FUEL PLATES DEVELOPMENT FOR FRM II CORE

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ABSTRACT

The new FRM II design is based on a compact core. The uranium fuel is silicide U_3Si_2.
A particularity of the fuel plates relates to the uranium distribution in the meat which consists of 2 areas of different uranium densities : 3 g/cm^3 and 1,5 g/cm^3.

In the first part, this paper describes the main characteristics of the fuel plates.

In the second part, the results of preliminary fabrication tests are given. Full size fuel plates have been produced using depleted uranium and adjusting the parameters of the production processes. These tests show that the fuel plates can be produced on industrial scale.

Additional developments are carried out to set up series inspection technics adapted to this double density product.

1. INTRODUCTION.

The Research Reactor of Münich, so-called FRM, will be replaced by a new, high performance neutron source named FRM II.

The new reactor design has previously been presented by Pr. Böning in other international meetings [1] - [2].

The reactor core consists of a single cylindrical fuel element containing 113 involute shape fuel plates. It is very compact. (Slide 1)
The outer radius is 121,5 mm and inner radius 59 mm only. The main characteristics of the fuel plates are summarized in slide 2.

Fuel material is U_3Si_2-Al. The cladding material is AlFeNi which is specially adapted to high temperature use.

The particularity of the plates lies in the fuel meat which is composed of two parts of different uranium densities. One part is loaded to 3 g U_T/cm^3, the other one to 1,5 g U_T/cm^3.
These two parts are positioned side by side along the plate length according to the sketch of slide 3. The low density part occupies one sixth of the total meat width. In the finished plate, it corresponds to the outer part of the fuel element. This disposition allows to flatten the power density profile accross the reactor core [1].

Due to the presence of this double density in the meat, it was necessary to check the industrial feasibility of such plates according to stringent specifications.

Two different densities create an heterogeneity in the plate meat which induces a mechanical behaviour during rolling or bending different from the one usually observed on classical plates.

It also implies adaptation of the inspection techniques for bonding (UT) and U distribution homegeneity (X-ray scanning).

Therefore, we started an investigation program in order to study the double density plate behaviour on the following points in particular :

- Quality of bonding
- Straightness of the meat and core location
- Homogeneity of uranium distribution in both cores
- Curving ability.

The purpose of this paper is to present the development status of these plates.

2. FUEL PLATES FABRICATION TESTS.

The production process was adapted and the fabrication parameters adjusted in order to take into account the previously explained particularity of the fuel plates.
This preliminary work done, 12 full size depleted uranium fuel plates were manufactured.
The observed results are described herebelow :

Bonding quality :

Blister test and UT inspection showed no evidence of lack of bonding between the meat and the cladding on the one hand and between the two cores on the other hand.

The good bonding quality is also visible on the micrographs of slide 4. The three micrographs were taken from a transversal cut of the plate. They respectively correspond to the high density, the transition between high and low density, and the low density zones.
The darker particles are fuel particles.
It can be seen that the thickness of the meat is quite the same on both sides and therefore the cladding thickness is regular.
It can also be noticed that the borderline between the two cores is very sharp and straight.

Dimensions - Radiographic inspection

The external dimensions of the plates were measured as for ordinary plates.
To check that the dimensions of the cores met the specifications, X-Ray films of the plates were taken.
Slide 5 shows one of these X-Ray films. The difference of uranium density is imaged by different grey levels. It can be noticed that the borderline between both parts of the meat is very straight.
Therefore the parameters used for rolling were appropriate.

Other defects such as U stray particles in forbidden aluminium areas can be revealed thanks to the X-Ray films. In our case, they did not show any tendancy to present stray particles.
The radiograph also shows qualitatively the good homogeneity of the uranium distribution in the two parts of the core.

Homogeneity of Uranium distribution

Specially designed X-Ray scanning machines are used to control quantitatively the homogeneity of uranium distribution in fuel plates. A focused beam of X-Rays goes through the thickness of the plate. By measuring the absorption of the beam across the plate, the uranium density variations are determined.
The whole plate surface is inspected by successive scanning along its core length.

