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Progress Report

"EPFL (Swiss) Fusion-Fission Hybrid Experiment"

MASTER

Nov. 1, 1981 - Jan. 31, 1982

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## I. Introduction

This is the first technical quarterly report concerning progress under the project "EPFL (Swiss) Fusion-Fission Hybrid Experiment." This project provides for support by the Department of Nuclear Engineering, University of Washington to the LOTUS project. LOTUS is the name for a facility and a series of experiments at the Institut de Genie Atomique at Ecole Polytechnique Federale de Lausanne (IGA-EPFL).

The status of the work and the technical progress during the reporting period are described in the attached Trip Report.

Trip Report

of

Gene L. Woodruff

to

Institut de Genie Atomique  
Ecole Polytechnique Federale de Lausanne  
Lausanne, Switzerland

1/13 - 1/24/82

## I. Purpose of Trip

This trip was performed under Contract No. DE-AM06-76RL-02225 (University of Washington Budget No. 61-8007; "EPFL (Swiss) Fusion-Fission Hybrid Experiment"). The trip provided an opportunity for extensive discussions with the staff of the Institut de Genie Atomique (IGA) of the Ecole Polytechnique Federale de Lausanne (EPFL). The discussions covered both the planning of the first series of experiments to be performed in the Hybrid Experiment, (hereafter referred to as LOTUS) and the status of calculational work being performed at the University of Washington in support of the LOTUS project.

## II. Technical Personnel Contacted

During the course of this trip the following personnel were contacted for technical discussion:

<u>Name</u>	<u>Organization</u>
M. Caro	IGA - EPFL
D. Dudziak	EIR (Wurenlingen) (Visiting Scientist from LASL)
P. Haldy	IGA - EPFL
L. Joseph	Department of Physics, University of Lausanne
J. Ligou	IGA - EPFL
S. Sahin	IGA - EPFL
J. Schneeberger	IGA-EPFL (Director)

Other personnel who either have or will have responsibilities associated with the LOTUS project include S. Sitaraman and L. Green. Sitaraman is a Research Assistant in the Department of Nuclear Engineering of the University of Washington. Green is a Staff Scientist in the Fusion Power Systems Group at Westinghouse - Pittsburgh.

### III. Technical Subjects

#### A. Facility Construction

The IGA-EPFL has recently moved from the old campus in the southern part of the city of Lausanne to a new campus in Ecublens, located in the western edge of Lausanne. The IGA now occupies a very modern set of office and laboratory spaces. In the basement of the wing of offices are located two large experimental bays. The two bays are served by a common control room and a common crane. The CROCUS critical facility has been rebuilt in the westernmost bay and is almost ready for operation. The LOTUS facility is to be constructed in the easternmost bay beginning approximately 1 June 1982. All the required contracts have apparently been signed and redundant analyses of the composition of the concrete to be used have been performed as shown in Table I. It is estimated that the construction period will last approximately 15 months so that completion will be in autumn 1983. It is likely that the first set of measurements utilizing the facility could begin near the end of 1983.

A license for operation of the LOTUS facility has not yet been obtained, although negotiations with the appropriate Swiss federal agencies are underway. The most significant licensing issue is related to potential flooding of the bay which is located at a level below that of the local groundwater table. The IGA staff does not anticipate any delay in the current schedule for operations due to licensing requirements.

#### B. Haefely Neutron Source

A sketch of the Haefely neutron source is given in Fig. 1. It produces 14 MeV neutrons from a 250 keV mixed D-T beam of 500 ma. The beam is accelerated from a ring source onto a conical target surface made of scandium

which contains about 500 Ci of tritium and an equal amount of deuterium. The expected lifetime of the target is about 500 hours. The neutron source strength is one of the highest available anywhere as noted below:

<u>Source</u>	<u>Intensity (n/sec)</u>
Haefely	$5 \times 10^{12}$
RTNS-I <sup>1,2</sup>	$6 \times 10^{12}$
RTNS-II <sup>1,2</sup>	$4 \times 10^{13}$

The neutron flux attainable from the Haefely source should decrease with distance somewhat more slowly than the fluxes from RTNS since the former is a somewhat more distributed source. The mean conical target diameter is  $\sim 4$  cm, the overall source assembly diameter is  $\sim 36$  cm.

Considerable discussion was held with the IGA staff regarding the modulation of the Haefely source. The normal application of this device is as a source for neutron cancer therapy. For this purpose simple on/off operation is apparently adequate. At the time of these discussions the Haefely Company would not warrant the source for operation below 50% of maximum beam current. This limitation represented a serious problem, because the resulting count rates in NE-213 neutron spectrometers would be excessive, precluding their use. It was agreed that the IGA staff would pursue this issue with Haefely in an effort to obtain modulation capability with the source. (Negotiations completed subsequent to the trip have apparently been successful and the source will be delivered with a full range of modulation capability.<sup>3</sup>)

Delivery of the Haefely source is available well in advance of the construction schedule.

### C. Neutron Spectroscopy and Reaction Rates

The IGA has purchased a complete system of electronics components for use with NE-213 liquid scintillation neutron detectors. The system includes the capability for two-parameter pulse-shape discrimination, a two-parameter multi-channel analyzer and a PDP-11/34 computer for dedicated on-line data logging.

