CERCA

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STATUS OF DEVELOPPEMENT

MAIN FEATURES

OF PLATES AND DUMMY ELEMENT FABRICATION

FOR FRM II

C. Ailloud, P. Colomb, J.P. Durand, G. Harbonnier

CERCA
Zone Industrielle Les Berauds
26104 Romans sur Isere France

Presented at the IGORR-IV meeting
May 24-25 1995
Gatlinburg, Tennessee, USA

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ABSTRACT

Dummy element fabrication is part of the developpement of FRM II concept.

CERCA has received order from Technical University of Munich (Germany) to ensure industrial possibility for fabrication and control of such element.

Main points about plates and element fabrication, and some of major difficulties in performing this order are outlined in following report.

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1 INTRODUCTION

Since the beginning of the FRM II project CERCA, as a major research reactor fuel manufacturer, has been involved in the developpement of the element concept as far as fabrication is concerned.

CERCA has received from Technical University of Munich in december 1993 the order for fabrication of two dummy elements and about 400 fuel plates loaded with depleted uranium. One of these elements has to be made with aluminium plates, the other with depleted uranium plates.

This order was aiming at following goals:

For CERCA:

- set up an industrial process for manufacture of fuel plates including all necessary control and quality steps
- develop the various tools required for plates fabrication and control, element assembly and welding
- prepare of a whole set of paperwork, as the result of prototype fabrication, needed for German licensing and surveying authorities, to get final approval for real element fabrication and reactor start-up

For TUM:

- validate the design of the element in an hydraulic test loop
- allow some tests in the future reactor itself for handling and non active flow-tests

At the 1992 IGORR meeting in Saclay, CERCA had already presented some features of the fuel plates, but this was more the summary of some kind of laboratory work, than the report about an industrial fabrication.

This present paper, will emphasis the status of plates and dummy elements fabrication, considered as the beginning of an industrial stage for such a fuel.

2 SCHEDULE OF FABRICATION

The dummy elements fabrication is planned over a duration total of two years and a half, starting in december 93.

Main milestones for the order are:

- september 95	completion of depleted uranium fuel plates fabrication
- december 95	delivery of the first dummy element (with aluminium plates)
- march 96	delivery of the second dummy element (with depleted uranium plates)

3 FRMII FUEL ELEMENT DESCRIPTION

FRM II reactor is a compact core design and the fuel element is very similar from ILL RHF fuel element altough smaller. In order to get a size comparison, FRM II element could be introduced inside ILL RHF element !

General shape of the element is a cylinder about 300 mm diameter and 1000 mm high.

The top outer nozzle has a cone shape on which the element stays in the reactor, and inside this upper nozzle a grove is used by the handling tools during handling of the element

The bottom nozzle has six nuts to allow guiding the element in the water channel, and the inner upper part has also six nuts which purpose is to guide the control rod assembly inside the fuel element.

113 plates with involute shape are the active part of this element whose total uranium loading is 8.106 kg uranium, with a nominal U235 enrichment of 93% for the real element.

Two combs welded to each plate, one at the inlet and one at the outlet of fuel section ensure that in all conditions the water channels keep their width, and a sieve, drilled with about 5000 holes 1.8 mm in diameter, is located between the inner and outer upper nozzles to prevent foreign material to clogg the channels.

All plates and All structural parts are attached to the tubes by EB welding.

A boron ring is inserted at the lower end of the element, on the bottom nozzle immediatly after the fuel plates, to minimize the neutron flux peak at this place.

The depleted Uranium dummy element is equipped with strain gages and pressure sensing probes which will be used during the hydraulic tests.

4 FRM II FUEL PLATES DESCRIPTION

Due to very high power load in this compact core design, distribution of Uranium loading throughout the plate cannot be constant.

Near the exterior of the element, where thermal and neutron flux are maximum, Uranium loading per surface unit must be lower than in the inner region. To achieve this goal, two approaches are to be considered:

- vary continuously Uranium loading across the plate by varying meat thickness, but with a constant u/cm^3 content.
- vary discontinuously Uranium loading across the plate with a constant meat thickness, and a variable U/cm^3 content.

The first approach had been choosen by the ANS project, but TUM has choosen the simpler second possibility.

Thence FRM II fuel plates cores are composed of two different parts, a large core with a high Uranium loading and a smaller one with a lower Uranium loading.
The smaller core with low U/cm3 content is located near the outside of the element.

The main caracteristics of fuel plates are described in the following table.

	SMALL CORE	LARGE CORE
Cladding material	AlFeNi	
Frame material	AG2NE	
U alloy	U_3Si_2	
Total U content (g)	6.38	60.33
U loading (g/cm^3)	1.5	3

5 FABRICATION OF FUEL PLATES

Fabrication of such fuel plates with two cores of different densities is not so easy as fabrication of normal fuel plates and some know-how must be acquired to achieve a good quality, acceptable for reactor use.

Large core is very similar to those used in usual fabrication, but small core pressing must be done with special tooling due to the very small width of the piece. Care must be taken to avoid inhomogeneity in powder distribution.

