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EFFECTS OF STOICHIOMETRY ON CLADDING ATTACK IN MIXED-OXIDE FUELS TO 3.6 AT% BURNUP

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By

D. C. Hala
L. A. Lawrence
J. W. Weber

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EFFECTS OF STOICHIOMETRY ON CLADDING ATTACK IN MIXED-OXIDE FUELS TO ∿ 3.6 at% BURNUP

D. C. Hata, L. A. Lawrence, and J. W. Weber

Effects of initial stoichiometry on the character and extent of fuel-cladding chemical interaction (FCCI) were established for mixed-oxide fuels irradiated to peak burnups of ∿ 3.6 at%. The present LMFBR design basis considers an initial reduction of 50 microns (2 mils) in cladding thickness to compensate for possible FCCI. This thickness loss represents a significant part of the total cladding wastage allowance for the LMFBR reference fuels design.[1] The reduction or elimination of FCCI would allow a corresponding reduction in cladding thickness resulting in an improvement in the breeding ratio and a reduction in system doubling time. Both mixed-oxide fuel pin irradiation experience[2-4] and laboratory studies[5] have indicated that a reduction in the initial fuel O/M results in a corresponding reduction in FCCI.

The HEDL P-23C subassembly, which is part of the HEDL high temperature test series in EBR-II,[1] was designed specifically to quantify these effects of initial fuel O/M on fuel pin performance. Fuel pins were irradiated in a 37 pin subassembly at peak linear heat ratings of ∿ 400 W/cm (12 kw/ft) at nominal peak cladding inner surface temperatures of ∿ 700°C (1300°F). Each fuel pin contained a 34.3 cm (13.5 inch) long column of UO_2 - 25 wt% PuO_2 sintered pellets, clad with 0.584 cm (.230 inch) diameter, .038 cm (0.15 inch) thick, 20% cold worked, Type 316 stainless steel. Fuel pins containing fuel fabricated with average initial O/M's of 1.94, 1.95, or 1.97 were placed in the subassembly such that fuel pins differing in O/M were irradiated under nearly identical conditions. Pins were removed from the subassembly at interim examinations to characterize effects of the differing O/M on performance. Examinations have been completed on the fuel pins removed at peak burnups of 1.2 at% and 3.6 at% at O/M's of 1.95 and 1.97 and at a burnup of 2.4 at% at O/M's of 1.94 and 1.97.

Both the average depth and maximum depth of attack in the pin increased with increasing burnup but the relative effects of initial fuel O/M do not appear to change significantly with increasing burnup.

The effects of O/M and temperature at the 3.6 at% burnup level are shown in Figure 1. Increasing temperature appeared to increase both the depth and the extent of the corrosive attack and there were no major changes in the character of the attack consistent with other observations from the test series.[6] The absence of any changes in character of the attack reflects the lower operating temperatures of P-23C compared to the P-23A or P-23B subassemblies[1] rather than any effect of O/M on character of the attack.

The FCCI in the lower O/M (1.95) fuel pin was uniform in depth and evenly distributed around the inner surface of the cladding. The FCCI could not be classified as either intergranular or matrix attack, rather it appeared as preferential loss of cladding at the grain boundaries and slip planes on the cladding inner surface. When etched, these surface grains and grain boundaries in the cladding were found to be denuded of carbides.

In contrast, the typical FCCI attack found in the higher O/M (1.97) fuel pin was matrix in character. The depth and distribution of the corrosive attack on the cladding circumference was generally nonuniform which is typical of matrix type attack. Regions of 15 micron (.5 mil) of cladding attack were found adjacent to regions with no apparent attack. In general, no carbide denuded grain boundaries were observed to proceed the matrix attack.

The depth of cladding attack was determined by measuring total cladding thickness and by measuring the depth of penetration from the estimated position of the original cladding inner surface. Results were essentially equivalent for both methods. The measured average depth of attack (Figure 2) shows a substantial reduction for a decrease in average O/M from 1.97 to 1.95.