During the visit, P. Haldy and G. Woodruff met with Prof. L. Joseph of the Department of Physics of the University of Lausanne. Joseph has had extensive experience with NE-213 neutron spectroscopy and has in his laboratory a 700 keV Van de Graaff accelerator. Joseph offered to make the accelerator available for calibrating the detector system at 14 MeV (D-T) and 2.5 MeV (D-D). With additional effort, which may or may not be justified, calibrations and response function measurements could also be performed at intermediate energies. The physics laboratory of the University of Lausanne is located across the street from the LOTUS facility and is, therefore, reasonably convenient for use by the IGA staff.

An extensive testing and calibration program is planned for the NE-213 system prior to initial operation of the LOTUS facility. A presently available Philips neutron source ( $10^7$  14 MeV n's/sec) and isotopic sources will be used in addition to the Van de Graaff at the University of Lausanne. This effort will include the acquisition and testing of necessary data unfolding codes in the IGA computer system. The most likely candidate is the FORIST code package.<sup>4</sup>

In addition to the NE-213 measurements an extensive set of foil measurements are planned. The following reactions will be included:

- (1)  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$
- (2)  $^{115}\text{In}(n,2n)^{114}\text{In}$

- (3)  $^{56}\text{Fe}(n,p) ^{56}\text{Mn}$   
 (4)  $^{115}\text{In}(n,n') ^{115\text{m}}\text{In}$   
 (5)  $^{238}\text{U}(n,\gamma) ^{239}\text{U}$   
 (6)  $^{238}\text{U}(n,f)$   
 (7)  $^{235}\text{U}(n,f)$

Experiments have already been performed with the first four reactions using the Philips neutron source.

Discussions were held regarding the feasibility of supplementing the fission rate measurements with the use of fission detectors. No decision was reached on this point. It was concluded that such an effort would be worthwhile only if costs of the fission detectors were moderate.

#### D. Analytical Methods

The Monte Carlo calculational effort at the University of Washington was described for the IGA staff. These calculations use the MCNP Code<sup>5</sup> with appropriately revised source routines. Initial efforts are focused on the characterization of the Haefely neutron source. Calculations are performed with an accurate description of the source configuration. Figure 2 shows the representation of the source as plotted by the MCNP Code. In comparing Figures 1 and 2 it should be noted that the outermost enclosing cylinder in Fig. 2 is an artificial surface used for calculational purposes. The neutron current emerging from the enclosing cylinder is tabulated according to spatial, energy, and angular variations. In subsequent work the source will be represented by the current from the simple cylinder. The presence of the copper coils will continue to be accounted for in case neutron scattering from the lattice should be significant.

Both one-dimensional<sup>6</sup> and two-dimensional<sup>7</sup> neutron transport calculations will be performed at IGA. It was agreed that a consistent 172 neutron group structure would be used for all the calculations. The set selected is the DLC-41 structure given in Table II. (MCNP is a continuous energy Monte Carlo Code, but the flux tallies require the specification of a group structure.)

Specifications for a LOTUS benchmark problem were discussed and agreed upon. These specifications include the following:

<u>Source</u>	location - on centerline of chamber
<u>First Wall</u>	location - 10 cm from source
	dimensions - 0.03 x 1 x 1 (meters)
	composition - 316 stainless steel
<u>Results</u>	neutron fluxes - DLC-41 group structure
	detector volume - 3.08 cm x 3.08 cm cylinder
	locations - $\Delta x$ (detector - first wall)
	0, 0.5, 1.0 meters
	- FH (height above centerline)
	0, 0.2, 0.4 meters

The layout of the Benchmark Problem is well illustrated in Fig. 3 which is available through the courtesy of P. Haldy.<sup>8</sup>

These results will be obtained from two-dimensional neutron transport calculations, Monte Carlo calculations, and experimental measurements.

#### E. Hybrid Configurations

The hybrid blanket assemblies will consist of rectangular arrays, one meter in height and one meter wide. The first wall will be made of 316

stainless steel and the thickness will vary from 0-2 cm in the first series of experiments. The  $\text{UO}_2$  and U metal fuel rods, which are described in Fig. 4, will form a tightly packed lattice (the maximum achievable fuel rod volume fraction is  $\sim 68\%$ ). The region behind the fuel rods will consist of a lithium matrix the composition of which is yet to be determined. Lithium metal and  $\text{Li}_2\text{O}$  have been ruled out on grounds of cost and experimental inconvenience. Three possibilities now under consideration are lithium aluminate ( $\text{LiAlO}_2$ ), lithium carbide ( $\text{Li}_2\text{C}_2$ ), and lithium carbonate ( $\text{Li}_2\text{CO}_3$ ). A graphite reflector region will be placed behind the lithium-containing region.