Special technics have been developped to insure same groth of the two parts of the core during rolling process, because of the difference in density of components (3 and 1.5 gU/cm^3) which leads to very different mechanical behaviour of the two cores.

Also special preparation of sandwiches is necessary to avoid stray particles and difference in bonding of the components of the plate.

Frame and cover material are well known from ILL RHF fuel plates fabrication, and CERCA has taken advantage of this experience to master the rolling skill.

6 FUEL PLATES CONTROL RESULTS

Special control technics have also been developped for FRMII especially in the field of ultrasonic and Uranium distribution homogeneity measurements.

Sensing parameters and standards have to be adjusted to allow an ultrasonic control of both parts of the plate at the same time. Interface between the two cores is fully checked as well as the ends of the plate in the dog-bone area.

For the homogeneity of Uranium distribution, CERCA has taken advantage of the new fully computerised machine, but nevertheless every plate must be controlled in two sequences, one for the small core and one for the large one with two different standards because of the large difference in Uranium loading.

Figures in appendix present some samples of the overall quality of plates fabrication.

Radiographic examination shows no or very small difference in the length of the two cores. Also homogeneity is excellent and stray particles are absent of extremity of fuel plates.

Micrographic examination shows no overshooting of one core on the other and cladding thickness is very regular all over the plate.

Uranium distribution test is excellent for the large core. The small core shows some variations due to its small size, but these variation stay within the allowable limit of ±12% in the middle portion of the plate.

Ultrasonic results are not presented here because they are merely numerical results and not easily interpreted outside of their environnement, but all plates tested up to now are within the allowable limits of the specification.

7 FUEL ELEMENT FABRICATION

Due to its small size compared to RHF ILL element, FRM II fabrication has necessited special machine development and numerous tooling and machining conception to achieve a reasonably easy assembly and welding on an industrial fabrication scale.

All structural parts, including inner and outer grooved tubes of the fuel section as well as the sieve, have been developed and machined in CERCA plant at Bonneuil sur Marne near Paris.

Fuel element assembly begins with plates insertion in the grooves of the tubes, before they are affixed to these tubes by EB welding.

As the inside diameter of the fuel element is only 104 mm,CERCA, in collaboration with equipement manufacturer, has developed a very small EB gun (100mm diameter).

Welding of plates on outer tube and of all accessories (end fittings, boron ring...) is done with a classical EB gun.

Boron ring was first intended to be an Al/B alloy, but no manufacturer was willing to develop such fabrication of special alloy for a very small quantity.
So CERCA has developped a boron ring concept derivated from the boronated side plates technic, taking advantage of the experience from other fabrications (HFR Petten or ORPHEE for instance).

A plate with a Boron/Al core is laminated like a fuel plate, and its geometry is checked by X radiographs and neutron radiography.
This plate is machined, rolled and welded to form a ring and this ring is then inserted at the bottom of the element and welded to the structural part.

Very tight geometrical tolerances on the finished element, and geometry of the seat which is a sphere portion require that the complete element is machined on a precision lathe as final operation.
Thermal deformations during welding are rather important, and it is not possible to achieve final geometry directly from the individually machined structural parts.

8 INSTRUMENTATION OF FRM II FUEL ELEMENT

In the instrumented element used for hydraulic tests, strain gages are attached to one fuel plate, and corresponding leads are routed along the plate and through a small hole drilled in the bottom nozzle before completion of assembly and welding.

Special care must be taken to avoid damage to these leads during welding and machining of the element.

Pressure probes oulets are also foreseen on two separate channel, and at several places on top and bottom nozzle to monitor the pressure drop during hydraulic tests.

9 FUEL ELEMENT CONTROL

Plates to tubes welds are controlled by ultrasonic under water test with a special equipement internally developed and all other welds are controlled by radiographic examination.

After assembly and welding of end fittings, every water channel is measured with strain gages, and the results are plotted.

10 STATUS OF FABRICATION

A dummy element internally used at CERCA to develop manufacturing process has been assembled and welded and is now ready for final machining.

Fuel plates with depleted Uranium have been fabricated. As to now about 150 plates over a total of 400 ordered have been rolled and are under quality control.

The first official dummy element as ordered by TUM is about to be assembled with aluminium plates and will be used to finally set-up all parameters and to check the feasability of strain gages and pressure probes installation and will be delivered during the third trimester of 95.

The depleted Uranium element will be assembled later this year, and will serve, in the factory, the purpose to make final welding agreement by customer and survey authorities, as well as demonstration for the industrial fabrication.

Delivery of this element to TUM will take place as foreseen at the beginning of 1996

11 CONCLUSION

FRM II fuel element has necessited the synthesis of various fields of know-how at CERCA.

Among these we may summarize mainly:

- manufacture of multi density cores plates
- adaptation of inspection devices
- EB welding

Completion of fabrication is now underway, and the hydraulic tests should begin early next year.

