IRRADIATION TESTING OF LEU FUELS IN THE SILOE REACTOR-PROGRESS REPORT

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ABSTRACT

Irradiation of uranium-silicide fuels has continued in the SILOE reactor during the past year. Thickness vs. fission density data from four U_3Si plates containing 5.5 and 6.0 g U/cm^3 have been analyzed, and the results are presented. The irradiation of a full 6.0 g U/cm^3 U_3Si element has begun. In addition, four U_3Si_2 plates containing 2.0 to 5.4 g U/cm^3 are now being irradiated. These irradiations and future plans are discussed in the paper.

GENERAL OUTLINES OF THE PROGRAM

Since the last meeting at Tokai-mura the program for the qualification of LEU fuel has been carried on in the SILOE Reactor. At that time the irradiation of four full-sized U_3Si fuel plates was almost completed. It was followed by postirradiation measurements on these four plates, and four new U_3Si_2 fuel plates and a complete U_3Si fuel element are now under irradiation. This paper will describe this program, which takes place within the framework of agreement between CEA, ANL, and CERCA. A standard 45%-enriched fuel element, containing UAl_x at 2.2 g U/cm^3, has been irradiated. The results of this irradiation and of the PIE have been given during the previous meeting[1] and will not, therefore, be discussed here. Four 19.75%-enriched U_3Si fuel plates were irradiated between June 1982 and November 1983. During and after the irradiation, various measurements were carried out, and some of the results obtained will be presented. Four U_3Si_2 fuel plates have been undergoing irradiation since July of this year. The first results will be also presented. Finally, the irradiation of a complete U_3Si fuel element began very recently, and preparations are being made for the irradiation of a U_3Si_2 fuel element. The status of all of these irradiations is shown in Table 1.

IRRADIATION OF FULL-SIZED U_3Si PLATES

The four U_3Si fuel plates are the same size as the plates of the standard fuel elements of SILOE. Two plates were loaded with 5.5 g U/cm^3 and two others with 6.0 g U/cm^3. The plates were subjected to different tests during their irradiation, in particular: cladding failure detection, visual examination, gamma scanning, and, especially, thickness measurement. The underwater facility for thickness measurement is described in Appendix 1. Table 2 summarizes the detailed irradiation conditions.

TABLE 1. STATUS OF THE IRRADIATIONS OF LOW ENRICHED FUEL
PERFORMED IN THE SILOE REACTOR
OCTOBER 1984

Fuel type	Geometry	Number of plates	Enrichment %	Density g/cm^3	Initial ^{235}U loading, g	Mean burn-up %	Observations
UAlx	Complete fuel element	23	45	2.2	418	50.4	Irradiation terminated PIE completed
U_3Si	Special support	2	19.75	5.5	20.2 x 2	56.1 55.5	Irradiation terminated PIE completed
U_3Si	Special support	2	19.75	6	22.1 x 2	55.7 58.9	Irradiation terminated PIE completed
U_3Si	Complete fuel element	23	19.75	6	507	-	Start of irradiation October 1984 Expected burn-up : 50 to 60%
U_3Si_2	Special support	4	19.75	2.0 to 5.4	22.4 x 4	17.0	Start of irradiation July 1984 Expected burn-up : 50 to 60%
U_3Si_2	Complete fuel element	23	19.75	5.2	-	-	Start of irradiation first half - Year 1985 Expected burn-up : 50 to 60%

TABLE 2

No. plates	Initial load of UT g/cm^3	maxi B. U. %	average B. U. %	Heat flux maxi w/cm^2	cycling (1)	thickness variation mini/maxi mm	irradiation time (days)
SAZW020	5.5	71.2	56.1	128	66	.01/.05	245
SAZW021	5.5	70.5	55.5	129	63	.02/.06	244
SAZW023	6	70.7	55.7	138	63	.02/.105	244
SAZW025	6	74.8	58.9	137	66	.01/.095	245

(1) Number of scheduled or unscheduled shutdowns and power reductions.

The thickness measurements were carried out after each operation cycle of the reactor from the fifth radiation cycle onwards. Plots of thickness along five parallel tracks were obtained for each plate. A typical example of the results obtained for one track is given in Fig. 1. These measurements have enabled a correlation to be determined between the thickness variation of the plate and the number of fissions per cm^3, as shown in Fig. 2.