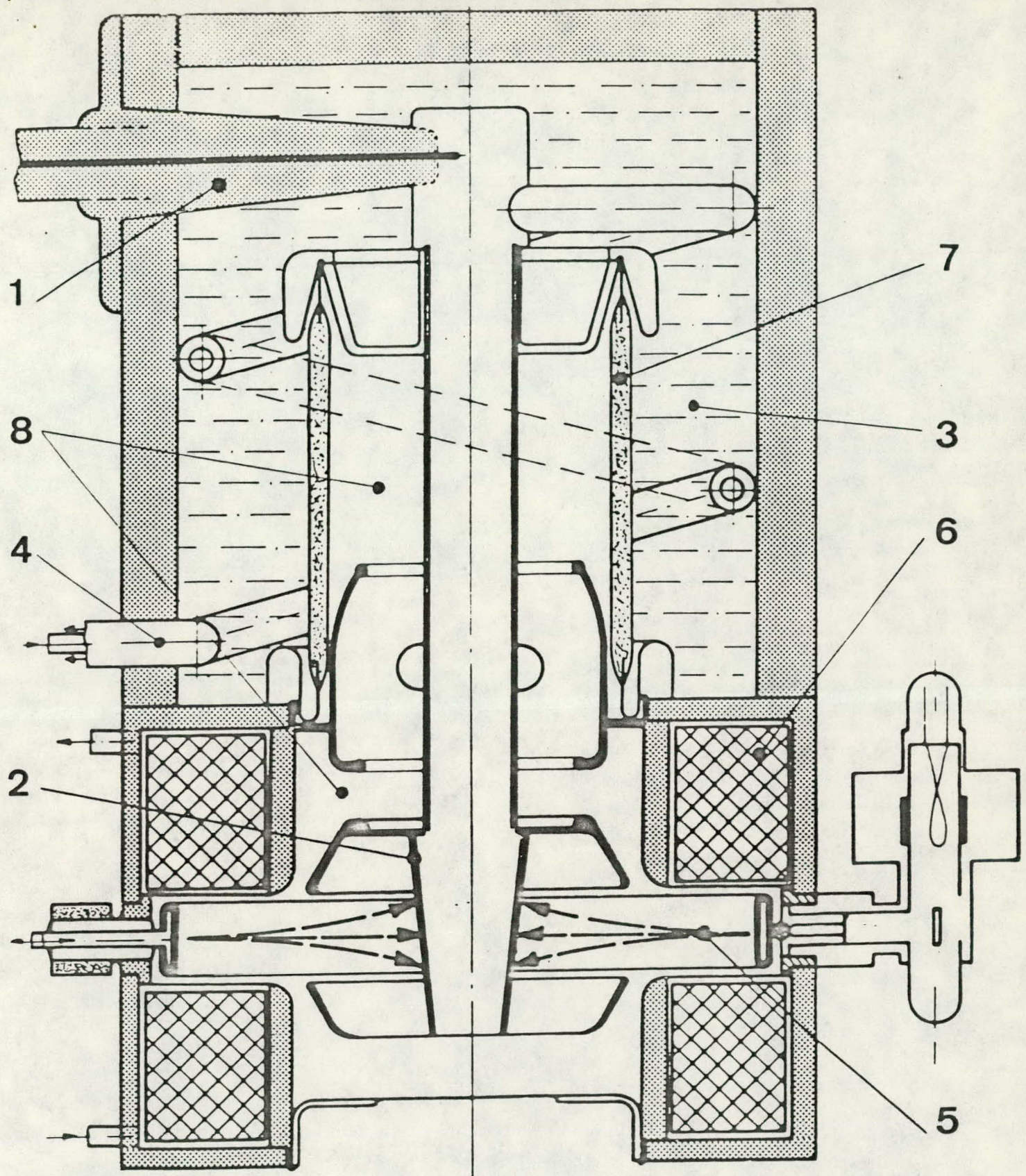
The NE-213 neutron detector and its associated photomultiplier tube and pre-amp represent a cylindrical apparatus having a diameter of approximately 6 cm and a length of about 15 cm. This is a significantly larger diameter than the largest fuel rods. The detector would, therefore, introduce an unacceptably large perturbation if placed inside the assembly. The plan, therefore, is to perform spectrum measurements at the successive outer boundaries of the configuration as the blanket is assembled.

From the beginning it has been planned that the LOTUS facility would be used for a variety of experiments in addition to the hybrid blanket configuration described here. It was noted during a recent visit to IGA-EPFL by Ken Schultz of General Atomic that the Lithium Blanket Module, (LBM), now being developed as a TFTR experiment, represents such a potential additional experiment. The possibility of performing such an experiment at IGA-EPFL is being considered by the technical staff of the LBM experiment.

References

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3. Telephone conversation with S. Sahin, 2/2/82.
4. R.H. Johnson, "FORIST CODE," Code Package RSIC #PSR-92, Radiation Shielding Information Center, Oak Ridge National Laboratory.
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6. Engle, W.W., Jr.: ANISN, A One-dimensional Discrete Ordinates Transport Code with Anisotropic Scattering, ORNL, K-1693 (1970).
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8. P. Haldy, private communication, January 27, 1982.
9. S. Sahin, private communication, January 19, 1982.