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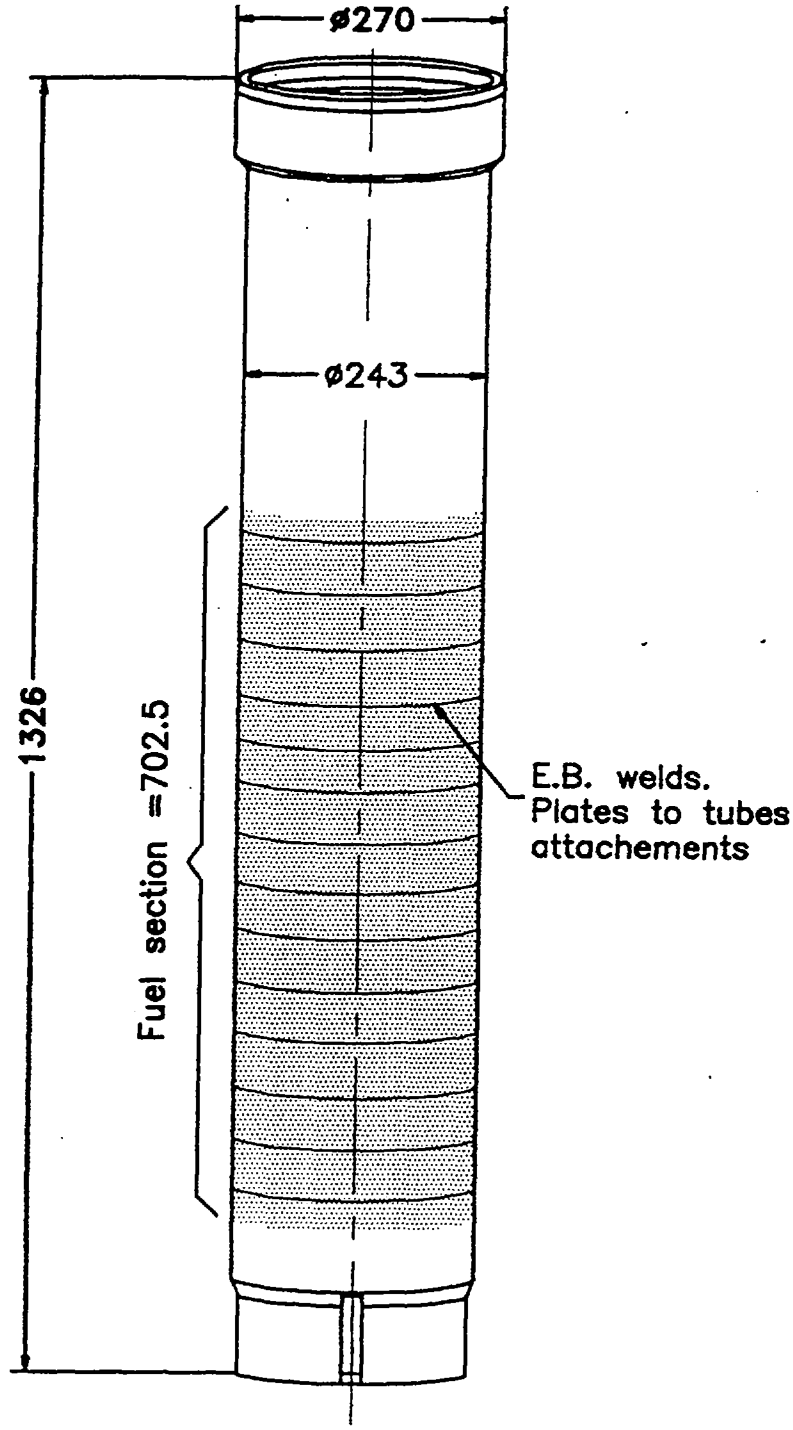
FRM II
External dimensions



