SPENT FUEL SITUATION OF BRAZILIAN RESEARCH REACTORS

A.J.Soares[1], M.S.Dias[2], J.B.M.Tondin[1], A.T. Silva[1]

Abstract

This paper presents a brief description of the four existing Brazilian Research Reactors. There are four research reactors in Brazil, and, because of the low reactor power and low burn-up of the fuel, for three of them spent fuel storage is not a problem, except for the concern about ageing. However for one of the reactors, more specifically IEA-R1 research reactor, spent fuel storage is a major concern, because, according to the new proposed operation schedule of the reactor, in the year 2007 there will be no more racks available to store spent fuel, and so far, no alternative has been proposed. The description of the type and amount of fuel elements utilized in each of the reactors with a short discussion about spent fuel storage capacity at each installation is presented in the paper.

1.INTRODUCTION

Actually there are 4 research reactors (RR) in operation in Brazil. IEA-R1, considered the most important Brazilian RR, is the oldest in the southern hemisphere /1/, /2/, /3/. Located at IPEN[1], in the campus of São Paulo University, in São Paulo city, it started to be built in 1956 within the US program Atoms for Peace. The reactor reached criticality for the first time on September 16th of 1957. Although designed to operate at 5 MW, from 1957 until 1961 the operation of the reactor was mainly for commissioning tests and some nuclear physics experiments, and the regime of operation of the reactor was during week days, less than 8 hours a day, with power level between 200 kW and 2 MW. In 1961 a program was established to produce ^{131}I, and the reactor started to be operated at a constant power of 2 MW, 8 hours per day, 5 days per week. In 1995 a new program was established with the objective to start immediate production of ^{153}Sm, and to prepare the reactor to produce ^{99}Mo. As result of this decision the regime of operation was changed to continuous 64 hours per week, from Monday through Wednesday, keeping the reactor power at 2 MW, and some modifications started taking place to comply the reactor with new national legislation to operate continuously during 120 hours per week at 5 MW. The burn-up rate, which is actually 240 MW-Day per year, is expected to increase to 1,100 MW-Day per year. Figure 1 shows the IEA-R1 reactor core.

IPR-R1 is the second Brazilian RR, located at CDTN[2], in the campus of Federal University of Minas Gerais, in Belo Horizonte city. The nominal power of the reactor is 100 kW and its first criticality was achieved on November of 1960. The regime of operation of the reactor is 4 hours per day, 5 days per week, 40 weeks per year. The integrated burn-up of the reactor since its first criticality until present time is about 130 MW-Days. Due to the low nominal power of the reactor, except for ageing concern, spent fuel is far from being a problem. The first

1-IPEN - Instituto de Pesquisas Energéticas e Nucleares
2-CDTN – Centro de Desenvolvimento de Tecnologia Nuclear
3-IEN- Instituto de Engenharia Nuclear

fuel assembly replacement of the reactor is expected to occur only in 2010.

The third Brazilian RR is called Argonauta, and is located at IEN[3], in the campus of the Federal University of Rio de Janeiro, in Rio de Janeiro city. The first criticality of the reactor, which has a nominal power of 200 W, was reached on February of 1965, and actually it operates 4 hours per day, 5 days per week, 43 weeks per year. The accumulated burn-up of the reactor since its first criticality is about 0.25 MW-Day, and as in the case of IPR-R1, due to the low nominal power, storage of spent fuel is not a problem.

The most recent Brazilian RR is IPEN/MB-01. Located at IPEN[1], it is the result of a national joint program developed by the Brazilian Nuclear Energy Commission and the Brazilian Navy. The reactor, a water tank type critical facility rated 100 W, is mainly used for simulation of small LWR and research in reactor physics. It reached criticality for the first time on November of 1988. For IPEN/MB-01 the accumulated burn-up is below 0.1 MW-Day.

2. REACTOR DESCRIPTION

Even considering that spent fuel storage is not a problem for IPR-R1, Argonauta and IPEN/MB-01 RRs, it is important to discuss some of the characteristics of such reactors. Table 1 summarizes the four Brazilian RRs, and gives a brief description of their fuel elements. The main characteristics of the reactors are described as follows.