Neutron Tube



- 1 HIGH VOLTAGE CABLE
- 2 TARGET ELECTRODE
- 3 OIL INSULATION
- 4 WATER COOLING

- 5 CONCENTRIC ION BEAM
- 6 MAGNET COILS
- 7 HIGH VOLTAGE INSULATOR
- 8 VACUUM SPACE

Fig. 1 Haefely Neutron Source

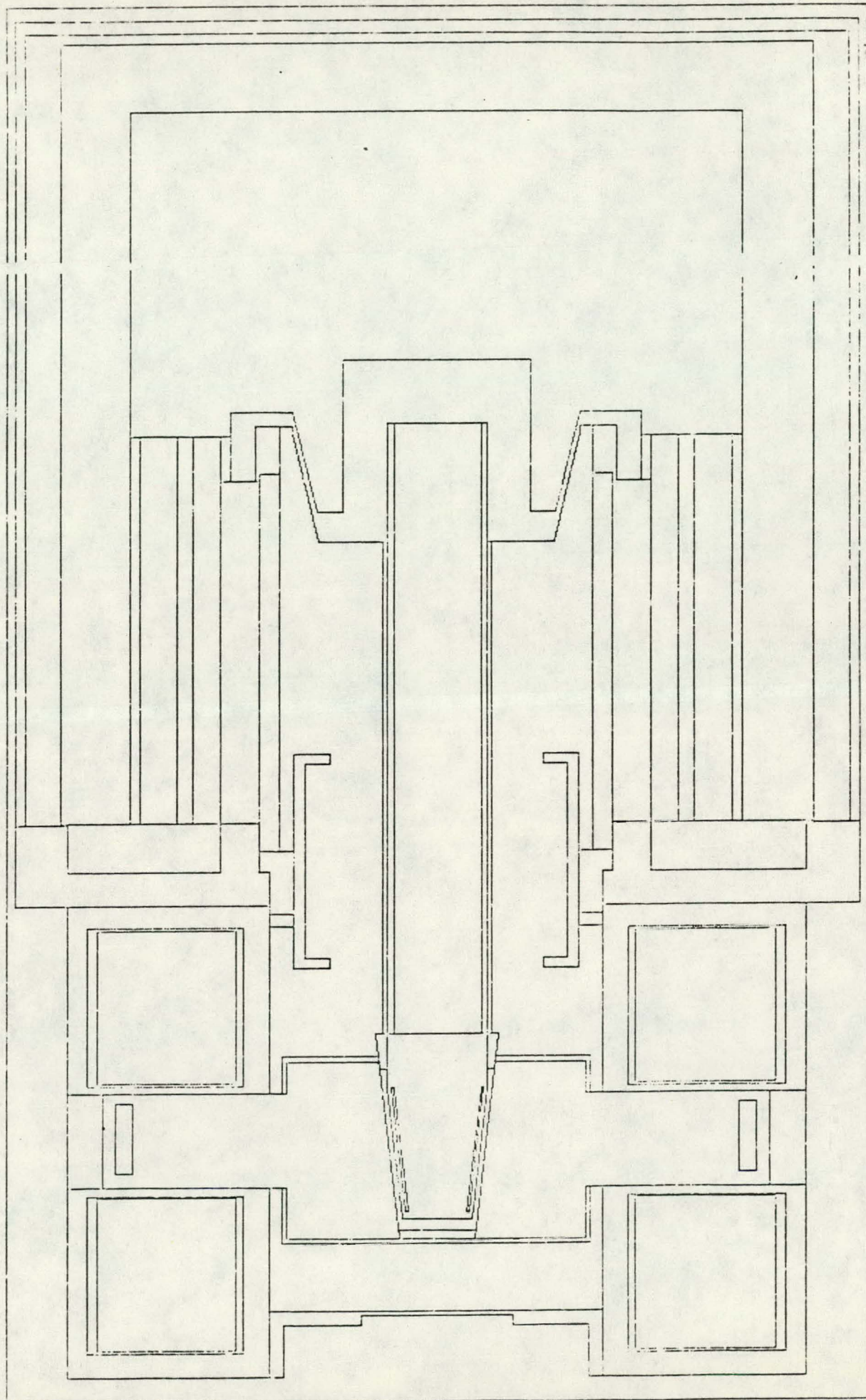


Fig. 2 Representation of Haefely Tube  
for Monte Carlo Source Calculations

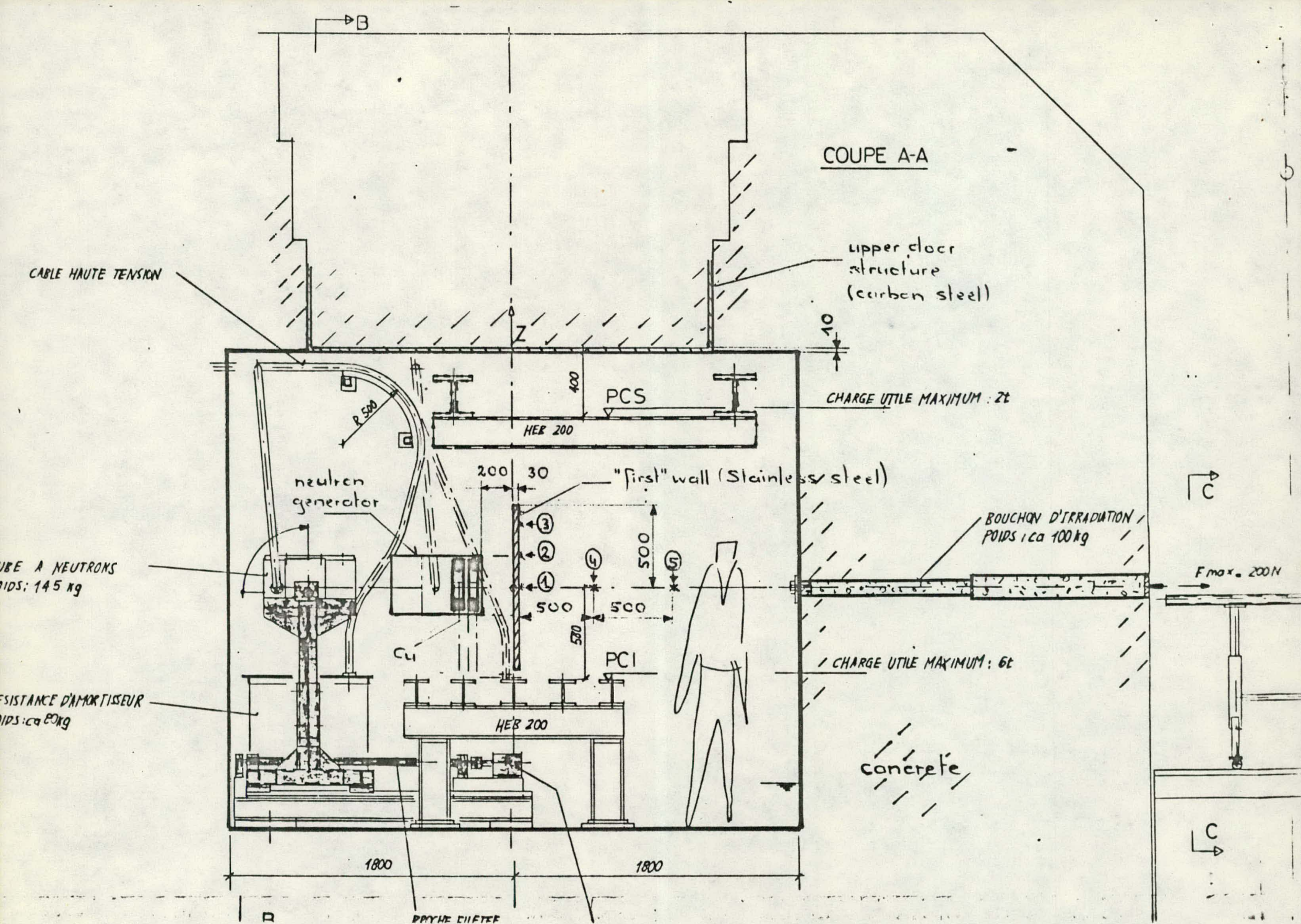
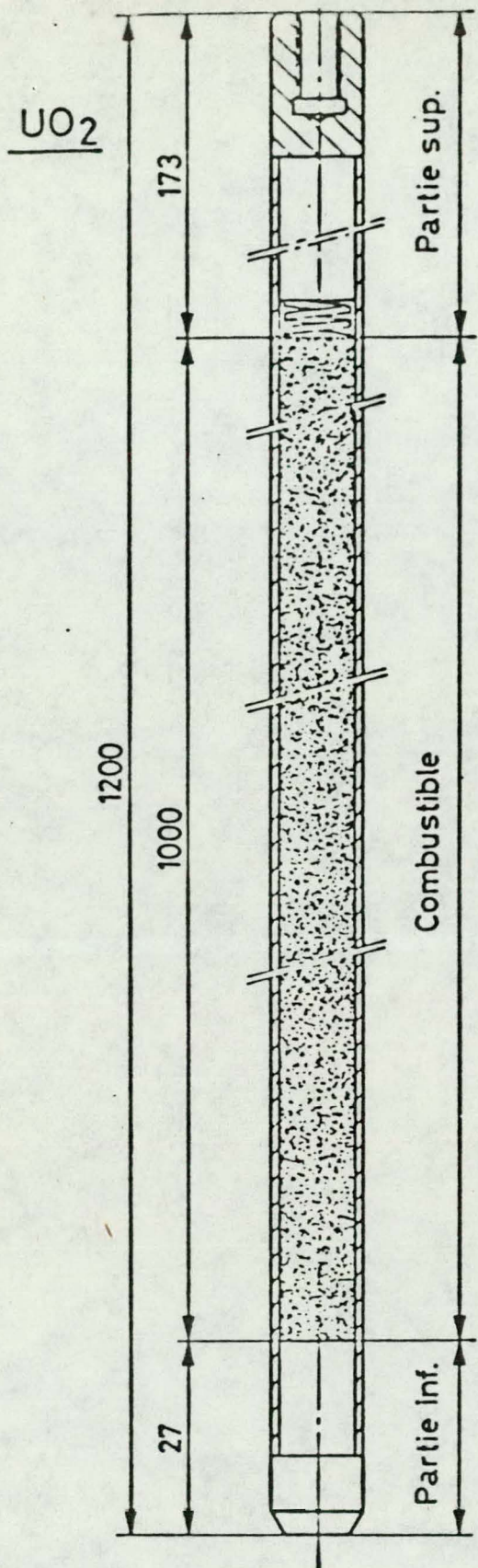
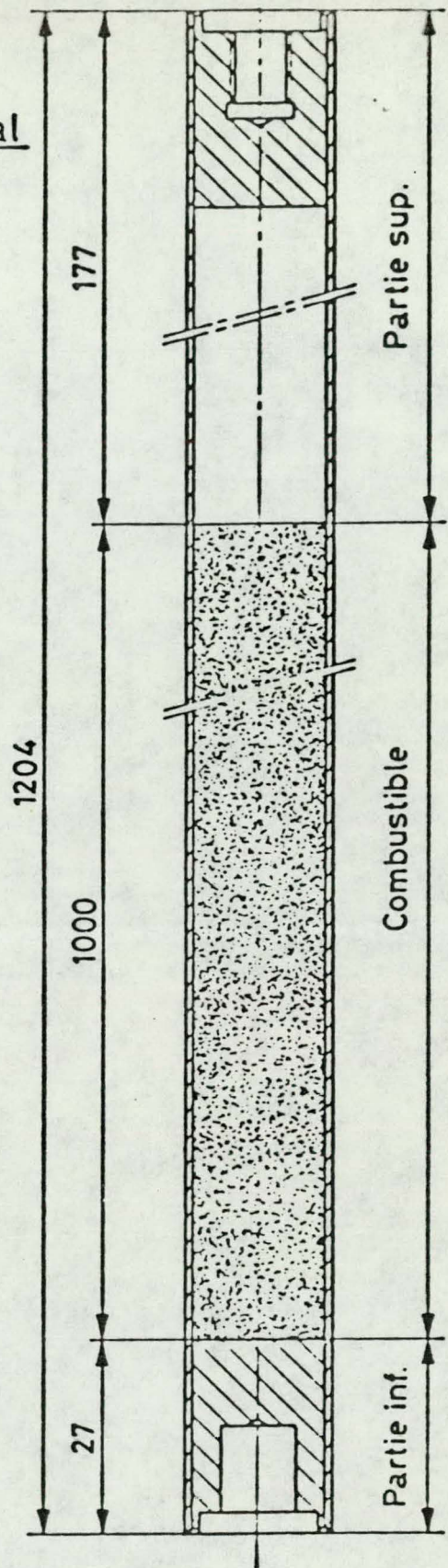


