

ANL/TD/RP-91010

HIGH DENSITY DISPERSION FUEL

G. L. Hofman
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439 USA

RECEIVED
SEP 19 1996
OSTI

A fuel development campaign that results in an aluminum plate-type fuel of unlimited LEU burnup capability with an uranium loading of 9 grams per cm^3 of meat (while at the same time meeting required homogeneity and formability criteria) should be considered an unqualified success. To put this goal in perspective, our current worldwide approved and accepted highest loading is 4.8 g cm^{-3} with U_3Si_2 as fuel. This fuel compound has excellent radiation performance to full ^{235}U burnup, but its modest density limits application for very high loadings.

The 4.8 g cm^{-3} loading corresponds to approximately 43 vol % U_3Si_2 in the meat which is, with conventional rolling techniques, an upper limit for commercial fabrication.

Recently several fabricators have reported satisfactory yields with up to 53 vol % U_3Si_2 achieved through optimized fabrication procedures. Assuming that these new processes prove commercially viable, we have now an upper limit of 6 g cm^{-3} with a proven fuel compound. Or in other words we are a factor of 1.5 short of our 9 g cm^{-3} goal. We can not expect to increase the fuel volume fraction significantly, if at all, beyond 53%. Thus our only hope lies in finding a much-higher-density fuel than U_3Si_2 with, however, similar characteristics such as fabricability, compatibility with aluminum, and stable irradiation behavior.

High-density uranium compounds are listed in Table 1 with, for comparison, U_3Si_2 and an older stable fuel, UAl_2 . Many of these compounds offer no real density advantage over U_3Si_2 and have less desirable fabrication and performance characteristics as well. Of the higher-density compounds, U_3Si has approximately a 30% higher uranium density but the density of the U_6X compounds would yield the factor 1.5 needed to achieve 9 g cm^{-3} uranium loading.

Unfortunately, irradiation tests proved these peritectic compounds as a group to have poor swelling behavior, as shown in Fig. 1. The high swelling rate of these compounds is associated with fission-induced amorphization, and, unless we can find a way to stabilize these compounds without reducing their density, it must be concluded that intermetallic compounds are not going to get us to our 9 g cm^{-3} goal. It is for this reason that we are turning to uranium alloys. The obvious question is, why not use pure uranium, for this would clearly result in the highest possible loading. The reason pure uranium was not seriously considered as a dispersion fuel is mainly due to its high rate of growth and swelling at low temperatures. This problem was solved at least for relatively low burnup application in non-dispersion fuel elements with small (a few hundred ppm) additions of Si, Fe, and Al. This so called adjusted uranium has nearly the same density as pure α -uranium and it seems prudent to reconsider this

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

alloy as a dispersant.

Further modifications of uranium metal to achieve higher burnup swelling stability involve stabilization of the cubic γ phase at low temperatures where normally α phase exists. Several low neutron capture cross section elements such as Zr, Nb, Ti and Mo accomplish this in various degrees. As shown in Fig. 2, combinations of Nb-Zr and Mo by itself appear most effective. The density of some of these alloys are given in Table II showing that U-5Mo is equivalent in density with the aforementioned U_6X compounds. Alloys around this composition, as well as the lower U-NbZr alloys, would meet our high loading requirements. The challenge is to produce a suitable form of fuel powder and develop a plate fabrication procedure, as well as obtain high burnup capability through irradiation testing.

In summary, as in the case of any new fuel development effort, there is no guarantee that we will reach our goal but we have enough promising options to hope for a high probability of success.

**Table I. Nominal Density, Uranium Content and
Melting Point of Uranium Compounds**

Compound	Density, g cm ⁻³	U-Density g cm ⁻³	Melting Point, °C
UO ₂	10.9	9.7	2750
U ₄ O ₉	11.2	9.7	a
UC	13.6	13.0	2400
UN	14.3	13.5	2650
UAl ₂	8.1	6.6	1590
U ₃ Si ₂	12.2	11.3	1650
U ₃ Si	15.4	14.8	930 ^b
U ₆ Ni	17.6	16.9	790 ^c
U ₆ Fe	17.7	17.0	815 ^c
U ₆ Mn	17.8	17.0	725 ^c

- a. Transforms to UO₂ at high temperatures
- b. Peritectoid temperature
- c. Peritectic temperature

