UAC-7022

ANL-FGF-399

(Presented at 15th Pacific Coast Regional Meeting, American Ceramic Society, Seattle, Washington, October 17-19, 1962)
also for pub. in suitable journal.

PRELIMINARY IRRADIATIONS OF PuC AND UC-PuC

by

J. H. Kittel, R. Carlander, L. A. Neimark, O. L. Kruger, and R. C. Lied

Argonne National Laboratory

Nov. 1962

The irradiation of plutonium monocarbide is of interest because of the potential use of this fuel in small high temperature fast reactors. Since uranium monocarbide has been shown to possess excellent high temperature irradiation properties there is some basis for the hope that PuC will also have high temperature irradiation characteristics that are an improvement over the poor performance of most plutonium alloys. Mixtures of UC and PuC are of interest because they combine the good qualities of carbide fuels with the capability of internal breeding in a fast plutonium-fueled reactor.

In order to explore the irradiation behavior of carbide fuels containing plutonium, preliminary irradiations were made in the EBR-I reactor on the nominal compositions PuC and UC-20 w/o PuC. The carbon content of the arc cast specimens ranged from 4.75 to 5.73%. The plutonium content in the mixed carbide was varied from 17.2 to 27.8%. The irradiations were made in a fast reactor because of the "blackness" of PuC in a thermal spectrum. All of the PuC specimens were arc cast. The UC-PuC specimens were made both by arc casting and by pressing and sintering. The sintered pellets averaged 55.1% of theoretical density and contained an axial hole to accommodate a central thermocouple. All of the specimens were 0.300 in. in diameter and were nominally 1 in. long. The uranium in the UC-PuC specimens was enriched to approximately 93% U^{235} to enhance the rate of burnup. The specimens were made up into three full-sized EBR-I fuel rods. Two rods contained alternately specimens of cast PuC and mixed carbide. The third rod was made up entirely of pressed and sintered specimens of mixed carbide. Bonding between the fuel specimens and the stainless steel cladding was provided by a 0.030 in. NaK annulus. Typical specimens before irradiation are shown in Figure 1.

Sixteen cast specimens consisting of eight PuC and eight mixed carbide specimens were irradiated to burnups ranging from 500 to 770 Mwd/MT at central temperatures ranging from 370° to 650°C. Fifteen pressed and sintered pellets of the mixed carbide were irradiated to burnups ranging from 540 to 810 Mwd/MT and with central fuel temperatures ranging from 260° to 380°C.

The arc melted UC-PuC specimens showed superior fracture resistance over that of the PuC specimens. The mixed carbide specimens were removed from the rods either in one piece or broken into no more than two pieces. Subsequent

Work performed under the auspices of the U. S. Atomic Energy Commissio:

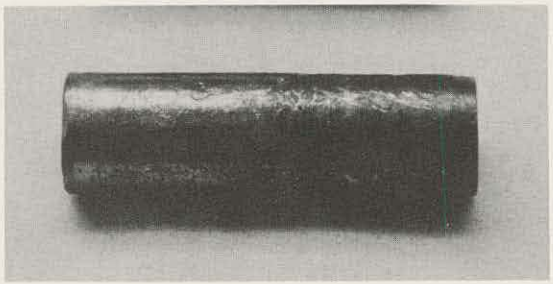
DISCLAIMER

handling in the hot cell, however, caused some of the specimens to break up into additional pieces. No conclusion could be drawn concerning a possible relationship between carbon content and fracture resistance in either the mixed carbide or the PuC. Dimensional changes were negligible in the cast specimens. Seven of the eight PuC specimens decreased in density with a maximum change of 1.44%. The remaining specimen showed an apparent increase in density of 0.44%. Seven of the eight UC-PuC specimens decreased in density with the maximum change being 1.57%. One specimen showed no apparent change in density. The surfaces of the PuC specimens were generally brighter than those of the UC-PuC specimens. Typical irradiated specimens of cast PuC and UC-PuC are shown in Figures 2 and 3, respectively.

All pressed and sintered mixed carbide pellets were removed intact from the rod in which they were irradiated. Two pellets were later broken on handling in the hot cell, but generally the pellets were very durable. Length increases of up to 0.015 in. and diameter increases of up to 0.004 in. were random and were not considered significant. Density measurements were not made on the pressed and sintered pellets because of the extensive open porosity. A typical irradiated specimen of pressed and sintered mixed carbide is shown in Figure 4.