Fig. 3  
Description of Benchmark Problem



$U_{\text{métal}}$



Ech: 1/1

épaisseur gaine : 0,85 mm  
 diamètre extérieur : 12,60 mm  
 "  $UO_2$  : 10,52 mm  
 enrichissement en  $U_{235}$ : 1,8 %  
 gainage en aluminium

épaisseur gaine : 1 mm  
 diamètre extérieur : 19,3 mm  
 " combustible : 17 mm  
 enrichissement en  $U_{235}$ : 0,947 %  
 gainage en aluminium

Fig. 4 -  $UO_2$  and U metal fuel rods to be used in LOTUS experiments (Ref. 9)

Probe Nr. Element	7	8	9	10	11	12					
	(%)	(%)	(%)	(%)	(%)	(%)					
Al	3,8	3,7	3,6	3,5	3,5	3,6	2,5				
C	3,5	3,5	3,5	3,6	3,6	3,5					
Ca	16,6	16,9	17,5	16,2	16,6	16,4	2,0				
Fe	1,36	1,31	1,29	1,30	1,27	1,28	1,10				
H							0,80				
K	1,3	1,28	1,07	1,19	1,30	1,18	1,00				
Mg	0,84	0,84	0,81	0,79	0,91	0,77	0,20				
Na	1,43	1,44	1,31	1,47	1,42	1,43	1,00				
O							50,00				
Si	18,6	18,9	18,0	19,1	18,5	19,3	50,00				
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	1,00				
Ag	<0,3	<0,3	<0,3	<0,3	<0,3	<0,3					
B											
Ba	300	300	300	300	300	300					
Bi	<5	<5	<5	<5	<5	<5					
Cd	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5					
Ce	29	29	26	28	26	24					
Co	12,5	10,4	8,9	9,4	9,3	9,1					
Cr	89	78	84	82	74	66					
Cs	2,2	2,2	2,1	2,2	2,1	2,2					
Cu	9	8	8	8	8	8					
Dy	2,9	2,9	2,3	2,9	2,8	3,0					
Er	2	1,8	1,9	1,9	1,7	1,7					
Eu	1,2	1,7	1,7	1,8	1,6	0,9					
Hf	1,9	1,8	1,6	1,9	1,9	1,7					
Ho	1	1	1	1	1	1					
Ir	<20	<20	<20	<20	<20	<20					
La	18,5	18,2	16,9	17,6	17,5	15,8					
Li	17,4	16,0	15,8	17,0	16,8	16,2					
Lu	0,20	0,24	0,20	0,21	0,21	0,19					
Mn	430	390	350	450	460	430					
Mo	<3	<3	<3	<3	<3	<3					
Nd	10	15	14	13	11	11					
Ni	26	22	33	24	25	19					
Pb	7,5	7	6	8	9	7					
Rb	55	56	51	54	51	52					
Sb	0,2	0,2	0,2	0,2	0,2	0,2					
Se	4,5	4,4	4,6	4,5	4,5	4,3					
Sm	4,3	4,7	4,2	4,5	4,2	4					
Sn	<20	<20	<20	<20	<20	<20					
Ta	0,44	0,51	0,42	0,40	0,42	0,42					
Tb	0,6	0,7	0,7	0,7	0,6	0,6					
Th	<0,2	<0,2	6,3	7,0	6,1	5,9					
Ti	1020	970	990	980	980	1020					
Tm	0,5	0,4	0,5	0,5	0,5	0,5					
U	1,7	1,6	1,5	1,5	1,3	1,3					
V	27	25	25	24	29	29					
W	0,9	0,7	0,5	0,6	0,6	0,6					
Y	14	11	11	10	10	10					
Yb	1,4	1,5	1,4	1,4	1,3	1,2					
Zn	<5	<4,8	<4,7	<4,7	<4,7	<4,7					
Zr	72	58	64	71	62	59					

16.12.21 TML

Table I - Results of analyses of composition of concrete

Table II  
 CTR-PMCSL Neutron Energy Group Boundaries  
 and Their Relationship to Those Used for Other Libraries

