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AHSB (S) HANDBOOK 5

United Kingdom Atomic Energy Authority

HANDBOOK OF EXPERIMENTAL CRITICALITY DATA
PART 1 - Chapters 1 to 4

1967

AUTHORITY HEALTH AND SAFETY BRANCH

RISLEY, WARRINGTON, LANCASHIRE

HANDBOOK OF EXPERIMENTAL CRITICALITY DATA

PART I*

Compiled by

F. Abbey Safeguards Division

Any comments or suggestions for further data to be included in this handbook should be addressed to:

J. H. Chalmers,
Criticality Inspectorate,
Authority Health and Safety Branch,
Risley, Near Warrington,
Lancashire.

*Parts II and III to be published later.

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PREFACE

The literature of critical size measurements is extensive and can be confusing, the same measurement may be reported in a number of places and there may sometimes be variation in detail in the different accounts. Access to papers and reports can also be difficult and will depend on the library facilities available. To establish what measurements have been made in a particular area of interest, and to find detailed and authoritative accounts of the measurements can, therefore, be a time-consuming exercise. Nevertheless this material is the basic data of criticality and the criticality specialist must have recourse to it from time to time. For instance, he may need to check a calculational method and any associated nuclear data against reference experiments or a particular criticality clearance may depend on a detailed comparison of parameters.

It was felt, therefore, that a need existed for a compilation of data in relatively detailed form reference to which could take the place, at least in the first instance, of reference to the original literature. It is hoped that the present handbook which is to be published in three parts, goes at least some way to meeting this need.

In compiling the handbook reference has been made, wherever possible, to the primary account of the critical measurements reported and assemblies are described in as close approximation as possible to the actual assemblies on which measurements were made, (thus, subsequent shape changes, homogenisation etc., have been ignored). This is not to say however, that later accounts of an experiment have not sometimes provided useful additional information. Many excellent review articles and handbooks already exist in the criticality field, providing generalised guidance and data correlations for more or less simplified systems. It is in no way the aim of this handbook to replace these: rather it is to supplement them for the criticality specialist by collecting and assimilating into tabular form, convenient for quick reference, the detailed results on which they are founded and on which similar correlations can be based in the future.

It is intended that the handbook should include only data for systems which are relatively 'clean' and where it is clear that the measurements were sufficiently painstaking and the system was carried close enough to critical for the result to be accurate. With this proviso it is believed that the handbook is reasonably comprehensive so far as material generally available up to about the beginning of the 1964 Geneva Conference is concerned.

Perhaps the most difficult problem in compiling the handbook has been the allocation of the data into tables, determining the length and complexity of the tables. Generally the allocations have been made as a compromise between a desire to associate results for comparable and related systems and the need to avoid tables which are so complex as to be difficult to read.

CONTENTS

PART I (this part)

INTRODUCTION TO THE TABLES

The Skeleton contents page given at the front of the handbook is supplemented at the beginning of each chapter by a separate contents page showing the organisation of the chapter and listing the tables the chapter contains. Tables are identified by a title and additionally by a two part number of which the first part denotes the chapter in which the table appears and the second part the position of the table in the chapter. Also, as a further aid to rapid reference, each page of the tables carries a 'page-title' in the top left hand corner briefly summarising the type of system to which that chapter or part-chapter refers, (i.e., the degree of heterogeneity - single units, interacting arrays or latticed systems; the nature of the fissile nuclide; the nature of any moderating nuclide; and, in the case of U^{235} systems, whether the uranium is of high (> 90%) or lower enrichment).

Separate compilations of bibliographic references are given for each chapter and follow immediately after the chapter contents pages.

To facilitate easy understanding of the tables a standard form of table layout has been adopted, so far as possible, and an attempt has been made to ensure that each Table is self-contained. As exceptions to these rules information common to all (or nearly all) of the entries in a table is usually brought to the head of the table in note form, thus reducing the complexity of the Table layout, and material compositions and densities are omitted where the materials concerned are commonly-occurring and feature in a large number of Tables. The following compositions in densities may be used for these commonly-occurring materials:

Type 304 Stainless Steel -

(American Iron and Steel Institute Designation); 18·0-20·0 wt% Cr, 8·0-12·0 wt% Ni, 2·0 wt% (max) Mn, 1·0 wt% (max) Si; density 7·9 gm/cc

Type 347 Stainless Steel -

(American Iron and Steel Institute Designation); 17·0-19·0 wt% Cr, 9·0-13·0 wt% Ni, 2·0 wt% (max) Mn, 1·0 wt% max Si; density 7·93 gm/cc

Type 2S Aluminium -

(US Aluminium Assoc. Designation, now renamed Type 1100); 99·0 % aluminium (min.)

Type 3S Aluminium -

(US Aluminium Assoc. Designation, now renamed Type 3003); 1·2 wt% Mn

Zircaloy -

(Westinghouse Designation); zirconium with 1·20-1·70 % Sn; density 6·57 gm/cc

Lucite, Plexiglas or Perspex -

Polymethyl methacrylate plastics, atomic composition $C_5H_8O_2$, density 1·18 gm/cc

Polyethylene -

Atomic composition CH_2, density 0·92 gm/cc

Paraffin Wax -

Atomic composition CH_2, density approx. 0·9 gm/cc

Boric acid -

Atomic composition H_3BO_3

Only numerical values actually provided by the authors of a measurement have been entered in the standard form of Table and, in consequence, there are omissions in certain Tables. These can usually be filled, by interpolation in surrounding data. For instance, aqueous solutions of uranium are sometimes characterised only by the H/U atomic ratio. The specific gravity, uranium content, etc., can, however, be derived by comparison with similar solutions used in other experiments.

Information which has been generally excluded from the Tables includes:

(a) temperature of the assembly, provided this is near ambient

(b) detailed isotopic analysis of fissile materials

(c) detailed analysis of materials of construction, etc., for trace impurities except where significant quantities of neutron poisons are found.

Notes appended to the Tables have been phrased so far as possible in the words of the authors of the measurements referred to. Generally the notes contain information which may be thought:

(a) to extend the usefulness of the measurements (e.g., a number of subcritical observations are included under this heading), or

(b) to bear on the validity of the results (e.g., where available, the values of corrections for unavoidable experimental perturbations from ideal conditions, such as incidental neutron reflection from room walls are given).