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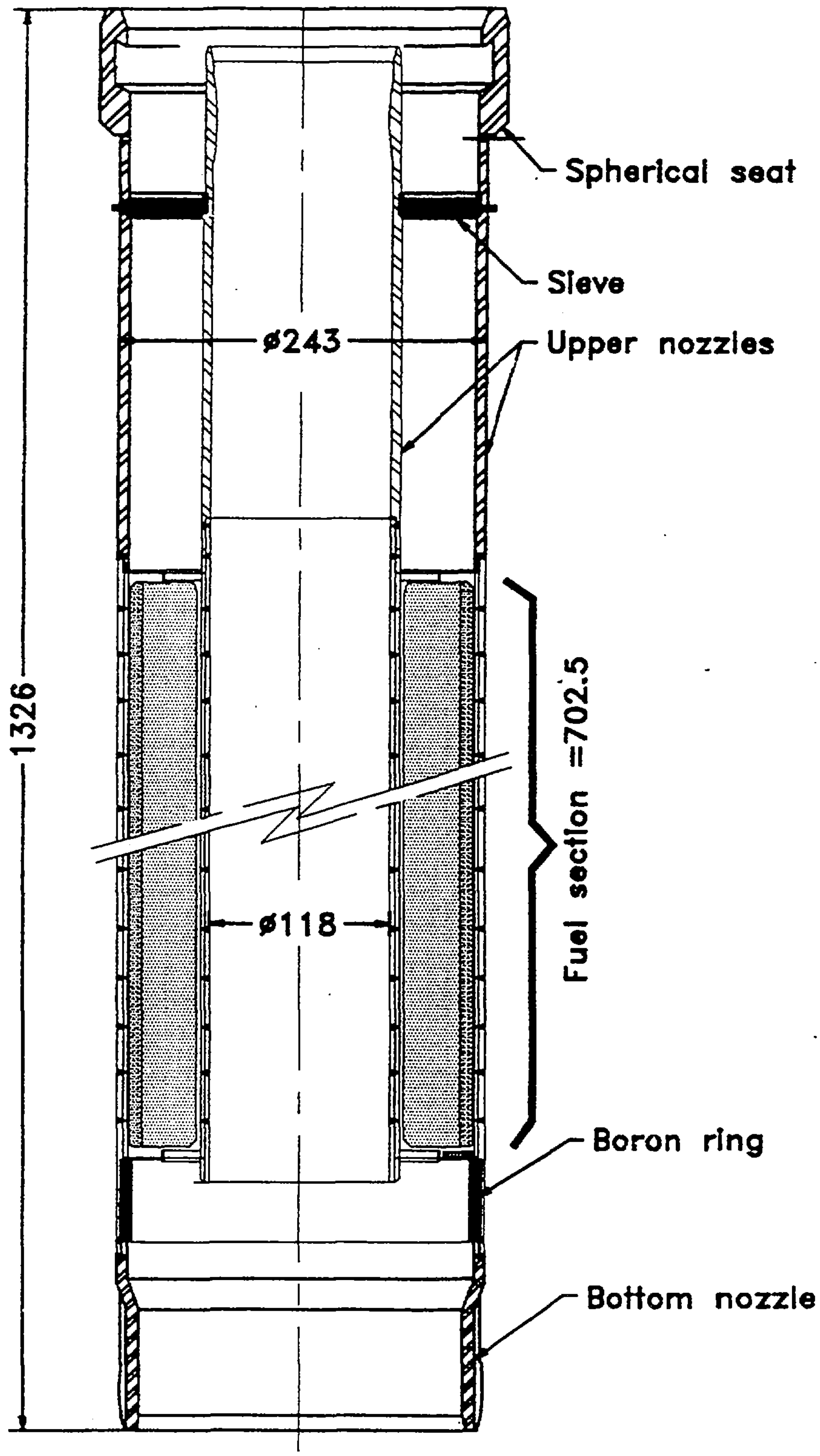
FRM II
Fuel element description



FRAMATOME