IEAR1 - It is a pool type, light water cooled and moderated reactor, with graphite reflector, designed by the Babcock & Wilcox Co. As shown in figure 1, the reactor core is composed of a square 5 x 5 lattice with 20 standard fuel elements, 4 control elements and one special irradiation device at the center of the lattice. The core is surrounded by aluminum canned graphite in a 8x10 grid plate, which is suspended by an aluminum structure. A layer of water 8 meters thick covers the reactor, and is used as radiation shielding. The standard fuel assemblies have 18 flat plates, and the control assemblies 12. Since 1997 all fuel assemblies used in the reactor core are made at IPEN, according to a fuel fabrication program established in 1985. According to the fabrication program, the first assemblies were made with a fuel "meat" of U_3O_8-Al, and Uranium density of 1.9 g/cm^3. In 1997 the fuel "meat" had its density increased to 2.3 g/cm^3, and in 1999 U_3Si_2-Al started to be used as "meat", instead of the U_3O_8-Al, with a Uranium density of 3.0 g/cm^3. Actually the composition of the reactor core is a mixing of uranium silicide fuel assemblies (5 of the standard type) and uranium oxide fuel assemblies (15 of the standard type and 4 of the control type). More details about IEA-R1 RR can be seen in reference 4.

IPR-R1 is a Triga-Mark-1 type reactor, supplied by General Atomics. The core of the reactor is composed by 59 UZrH rods, with aluminum cladding, within a large ring of graphite canned in an aluminum tank. Enrichment of the fuel is 20%, and the rods have a diameter and length of 37.6 and 724 mm, respectively. More details about IPR-R1 RR can be seen in reference 4.

TABLE 1. Research Reactors in Brazil.

Reactor name	IEA-R1	IPR-R1	ARGONAUTA	IPEN/MB-01
Type	MTR- Open Pool	Triga-Mark-1	ARGONAUTA	Critical Assembly (Tank Type)
First criticality	Sep-1957	Nov-1960	Fev-1965	Nov-1988
Power (kW)	5,000	100	0.2	0.1
Type of fuel element	U_3O_8-Al and U_3Si_2-Al plates	UZrH rods	U_3O_8-Al Plates	UO_2 pellets within SS tubes
Fuel elements per assembly	Standard: 18 Control: 12	1 (each rod is one assembly)	Standard: 17 Control: 7	1 (each tube is one assembly)
Number of fuel assemblies in core	Standard: 20 Control: 4	59	Standard: 6 Control: 2	680

