DEVELOPMENT OF A RADIOGRAPHIC EXAMINATION METHOD FOR SAFARI-1 LEU FUEL PLATES

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The development of the radiographic examination method for SAFARI-1 Low Enriched Uranium (LEU) dispersion fuel plates has been set-up to achieve repeatable results during normal operational throughput in the plant. A system was put in place where evaluation of the fuel plates can be done successfully with the help of equipment, films, film processing and film evaluation for quality and sensitivity of the system to detect defects.

The fuel plate geometry was approximately the same as for the Uranium – Aluminium alloy fuel plates that are currently being manufactured. It was established that the equipment available in the plant is capable to process the LEU fuel plates .

FILM DENSITY

Film density [1] for the LEU fuel plates shall conform to the following requirements:

- 1.1 minimum to 2.1 maximum for core homogeneity and other core defects evaluation (U_3Si_2). The darker parameters allow you to check that dispersion between the U_3Si_2 powder and Al powder is uniformly distributed over the whole length of the fuel plate.
- 0.7 minimum to 1.3 maximum for core geometry and stray particle evaluation. Film density in this range allows you to identify stray particles.

RESULTS

The results shown in table 1 for homogeneity measurements were measured with a 1 mm diameter area film densitometer in the dog-bone region and 70 mm away from the end of the fuel plate. The specification requires that the uranium content of any region of a fuel plate core shall not deviate from the nominal uranium content by more than ± 30%.