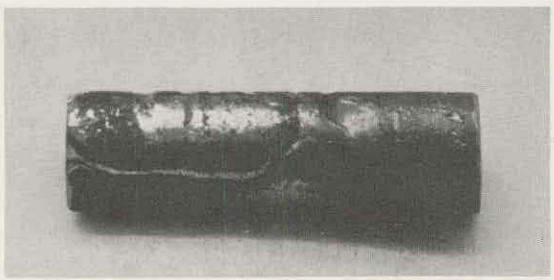
A measurement of fission gas release on one rod containing arc melted specimens was unsuccessful because of equipment failure. The measurement on the second rod containing arc melted specimens showed that gas release was 0.24% of theoretical. As might be expected, the gas release from the pressed and sintered pellets of mixed carbide was higher than from the cast pellets. The gas release in the rod containing sintered pellets was 12.01% of theoretical. The extensive open porosity in the sintered pellets is considered to be responsible for their much larger fission gas release. Sufficient gas was available from the sintered pellets to obtain a mass spectrometric analysis of the stable xenon and krypton isotopes and of Kr^{85}. It was found that 11.25% of the xenon was released and 19.09% of the krypton was released, giving the overall value of 12.01%. It is possible that either krypton diffused from the pellets more rapidly than xenon or the theoretical yield of krypton used in the calculation is low.

After the preliminary irradiations were made in EBR-I, we prepared a group of vibratory compacted specimens of fused PuC powder. The fuel is compacted to about 80% of theoretical density in a 2 in. length and 0.156 in. diameter. The compacted powder is contained in Nb-1 w/o Zr alloy Type 304 stainless steel tubing with a 0.009 in. wall. The first of these specimens is being irradiated in the CP-5 reactor with a maximum cladding surface temperature of 435°C and to date has achieved a burnup of approximately 11,000 Mwd/MT. This specimen contains 6.22 w/o carbon. A thermocouple is located adjacent to the surface of the specimen and from the temperature readings that we have obtained to date it appears that the specimen is performing satisfactorily.

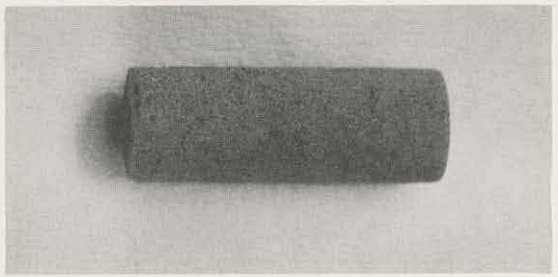


PuC
(Arc - Cast)

1 in.

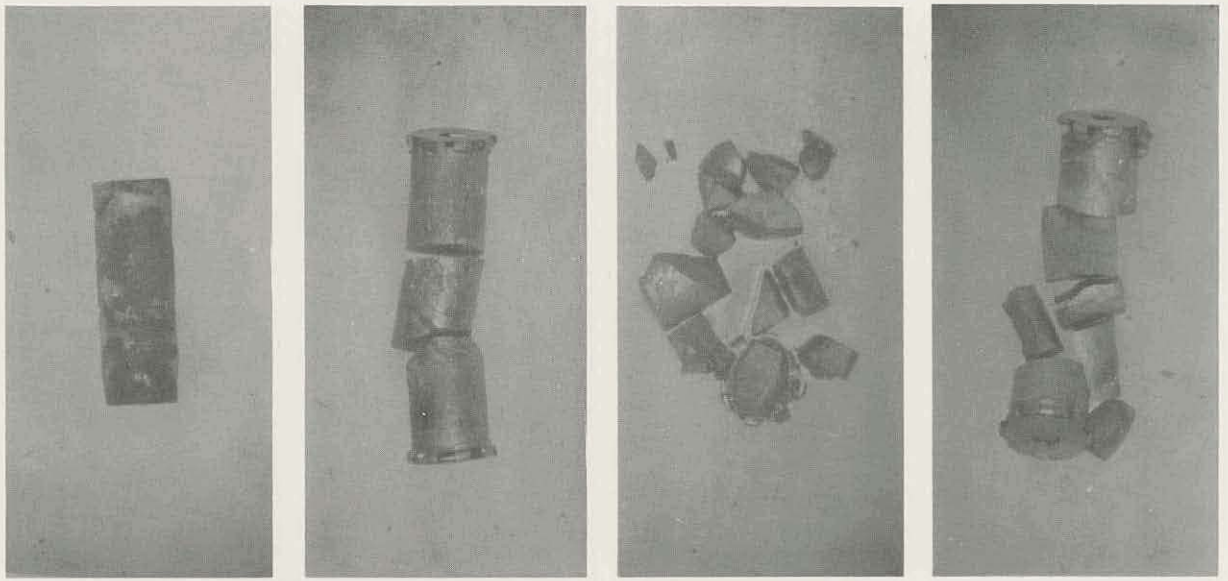


UC - 20 PuC
(Arc - Cast)