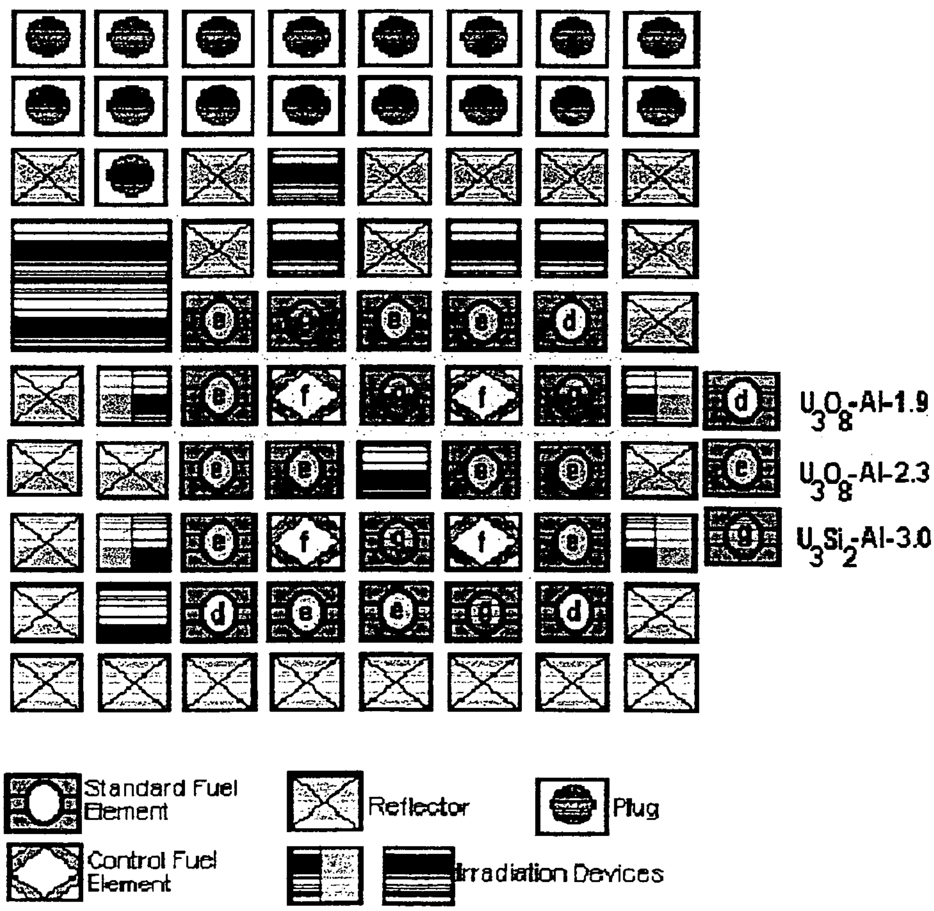

Figure 1 – IEA-R1 Reactor Core.

ARGONAUTA - It is an Argonauta type reactor, built by Brazilian engineers and researchers, according to a project supplied by Argonne National Laboratory of the United States. In its actual configuration the reactor has 8 fuel assemblies, being 6 of the standard type and 2 of the control type. Standard and control type assemblies have 17 and 7 flat plates, respectively. The plates containing U_3O_8 are covered with aluminum. Enrichment of the fuel is between 19.0 and 19.9 %. More details about ARGONAUTA RR can be seen in reference 4.

IPEN/MB-01 – As mentioned before, IPEN/MB-01 is the result of a national joint program developed by the Brazilian Nuclear Energy Commission and the Brazilian Navy used for simulation of small LWR and research in reactor physics. It has 680 stainless steel fuel pins with UO_2 pellets inside. Fuel pins are 1,194 mm long with and active length of 546 mm. The remainder of the pin is filled with Al_2O_3 pellets. Pin diameter is 9.8 mm and fuel enrichment is 4.3%. More details about IPEN/MB-01 RR can be seen in reference 4.

3. SPENT FUEL STORAGE CAPABILITY

As explained before, due to the low nominal power rating of IPR-R1, ARGONAUTA and IPEN/MB-01 RRs, for them storage of spent fuel is not a problem, except for ageing concern. In the case or IPR-R1, the first refueling is expected to occur around 2010, and the spent fuel capacity of the installation is 60. As it is for IPR-R1, also for the ARGONAUTA spent fuel storage is not a problem, because it has fuel storage capacity of 12 elements, in dry storage, and there is no expectation to replace any assembly in the next 10 years. IPEN/MB-01 also has a very comfortable situation, since it has only 680 fuel elements and 3500 position available for dry storage. Since it is a critical assembly, the expectation is to replace all fuel elements (with low burn-up) at the same time, to study a new core configuration.

When we analyze the situation for IEAR1, we see that its situation is not so comfortable, if we consider the new proposed operation schedule of the reactor, even considering that 3 years ago, in 1999, 127 spent fuel elements were sent back to United States of America, as result of a joint work with USA Department of Energy and German companies Nuclear Cargo + Service GMBH (NCS) and Gesellshaft fur Nuklear-Service (GNS), within the USA "Research Reactor Spent Nuclear Fuel Acceptance Program". According to the new proposed operation schedule of the reactor, the refueling frequency is expected to be between 18 and 20 fuel assemblies per year, for a total storage capacity of 156 assemblies in the storage area of the pool, as shown in Figure 2. From these, about 30 are already being used to store spent fuel which means that only 126 are available for storage, and if no action is taken until 2007, there will be no more racks available to store new spent fuel assemblies. As shown in Figure 3 the installation has 50 tubes designed for dry storage but, because of infiltration problems, a lot of work will be required before any decision to store spent fuel there can be taken.

Annex 1 present the Data Basis concerning the IEA-R1 RR fuels.