This correlation, obtained by using all of the measurements carried out on the four plates, indicates that a swelling of about 0.1 mm occurs for the current maximum burnup. It is estimated that the aluminum-oxide layer thickness is around 0.01 mm. This value comes from measurements made on aluminum plates irradiated during two cycles.

Finally, as regards this irradiation, it should be noted that the gamma spectrometry tests were carried out on the fifth irradiation cycle and at the end of the irradiation. They have enabled the calculated values of the fission density, which were used for the determination of the correlation of Fig. 2, to be readjusted. The difference between calculation and measurement is some percent for the large fission density at the center of the fuel plate. The difference appears to be larger, up to 30%, for the smaller fission densities at the edge of the fuel plate.

IRRADIATION OF FULL-SIZED U_3Si_2 PLATES

As mentioned earlier, the irradiation of the four U_3Si_2 fuel plates began in July 1984. This irradiation, which will require approximately one year, will therefore finish in the middle of the next year. The plates have different loadings from 2.0 to 5.4 g U/cm^3. During irradiation the plates are placed in the casing previously used for the irradiation of the four U_3Si fuel plates. Since they are not attached to the casing, they can be removed from the casing to be placed in the thickness measurement bench after each irradiation cycle. After three irradiation cycles, the thickness increase is rather low, i.e., 0.02 mm, and the burnup at mid-October is around 20%.

IRRADIATION OF COMPLETE U_3Si AND U_3Si_2 ELEMENTS

The irradiation of the complete U_3Si fuel element was approved by our safety authorities at a later date than expected, and it has just begun at the beginning of this month. This element has the same geometry as a SILOE standard fuel element. The ^{235}U loading is equal to 507 g of ^{235}U and the uranium density is 6.0 g U/cm^3. This fuel element has an interesting characteristic. Two of the plates of the fuel assembly are effectively removable, which will enable the thickness variation in these two plates to be followed during the irradiation and compared to results of previous measurements. This measurement will be carried out at the end of each reactor cycle. Before the

