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FUEL MINIPLATE THICKNESS MEASUREMENT SYSTEM FOR DISPERSION FUEL SWELLING EVALUATION

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ABSTRACT

This paper presents the commissioning test results of a system designed for fuel swelling evaluation, and constructed at IPEN-CNEN/SP. The system will be used in the qualification process of U_3O_8-Al and U_3Si_2-Al dispersion fuels with 3.0 gU/cm^3 and 4.8 gU/cm^3, respectively. The determination of the fuel swelling will be performed by means of fuel miniplate thickness measurements along the irradiation time, during the shutdown period between the operational cycles of the IEA-R1 reactor. The system will be located at the reactor pool fuel storage area and it will be operated from the reactor pool border, allowing the measurement of the fuel miniplate thickness along its surface by electronic probes (LVDT). The results will be obtained by the instrumentation connected to the probes.

1. INTRODUCTION

Since 1998, IPEN has been producing and qualifying its own U_3O_8-Al and U_3Si_2-Al dispersion fuels. The U_3O_8-Al dispersion fuel is qualified up to a uranium density of 2.3 gU/cm^3 and the U_3Si_2-Al dispersion fuel up to 3.0 gU/cm^3[1]. To assure a better utilization of the nuclear fuel in the IEA-R1 reactor, IPEN/CNEN-SP has decided to produce these U_3O_8-Al e U_3Si_2-Al dispersion fuels in the maximal qualified densities in the world, (i.e. 3.0 gU/cm^3 and 4.8 gU/cm^3, respectively). The fuel development program included the fabrication and irradiation of fuel miniplates. Ten miniplates being five of U_3O_8-Al fuels with 3.0 gU/cm^3 and five U_3Si_2-Al fuels with 4.8 gU/cm^3 were fabricated. To allow the fuel miniplate performance evaluation during the irradiation time, a set of pool-side non-destructive tests (NDT) will be performed periodically at the IEA-R1 research reactor. These tests will consist in: (i) visual inspection, (ii) sipping tests in case of fuel miniplate failure, (iii) miniplate thickness measurements, to evaluate the fuel swelling.

To measure the fuel swelling along the irradiation time, it was designed and constructed a special system that will allow the miniplate thickness measurement during the irradiation time. The measurements will be performed periodically during the reactor shutdown periods, whenever the ^{235}U burnup level reaches a multiple of 5% up to 80%. During the measuring period, the fuel miniplates will be transferred from the reactor core to the measurement system. The miniplate swelling will be measured until the ^{235}U burnup reaches a value of 80%.

The Figure 1 shows the fuel miniplate thickness measurement system. It consists of a mobile metallic column, held by an X-Y coordinate table system for miniplate thickness measurement. The table is supported by another metallic structure fixed at the border of the reactor pool. The thickness measurement is performed by electronic probes (LVTD). The results are obtained by the instrumentation connected to the probes. The system will be operated from the reator pool border.