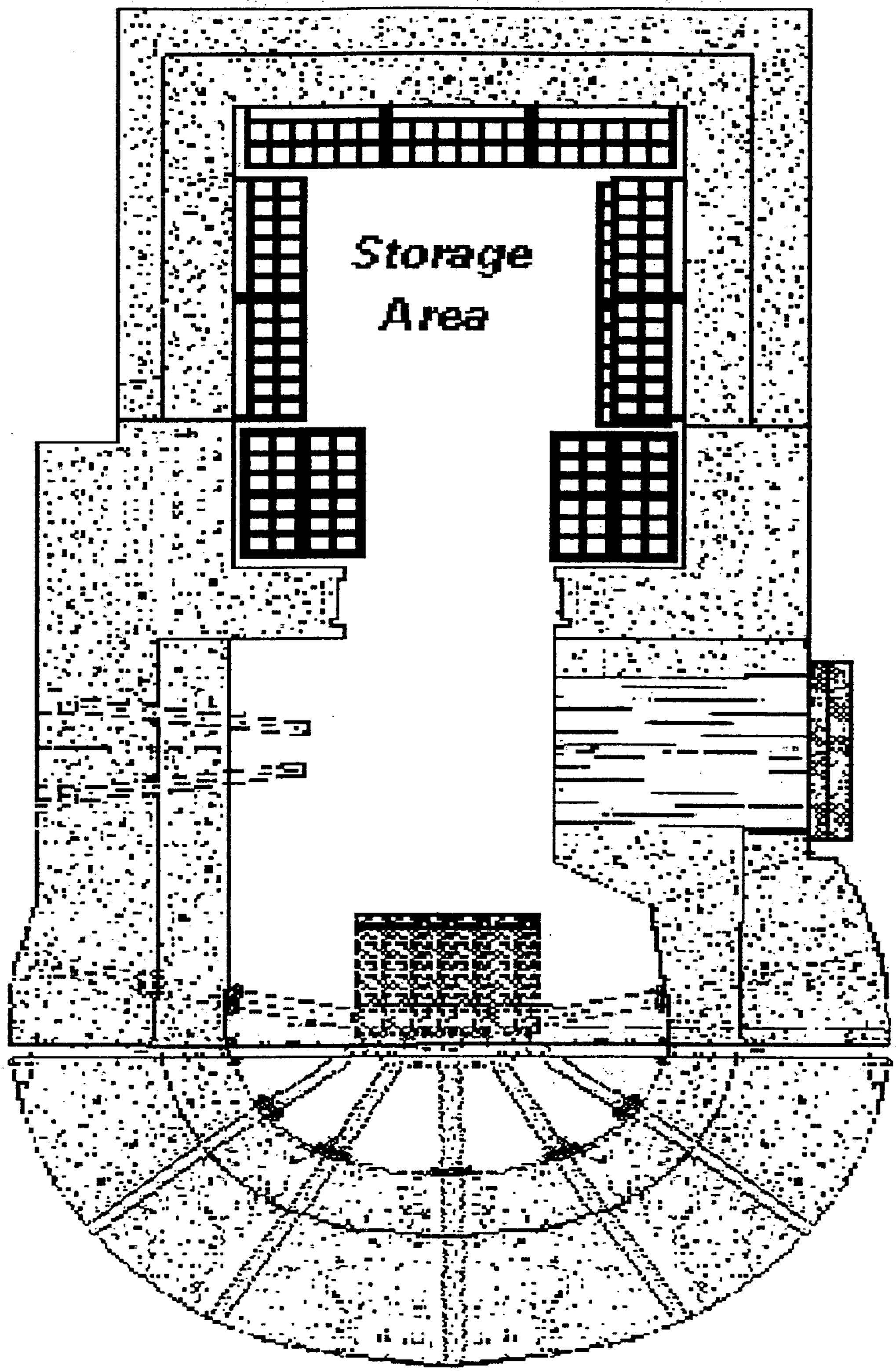

Figure 2– Top View of IEA-R1 Reactor Pool.