100n*	52n**	Suggested Upper Energy (eV)	Lethargy	239n***	126n***	
		1	.17333E+08	-.55000E+00	7	
		2	.16487E+08	-.50000E+00	9	
		3	.15683E+08	-.45000E+00	11	
1	1	4	.14918E+08	-.40000E+00	13	1
		5	.14550E+08	-.37500E+00	14	
		6	.14191E+08	-.35000E+00	15	
		7	.13840E+08	-.32500E+00	16	
2	2	8	.13499E+08	-.30000E+00	17	
		9	.12840E+08	-.25000E+00	19	
3	3	10	.12214E+08	-.20000E+00	21	2
		11	.11618E+08	-.15000E+00	23	
4	4	12	.11052E+08	-.10000E+00	25	
		13	.10513E+08	-.50000E-01	27	
5	5	14	.10000E+08	0.	29	3
		15	.95123E+07	.50000E-01	31	
6	6	16	.90484E+07	.10000E+00	33	
		17	.86071E+07	.15000E+00	35	
7	7	18	.81873E+07	.20000E+00	37	4
		19	.77860E+07	.25000E+00	39	
8	8	20	.74082E+07	.30000E+00	41	
		21	.70469E+07	.35000E+00	43	
9	9	22	.67032E+07	.40000E+00	45	5
		23	.65924E+07	.41667E+00	47	
		24	.63763E+07	.45000E+00	49	
10	10	25	.60653E+07	.50000E+00	51	6
		26	.57695E+07	.55000E+00	53	
11	11	27	.54881E+07	.60000E+00	54	7
		28	.52205E+07	.65000E+00	55	
12	12	29	.49659E+07	.70000E+00	56	
		30	.47237E+07	.75000E+00	58	
13	13	31	.44933E+07	.80000E+00	60	8
14	14	32	.40657E+07	.90000E+00	62	
15	15	33	.36788E+07	.10000E+01	64	9
16	16	34	.33287E+07	.11000E+01	66	
		35	.31664E+07	.11500E+01	68	10
17	17	36	.30119E+07	.12000E+01	70	11
		37	.28650E+07	.12500E+01	71	12
18	18	38	.27253E+07	.13000E+01	72	13
		39	.25924E+07	.13500E+01	73	14
19	19	40	.24660E+07	.14000E+01	74	15
		41	.23852E+07	.14333E+01	76	16
		42	.23653E+07	.14417E+01	77	17
		43	.23457E+07	.14500E+01	78	
		44	.23069E+07	.14667E+01	79	18

20	20	45	.22313E+07	.15000E+01	81	19
		46	.21225E+07	.15500E+01	82	20
21	21	47	.20190E+07	.16000E+01	83	21
		48	.19205E+07	.16500E+01	85	22
22	22	49	.18268E+07	.17000E+01	87	23
		50	.17377E+07	.17500E+01	88	24
23	23	51	.16530E+07	.18000E+01	89	25
		52	.15724E+07	.18500E+01	91	26
24	14	53	.14957E+07	.19000E+01	93	27
		54	.14227E+07	.19500E+01	94	28
25	25	55	.13534E+07	.20000E+01	95	29
		56	.12873E+07	.20500E+01	96	30
26	26	57	.12246E+07	.21000E+01	97	31
		58	.11648E+07	.21500E+01	99	32
27	27	59	.11080E+07	.22000E+01	100	33
28	28	60	.10026E+07	.23000E+01	102	34
		61	.96164E+06	.23417E+01	104	35
29	29	62	.90718E+06	.24000E+01	106	36
		63	.86294E+06	.24500E+01	107	37
30	30	64	.82085E+06	.25000E+01	108	38
		65	.78082E+06	.25500E+01	109	39
31	31	66	.74274E+06	.26000E+01	110	40
		67	.70651E+06	.26500E+01	111	41
32	32	68	.67206E+06	.27000E+01	112	42
		69	.63928E+06	.27500E+01	113	43
33	33	70	.60910E+06	.28000E+01	114	44
		71	.57844E+06	.28500E+01	115	45
34	34	72	.55023E+06	.29000E+01	116	46
		73	.52340E+06	.29500E+01	118	47
35	35	74	.49787E+06	.30000E+01	120	48
36	36	75	.45049E+06	.31000E+01	122	49
37		76	.40762E+06	.32000E+01	124	50
		77	.38774E+06	.32500E+01	125	
38		78	.36883E+06	.33000E+01	126	51
39		79	.33373E+06	.34000E+01	128	52
40	37	80	.30197E+06	.35000E+01	131	53
		81	.29850E+06	.35116E+01		54
		82	.29720E+06	.35159E+01		55
		83	.29452E+06	.35250E+01	132	56
		84	.28725E+06	.35500E+01	133	57
41		85	.27324E+06	.36000E+01	135	58
42		86	.24724E+06	.37000E+01	137	59
		87	.23518E+06	.37500E+01	138	
43		88	.22371E+06	.38000E+01	139	60
		89	.21290E+06	.38500E+01	140	61
44	38	90	.20242E+06	.39000E+01	141	62
		91	.19255E+06	.39500E+01	142	63-
45		92	.18316E+06	.40000E+01	143	64
		93	.17422E+06	.40500E+01	144	65