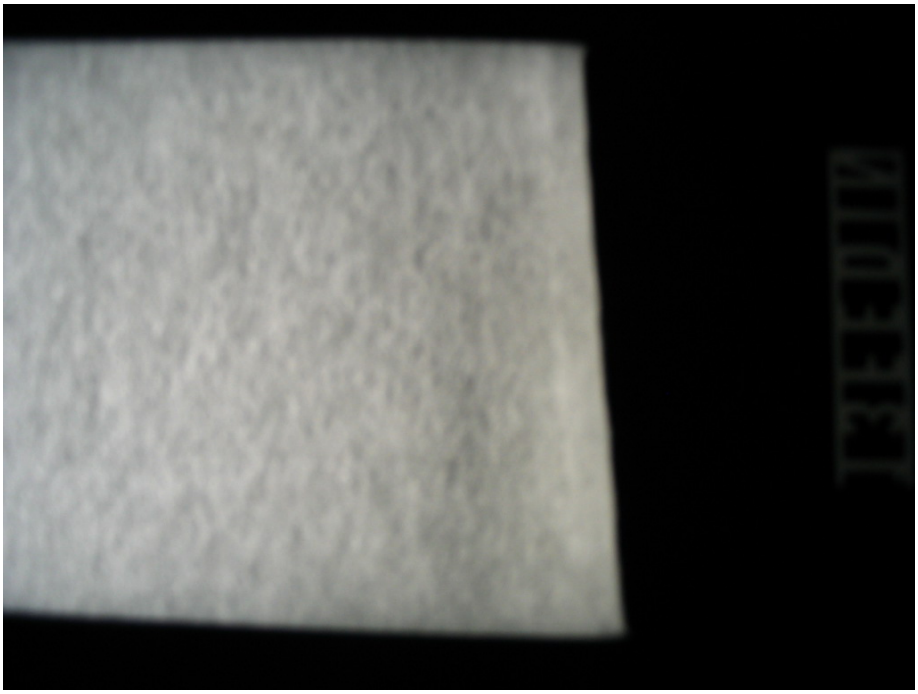
TABLE 1: Film density readings

Plate number end				**Trailing end**		
Plate number	**Dog-bone area**	**70 mm away**	**Variation %**	**Dog-bone area**	**70 mm away**	**Variation %**
SEP/AC045N	0.81	0.94	14	0.96	1.07	10
SEP/AC046N	0.84	0.96	13	0.89	1.04	14
SEP/AC047N	0.82	0.91	10	0.88	1.01	13
SEP/AC048N	0.85	0.94	10	0.86	1.05	18
SEP/AC049N	0.86	0.94	8	0.93	1.04	11
SEP/AC050N	0.81	0.89	9	0.84	1.01	17
SEP/AC051N	0.88	0.92	4	0.94	0.98	4
SEP/AC052N	0.81	0.97	17	0.88	1.08	19
SEP/AC053N	0.80	0.94	15	0.93	1.09	15
SEP/AC054N	0.75	0.93	19	0.91	1.06	14
SEP/AC057N	0.77	0.93	17	0.86	1.05	18
SEP/AC058N	0.80	0.92	13	0.90	1.05	14
SEP/AC061N	0.81	0.95	15	0.89	0.98	9
SEP/AC062N	0.86	0.94	9	0.82	0.95	14
SEP/AC063N	0.84	0.92	9	0.93	1.00	7
SEP/AC064N	0.80	0.89	10	1.04	1.04	0

IMAGE QUALITY INDICATORS (IQI)

To verify that radiographic film sensitivity is correct, image quality indicators (step wedges or wires) are used to indicate sensitivity of a specific method.

We used two different material IQI due to the difference in material density that we have in our fuel plates (U_3Si_2 and Al). We use the DIN 10 FE [2] where the U_3Si_2 is the area of interest and the No. 13 wire (0.2 mm diameter) must be visible for at least 10 mm on the radiograph in order to have an acceptable sensitivity. The iron wires have a density value 7.86 g/cm^3, which is close to that of the U_3Si_2 alloy density value 4.8g/cm^3.



Sensitivity is determined by identifying the No. 16 wire (0.1 mm diameter) of the DIN 10 AL [1] where the Aluminium is the area of interest.

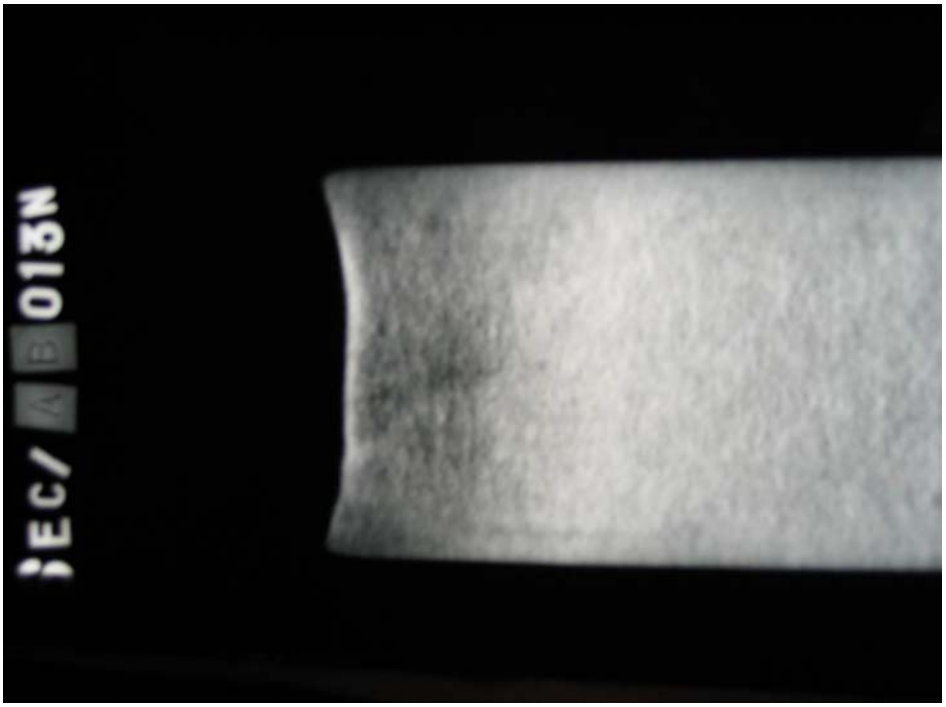
The image quality indicator (IQI) is placed at the source side of the product being examined.