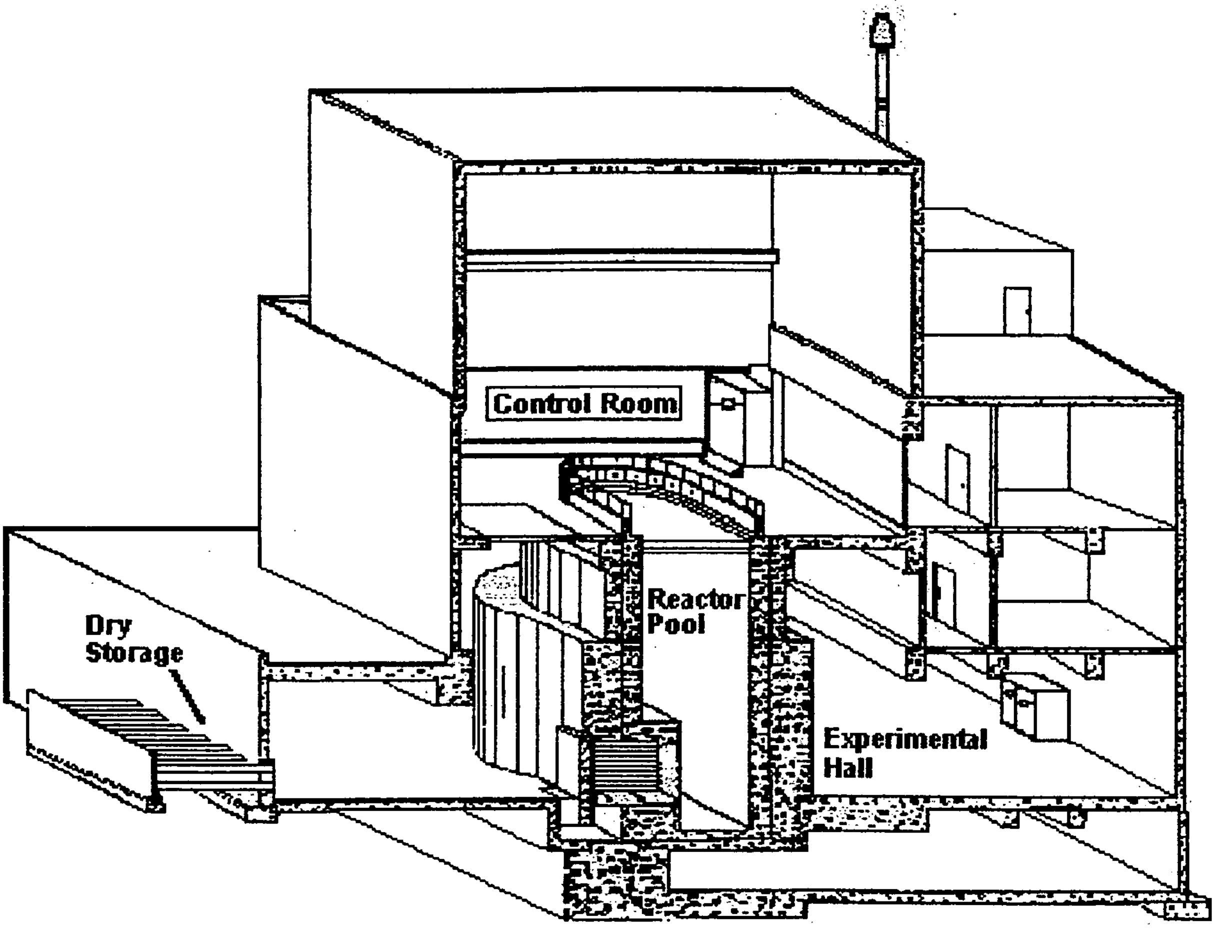

Figure 3 – Reactor Building.

References:

1- J.R.Maiorino – The Brazilian Research Reactor IEAR1- Presented at the Advisory Group Meeting on Optimization of Research Reactor Utilization for Production of Radioisotopes – October 1995.

2- J.R.Maiorino – The Utilization and Operational Experience of IEA-R1 Brazilian Research Reactor - IAEA-SM-360/007 – Research Reactor Utilization, Safety and Management – Proceedings of Symposium held in Portugal – September 1999.

3- Safety Analysis Report of IEA-R1 Research Reactor, vol. 1 and 2, São Paulo, Brazil (1997)

4- A J Soares, M.S. Dias, J. B. M. Tondin – Spent Fuel Situation of Brazilian Research Reactors, presented at the Coordinators Meeting of Project IAEA RLA/4/018, Santiago, May 28 to June 06, 2001.