Where corrections for experimental conditions are not given it may be assumed that suitable corrections have already been applied to the quoted result. If this is not the case, or is believed not to be the case, appropriate comment is made.

The following terminology and abbreviations are used:

Water - unless qualified this refers to ordinary light water

Mixture - unless qualified this means a mixture which is effectively homogeneous

O.D. - outer diameter

I.D. - inner diameter.

Where the information required to fill a space in a table is not available this is indicated by placing a dash - in the space.

(Note: as will be clear from an examination of the Tables an empty space in a Table implies repetition of the data for the preceeding entry in the Table. This is a device sometimes used to improve the legibility of the sentence).

CHAPTER 1 - SINGLE, UNMODERATED U^{235} CORES

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1. HANSEN, G. E., and WOOD, D. P. Precision Critical-Mass Determinations for Oralloy and Plutonium in Spherical Tuballoy Tampers, USAEC Report LA-1356 Revised, Los Alamos Scientific Laboratory, to be issued

2. PETERSON, R. E., and NEWBY, G. A. Lady Godiva: An Unreflected Uranium-235 Critical Assembly, USAEC Report LA-1614, Los Alamos Scientific Laboratory, 1953

3. PETERSON, R. E., and NEWBY, G. A. An Unreflected U-235 Critical Assembly, Nucl. Sci. Eng., 1:112-125 (1956)

4. HANSEN, G. E., PAXTON, H. C., and WOOD, D. P. Critical Masses of Oralloy in Thin Reflectors, USAEC Report LA-2203, Los Alamos Scientific Laboratory, July 16, 1958

5. WHITE, R. H. Topsy, A Remotely Controlled Critical Assembly Machine. Nucl. Sci. Eng. 1:53-61 (1955)

6. ORNDOFF, I. D., PAXTON, H. C., and HANSEN, G. E. Critical Masses of Oralloy at Reduced Concentrations and Densities, USAEC Report LA-1251, May 1, 1951

7. WOOD, D. P., and PENA, B. Critical Mass Measurements of Oy and Pu Cores in Spherical Aluminium Reflectors, USAEC Report LAMS-2579, Los Alamos Scientific Laboratory, November 2, 1961

8. U.K.A.E.A. - Internal Document

9. JOSEPHSON, V. Critical Mass Measurements on Oy in Pu and WC Tampers, USAEC Report LA-1114 (DEL), May, 1950

10. MALLARY, E. C. Oralloy Cylindrical Shape Factor and Critical Mass Measurements in Graphite, Paraffin and Water Tampers, USAEC Report LA-1305, October, 1951

11. RALSTON, H. R. Critical Masses of Spherical Systems of Oralloy Reflected in Beryllium, USAEC Report UCRL-4975, University of California Radiation Laboratory, Livermore, October 10, 1957

12. JOSEPHSON, V., PAINE, R. W., and WOODWARD, L. L. Oralloy Shape Factor Measurements, USAEC Report LA-1155 (DEL), August 1950

13. HANSEN, G. E., PAXTON, H. C., and WOOD, D. P. Critical Plutonium and Enriched-Uranium-Metal Cylinders of Extreme Shape, Nucl. Sci. Eng., 8:570-577 (1960)

14. USAEC Report LA-1217

15. PAXTON, H. C. Los Alamos Critical-Mass Data, USAEC Report LAMS-3067 Los Alamos Scientific Laboratory, May 6, 1964

16. KINNEY, W. E., and MIHALCZO, J. T. Oak Ridge National Laboratory Fast Burst Reactor, USAEC Report ORNL CF-61-8-71, Oak Ridge National Laboratory, 1961

17. HANSEN, G. E., WOOD, D. P., and GEER, W. U. Critical Masses of Enriched-Uranium Cylinders with Multiple Reflectors of Medium-Z Elements, Nucl. Sci. Eng. 8:588-594 (1960)

18. PAXTON, H. C., LINENBERGER, G. A., LOWRY, L. L., OLCOTT, R. N., ORNDOFF, J. D., and SALTIZAHN, J. D. Bare Critical Assemblies of Oralloy at Intermediate Concentrations of U235, USAEC Report LA-1671, Los Alamos Scientific Laboratory, 1954

19. DOMINEY, G. R., LANE, R. C., and THOMAS, A. F. Critical Mass Measurements with Thin Discs of 45·5% Enriched Uranium, UKAEA Report AWRE NR/A-1/62, Atomic Weapons Research Establishment, Aldermaston, March 1962

20. NEVER, J. J., HANSEN, G. E., JARVIS, G. A., LINENBERGER, G. A., and YOUNG, D. S. Critical Assembly of Uranium Metal at an Average U235 Concentration of 16¼%. USAEC Report LA-2085, Los Alamos Scientific Laboratory, 1956

21. MIHALCZO, J. T., and LYNN, J. J. Neutron Multiplication Experiments with Enriched Uranium Metal in Slab Geometry, USAEC Report ORNL CF-61-4-33, Oak Ridge National Laboratory, 1961

22. MIHALCZO, J. T., and LYNN, J. J. Critical Parameters of Bare and Reflected 93·4 wt% U235 - Enriched Uranium Metal Slabs, in Neutron Physics Division Annual Progress Report for Period Ending September 1, 1960, USAEC Report ORNL-3016, pp. 73-76, Oak Ridge National Laboratory, Sept. 1, 1960

23. MIHALCZO, J. T. Prompt Neutron Decay in a Two-Component Enriched Uranium Metal Critical Assembly, USAEC Report ORNL-TM-470, Oak Ridge National Laboratory, Jan. 11, 1963

24. LANE, R. C., and PERKINS, O. J. E. Measurement of the Critical Mass of 37½% Enriched Uranium in Reflectors of Wood, Concrete, Polyethylene and Water. UKAEA Report AWRE NR1/66, Atomic Weapons Research Establishment, Aldermaston, February 1966