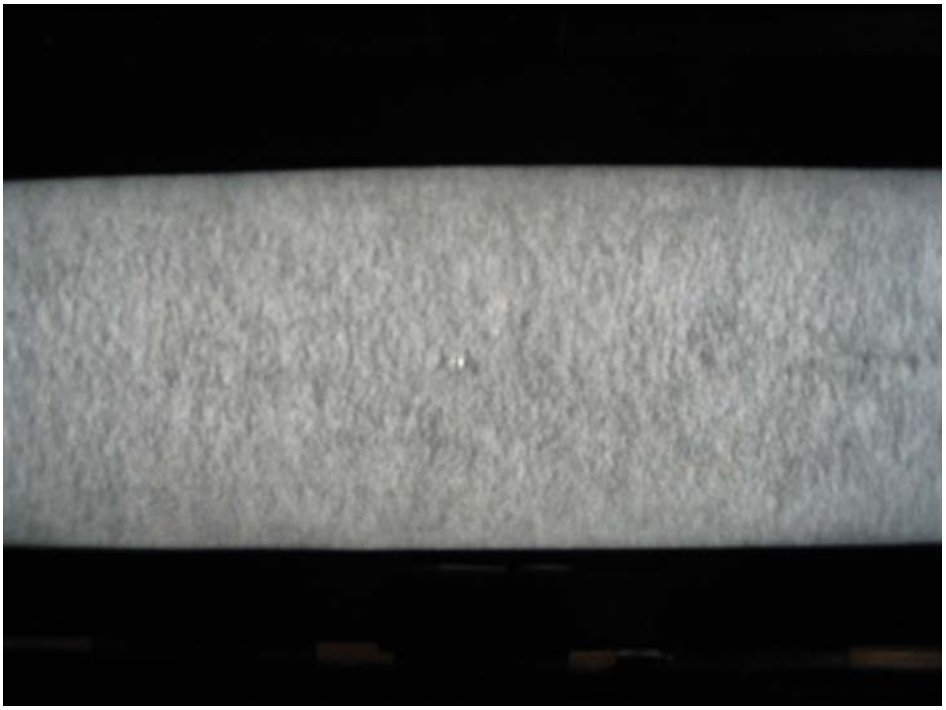
FILM INTERPRETATION

The films are examined with a viewer in darkness or filtered light that does not cause reflections.

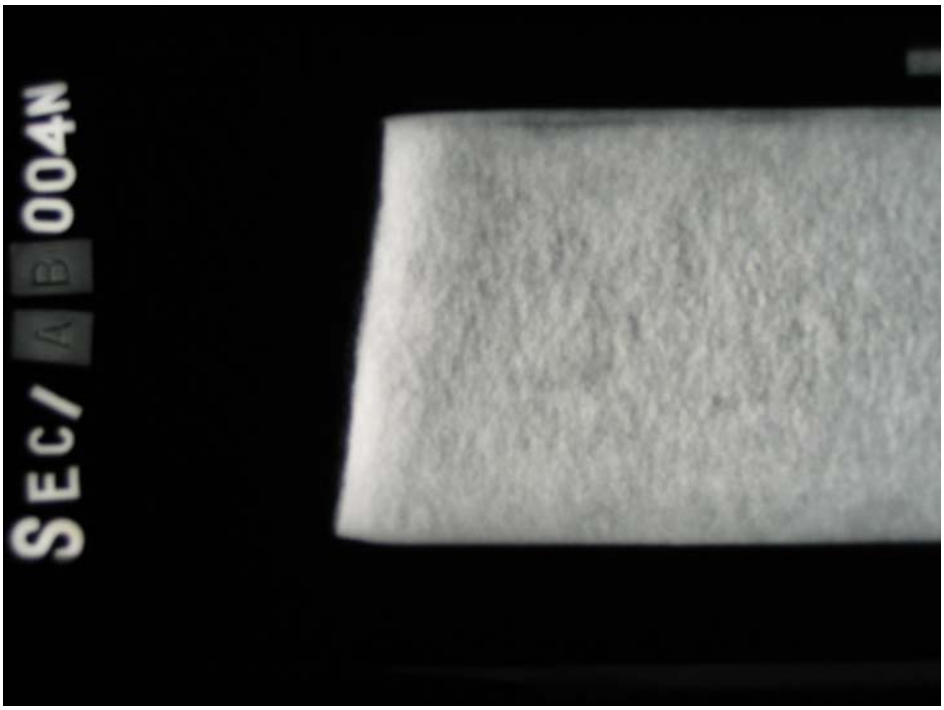
Examine the film with the unaided eye for:

