CRITICAL EXPERIMENTS WITH MIXED OXIDE FUEL

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One alternative for the disposal of excess (~100 MT) weapons-grade plutonium (<7 wt% Pu-240) is to burn it as mixed fuel in power reactors (PWRs).[1] The plutonium remaining in discharge fuel would be denatured by increased Pu-240 content (>20 wt% Pu-240) resulting from long residence times. The increased cost from the introduction of plutonium into the fuel cycle would be partially offset by the sale of electricity. Early studies of the use of plutonium in PWRs showed the advisability of a number of modifications in plant design and operation. Several considerations which relate to core physics and safety are (a) higher fissile-to-fertile ratios, (b) lower beta effective, and (c) enhanced use of burnable poisons. Recent studies emphasize the use of distributed Er_2O_3 burnable poison, an important effect of which is to make the temperature coefficient of reactivity more negative.[2] This change occurs because the negative effect of the twin capture resonances in Er-167 at 0.5 eV cancel the positive effect of the 0.3-eV fission-capture resonance in Pu-239.

It is prudent to back up core physics analyses with critical experiment measurements of power shapes, coefficients of reactivity, and critical states. Such analyses[2] for the proposed System 80+ plutonium burner were benchmarked by comparison with results from the Saxton,[3] WREC,[4] and Rensselaer Polytechnic Institute (RPI)[5,6] borated and unborated critical experiments. The Saxton experiments used fuel with relevant fuel composition (6.6 wt% PuO_2 + $U_{nat}O_2$, 90.5 wt% Pu-239 + 8.5 wt% Pu-240) and the RPI experiments used normal enrichment UO_2 fuel with relevant Er_2O_3 concentrations. No critical experiments have yet been conducted for fuel with weapons-grade plutonium and Er_2O_3 together, at various dissolved boron levels, and for specific fuel assemblies such as the ABBCE fuel assembly with its five large water holes. Here we examine the technical considerations involved in carrying out such experiments at the RPI Reactor Critical Facility (RCF). The topics dealt with are the core, the measurements, safety, security, radiological matters, and licensing. It is concluded that the experiments are feasible at RPI.

A representative core could consist of an ABBCE 16x16 fuel assembly surrounded by a 4.81wt% enriched UO_2 driver lattice of SPERT(FI) fuel pins, all in 1/8 core symmetry. All pins would be 6.75wt% Pu in HM + depleted UO_2 at 0.2 wt% tails, 93.5 wt% Pu-239 + 6.5 wt% Pu-240 and normal diameter.[2] Core support, water treatment, control, and instrumentation would be normal.[5] The experiments would be conventional as follows:

a. approach to critical,
b. control rod worths,

c. isothermal temperature coefficient of reactivity,
d. fuel pin worth,
e. void coefficient of reactivity,
f. pin-wise power shape, and
g. absolute power calibration, all at various boric acid levels in the water up to about 300 ppm.

Some of these experiments are carried out solely to satisfy Tech Spec requirements as startup measurements to verifying pre-calculated safety parameters. The control rods are fully withdrawn in the experiments after (b), so all measurements are done on rising periods. The entire campaign of experiments is estimated to involve about 100 periods performed in one calendar month. The total energy production in the campaign would be about 25 W per fuel pin, so the fuel is essentially unchanged. There is negligible fission product inventory at any time, and after a few days the radiation from the pin will decay back to previous levels.

RCF security must be upgraded to Category 1 in accord with 10CFR73.60.[7] Two or more round-the-clock guards are required with adequate training and drills. Required modifications to security hardware include (a) three-strand wire on the top of the security fence, (b) enhanced motion sensors, and (c) bullet-resistant glass on the guard building. The radiological safety requirements at RPI meet or exceed the requirements of 10CFR20. The only upgraded hardware for radiological safety would be better alpha monitoring sensors. The Emergency Procedures should be modified to include ruptured PuO_2 fuel pins. It is anticipated that no information security would be required.

Document submittals would include

a. Amendments to License CX-22 and technical specifications,
b. Amendments to security plan and procedures (10 CFR 73 App C),
c. Modifications to the Safety Analysis Report to note the presence of Pu (no change in the design basis accident, safety limits, or consequences are required),
d. Modified emergency procedures.

In summary, critical experiments at the RCF on weapons-grade plutonium mixed-oxide fuel assemblies appear to be technically and administratively feasible. They would be of appropriate quality and at relatively little cost.[9]

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