FABRICATION COMBUSTIBLE

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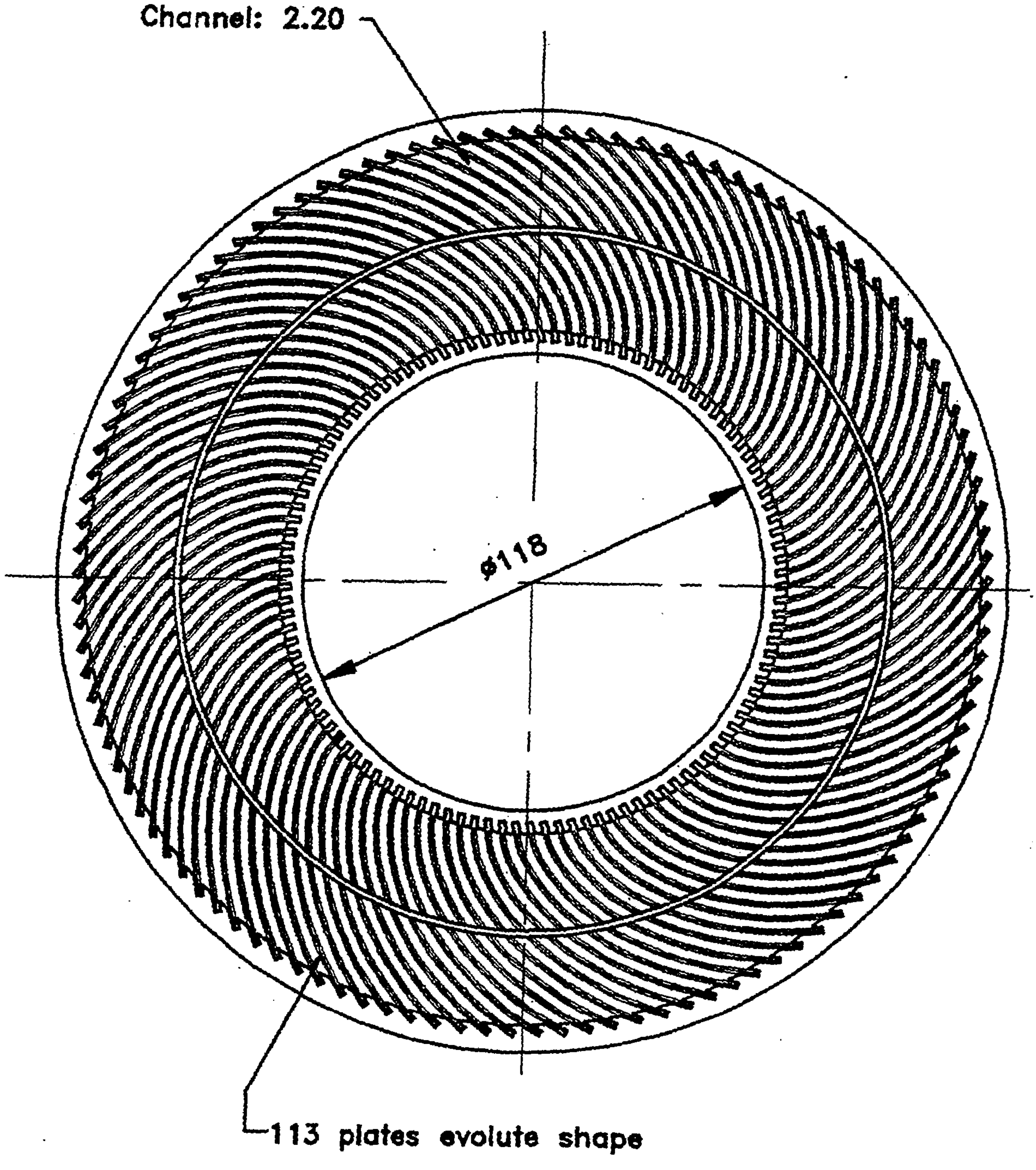
FRM II
FUEL SECTION