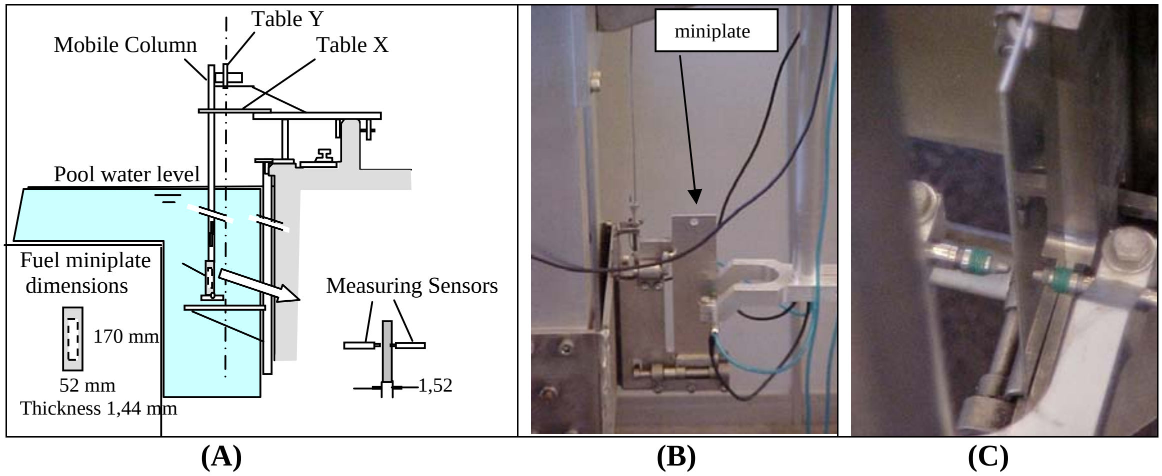

Figure 1. Fuel miniplate thickness measurement apparatus at IEA-R1 reactor pool: (A) schematic view at the reactor pool border; (B) lateral view; C) profile view (thickness).

2. COMISSIONING TEST OF THE THICKNESS MEASUREMENT SYSTEM

For commissioning of the measurement system, two sets of measurements were made. The first set of measurements has consisted of thickness measurements of an aluminum dummy miniplate, outside the reactor pool. These measurements have evaluated the system performance in dry condition. The second set of measurements was performed for another dummy miniplate in the IEA-R1 reactor pool.

The thickness measurement is performed by means of two LVDT (*Linear Variable Differential Transformer).* They are fitted by a metallic structure, in opposite direction, one in front of another. The Figure 2 shows a LVDT probe similar to the used in the measurement system.

Figure 2. LVDT probe.

The dislocation measurement is given by a tension variation, result of the change in the magnetic resistance between two or more bobbins. In the LVDT probes, three coins symmetrically spaced and a mobile magnetic core constitute the magnetic coupling system. The core position changing is electronically detected and adequately processed to generating an accurate lecture of the applied dislocation. The GTL 222 probes (from Swiss) are compatible with commercial LVDT probes and gives maximum precision of 0.1 µm.

2.1. Equipments

The following equipments were used:

- Special TESA Electronic Probe at the Forefront in Precision Measurement GTL 222 (linear probe LVDT) pneumatically actuated;
- Module for electronic length measurements; TESA, model TESATRONIC TT60 [1];
- Pump FMS-C 115V Electro-pneumatic, FMS, for pneumatic drive of the linear probes;
- (Auxiliary) compressed air line.
- Sub-aquatic camera and DVD recording system for documentation.

2.2. Experimental Apparatus

The Figure 3 shows the schematic assembling of the probes and equipments:

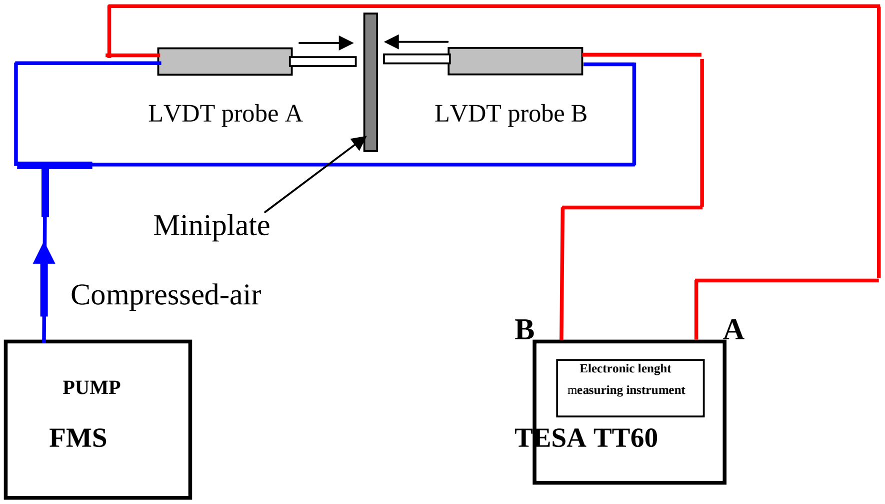

Figure 3. Schematic assembling of the fuel miniplate thickness measurement system.