Annex 1

IEA-R1 RR Data Base

1. DATOS GENERALES DEL REACTOR

Reactor Name: IEA-R1
Site: SÃO PAULO
Country: BRAZIL
Licensed Power Level: 5 MW
Status:

Operating	Operational but has not operated since	Shutdown
X		
	Date:	Date:

Data Valid as of (2002/02/08):

2. DESCRIPCION DEL COMBUSTIBLE

2.1.- GENERAL

	Fuel Type	Element Type	Enrichment (%)	Fuel Meat Material	Nominal Weight U-235 per Assy (g)	Cladding Material	Average Bu (%) per Assy
a)	**MTR-P**	**Flat Plate**	**20,25**	U_3O_8-Al	**20,56**	**Al**	11,09
b)	**MTR-P**	**Flat Plate**	**20,26**	U_3O_8-Al	**100,64**	**Al**	18,60
c)	**MTR-S**	**Flat Plate**	**19,91**	U_3O_8-Al	**177,0±1,0**	**Al**	25,61
d)	**MTR-C**	**Flat Plate**	**19,91**	U_3O_8-Al	**118,2±0,2**	**Al**	31,88
e)	**MTR-S**	**Flat Plate**	**19,87**	U_3O_8-Al	**210,8±0,5**	**Al**	19,57
f)	**MTR-C**	**Flat Plate**	**19,89**	U_3O_8-Al	**140,8±0,3**	**Al**	17,16
G)	**MTR-S**	**Flat Plate**	**19,92**	U_3Si_2-Al	**278,7±0,5**	**Al**	7,98

P – Partial S – Standard C – Control

2.2.- DESCRIPCION DEL ELEMENTO COMBUSTIBLE

a) (En caso de haber más de un tipo de combustible, repetir la siguiente tabla para c/u de ellos si fuera necesario)

1.	Fuel element type (curved or flat plate, disc, rod, tube, etc.)	Flat plate
2.	Nominal length and cross sectional dimensions of element (cm)	Inner plate: 0,152 x 7,075 x 62,5 Outer Plate: 0,152 x 7,075 x 71,44
3.	Nominal total weight of fuel element (g)	See 2.4
4.	Nominal dimensions of fuel meat (cm)	0,082 x 6,25 x 600
5.	Nominal total weight of fuel meat (g)	See 2.4
6.	Chemical form of fuel meat (e.g., U_3O_8-Al, U-Al_x alloy, UAl_x-Al, U_3Si_2-Al, UZrHx, UO2, etc.)	See 2.4
7.	Weight of total U, weight of U-235 (g)	See 2.4
8.	Alloy or compound material	-x-
9.	Dispersing material	Al
10.	Fuel additives (poison, organics, etc.)	none
11.	Cladding material & method of sealing	Al – Rolling
12.	Clad thickness (mm)	0,38
13.	Bonding material, if any (Na, Al-Si, etc.)	-x-

2.3.- DESCRIPCION DE LA CAJA (ASSEMBLY)

a) (En caso de haber más de un tipo de combustible, repetir la siguiente tabla para c/u de ellos si fuera necesario)

COMBUSTIBLE STANDARD

1.	Number of elements per assembly	18
2.	Over-all dimensions (cm)	7,58 x 7,98 x 87,3
3.	Over-all weight (g)	See 2.4
4.	Total weight of U (g ± g uncertainty)	See 2.4
5.	Total weight of U^{235} (g ± g uncertainty)	See 2.4
6.	Enrichment (%)	See 2.1
7.	Plates bonding method (braze, welding, swaging, etc.)	Swaging
8.	Side plate: material, over-all dimensions (cm)	Al – 0,46 x 7,972 x 71,43
9.	Spacer: material, over-all dimensions	Al – 2,89 mm
10.	End box or fitting: material, over-all dimensions	Al – 7,35 x 6,74 x 18,5
11.	Other structural parts (e.g. screws, rivets, bail, etc.): material, quantity and over-all dimensions.	pin / screws – Al 6262
12.	Other components in assembly (e.g. dummy plates, thermocouples, etc.): material, quantity and over-all dimensions.	None