25. MIHALCZO, J. T. Critical Experiments with Annular Cylinders of U(93·2) Metal in Neutron Physics Division Annual Progress Report for Period Ending August 1, 1963, USAEC Report ORNL 3499, pp. 62-63, Oak Ridge National Laboratory, Dec. 10, 1963

26. MIHALCZO, J. T. Prompt-Neutron Lifetime in Critical Enriched-Uranium Metal Cylinders and Annuli, Nucl. Sci. Eng., 20:60-65 (1964)

27. HOOGTERP, J. C. Critical Masses of Graphite - Tamped Heterogeneous Oy-Graphite Systems, USAEC Report LA-1732, May 1954

28. KINNEY, W. E., and MIHALCZO, J. T. Critical Experiments and Calculations on the ORNL Fast Burst Reactor in Neutron Physics Division Annual Progress Report for Period Ending September 1, 1961, USAEC Report ORNL 3193, Oak Ridge National Laboratory, Nov. 17, 1961

29. MIHALCZO, J. T. Prompt-Neutron Decay in a Two-Component Enriched-Uranium-Metal Critical Assembly, Trans. Am. Nucl. Soc., 6(1):60 (1963

30. MIHALCZO, J. T. Prompt Neutron Decay Constants for Unmoderated Uranium Metal Critical Assemblies with Large Gaps, in Neutron Physics Division Annual Progress Report for Period Ending September 1, 1962, USEAC Report ORNL-3360, pp. 39-40, Oak Ridge National Laboratory, Jan. 11, 1963

31. HANSEN, G. E., WOOD, D. P., and PENA, B. Reflector Savings of Moderating Materials on Large Diameter U(93·2%) Slabs, USAEC Report LAMS-2744, (June 1962)

32. DONALDSON, R. E., and BROWN, W. K. Critical Mass Determinations of Lead Reflected Systems, USAEC Report UCRL-5255, University of California Radiation Laboratory, Livermore, June 9, 1958

33. LANE, R. C. Measurements of the Critical Parameters of Under-Moderated Uranium Hydrogen Mixtures at Intermediate Enrichments in Criticality Control of Fissile Materials, I.A.E.A., Stockholm, 1966.

EXPERIMENTAL RESULTS FOR SINGLE, UNMODERATED U^{235} CORES - HIGHLY ENRICHED

Table 1.1

Unreflected Spheres of Uranium Metal

ENRICHMENT (wt%)	AVERAGE DENSITY (gm/cc)	GEOMETRY	DELAYED CRITICAL MASS (kgm)	REFERENCES
93·9	18·75	Thick shells	51·9	1
93·71	18·71	Thick sections	52·25[a]	2,3

a. Corrected for slight asphericity. Uncorrected value 52·65 kgm

Effect of stray reflection said to be equivalent to less than 0·14 kgm change in critical mass

Table 1.2

Spheres of Uranium Metal with Non-moderating Reflectors
(See also Table 1.3 for Tungsten Carbide Reflectors)

CORE			REFLECTOR			DELAYED CRITICAL CORE MASS (kgm)	REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (ins)	Average Density (gm/cc)		
93·9	18·75	Nesting Shells	Natural Uranium	0·695	19·0	36·2	1
93·9	18·75	Nesting Shells		1·76	19·0	26·5	1,4
93·9	18·75	Nesting Shells		3·52	19·0	20·5	1,4
93·9	18·75	Nesting Shells		3·92	19·0	19·75	1,4
93·2	18·62	Hemispheres		7·09	19·0	17·86	15
94·13	18·72	↑		9·00[a]	~19·0	17·41	5,6
94	18·7 x 0·854	Pseudosphere of ½ in. cubic units. Reduced density simulated by distributing ½ in. cubic voids in core		8·75[a]	~19·0	20·93	6
94	18·7 x 0·846			8·75[a]	~19·0	21·34	6,5
94	18·7 x 0·702			8·25[a]	~19·0	26·93	6,5
94	18·7 x 0·500	↓		7·25[a]	~19·0	39·34	6,5
93·18	18·4	Nesting Shells	Aluminium[b]	2·610	2·82	37·3	7
93·9	18·6	0·375 in. diameter x 0·45 in. central source cavity	Cast Iron	2·00	7·16	31·6	4,8
93·9	18·4	0·375 in. diameter x 0·45 in. central source cavity		4·00	7·16	27·7	4,8
93·9	18·52	Thick Shells	Steel	-[d]	~7·7	24·9	15
93·9	18·4	0·375 in. diameter x 0·45 in. central source cavity	Nickel	2·00	8·35	29·4[c]	4,8
94	18·7	Pseudosphere of ½ in. cubic units	[e]	8·75[a]	8·88	21·2	9,5
93·9	18·4	0·375 in. diameter x 0·45 in. central source cavity	Nickel-Silver ($Zn\ Ni_{1.27}Cu_{1.47}$)	1·88	8·55	28·4	4,8
93·9	18·75	0·375 in. diameter x 0·45 in. central source cavity		2·02	8·55	27·4[c]	4,8

Table 1.2 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE MASS (kgm)	REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (ins)	Average Density (gm/cc)		
93·9	18·75	0·375 in. diameter x 0·45 in. central source cavity	Copper	2·00	8·88	27·1[c,f]	4,8
93·9	18·75	0·375 in. diameter x 0·45 in. central source cavity		4·175	8·88	22·0[g]	4,8
93·9	18·7	0·375 in. diameter x 0·45 in. central source cavity	Zinc	2·00	7·04	31·9[c]	4,8
93·9	18·5	0·375 in. diameter x 0·45 in. central source cavity		4·075	7·04	27·0[c]	4,8
93·9	18·75	0·375 in. diameter x 0·45 in. central source cavity	Tungsten-Alloy ($Cu\ Ni_{2\cdot33}W_{10\cdot36}$)	2·00	17·39	25·7	4,8
93·9	18·75	0·375 in. diameter x 0·45 in. central source cavity		4·00	17·39	20·7	4,8
93·1	18·7	Nesting Shells	Lead (0·028 wt% Calcium)	8·99	11·3	32·65	32
93·1	18·7	Nesting Shells		17·22	11·3	27·99	32
93·9	18·6	0·375 in. diameter x 0·45 in. central source cavity	Thorium	1·81	11·48	37·0	4,8
93·9	18·45	Shells 0·83 in. diameter central cavity	Natural Uranium (against core)	9·0	19·0	21·5	15
			Aluminium	9·5	2·7		
93·9	18·5	Shells 0·83 in. diameter central cavity	Natural Uranium (against core)	9·0	19·0	23·2	15
			Aluminium	4·7	2·7		
93·9	18·75	0·375 in. diameter x 0·45 in. central source cavity	Tungsten-Alloy (against core)	2·0	17·39	22·4	4,8
			Cast Iron	2·0	7·6		