2.2.1. Routine for equipment assembly in the IEA-R1 reactor pool

1. Assembly the sub aquatic camera system from IFVIS (Irradiated Fuel Visual Inspection System) for visual following and recording inspection;
2. Assembly the equipment main structure containing the probes inside the pool.

3. Assembly the electronic instrumentation for measuring;
4. Connection of the compressed-air line in the FMS module. To maintain the pressure in the compressed-air line in 2 ± 0,5 bar;
5. Performing functional tests to verify the actuation of the probes and measurement system functionality.

2.2.2. Equipment Calibration and reading modes

A set of measurements using standards block (2.000 mm and 4.000 mm) supplied by the equipment supplier (TESA) were made in order to verify the good response of the system. The obtained measurements were in great accordance with each standard block thickness. The procedure adopted for periodically thickness measurements of the irradiated miniplates include performing tests with these standards blocks before use.

The equipment gives several reading modes of measurements. These modes were tested and the same results were obtained.

2.3. Experimental Assembling Pictures

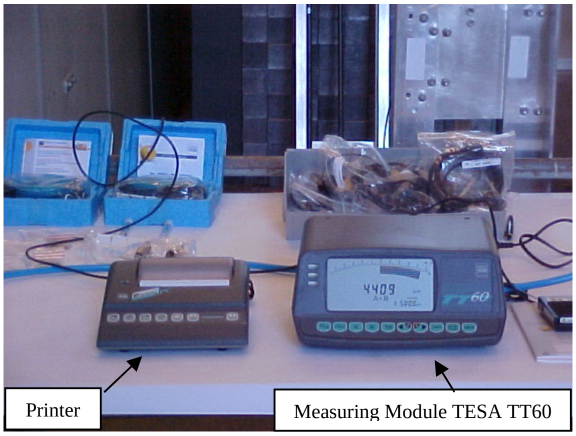

Figure 4. Electronic equipment.

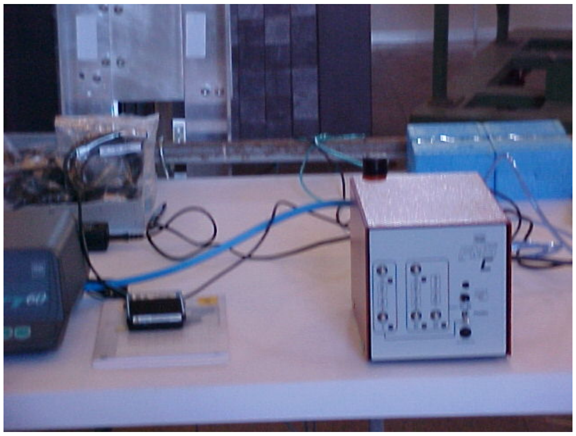

Figure 5. Electro-pneumatic Pump FMS.

Figure 6. General view of the metallic structure.

Figure 7. General view of the metallic structure.

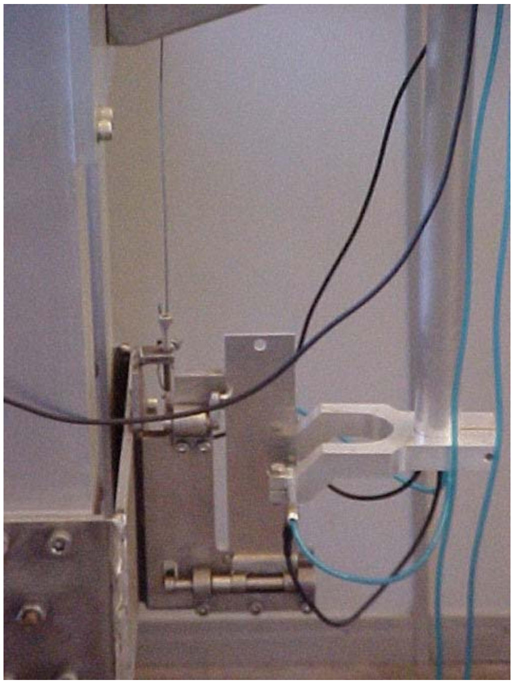

Figure 8. Miniplate thickness measuring.