BARRA DE CONTROL

1.	Number of elements per assembly	12
2.	Overall dimensions (cm)	7,58 x 7,98 x 141,9
3.	Overall weight (g)	See 2.4
4.	Total weight of U (g ± g uncertainty)	See 2.4
5.	Total weight of U^{235} (g ± g uncertainty)	See 2.4
6.	Enrichment (%)	See 2.1
7.	Plates bonding method (braze, welding, swaging, etc.)	Swaging
8.	Side plate: material, over-all dimensions (cm)	Al – 0,46 x 7,98 x 126,0
9.	Spacer: material, over-all dimensions	Al - 2,89 mm
10.	End box or fitting: material, over-all dimensions	Al – 7,35 x 6,74 x 18,5
11.	Neutron absorber plates: absorber and cladding material, quantity, over-all dimensions (cm)	Ag – In – Cd covered with Ni 0,31 x 6,6 x 125,0
12.	Other structural parts (e.g. screws, rivets, bail, guides, etc.): material, quantity and over-all dimensions.	Dash pot / pin / screws – Al 6262
13.	Other components in assembly (e.g. dummy plates, thermocouples, etc.): material, quantity and over-all dimensions.	Ext. Guide Plate : Al 6262 0,15 x 7,07 x 126,0

2.4.- ADITIONAL DATA

	NTWFM grams	CFFM	WUTotFE grams	WU236FE grams	OVWA Kg	WUTotAss grams	WU235Ass grams
a)	**105,2**	**U_3O_8-Al**	**50,77**	**10,28**	**5,30**	**101,53**	**20,56**
b)	**105,2**	**U_3O_8-Al**	**49,67**	**10,06**	**5,48**	**496,70**	**100,64**
c)	**105,2**	**U_3O_8-Al**	**49,46**	**9,85**	**5,65**	**890,35**	**177,26**
d)	**105,2**	**U_3O_8-Al**	**49,45**	**9,85**	**7,64**	**593,38**	**118,15**
e)	**110,8**	**U_3O_8-Al**	**58,98**	**11,72**	**5.75**	**1061,55**	**210,92**
f)	**110,8**	**U_3O_8-Al**	**58,97**	**11,73**	**7,71**	**707,65**	**140,76**
G)	**131,0**	**U_3Si_2-Al**	**77,75**	**15,49**	**6,13**	**1399,57**	**278,81**

NTWFM : Nominal total weight of fuel meat (g)
CFFM : Chemical form of fuel meat (U_3O_8-Al, U-Al_x alloy, UAl_x-Al, U_3Si_2-Al, UZrHx, UO2, etc.)
WUTotFE : Weight of total U (g)
WU235FE : Weight of U-235 (g)
OVWA : Over-all weight of assembly (g)
WUTotAss : Total weight of U in assembly (g ± g uncertainty)
WU235Ass : Total weight of U^{235} in assembly (g ± g uncertainty)

3. INVENTARIO ACTUAL DE COMBUSTIBLE IRRADIADO

Fuel Type	# assies in current core	Average # used per year	# irradiated assies in storage		# failed during:	
			In Reactor	In Stor.Fac.	Operation	Storage
a)	0	Test	1	0	0	0
b)	0	Test	1	0	0	0
c)	3	3	14	0	0	0
d)	0	0	4	0	0	0
e)	12	4	1	0	1	0
f)	4	4	0	0	0	0
g)	5	18(*)	0	0	0	0

(*) [illegible]

Fuel Type	Decay Time (years out of core)			Burn Up (% U-235)			Decay Heat (watts) as of:		
	Oldest	Newest	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
a)	11	11	11	11,9	11,09	11,09			
b)	9	9	9	18,6	18,6	18,6			
c)	4	0	2	35,3	19,3	27,3			
d)	3	2	2,5	33,5	30,5	32,0			
e)	1/2	0	0	24,9	9,6	20,0			
f)	0	0	0	24,3	9,5	16,9			
g)	0	0	0	8,2	0	4,1			

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APROVAÇÕES		Rubrica	Data
Chefe de Área	José Eduardo Rosa da Silva		20/11/02
Lider de Projeto	Antonio Teixeira e silva		20/11/02
Gerente do Centro	Antonio Teixeira e Silva		20/11/02

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AUTOR(ES) DO TRABALHO: Soares, A.J.; Dias, M.S.; Tondin, J.B.M. e Silva, A.T.

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