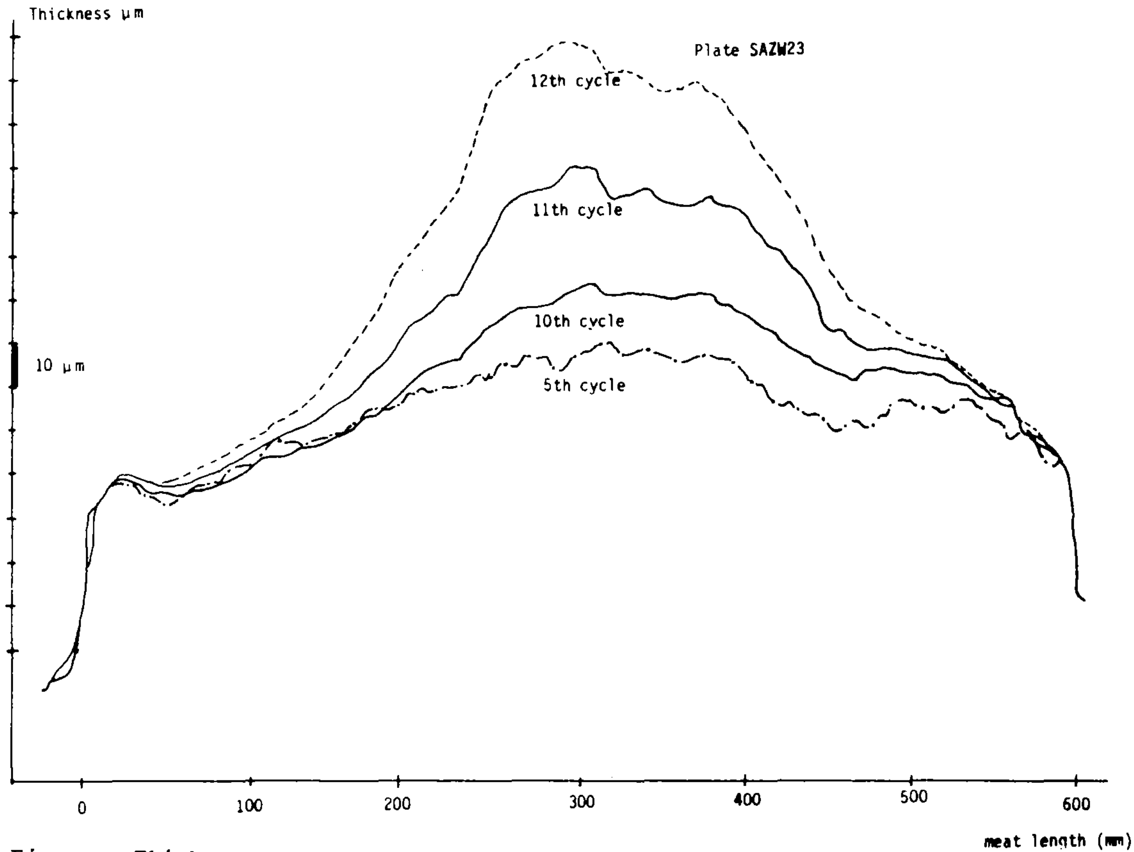

Fig. 1. Thickness measurement

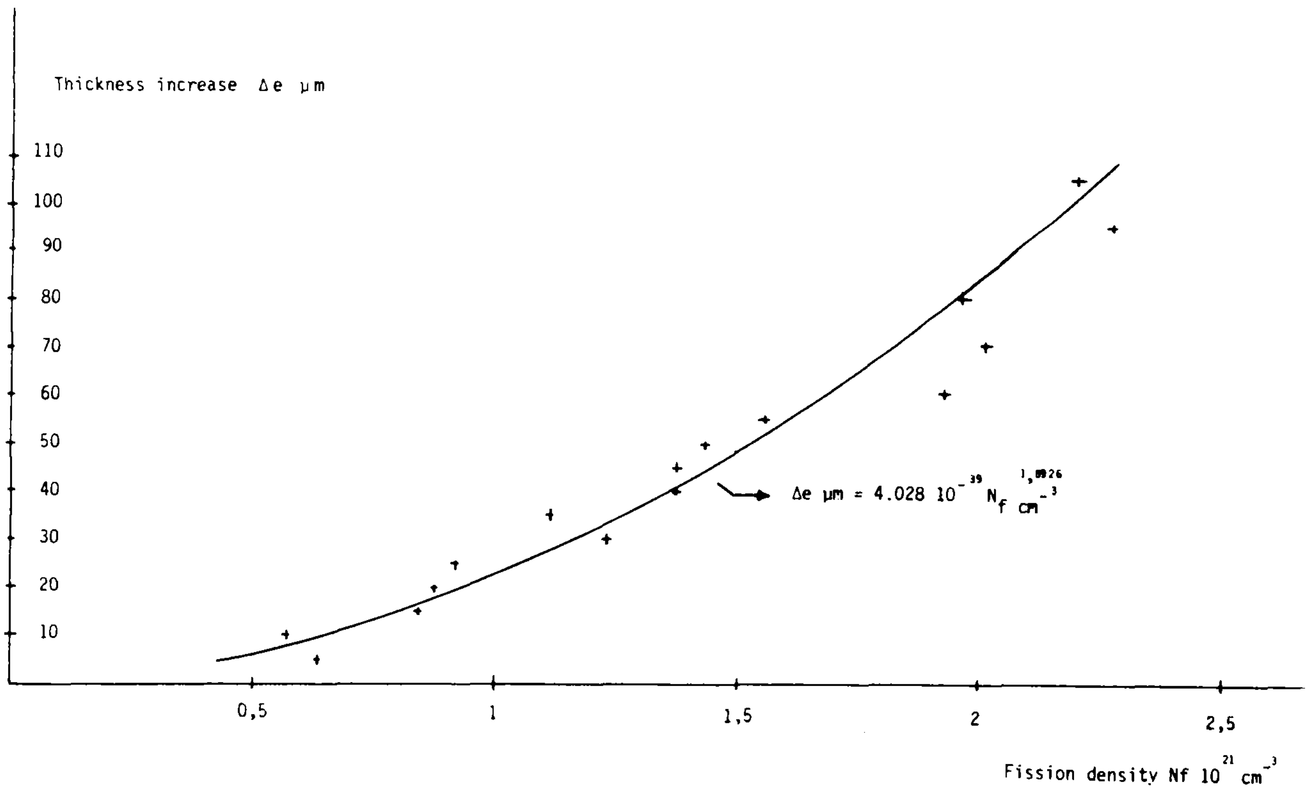

Fig. 2. Thickness change

irradiation, different measurements have been carried out: hydraulic measurements to determine the flow rate-pressure drop characteristics; and some neutronic measurements to determine the flux inside the fuel element and its reactivity effect. The reactivity of this element is slightly higher than that of a standard SILOE fuel element. During its irradiation, this fuel element will be considered as a normal standard SILOE fuel element. Therefore, it will be placed in different positions in the core, after having checked each time that the thermal-hydraulic condition remains satisfactory. The heat flux is quite high in this fuel element, and it is one of the hottest fuel elements in the core. The irradiation should last approximately ten cycles and therefore finish before the end of 1985 after having reached an average burnup of approximately 50%.

A complete U_3Si_2 fuel assembly with 23 fuel plates loaded with 5.2 g U/cm^3 will be delivered by CERCA within the next several weeks. Its irradiation will begin at the first opportunity after reception, i.e., at the beginning of 1985.

CONCLUSIONS

On the basis of the results obtained from the tests listed in Table 1, it will then be possible to determine, as exactly as possible, the definitive characteristics of the silicon-based fuel elements (geometry and loading) which could be used to build a complete core for the SILOE reactor. The configuration of this core will have to be optimized, and the general neutronic performance will have to be compared with that of the core and the fuel presently used, specifically from the point of view of the fluxes available in the reflector. At the same time, the economic performance of this new fuel will have to be carefully evaluated, taking all the aspects into account - fabrication, uranium supply, and the reprocessing costs.

REFERENCE

1. F. Merchie, C. Baas, and M. Trotabas, "Progress Report on the Qualification in the Reactor SILOE of Low Enriched Fuels for Research and Test Reactors," Proceedings of the International Meeting on Reduced Enrichment for Research and Test Reactors, 24-27 October, 1983, Tokai, Japan, JAERI-M 84-073 (May 1984), pp. 131-138.