a. Pseudospherical reflector
b. USAA Type 2014 aluminium (3·9 - 5·0 wt% Cu, 1 wt% Fe, 0·5 - 1·2 wt% Si, 0·40 - 1·2 wt% Mn)
c. Adjusted using $\Delta^{\frac{1}{m}}/\Delta\ (r/r_c) = 1\cdot15$
d. 60 in. cube reflector
e. Type A commercial nickel. (Not less than 99·0 wt% Ni and not less than 99·4 wt% (Ni + Co). Nominal composition includes 0·2% Mn)
f. Critical mass increased 0·5 kgm with 0·83 in. diameter central cavity (-84 gm Uranium)
g. Critical mass increased 0·3 kgm with 0·83 in. diameter central cavity (-84 gm Uranium)

Table 1.3

Spheres of Uranium Metal with Moderating Reflectors
(Includes Cadmium Shielded Systems)

CORE			REFLECTOR			DELAYED CRITICAL CORE MASS (kgm)	REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (ins)	Average Density (gm/cc)		
93·9	18·5	0·4 in. diameter central cavity	Water	3·25	1·0	25·0	15
93·9	~18·5	0·83 in. diameter central cavity		>12[a]	1·0	24·9	15
93·9	~18·5	0·375 in. diameter x 0·45 in. central source cavity		>12[a]	1·0	24·7[b]	10
93·9	18·4	Shells 0·83 in. diameter central cavity		>12[a]	1·0	35·0[h]	15
93·9	18·5	0·83 in. diameter central cavity	Paraffin	>8[a]	0·89	24·3	15
93·9	18·5	0·83 in. diameter central source cavity		>8[a]	0·89	24·0	8,10
93·9	18·5	0·4 in. diameter central cavity	99·8 wt% heavy water (in 0·04 in. thick stainless steel vessel)	3·28	-	24·8	15
93·9	18·5	Nesting Shells	99·8 wt% heavy water (in 0·01 in. thick aluminium vessel)	4·59	-	21·8	15
93·9	18·5	Nesting Shells	99·8 wt% heavy water (in 0·04 in. thick stainless steel vessel)	5·50	-	20·2	15
93·9	18·5	Nesting Shells	99·8 wt% heavy water (in 0·04 in. thick stainless steel vessel)	6·84	-	18·2	15
93·7	18·5	0·83 in. diameter central cavity	99·8 wt% heavy water (in 0·02 in. thick stainless steel vessel)	15·3	-	14·3	15
93·9	18·5	Nesting Shells	99·8 wt% heavy water (in 0·02 in. thick stainless steel vessel)	15·1	-	21·5[h]	15
93·17	18·59	0·4375 in. diameter central source cavity	Beryllium	0·875	1·84	32·7	11
93·17	18·59	0·4375 in. diameter central source cavity		1·285	1·84	28·0	11
93·9	18·5	0·375 in. diameter x 0·45 in. central source cavity		1·851	1·84	23·6	8
93·17	18·59	0·4375 in. diameter central source cavity		2·14	1·84	21·8	11
93·17	18·59	0·4375 in. diameter central source cavity		3·651	1·84	16·3	11
93·6	18·6	0·375 in. diameter x 0·45 in. central cavity		4·64	1·84	14·0	4,8
93·17	18·49	0·4375 in. diameter central source cavity		7·98	1·84	10·8	11

Table 1.3 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE MASS (kgm)	REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (ins)	Average Density (gm/cc)		
94	~18·7	Pseudosphere of ½ in. cubic units with 0·4 in. diameter x 0·46 in. central source cavity	Beryllium Oxide	2·35[c]	2·69	21·0	4,8
94	~18·7	Pseudosphere of ½ in. cubic units with 0·4 in. diameter x 0·46 in. central source cavity	Beryllium Oxide	3·5[c]	2·69	17·6	4,8
82·7	17·8	Psuedosphere of ½ in. cubic units		-[d]	~2·69	12·5	15
93·9	18·7	Nesting Shells	Type CS-312 graphite	2·0	1·67	31·5	4, 10, 15
93·9	18·7	Nesting Shells		4·0	1·67	25·9	4, 10, 15
93·9	18·45	Nesting Shells		6·0	1·67	22·9	10, 15
93·9	18·75	Nesting Shells		8·0	1·67	20·8	10, 15
93·9	~18·5	0·83 in. diameter central source cavity	[e]	~17	1·67	18·1	10, 15
93·9	18·45	Shells 0·83 in. diameter central cavity	Tungsten Carbide	2·9[f]	~14·7	19·9	9
93·9	18·45	Shells 0·83 in. diameter central cavity		4·5[f]	~14·7	17·7	9
93·9	18·45	Shells 0·83 in. diameter central cavity		6·5[f]	~14·7	17·4	9
78·5	17·8	Pseudosphere of ½ in. cubic units		-[g]	14·7	26·50	15
93·9	~18·5	Shells 0·83 in. diameter central cavity	Natural Uranium (against core) Beryllium	9·0 4·0	19·0 1·84	18·8	15
93·2	18·4	Thick Shells	Natural Uranium (against core) Beryllium	0·50 1·30	19·0 1·84	24·7	15

a. Cylindrical reflector
b. With 0·83 in. diameter cavity critical core mass -25·1 kgm
c. Pseudospherical reflector of ½ in. cubic units
d. 24 in. cube reflector
e. Type CS-312 graphite against core, reactor grade outside
f. Pseudospherical reflector
g. 14 in. cube reflector
h. 0·01 in. thick cadmium between core and reflector