Figure 9. Another view of miniplate thickness measuring.

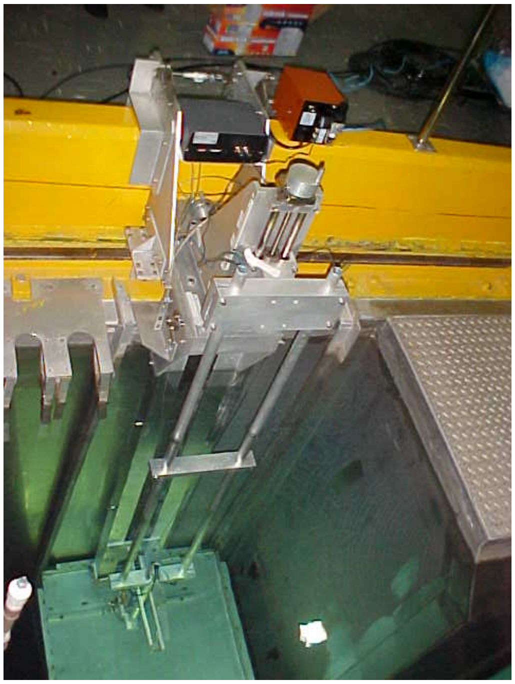

Figure 10. General view of the assembling.

Figure 11. General view of the assembling.

2.4. Measurements

To ensure the accuracy of the equipment under different conditions of operation were measured with the system inside and outside of the reactor pool. Measurements outside the pool were performed in order to obtain the equipment response to the standard block thickness. It was used a dummy aluminum miniplate with the following dimensions: 170 mm x 52 mm x 1.44 mm. The measurements were performed using two dummy miniplates with the thickness of 1,44 mm and 1,41 mm respectively, measured by a digital vernier caliper.

2.4.1. Results for the outside measurements (miniplate thickness 1,44 mm)

Table 1. Results obtained for the outside measurements

	MODE	1ª reading A	2ª reading B	Difference	Result (µm)
1)	A+B	-530	910		1440
2)	A	-344	-77	-344-(-77)= -267	1442
	B	-190	985	-190-(985)= -1175	
3)	A-B	-526	916		1442
4)	-A+B	-531	906		1437
5)	A	-335	-75	-335-(-75)= -260	1442
	B	-193	989	-193-(989)= -1182	