**Table II. Density, Uranium Content and Melting Point
Of γ Stabilized Uranium Alloys**

Alloy W. %	Density, g cm	U-Density, g cm ⁻³	Melting Point, °C
U	19.0	19.0	1135
U-2Mo	18.5	18.1	1135
U-5Mo	17.9	17.0	1135
U-6.5Mo	17.5	16.4	1135
U-8Mo	17.3	15.9	1135
U-9Mo	17.0	15.5	1160
U-4Zr-2Nb	17.3	16.2	1160
U-6Zr-41Nb	16.4	15.8	1160
U-7Nb	17.0	15.0	1160
U-10Zr	16.0	14.4	1160

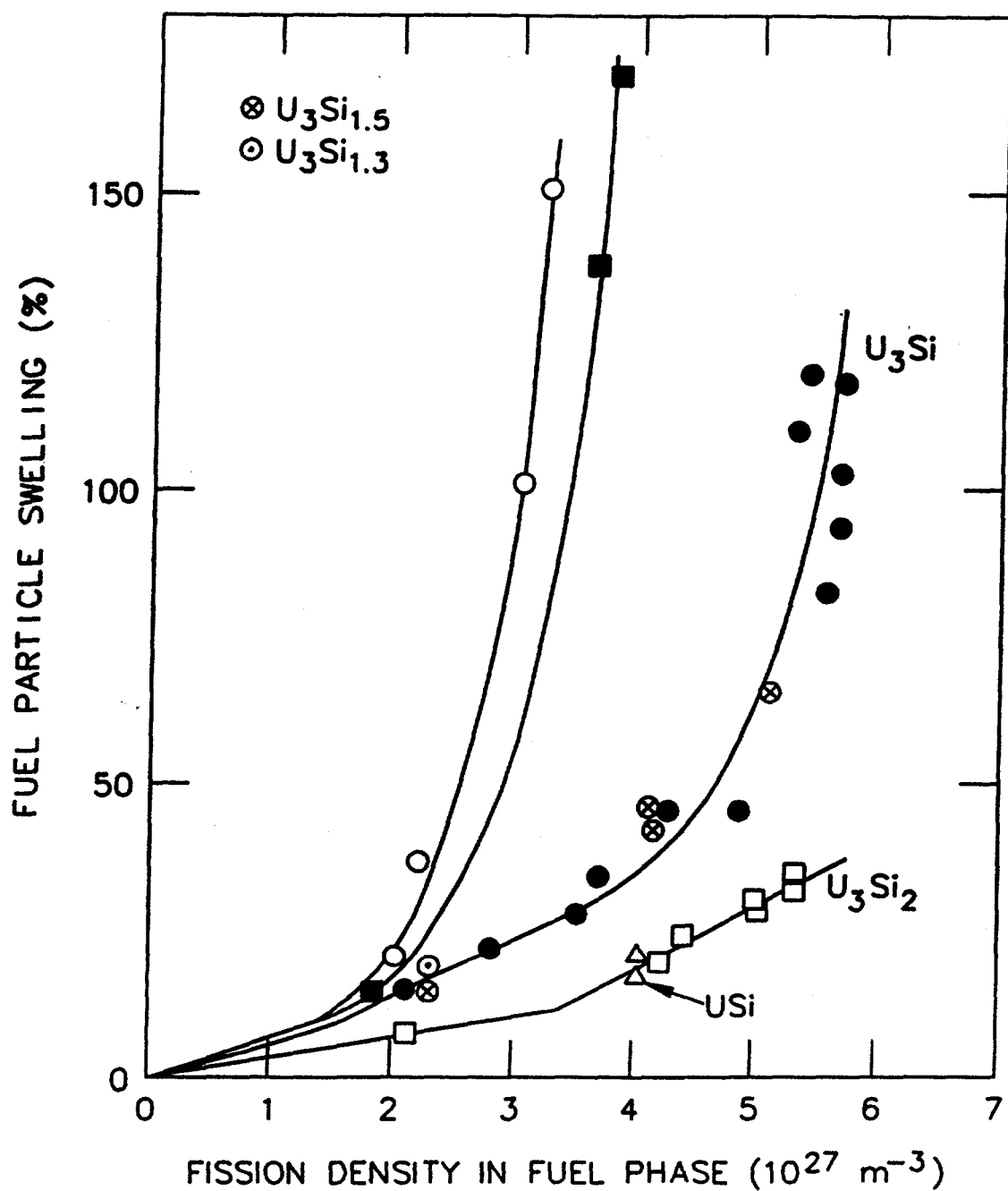


Fig. 1. Swelling of LEU fuel particles in experimental aluminum dispersion fuel plates irradiated in the ORR.