APPENDIX 1

POOL BENCH FOR UNDERWATER PLATE THICKNESS MEASUREMENT

This bench is the "automatic" version of the bench previously used for the measurement of thickness of the U_3Si plates which were irradiated in SILOE between June 1982 and November 1983.

Like the former, it enables thickness measurements to be carried out directly in the pool on the total length of the plates along five equidistant tracks.

This bench comprises :

- an immersed mechanical part,
- a computing system for control and a data logging and processing system.

The immersed mechanical part comprises a framework supporting :

- a fixed frame in which the plate to be checked is inserted,
- two measurement sensors (mobile) mounted on a trolley. The exit signal from the sensors, proportional to the thickness, is transmitted to the computing system. The movement of the sensors is ensured by two stepping motors which enable a vertical movement to be obtained according to a track, and a horizontal movement for passage from one track to another.

Finally, this immersed part comprises two calibration blocks which are examined on each trace and which enable, thanks to the data processing system, the slope of the sensor response curve to be continually calculated.

The data processing system uses :

- on the one hand a mini-computer using a 6809 microprocessor,
- on the other hand the acquisition system of the SILOE reactor (GENEPI system).

The mini-computer ensures by program:

- the control of the motors (movement the length of a trace or passage from one trace to another),
- the calculation of the slope of the sensor response curve,
- the screen visualisation in real time of the X-Y curve of the measurements carried out.

These measurements are processed elsewhere by the GENEPI system which ensures the plotting of the thickness (e) and thickness variation curves (Δe). All the measurements carried out since the beginning of the irradiation are stored in the GENEPI system memories. It is also possible to obtain the correlations $e = f$ (volumic number of fissions). The volumic number of fissions is obtained either by neutronic calculation codes or after passing irradiated plates on the gamma scanning bench located in the pool of SILOE.