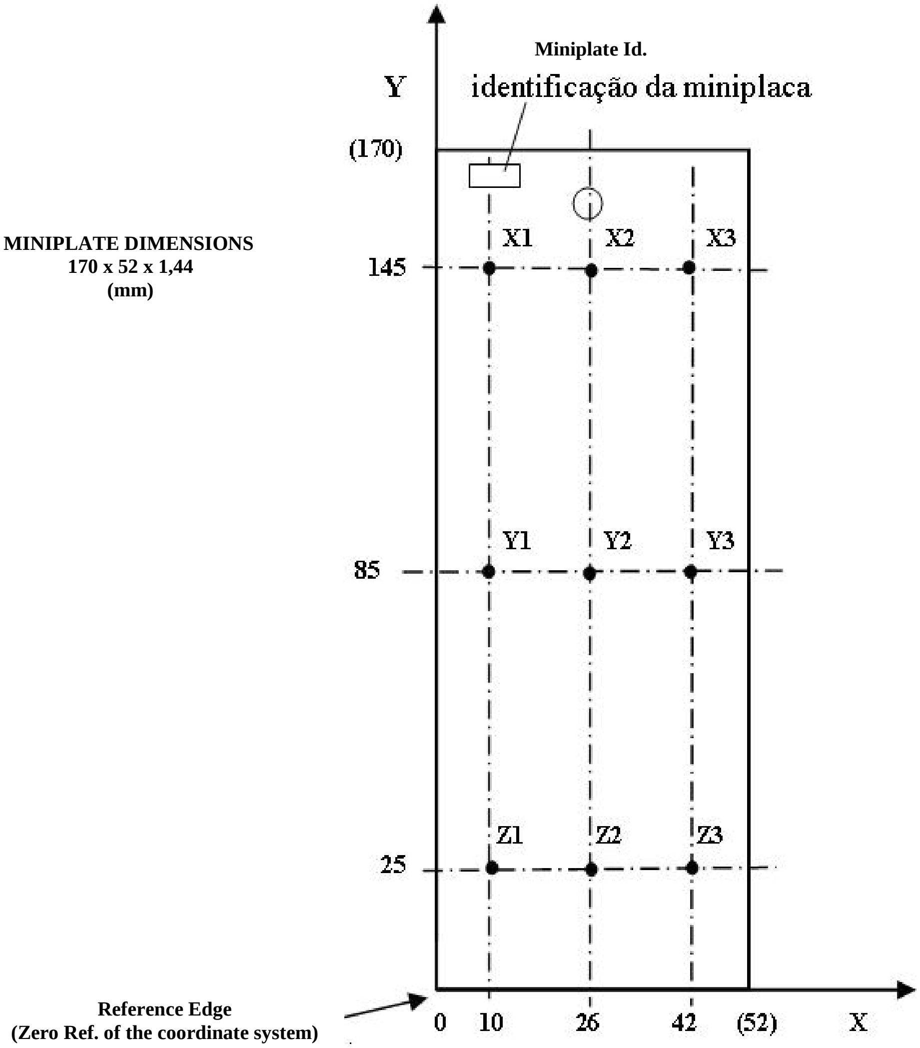

Figure 12. Identification of the thickness measurement position.

2.4.2. Results for measurements inside the pool (miniplate 1,41 mm)

During the measurements made inside the reactor pool of the system was removed from the pool and reattached back to test whether their accuracy was affected in the displacement of the structure, since it not been attached to the reactor pool, but only the period of inspections of the miniplates every six months.

The experiment shows that the system can be removed without changing its accuracy in the next measures as seen in tables to 2 the 6 and in figure 13.

Table 2. 1st Measurements

	MODE	1st reading (end-to-end)	2nd reading	Difference	Result (μm)
X1	-A+B	-266	1144	266+1144=	1410
X2	-A+B	-266	1144	266+1144=	1410
X3	-A+B	-266	1141	266+1141=	1407
Y1	-A+B	-266	1145	266+1145=	1411
Y2	-A+B	-266	1147	266+1147=	1413
Y3	-A+B	-266	1146	266+1146=	1412
Z1	-A+B	-266	1150	266+1150=	1416
Z2	-A+B	-266	1149	266+1149=	1415
Z3	-A+B	-266	1147	266+1147=	1413

Table 3. 2nd Measurements

	MODE	1st reading (end-to-end)	2nd reading	Difference	Result (μm)
X1	-A+B	-266	1145	266+1145=	1411
X2	-A+B	-266	1145	266+1145=	1411
X3	-A+B	-266	1141	266+1141=	1407
Y1	-A+B	-266	1147	266+1147=	1413
Y2	-A+B	-266	1148	266+1148=	1414
Y3	-A+B	-266	1148	266+1148=	1414
Z1	-A+B	-266	1148	266+1148=	1414
Z2	-A+B	-266	1147	266+1147=	1413
Z3	-A+B	-266	1149	266+1149=	1415

Table 4. 3rd Measurements

	MODE	1st reading (end-to-end)	2nd reading	Difference	Result (μm)
X1	-A+B	-266	1146	266+1146=	1412
X2	-A+B	-266	1144	266+1144=	1410
X3	-A+B	-266	1144	266+1144=	1410
Y1	-A+B	-266	1147	266+1147=	1413
Y2	-A+B	-266	1148	266+1148=	1414
Y3	-A+B	-266	1149	266+1149=	1415
Z1	-A+B	-266	1150	266+1150=	1416
Z2	-A+B	-266	1148	266+1148=	1414
Z3	-A+B	-266	1150	266+1150=	1416