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FABRICATION COMBUSTIBLE

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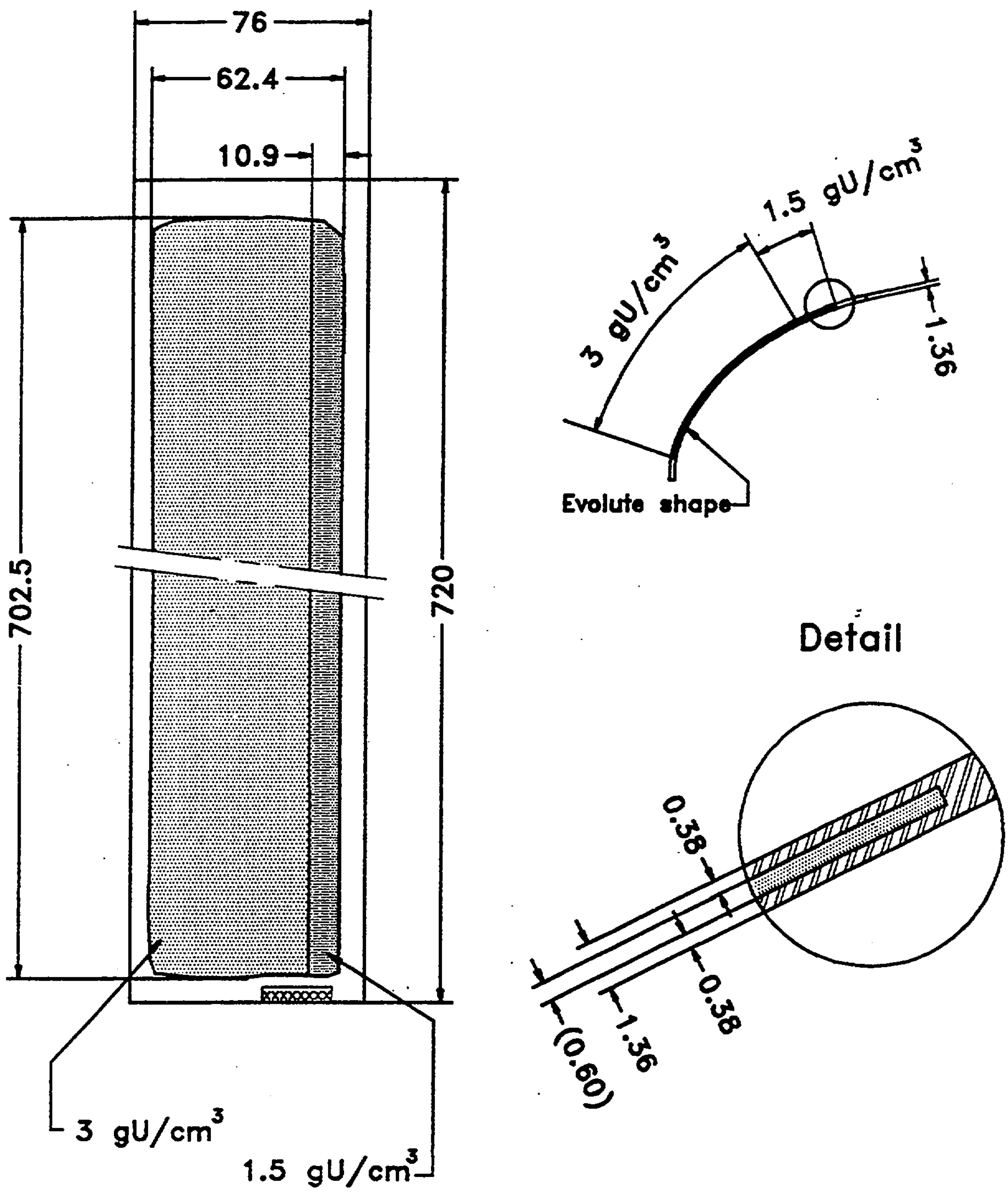
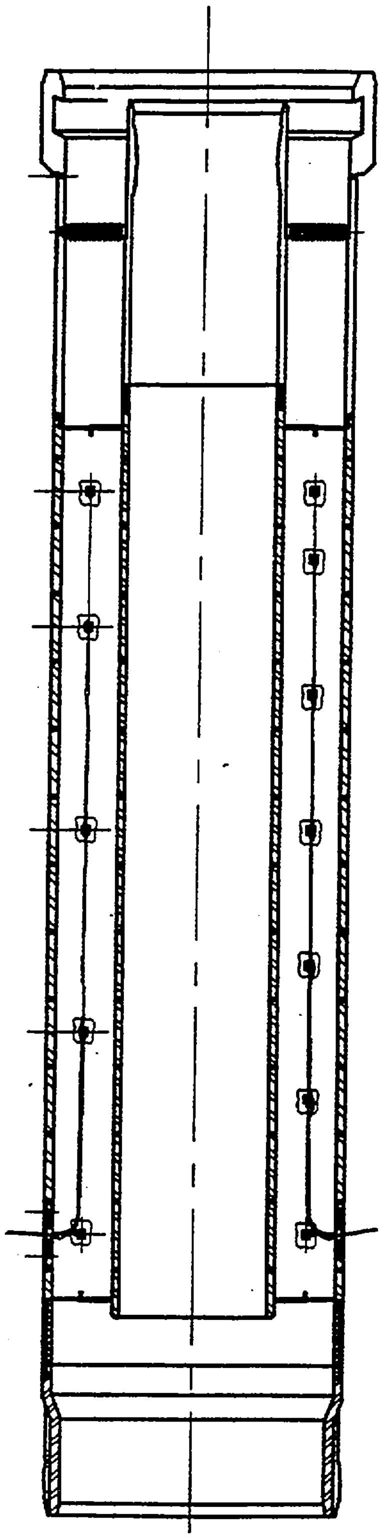
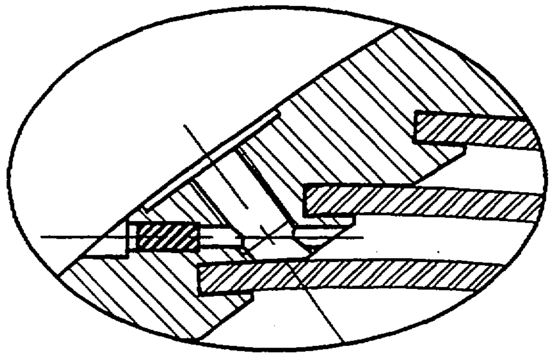
FRM II
Fuel plate