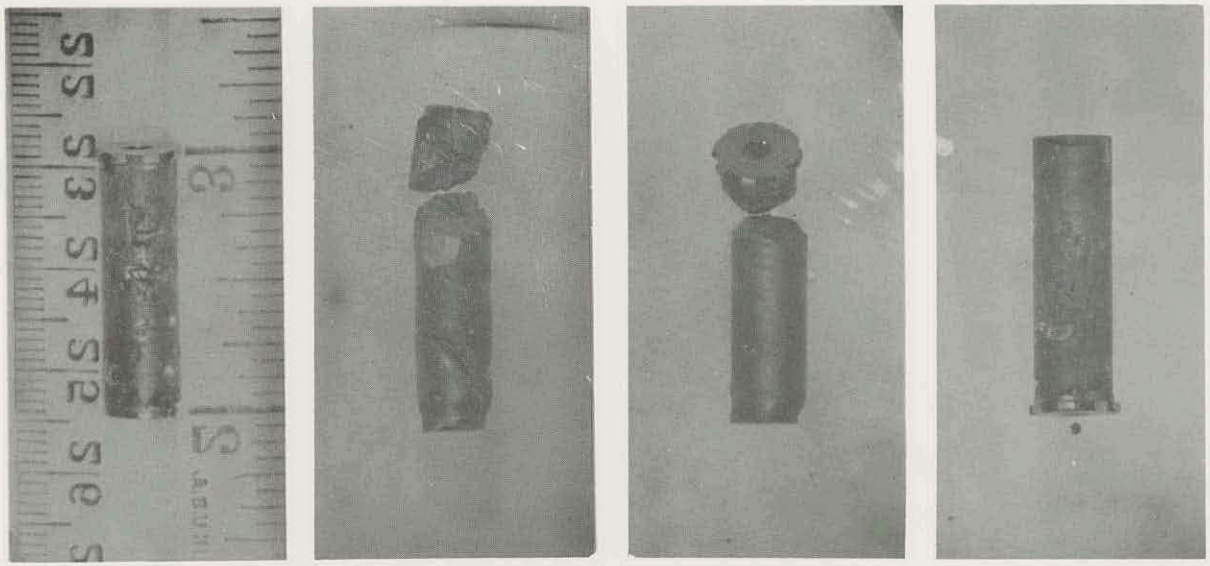
UC - 20 PuC
(Pressed and Sintered)

Figure 1. CARBIDE FUEL IRRADIATION SPECIMENS



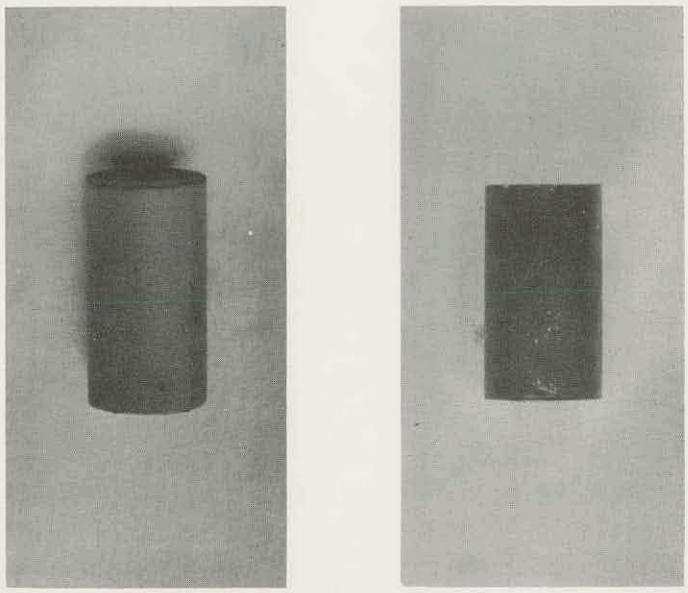
Burnup, MWD/MT	580	680	750	770
Cent. Irrad. Temp., ^{o}C	370	550	590	650
Density Change, %	-0.69	+0.66	-	-1.44
Carbon, w/o	5.45	4.94	4.93	5.17

Figure 2. EFFECTS OF IRRADIATION ON PuC



Burnup, MWD/MT	500	590	650	670
Cent. Irrad. Temp., °C	390	490	460	460
Density Change, %	-0.75	-1.00	-0.46	-1.57
Carbon, w/o	4.83	5.68	5.50	4.78
Plutonium, w/o	18.2	27.6	18.1	18.3

Figure 3. EFFECTS OF IRRADIATION ON (U,Pu) C



Before Irradiation

After Irradiation

Figure 4. EFFECT OF 830 MWD/MT BURNUP AT 340°C ON PRESSED AND SINTERED UC-20 w/o PuC