Table II Cont'd

100n*	52n**	Suggested Upper Energy (eV)	Lethargy	235n***	126n****	
46		94	.16573E+06	.41000E+01	146	66
		95	.15764E+06	.41500E+01	148	67
47		96	.14996E+06	.42000E+01	149	68
		97	.14264E+06	.42500E+01	150	69
48	39	98	.13569E+06	.43000E+01	151	70
		99	.12907E+06	.43500E+01	152	71
49		100	.12277E+06	.44000E+01	153	72
		101	.11679E+06	.44500E+01	154	73
50		102	.11109E+06	.45000E+01	155	74
		103	.98037E+05	.46250E+01	156	75
51		104	.86517E+05	.47500E+01	157	76
		105	.82500E+05	.47975E+01		77
		106	.79500E+05	.48346E+01		78
		107	.72000E+05	.49337E+01		79
52	40	108	.67379E+05	.50000E+01	159	80
		109	.56562E+05	.51750E+01	162	81
53		110	.52475E+05	.52500E+01	163	82
		111	.43309E+05	.53750E+01	164	83
54		112	.40868E+05	.55000E+01	165	84
		113	.34307E+05	.56750E+01	168	85
55		114	.31828E+05	.57500E+01	169	86
		115	.28500E+05	.58604E+01		87
		116	.27000E+05	.59145E+01		88
		117	.26058E+05	.59500E+01	171	89
56	41	118	.24788E+05	.60000E+01	172	90
		119	.24176E+05	.60250E+01	173	
		120	.23579E+05	.60500E+01	174	91
		121	.21875E+05	.61250E+01	175	92
57		122	.19305E+05	.62500E+01	177	93
58		123	.15034E+05	.65000E+01	179	94
59		124	.11709E+05	.67500E+01	181	95
60	42	125	.91188E+04	.70000E+01	183	96
61		126	.71017E+04	.72500E+01	185	97
62		127	.55308E+04	.75000E+01	187	98
63		128	.43074E+04	.77500E+01	190	99
		129	.37074E+04	.79000E+01	192	100
64	43	130	.33546E+04	.80000E+01	193	101
		131	.30354E+04	.81000E+01	194	102
		132	.27465E+04	.82000E+01	196	103
65		133	.26126E+04	.82500E+01	197	104
		134	.24852E+04	.83000E+01	198	105
		135	.22487E+04	.84000E+01	199	106
66		136	.20347E+04	.85000E+01	200	107
67		137	.15846E+04	.87500E+01	203	108
68	44	138	.12341E+04	.90000E+01	206	109
69		139	.96112E+03	.92500E+01	207	110
70		140	.74852E+03	.95000E+01	208	111
71		141	.58295E+03	.97500E+01	209	

Table II Cont'd

100n*	52n**	Suggested	Upper Energy (eV)	Lethargy	239n***	126n****
72		142	.45400E+03	.10000E+02	210	112
73		143	.35358E+03	.10250E+02	211	
74		144	.27536E+03	.10500E+02	212	113
75		145	.21445E+03	.10750E+02	213	114
76	46	146	.16702E+03	.11000E+02	214	115
77		147	.13007E+03	.11250E+02	215	
78		148	.10130E+03	.11500E+02	216	116
79		149	.78893E+02	.11750E+02	217	
80	47	150	.61442E+02	.12000E+02	218	117
81		151	.47851E+02	.12250E+02	219	118
82		152	.37267E+02	.12500E+02	220	119
83		153	.29023E+02	.12750E+02	221	
84	48	154	.22603E+02	.13000E+02	222	120
85		155	.17603E+02	.13250E+02	223	
86		156	.13710E+02	.13500E+02	224	
87		157	.10677E+02	.13750E+02	225	121
88	49	158	.83153E+01	.14000E+02	226	
89		159	.64760E+01	.14250E+02	227	
90		160	.50435E+01	.14500E+02	228	122
91		161	.39279E+01	.14750E+02	229	
92	50	162	.30590E+01	.15000E+02	230	
93		163	.23824E+01	.15250E+02	231	123
94		164	.18554E+01	.15500E+02	232	
95		165	.14450E+01	.15750E+02	233	
96	51	166	.11254E+01	.16000E+02	234	124
97		167	.87642E+00	.16250E+02	235	
98		168	.68256E+00	.16500E+02	237	
99		169	.53156E+00	.16750E+02	239	
100	52	170	.41399E+00	.17000E+02		125
		171	.10000E-00			126
		172	.10000E-04			

\*100 GAM Group Structure of DLC-2 and DLC-37 (Refs. 10 and 11)

\*\*52 Group Structure of Kriese DLC-28 (Ref. 12)

\*\*\*239 Group CSEMG Standard of Weisbin and La Bauve (Ref. 13)

\*\*\*\*126 Group of the DRRD LMFBR Neutron-Gamma Library (Ref. 9)

Table II Cont'd

CTR-PMCSL Gamma-Ray Energy Group Boundaries  
and Their Relationship to Those Used for Other Libraries

Group Number	Energy (MeV)	21r*	Bartine**	Straker***
1	14.0	1	1	1
2	12.0	2		
3	10.0	3	2	2
4	8.0	4	3	3
5	7.5	5		
6	7.0	6	4	4
7	6.5	7		
8	6.0	8	5	5
9	5.5	9		
10	5.0	10	6	6
11	4.5	11		
12	4.0	12	7	7
13	3.5	13		8
14	3.0	14	8	9
15	2.5	15	9	10
16	2.0	16	10	11
17	1.66			12
18	1.50	17	11	
19	1.33			13
20	1.0	18	12	14
21	0.60			15
22	0.70		13	
23	0.60			16
24	0.512			
25	0.510			
26	0.45		14	17
27	0.40	19		
28	0.30		15	18
29	0.20	20		
30	0.15		16	19
31	0.10	21	17	20
32	0.075			
33	0.060			21
34	0.045		19	
35	0.030		20	22
36	0.020		21	
	0.010			

\*21 Group structure of DLC-28 and DLC-37 (Refs. 12 and 11).

\*\*D. Bartine 21 group structure of DLC-31/(DPL-1/FENSI) (Ref. 14).

\*\*\*E. Straker suggested few group version of CSEWG standard (Ref. 15).

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