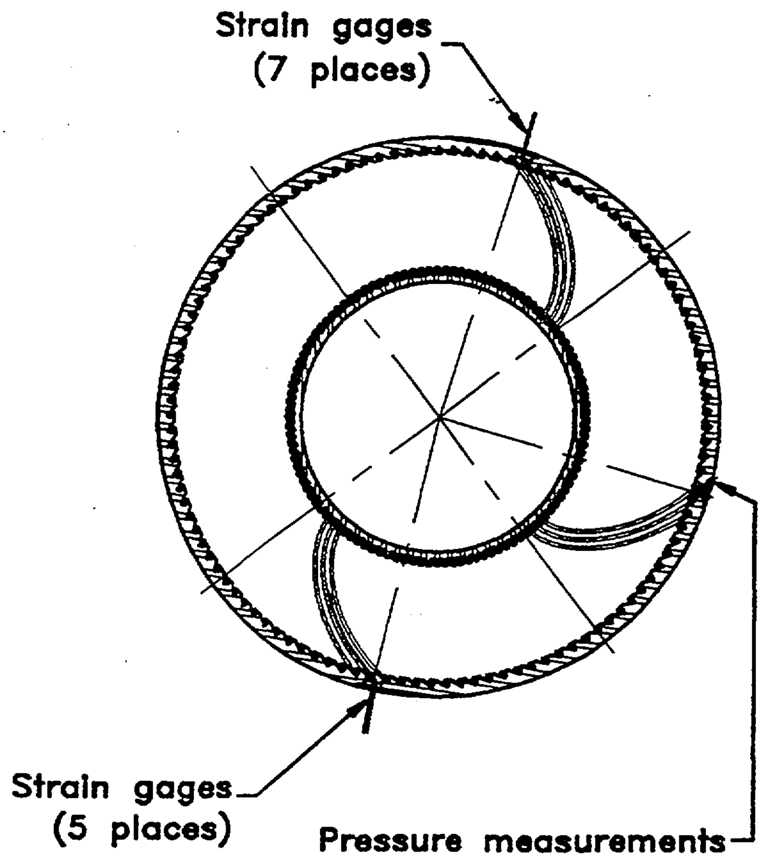


FRM II
Instrumentation



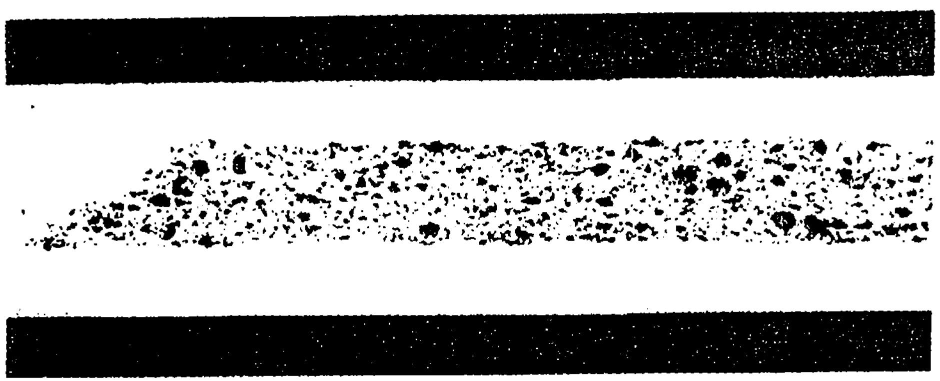
Detail for pressure pick-up

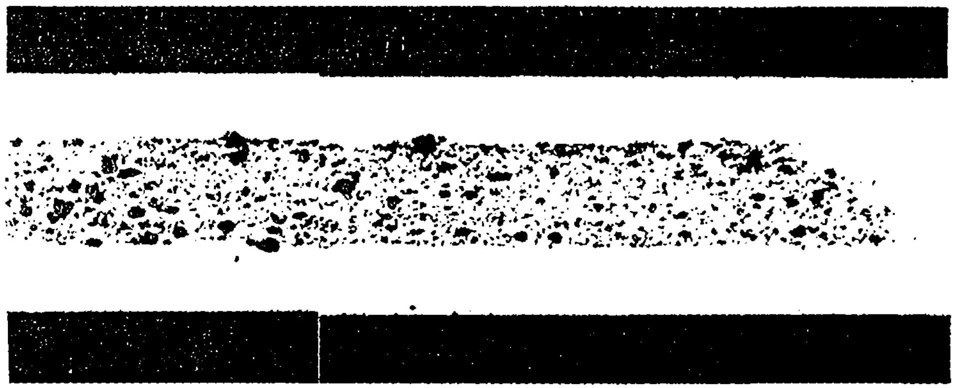




FRM2 U3Si2 FUEL PLATE

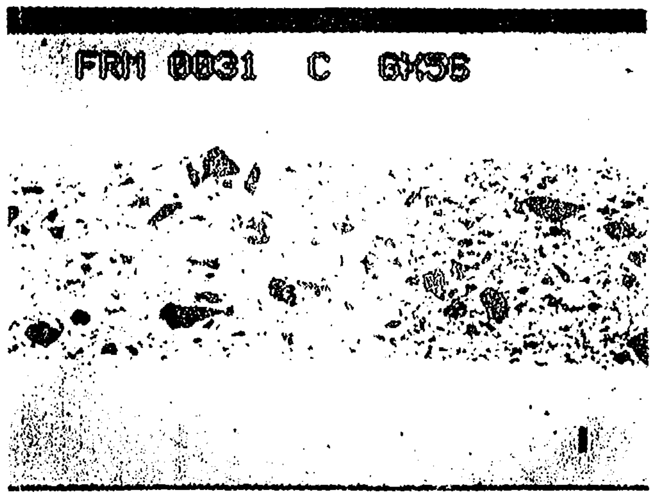
CERCA



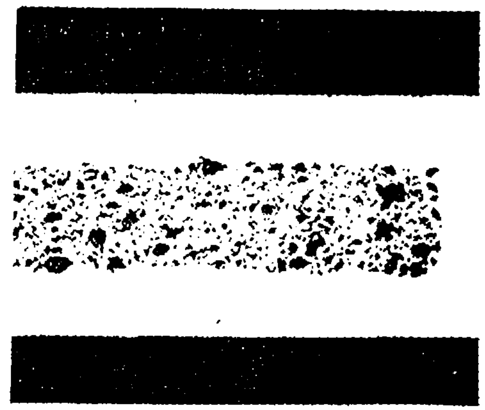


3.0 gUt/cm3 CORE (dog-bone area)