EXPERIMENTAL RESULTS FOR SINGLE UNMODERATED U^{235} CORES - HIGHLY ENRICHED

Table 1.4

Unreflected Cylinders of Uranium Metal

ENRICHMENT (wt%)	AVERAGE DENSITY (gm/cc)	GEOMETRY	DELAYED CRITICAL PARAMETERS				REFERENCES
			Diameter	Height	Height / Diameter	Mass (kgm)	
93·8	18·5	0·4 in. rings	4·75 in.			>100·21	12
93·8	~18·5	~0·4 in. rings, 0·4 in. d x 0·47 in. central source cavity	5·50 in.	-	1·76	70·6	12
94	~18·5	~0·4 in. rings, 0·4 in. d x 0·47 in. central source cavity	6·37 in.	-	0·953	58·81	12
93·15	18·76	- b	17·771 cms	12·629 cms	-	58·759	26
93·8	~18·5	~0·4 in. rings, 0·4 in. d x 0·47 in. central source cavity	7·00 in.	-	0·723	59·2	12
94	~18·5	~0·4 in. rings, 0·4 in. d x 0·47 in. central source cavity	7·50 in.	-	0·61	61·9	12
93·15	18·76	b	22·850 cms	9·748 cms	-	74·861	26
93·15	18·76	b	27·931 cms	8·642 cms	-	99·064	26
93·15	18·76	b	33·010 cms	8·080 cms	-	129·355	26
93·15	18·76	b	38·086 cms	7·708 cms	-	164·270	26
93·4	17·70	b	15·00 in.	3·25 in.	0·214	165·7[a]	13
93·3	18·06	0·3 cm thick discs	15·00 in.	3·18 in.	0·212	166·35	15
93·3	17·9	0·3 cm thick discs	15·00 in.	-	0·214	166·45	31
93·2	17·9	0·3 cm thick discs	21·00 in.	-	0·141	301·72	31

a. Assembly divided into two parts by a 0·019 in. thick stainless steel diaphragm

b. These cores were assembled from 1 in. wide cylindrical annuli and 7 in. diameter discs ranging in thickness from $\frac{1}{8}$ in. to $\frac{1}{2}$ in. Annuli and discs were fabricated with a ± 0·0002 in. variation in any dimension and a total variation in flatness of ± 0·0002 in. so that the gap between nesting pieces was no more than 0·0006 in.

Table 1.5

Cylinders of Uranium Metal with Non-moderating, Single Material Reflectors

(See also Tables 1.6, 1.7 for a number of steel, copper, nickel and zinc reflected systems and Table 1.8 for tungsten carbide and molybdenum carbide reflectors)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height/Diameter	Mass (kgm)	
93·18	18·70	-	Depleted Uranium	2·75 in.	18·90	3·24 in.	27·8 in.	8·6	70·3	13
93·5	18·8	Discs 0·075 to 1·200 in. thick	Natural Uranium	0·5 in.	18·8	5·25 in.	-	1·26	43·2	4
93·5	18·8	Discs 0·075 to 1·200 in. thick		1·0 in.	18·8	5·25 in.	-	0·97	33·4	4
93·7	~18·5	0·4 in. diameter x 0·47 in. central source cavity		1·12 in.	~18·7	3·98 in.	-	3·51	52·8[a]	12
93·8	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	4·75 in.	-	1·38	35·2[b]	12
93·8	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	5·50 in.	-	0·84	33·4[b]	12
94·0	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	6·37 in.	-	0·565	34·5[b]	12
94·0	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	7·00 in.	-	0·46	37·6	12
94·0	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	7·50 in.	-	0·41	40·4	12
93·7	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity		1·87 in.	~18·7	3·98 in.	-	2·15	32·4[c]	12
93·8	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity		2·00 in.	~18·7	4·75 in.	-	1·03	26·2[b]	12
93·8	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	5·50 in.	-	0·67	26·7[b]	12
94·0	~18·5	Universal rings, 0·4 in. diameter x 0·47 in. central source cavity			~18·7	6·37 in.	-	0·47	29·2[b]	12
93·4	17·70	-		3·00 in.	18·9	15·00 in.	1·37 in.	0·091	70·0	13
94·0	18·7	Pseudocylinder of ½ in. cubic units		~8 in.[d]	18·9	3·0 in.	-	3·08	22·7	12
94·0	18·7	Pseudocylinder of ½ in. cubic units		~9 in.[d]	18·9	4·0 in.	-	1·00	17·72	12
94·0	18·7	Pseudocylinder of ½ in. cubic units		~9 in.[d]	~19·0	4·5 in.	4·0 in.	-	18·0	9
94·0	18·7	Pseudocylinder of ½ in. cubic units		~8·5 in.[d]	18·9	6·5 in.	-	0·31	21·6	12
94·0	18·7	Pseudocylinder of ½ in. cubic units		~7·75 in.[d]	18·9	8·3 in.	-	0·18	27·3	12

Table 1.5 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height/Diameter	Mass (kgm)	
93·5	18·8	Discs 0·075 to 1·200 in. thick	Magnesium [e]	0·5 in.	1·77	5·25 in.	-	1·69	57·6	4
			[e]	1·00 in.			-	1·48	50·7	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Type 2S Aluminium	0·5 in.	2.70	5·25 in.	-	1·61	55·2	4
				1·0 in.			-	1·37	46·9	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Aluminium (>99 wt%)	0·5 in.	2·76	5·25 in.	-	1·41	48·5	4
				1·0 in.			-	1·15	39·6	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Titanium (96·5 wt%)	0·5 in.	4·50	5·25 in.	-	1·63	55·7	4
				1·0 in.			-	1·40	47·8	4
93·5	18·7	-	Type SAE 1020 steel	4·0 in.	7·78	4·25 in.	-	-	35·9	15
93·5	18·8	Discs 0·075 to 1·200 in. thick		0·5 in.	7·78	5·25 in.	-	1·44	49·2	4
93·5	18·8	Discs 0·075 to 1·200 in. thick		1·0 in.	7·78	5·25 in.	-	1·19	40·8	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Nickel [f]	0·5 in.	8·79	5·25 in.	-	1·30	49·2	4
			[f]	1·0 in.			-	1·05	36·0	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Cobalt (Reagent material)	0·5 in.	8·72	5·25 in.	-	1·28	44·1	4
				1·0 in.			-	1·03	35·4	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Copper (99-99·5 wt%)	0·5 in.	8·87	5·25 in.	-	1·31	44·7	4
				1·0 in.			-	1·03	35·6	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Molybdenum (99·8 wt%)	0·5 in.	10·53	5·25 in.	-	1·30	44·5	4
				1·0 in.			-	1·02	35·0	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Tungsten (~91·3 wt%)	0·5 in.	17·3	5·25 in.	-	1·26	43·2	4
				1·0 in.			-	0·98	33·7	4