Slide 6 shows the results of this control on a scanning length on each part of the core. The machine was successively calibrated to inspect each uranium density zone.
It can be noticed that each profile is very linear in both low and high density zones, which proves the good homogeneity of U distribution.

Curving ability

The previous inspection carried out on the flat products had shown that the fuel plates could be produced according to specifications.

It remained to be checked that the double core was not detrimental to the plate curving ability. Therefore, 6 fuel plates were curved to obtain the appropriate involute shape. The results of the bending test were satisfactory; the involute shape was correct. In particular, no lack of continuity was observed along the borderline separating the two cores.

3. FUTURE WORK

3.1 Manufacturing.

Previous work corresponds to preliminary tests to check the feasibility of FRM II double core plates. It was carried out on a small quantity of full size plates. As for any new product, reproducibility tests have to be done. For this purpose, in the frame of the cooperation between FRM and CERCA, full size depleted uranium plates will be manufactured in quantity large enough to allow the production of a complete dummy fuel element.

3.2 Inspection.

The test plates have been inspected by adjusting the calibration of inspection equipment for each uranium density area.
For industrial production, inspection procedures will have to be adapted to minimize the time length required for plate inspection.

CONCLUSION.

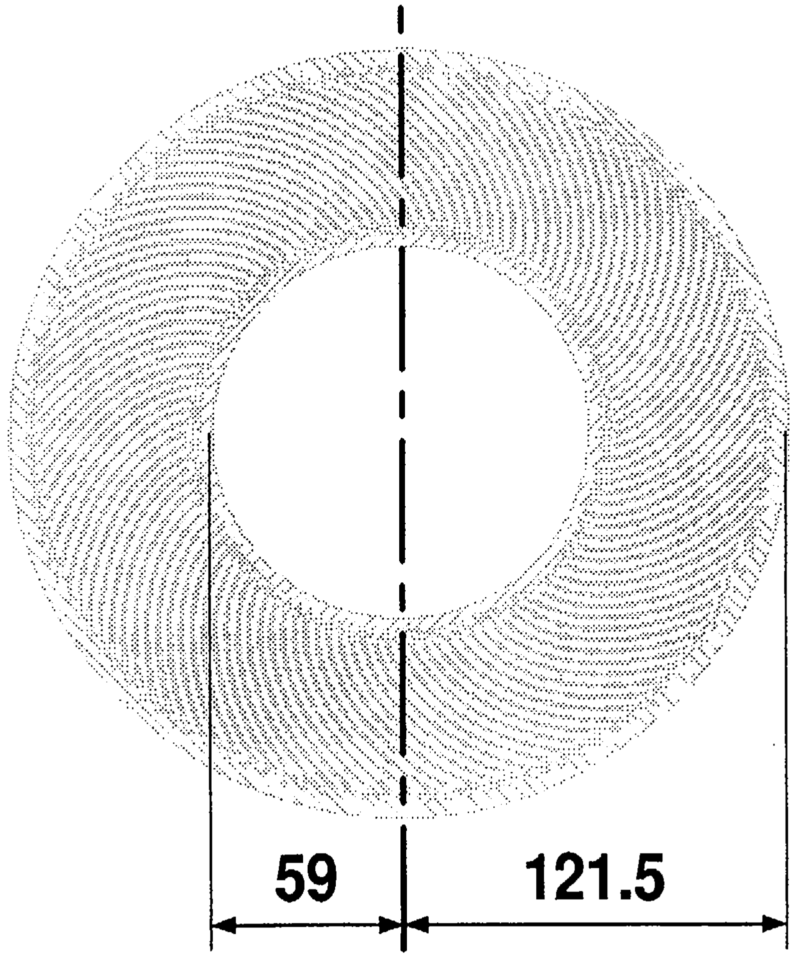
The test results which have been exposed previously show the feasibility of full size fuel plates for FRM II. The adaptation of the existing production processes permits the fabrication of fuel plate containing a double core, insuring a good quality of the bonding between the cladding and each uranium part, a good homogeneity of the uranium distribution, and meeting the geometry requirements of the double core and the final involute plate.