Use of low O/M fuel has been proposed as one of the best methods of reducing or eliminating FCCI.[2] These results have quantified this effect to burnups of ∿ 3.6 at% showing an almost 3 fold reduction in FCCI for a reduction of the O/M from 1.97 to 1.95. Therefore, the use of oxygen chemical getters[7] to control FCCI may not be necessary. Data being obtained from P-23C at peak burnup levels of 6.7 at%, 7.2 at%, and 8.3 at% will form the basis for the incorporation of an initial O/M dependence in the FCCI wastage correlation being developed at HEDL.[3]

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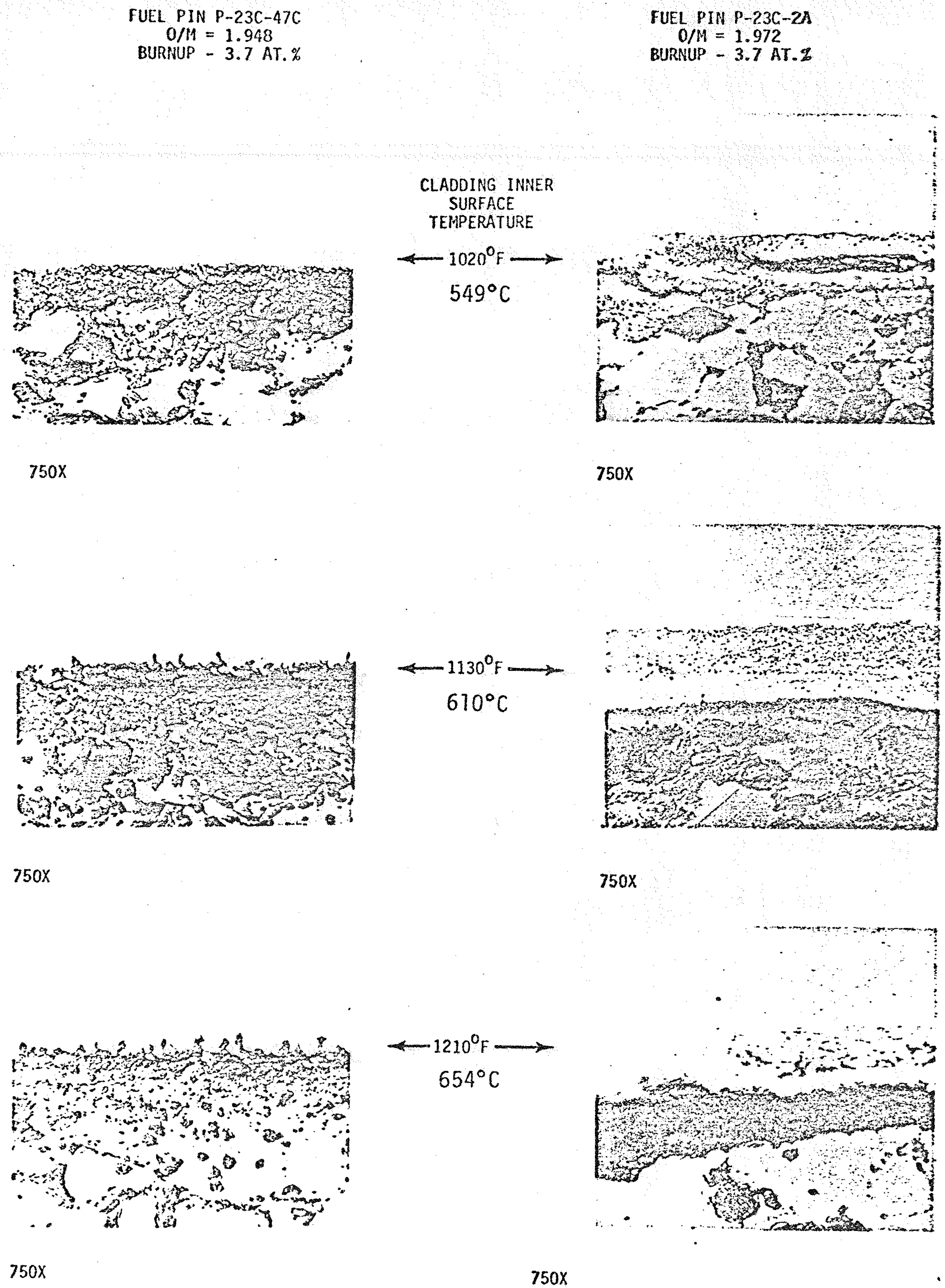

FIGURE 7 THE EFFECT OF INITIAL FUEL STOICHIOMETRY ON FCCI AT 3.7 AT.% BURNUP.