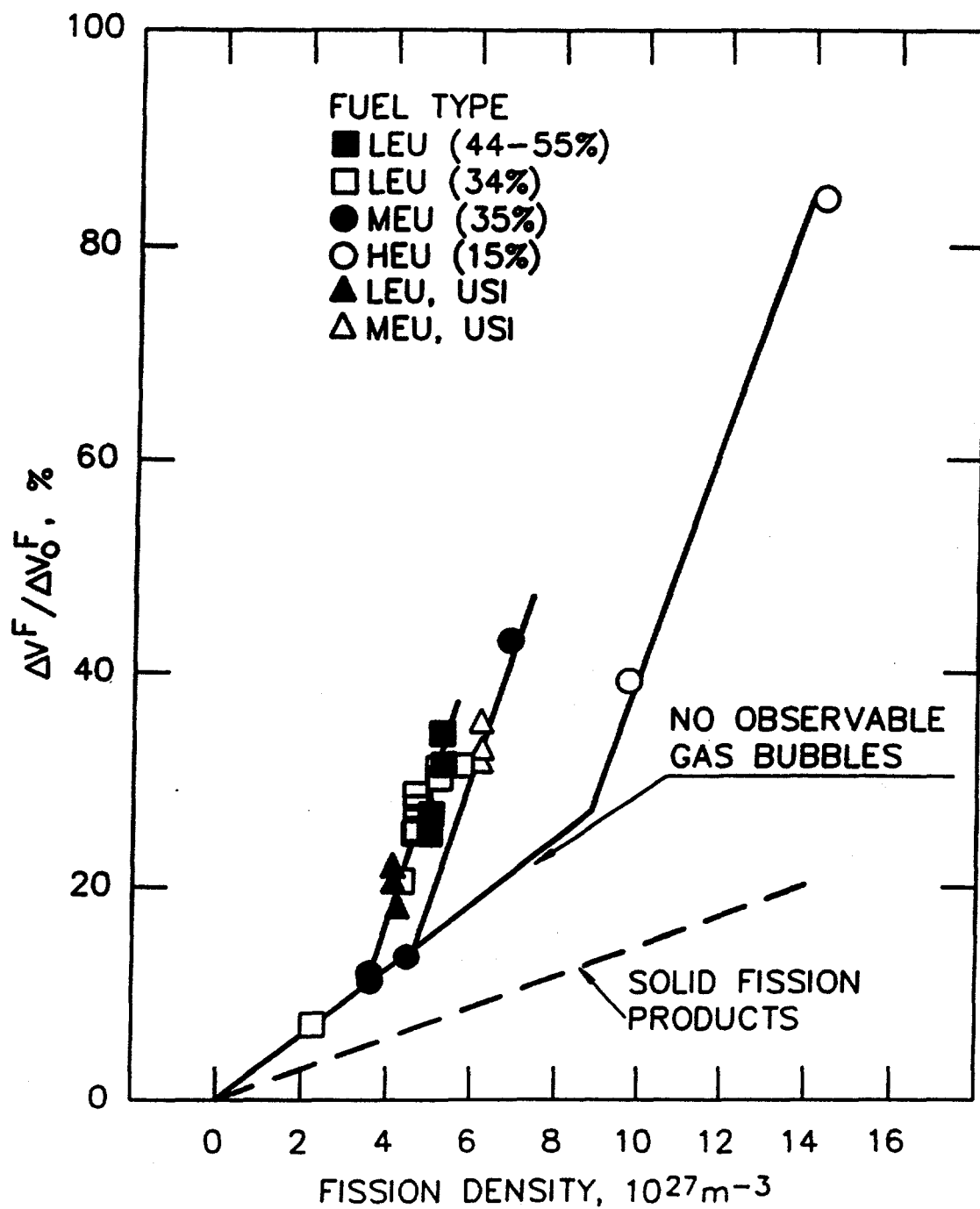


Fig. 2. Swelling of U_3Si_2 of various enrichment and fuel dispersion loadings as a function of fission density (USi data included).