REFERENCES.

[1] K. Böning, J. Blaubach : "Design and Safety features of the planned compact core research reactor FRM II" International meeting on Reduced Enrichment for Research and Test Reactors, Jakarta (Indonesia) Nov 4-7, 1991.

[2] K. Böning, W. Gläser, J. Meier, G. Rau, A. Röhrmoser, E. Steichele : "Status of the Munich Compact Core Reactor Project". Proceedings of the XII. Int. Meeting on Reduced Enrichment for Research and Test Reactors 1989, Berlin Germany (FRG), September 10-14, 1989; Report of the KFA Jülich GmbH, Konferenzen Band 4/1991, ISBN 3-89336-063-8, page 473-483 (1991)

FRM-II
FUEL ELEMENT SECTION



MAIN CHARACTERISTICS OF FRM-II FUEL PLATES

U DENSITY	:	1.5 and 3.0 g U_T/cm^3
FUEL MEAT	:	$U_3 Si_2 + Al$
CLADDING	:	Al Fe Ni/AG_3 NE
CLADDING THICKNESS	:	Nominal : 0.38 mm Mini : 0.25 mm
MEAT THICKNESS	:	Nominal : 0.60 mm
PLATE SHAPE	:	INVOLUTE

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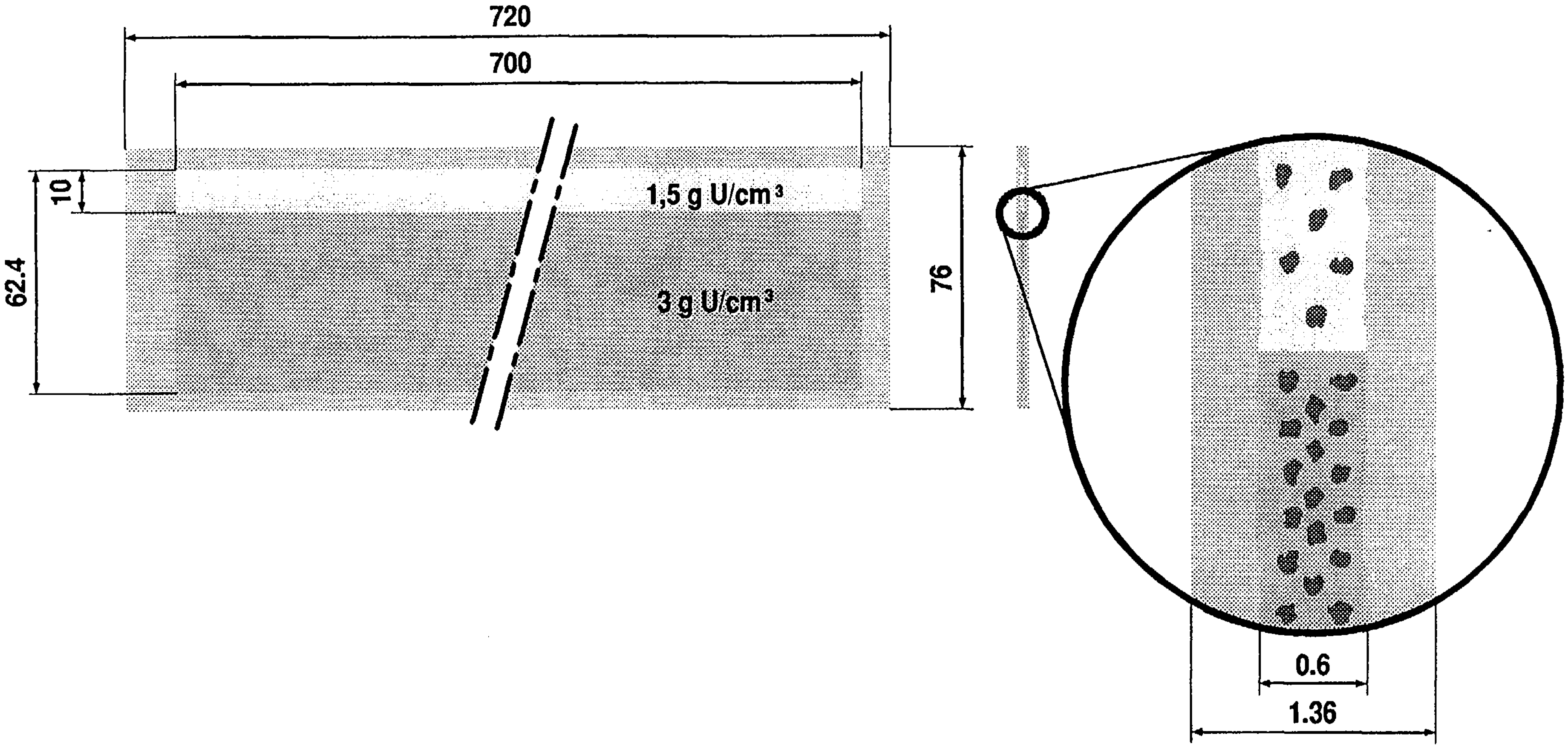
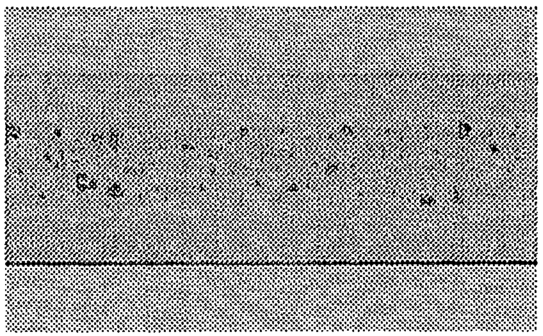
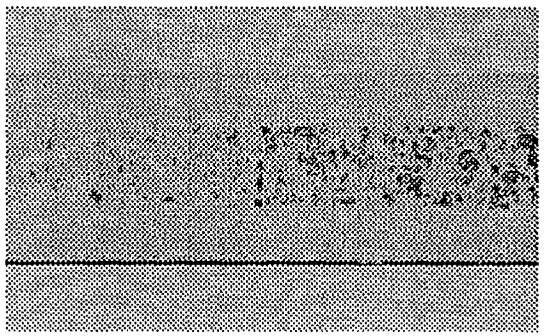
FRM-II DOUBLE-CORE FUEL PLATE
(flat condition)