- Fuel core end margin (with overlay chart).
- Fuel core position (with overlay chart).
- Uranium homogeneity of fuel core.

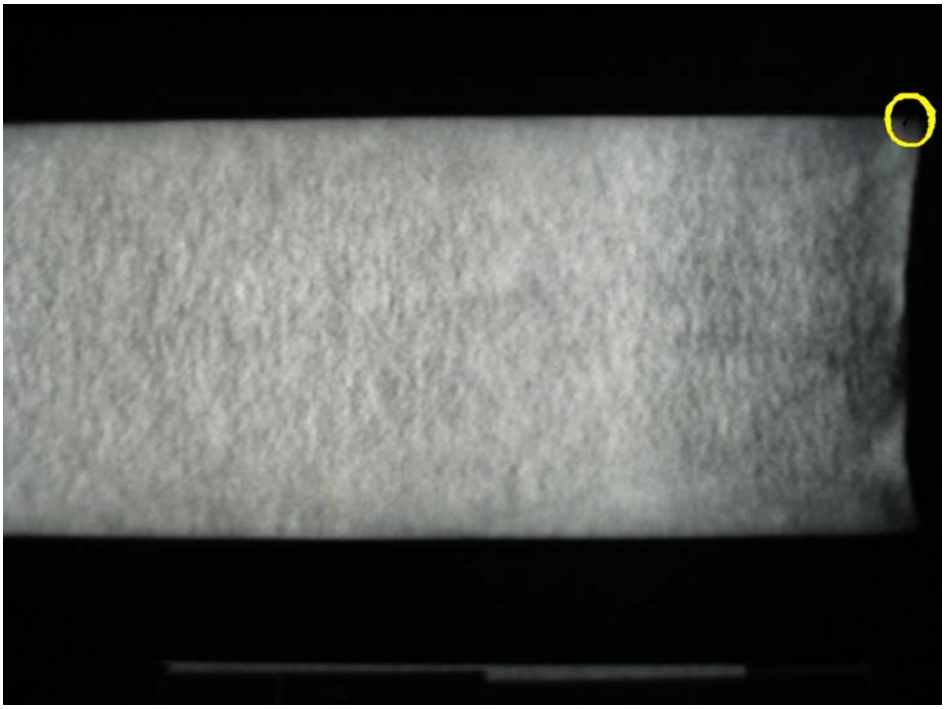




- Deformation zones (with overlay).



- Core width (with overlay chart).
- Core length (with overlay chart).
- Cracks and Inclusions in the cladding.
- Cracks or Pin Holes in the fuel core.



Stray particles in the cladding shall be detected with a magnifier. The uranium appears as a white spot on the X-ray film.

QUALIFICATION OF PROCESS

Part of the fuel plate qualification is the measurement of the fuel plate core geometry, homogeneity and checking for defects in the core and clad material. It is therefore essential that measurements can be performed reliably and consistently. Film exposure, development and evaluation are the backbone to qualify fuel plates to be used in the SAFARI-1 reactor that conform to international standards and requirements.

Personnel that carry out evaluation of fuel plate films shall be trained and qualified.

CONCLUSION

Fuel plate geometry obtained conformed to the engineering technical file requirements of SAFARI-1. Evaluation of the core for defects (stray particles, homogeneity, cracks, etc.) is acceptable with the method developed at SAFARI-1. Homogeneity measurements for U_3Si_2 + Al powder composition in the fuel plate dog-bone area gives acceptable results. See table 1 for film density measurements.