Table 1.5 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFLECTOR
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height/Diameter	Mass (kgm)	
93·5	~18·7	-	Tungsten Alloy	2 in. (walls and one end) 3 in. (one end)	17·3	4·25 in.	-	-	29·26	4
93·2	18·8	-	Lead (0·028 wt% calcium)	12·7 cm	11·3	11·17 cm	-	-	34·7	32
		-		g			-	-	41·8	32
		-		13·3 cm	11·3	9·88 cm	-	-	41·8	32
		-		g			-	-	63·9	32
93·16	18·75	-	Thorium	- h	11·9	5·967 in.	-	0·59	30·06	15

a. Uncorrected for 1 in. Aluminium plate and steel platen supporting cylinder, critical core mass less than 2 kgm low
b. Effect of 0·015 in. steel diaphragm across median plane and candelabra support less than 0·1% of critical core mass
c. Uncorrected for 1 in. Aluminium plate and steel platen supporting cylinder, critical core mass less than 1 kgm low
d. Pseudospherical reflector
e. Type FS-1 Magnesium (3 wt% Al, 1 wt% Zn, 0·3 wt% Mg)
f. Electrolytic nickel (not less than 99·5 wt% Ni + Co, not more than 0·25 wt% Fe, 0·1 wt% C, 0·02 wt% S)
g. Radial reflector only
h. 21·0 in. equilateral cylinder reflector

Table 1.6

Cylinders of Uranium Metal with Non-Moderating, Composite Reflectors

(See also Table 1.7)

Reference : 17
Uranium enrichment : 93·2 wt%

These experiments were performed on a vertical approach machine. The cores were assembled from 0·125 in. thick discs and the reflectors from 0·375 in. thick discs, the reflector discs being machined to 0·0005 in. flatness. Core and reflector formed a 15·0 in. dia. cylinder, the core being reflected on the lower end only.

The reflectors contained 27 discs and were supported, together with the lower 9 core discs, on a low mass aluminium cylinder attached to the lift. The remainder of the core was supported on a 0·019 in. thick stainless steel diaphragm.

A series of reflectors consisting of a single material or of two materials at ~25 vol.% increments was investigated (see Figure 1.1). Results indicated that any effects introduced by the non-homogeneity of the reflectors were within the total uncertainty of the critical mass measurements (± 0·3 kgm).

REFLECTOR AVERAGE COMPOSITION (Vol.%)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
Mild Steel	-	-	129·3
Type 347 Stainless Steel	-	-	125·8
Nickel	-	-	123·8
Copper	-	-	121·0
Zinc	-	-	126·9
15% Mild Steel 85% Nickel	-	-	123·5
25·9% Mild Steel 74·1% Nickel	-	-	123·5
48·2% Mild Steel 51·8% Nickel	-	-	123·9
74·1% Mild Steel 25·9% Nickel	-	-	125·7

Table 1.6 (Cont'd)

REFLECTOR AVERAGE COMPOSITION (Vol.%)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
25·9% Mild Steel 74·1% Copper	-	-	122·3
48·2% Mild Steel 51·8% Copper	-	-	123·4
74·1% Mild Steel 25·9% Copper	-	-	125·3
25·9% Mild Steel 74·1% Zinc	-	-	126·2
48·2% Mild Steel 51·8% Zinc	-	-	126·4
74·1% Mild Steel 25·9% Zinc	-	-	127·7
25·9% Type 347 Stainless Steel 74·1% Nickel	-	-	122·9
48·2% Type 347 Stainless Steel 51·8% Nickel	-	-	122·8
51·8% Type 347 Stainless Steel 48·2% Nickel	-	-	122·8
74·1% Type 347 Stainless Steel 25·9% Nickel	-	-	124·2
25·9% Nickel 74·1% Copper	-	-	121·3
48·2% Nickel 51·8% Copper	-	-	121·1
74·1% Nickel 25·9% Copper	-	-	122·0
25·9% Nickel 74·1% Zinc	-	-	124·6
51·8% Nickel 48·2% Zinc	-	-	123·9
74·1% Nickel 25·9% Zinc	-	-	123·9

Table 1.6 (Cont'd)

REFLECTOR AVERAGE COMPOSITION (Vol%)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
25·9% Copper 74·1% Zinc	-	-	124
51·8% Copper 74·1% Zinc	-	-	122·9
74·1% Copper 25·9% Zinc	-	-	122·3

Table 1.7

Cylinders of Uranium Metal with Non-Moderating, Composite Reflectors

(See also Table 1.6)

Reference : 17
Uranium enrichment : 93·2 wt%

These experiments were performed on a vertical approach machine. The cores were assembled from 0·125 in. thick discs and the reflectors from 0·375 in. thick discs, the reflector discs being machined to 0·0005 in. flatness. Core and reflector formed a 15·0 in. dia cylinder, the core being reflected on the upper and lower ends only.

The upper reflector contained 13 discs and was supported, together with the upper 6 core discs on a 0·019 in. thick stainless steel diaphragm. The lower reflector contained 14 discs and was supported, together with the remainder of the core on a low mass aluminium cylinder attached to the lift.

A series of reflectors consisting of a single material or of two materials at ~25 vol.% increments were investigated (see Figure 1.2). Results indicated that any effects introduced by the non-homogeneity of the reflectors were within the total uncertainty of the critical mass measurements (± 0·3 kgm).