Table 5. 4th Measurement

	MODE	1st reading (end-to-end)	2nd reading	Difference	Result (µm)
X1	-A+B	-266	1145	266+1145=	1411
X2	-A+B	-266	1146	266+1146=	1412
X3	-A+B	-266	1145	266+1145=	1411
Y1	-A+B	-266	1148	266+1148=	1414
Y2	-A+B	-266	1148	266+1148=	1414
Y3	-A+B	-266	1148	266+1148=	1414
Z1	-A+B	-266	1151	266+1151=	1417
Z2	-A+B	-266	1151	266+1151=	1417
Z3	-A+B	-266	1152	266+1152=	1418

Table 6. 5th Measurement

	MODE	1st reading (end-to-end)	2nd reading	Difference	Result (µm)
X1	-A+B	-266	1148	266+1148=	1414
X2	-A+B	-266	1145	266+1145=	1411
X3	-A+B	-266	1144	266+1144=	1410
Y1	-A+B	-266	1149	266+1149=	1415
Y2	-A+B	-266	1146	266+1146=	1412
Y3	-A+B	-266	1150	266+1150=	1416
Z1	-A+B	-266	1149	266+1149=	1415
Z2	-A+B	-266	1149	266+1149=	1415
Z3	-A+B	-266	1146	266+1146=	1412

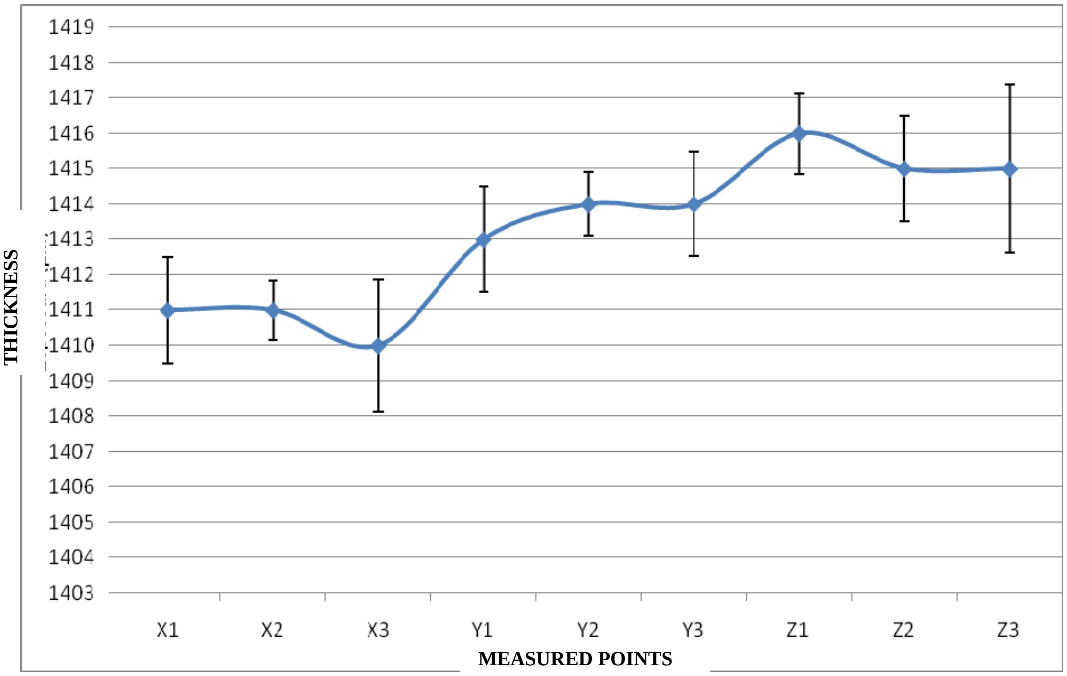

Figure 13. Average measurements inside the pool with standard deviation.

3. CONCLUSIONS

The fuel miniplate thickness measurement system showed good response. Dimensional results were in good accordance with those of the standards blocks supplied by TESA. The results show that the equipment is efficient and accurate, with measurement precision of 1 µm.

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