladding must be vigorously cleaned to remove all contamination and to ensure a high integrity weld.

Once the ends are cleaned, up to eighty fuel pins are placed into a welding chamber. The chamber is then evacuated and backfilled with high purity helium gas. Tungsten inert gas welding of the second end cap is then performed using automated electronic welding controllers. Welding equipment and processes have been developed to the extent that less than 0.6% of welds are reworked or rejected.

5. Fuel Pin Finishing

To determine if any leaks are present in the welded pins, they are placed in a vacuum chamber and the chamber is evacuated. The presence of helium in the detector indicates a leak.

A very stringent dimensional and visual inspection is then performed by Quality Control personnel. Items inspected include fuel pin length, concentricity, and alignment of the holes in the end cap. Visual inspection checks, include surface defects, scratches, inclusions, and pits. All items must meet strict customer specifications prior to acceptance. Following dimensional and visual inspection, the fuel pins are X-rayed to determine if any porosity or lack of fusion is present in the weld zone and to verify component placement. Accepted pins are then final cleaned which takes six separate steps. The pins are placed in a hot alkaline cleaner, rinsed in tap water, immersed in nitric acid, and sequentially rinsed in tap water, cold deionized water and finally hot deionized water. Cleaning by this process removes all impurities and assures the residual fluoride and chloride are within specified limits. Up to 100 pins can be cleaned in the specially designed cleaning fixture, which ensures no contact between pins.

Final Quality Control inspection for surface cleanliness and residual fluoride and chloride is performed.

Certified pins are released by Quality Assurance for loading into shipping containers. Just prior to loading, the Health and Safety Section smears each pin to be certain no contamination is present. Each pin is placed into a polyethylene tube within the shipping container which holds 120 fuel pins. Pins are then shipped by government transportation to Hanford Engineering Development Laboratory (HEDL) in Richland, Washington for bundle assembly, storage and/or insertion into the FFTF development breeder reactor.

Besides the stringent Reactor Development Technology (RDT) quality requirements, FFTF plutonium breeder fuel must meet ever increasing Federal and State safeguards and health and safety requirements. Although our safeguards program is considered sensitive information and therefore cannot be described in detail, it can be said that we do maintain accountability and security programs which satisfy or exceed all existing government regulations.

The ALARA philosophy is stressed in all aspects of health and safety and it is continually demonstrated that exposures to personnel are well below required levels.

This presentation has attempted to provide a brief summary of Babcock and Wilcox FFTF manufacturing operations stressing where developments have led to a commercially acceptable and relatively economic processes. Although support operations such as recycle, scrap recovery, and reconversion, have not been addressed, it is hoped that you generally understand how breeder fuel manufacture is now routinely performed at Babcock and Wilcox. I would be glad to expand on any area covered and to answer questions following this meeting. Thank you for your attention.