1.5 gUt/cm3 CORE SIDE



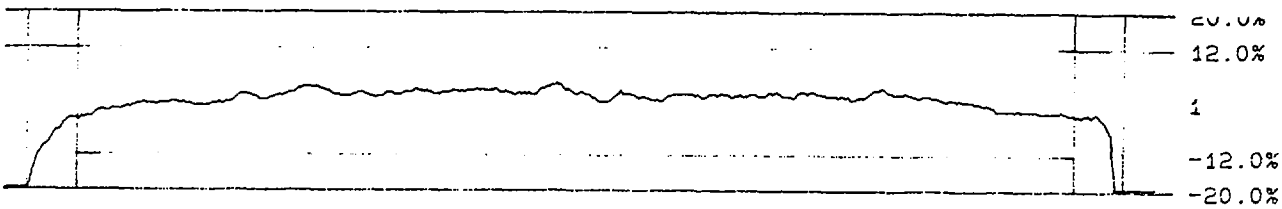
1.5 and 3.0 gU/cm3 CORE INTERFACE



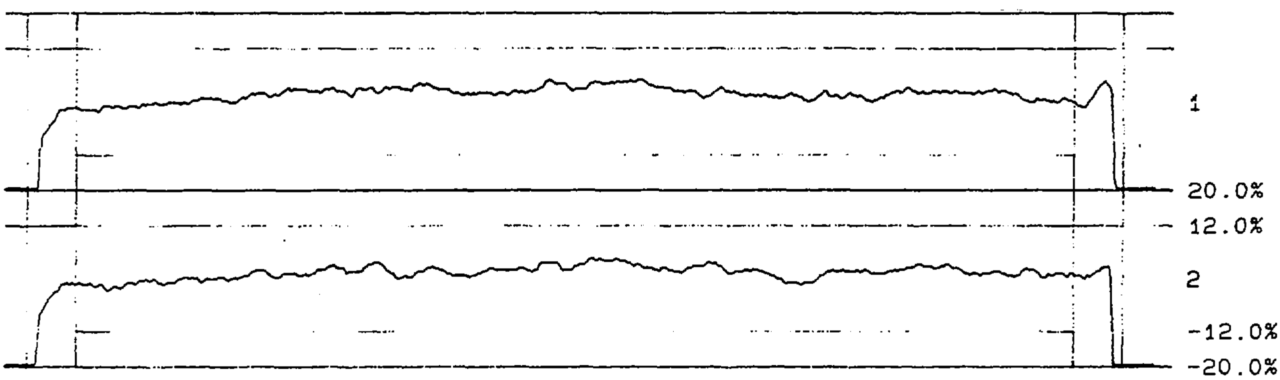
3.0 gUt/cm3 CORE

URANIUM DISTRIBUTION HOMOGENEITY

SMALL CORE



LARGE CORE



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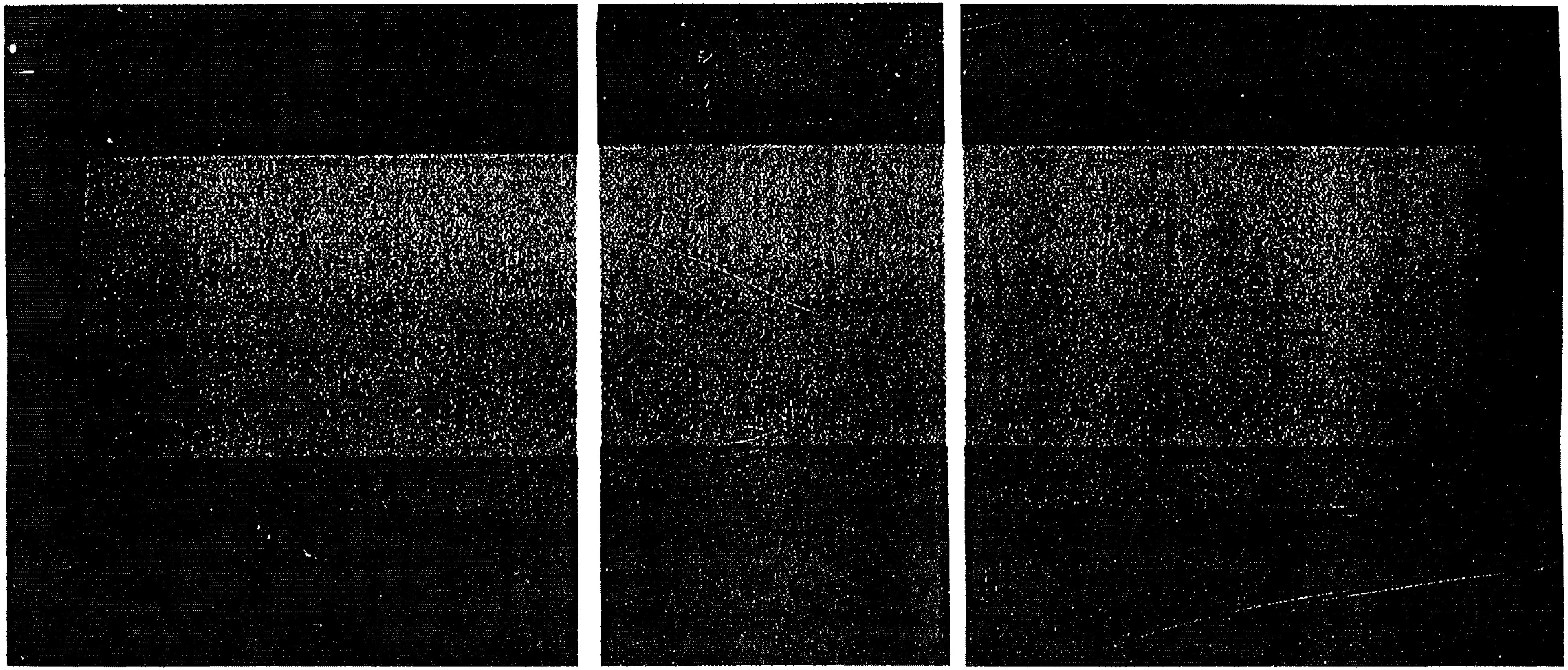

FRM II PLATE X-RAY RADIOGRAPH