REFLECTOR AVERAGE COMPOSITION (Vol.%)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
Mild Steel	-	-	95
Type 347 Stainless Steel	-	-	88
Nickel	-	-	82·5
Copper	-	-	76·5
Zinc	-	-	89
25·9% Mild Steel 74·1% Nickel	-	-	82·5
51·8% Mild Steel 48·2% Nickel	-	-	83·5
74·1% Mild Steel 25·9% Nickel	-	-	87·5

Table 1.7 (Cont'd)

REFLECTOR AVERAGE COMPOSITION (Vol.%)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
25·9% Mild Steel 74·1% Copper	-	-	79
51·8% Mild Steel 48·2% Copper	-	-	82·5
74·1% Mild Steel 25·9% Copper	-	-	87
25·9% Mild Steel 74·1% Zinc	-	-	88·5
51·8% Mild Steel 48·2% Zinc	-	-	88·5
74·1% Mild Steel 25·9% Zinc	-	-	92
25·9% Type 347 Stainless Steel 74·1% Nickel	-	-	82·5
51·8% Type 347 Stainless Steel 48·2% Nickel	-	-	83
74·1% Type 347 Stainless Steel 25·9% Nickel	-	-	85
25·9% Nickel 74·1% Copper	-	-	77·5
48·2% Nickel 51·8% Copper	-	-	78
74·1% Nickel 25·9% Copper	-	-	79
25·9% Nickel 74·1% Zinc	-	-	85·5
48·2% Nickel 51·8% Zinc	-	-	83·5
74·1% Nickel 25·9% Zinc	-	-	82·5

Table 1.7. (Cont'd)

REFLECTOR AVERAGE COMPOSITION (Vol.%)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
25.9% Copper 74.1% Zinc	-	-	85
48.2% Copper 51.8% Zinc	-	-	81
74.1% Copper 25.9% Zinc	-	-	78.5

EXPERIMENTAL RESULTS FOR SINGLE, UNMODERATED U^{235} CORES - HIGHLY ENRICHED

Table 1.8

Cylinders of Uranium Metal with Moderating Reflectors
(includes Cadmium Shielded Systems)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (in.)	Average Density (gm/cc)	Diameter (in.)	Height (in.)	Height/Diameter	Mass (kgm)	
93·3	17·9	0·3 cm thick plates and rings	Water	6·00 [a]	1·0	15·00	-	-	117·5	15
93·2	18·2	0·3 cm thick plates and rings		[b]		21·00	-	-	202·3	15
93·7	~18·5	0·4 in. diameter x 0·47 in. central source cavity		12	1·0	3·98	-	1·9	28·5	10, 15
93·8	~18·5	0·4 in. diameter x 0·47 in. central source cavity				4·75	-	0·98	25·3	10, 15
93·8	~18·5	0·4 in. diameter x 0·47 in. central source cavity				5·50	-	0·66	26·0	10, 15
94·0	~18·5	0·4 in. diameter x 0·47 in. central source cavity				6·375	-	0·46	27·6	10, 15
94·0	~18·5	0·4 in. diameter x 0·47 in. central source cavity				7·00	-	0·365	29·5	10, 15
94·0	~18·5	0·4 in. diameter x 0·47 in. central source cavity				7·50	-	0·300	30·9	10, 15
93·18	18·70	-		eff. inf.	1·0	3·24	39·5	12·2	100	13
93·4	17·70	-				15·00	1·23	0·082	63·2	13
93·3	17·9	0·3 cm thick plates and rings	Paraffin	6·00 [a]	0·87	15·00	-	-	117·1	15
93·2	18·2	0·3 cm thick plates and rings		[b]		21·00	-	-	202·3	15
93·7	18·5	0·4 in. diameter x 0·47 in. central source cavity		8	0·89	3·98	-	1·8	26·7	10, 15
93·8	18·5	0·4 in. diameter x 0·47 in. central source cavity				4·75	-	0·915	23·7	10, 15

Table 1.8 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (in.)	Average Density (gm/cc)	Diameter (in.)	Height (in.)	Height/Diameter	Mass (kgm)	
93·8	18·5	0·4 in. diameter x 0·47 in. central source cavity	Paraffin	8	0·89	5·50	-	0·605	23·9	10, 15
94·0	18·5	0·4 in. diameter x 0·47 in. central source cavity				6·375	-	0·450	26·1	10, 15
94·0	18·5	0·4 in. diameter x 0·47 in. central source cavity				7·50	-	0·280	28·6	10, 15
93·5	18·8	Discs 0·075 to 1·200 in. thick	Polyethylene	0·5	0·921	5·25	-	1·35	46·4	4
93·5	18·8	Discs 0·075 to 1·200 in. thick		1·0	0·921	5·25	-	1·01	34·7	4
93·3	17·9	0·3 cm thick plates and rings		[a]	0·925	15·00	-	-	137·4	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	245·1	15
93·4	17·7	-		2·0	0·92	15·00	1·43	0·095	73·2	13
93·3	17·9	0·3 cm thick plates and rings		[a]	0·925	15·00	-	-	121·8	15
93·3	17·9	0·3 cm thick plates and rings		[a]	0·925	15·00	-	-	78·3	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	213·0	15
93·2	18·2	0·3 cm thick plates and rings		[d]	0·925	21·00	-	-	126·0	15
93·3	17·9	0·3 cm thick plates and rings		3·0 [a]	0·925	15·00	-	-	117·1	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	204·2	15
93·18	18·70	-		4·0	0·92	3·24	26·0	8·0	65·8	13
93·3	17·9	0·3 cm thick plates and rings		[a]	0·925	15·00	-	-	116·3	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	202·3	15