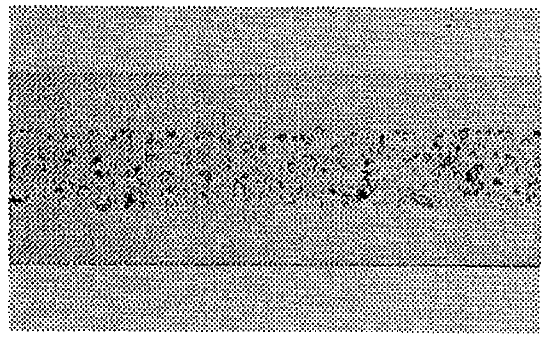
FRM-II DOUBLE-CORE FUEL PLATE TRANSVERSE SECTION



Low density zone

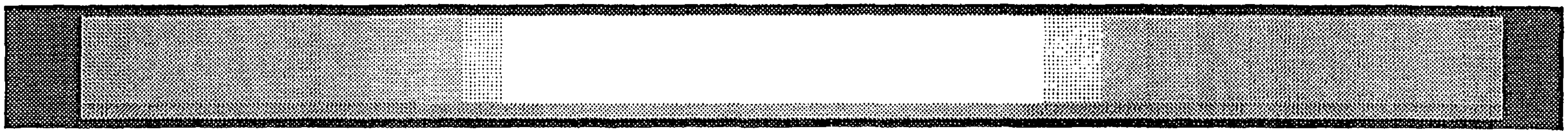


Transition zone



High density zone

FRM-II PLATE
FUEL CORE LOCATION



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U DISTRIBUTION HOMOGENEITY ALONG FRM-II PLATE HIGH AND LOW DENSITY ZONES