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HEDL HIGH CLADDING TEMPERATURE TESTS

THE EFFECT OF INITIAL FUEL O/M ON DEPTH OF FCCI AT 3.6 AT. % BURNUP

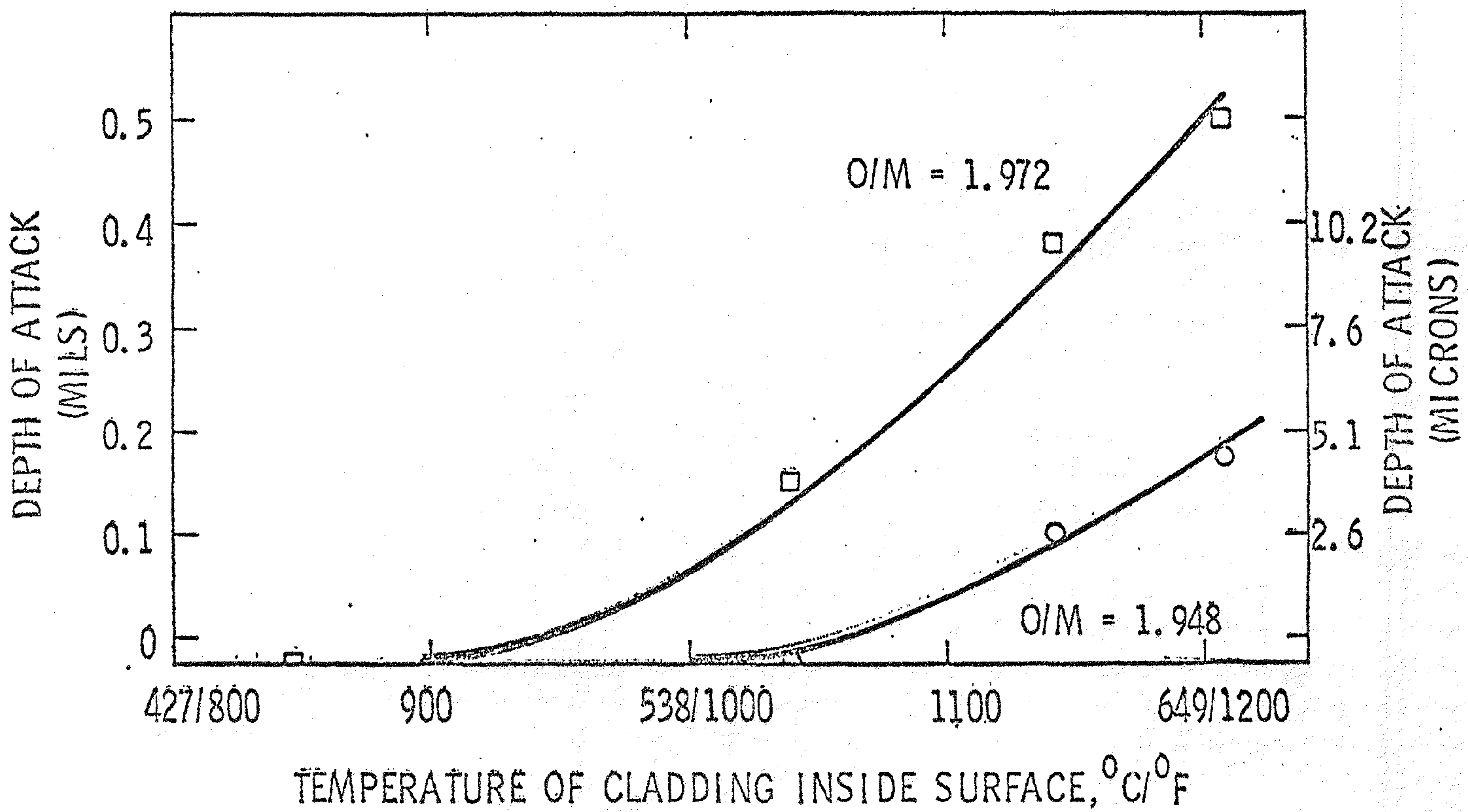

Figure 2.

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