Table 1.8 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (in.)	Average Density (gm/cc)	Diameter (in.)	Height (in.)	Height/Diameter	Mass (kgm)	
93·3	17·9	0·3 cm thick plates and rings	Polyethylene	6·0 [a]	0·925	15·00	-	-	116·5	15
93·3	17·9	0·3 cm thick plates and rings		[a]	0·925	15·00 [n]	- [n]	- [n]	138·3 [n]	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	201·6	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00 [n]	- [n]	- [n]	245·1 [n]	15
93·3	17·9	0·3 cm thick plates and rings		8·0 [a]	0·925	15·00	-	-	116·3	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	201·5	15
93·3	17·9	0·3 cm thick plates and rings		10·0 [a]	0·925	15·00	-	-	116·3	15
93·2	18·2	0·3 cm thick plates and rings		[b]	0·925	21·00	-	-	201·3	15
93·3	17·9	0·3 cm thick plates and rings	Lucite	6·0 [a]	1·18	15·00	-	-	114·0	15
93·2	18·2	0·3 cm thick plates and rings		[b]		21·00	-	-	195·4	15
93·5	18·8	Discs 0·075 to 1·200 in. thick	Beryllium [e]	0·5	1·84	5·25	-	1·20	41·3	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	[e]	1·0	1·84	5·25	-	0·90	31·1	4
93·4	17·7	-			1·80	15·00 [f]	1·96 [f]	0·131 [f]	100·5 [f]	13
93·4	17·7	-		2·0	1·80	15·00 [f]	1·35 [f]	0·09 [f]	69·5 [f]	13
93·4	17·7	-		3·0	1·80	15·00 [f]	1·02 [f]	0·068 [f]	52·5 [f]	13
93·4	17·70	-		4·0	1·80	15·00 [f]	0·79 [f]	0·053 [f]	40·5 [f]	13
93·4	17·7	-		5·0	1·80	15·00 [f]	0·635 [f]	0·042 [f]	32·5 [f]	13
93·5	18·8	Discs 0·075 to 1·200 in. thick	Graphite [g]	0·5	1·67	5·25	-	1·44	49·2	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Graphite [g]	1·0	1·67	5·25	-	1·17	40·1	4

Table 1.8 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (in.)	Average Density (gm/cc)	Diameter (in.)	Height (in.)	Height / Diameter	Mass (kgm)	
93·3	17·9	-		a	1·79	15·0	-		145·2	4
93·2	18·2	-		b	1·73	21·0	-	-	260·0	4
93·4	18·7	0·315 in. thick discs			1·68	10·5	-	0·192	53·5	27
93·4	18·7	-		2·0 h	1·71	10·5		0·226	62·8	15
93·3	17·9	-		a	1·79	15·0	-	-	134·4	15
93·2	18·2	-		b	1·73	21·0	-	-	238·5	15
93·18	18·7	-		4·85	1·60	3·24	22·0	6·79	55·5	13
93·18	18·7	-		5·75	1·60	3·24	16·1	4·97	40·7	13
93·3	17·9	-		6·00 a	1·70	15·0	-	-	123·2	15
93·3	17·9	-		c	1·7	15·0	-	-	80·8	15
93·2	18·2	-		b	1·76	21·0	-	-	206·3	15
93·2	18·2	-		d	1·7	21·0	-	-	111·1	15
93·18	18·7	-		6·25	1·60	3·24	14·3	4·41	36·1	13
93·18	17·7	-		7·00	1·60	15·0	1·09	0·073	55·8	13
93·3	17·9	-		a	1·71	15·0	-	-	122·1	15
93·3	17·9	-		c	1·7	15·0	-	-	78·2	15
93·2	18·2	-		b	1·76	21·0	-	-	204·1	15
93·2	18·2	-		d	1·7	21·0	-	-	106·7	15
93·3	17·9	-		8·00 a	1·72	15·0	-	-	121·3	15
93·2	18·2	-		b	1·75	21·0	-	-	202·1	15
93·3	17·9	-		12·00 a	1·70	15·0	-	-	121·5	15
93·2	18·2	-		b	1·76	21·0	-	-	199·2	15
93·3	17·9	-		14·00 a	1·71	15·0	-	-	121·4	15
93·2	18·2	-		b	1·76	21·0	-	-	198·8	15
93·7	~18·5	0·4 in. diameter x 0·47 in. central source cavity	i	~17 j	1·66	3·25	-	2·95	24	15

Table 1.8 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (in.)	Average Density (gm/cc)	Diameter (in.)	Height (in.)	Height / Diameter	Mass (kgm)	
94	~18·7	Pseudocylinder of ½ in. cubic units with 0·4 in. x 0·46 in. central source cavity	Graphite [i]		1·66	3·62	-	1·85	21·4	15
93·7	~18·5	0·4 in. diameter x 0·47 in. central source cavity	[i]		1·66	3·98	-	1·3	19·5	15
93·7	18·5	0·4 in. diameter x 0·47 in. central source cavity	[i]		1·66	4·75	-	0·815	18·7	15
93·8	18·5	0·4 in. diameter x 0·47 in. central source cavity	[i]		1·66	5·50	-	0·495	19·7	15
94·0	18·5	0·4 in. diameter x 0·47 in. central source cavity	[i]		1·66	6·375	-	0·345	21·3	15
94·0	18·5	0·4 in. diameter x 0·47 in. central source cavity	[i]		1·66	7·50	-	0·235	24·1	15
94·0	18·7	Pseudocylinder of ½ in. cubic units with 0·4 in. x 0·46 in. central source cavity	[i]		1·66	8·50	1·50	0·177	26·2	15
94·0	18·7	Pseudocylinder of ½ in. cubic units with 0·4 in. x 0·46 in. central source cavity	[i]		1·66	12·4	1·00	0·0806	37·0	15
93·5	18·7	-	Tungsten Carbide	2·0	~14·7	4·25	-	-	26·10	15
93·3	17·7	-	Concrete [k]	2·0 [a] (31 lb)	~2·3	15·0	- [l]	- [l]	137·1 [l]	15
		-	[k]	4·0 [a] (58 lb)			- [l]	- [l]	128·1 [l]	15
		-	[k]	6·0 [a] (89 lb)			- [l]	- [l]	125·9 [l]	15
		-	[k]	8·0 [a] (116 lb)			- [l]	- [l]	124·8 [l]	15
		-	[k]	12·0 [a] (178 lb)			- [l]	- [l]	124·4 [l]	15

Table 1.8 (Cont'd)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter (in.)	Height (in.)	Height / Diameter	Mass (kgm)	
93·3	17·7	-	Concrete [k]	28·0 [a] (406 lb)	~2·3	15·0	- [l]	- [l]	124·1 [l]	15
93·5	18·8	Discs 0·075 to 1·200 in.	Molybdenum Carbide (95-96 wt% Mo_2C)	0·5	9·57	5·25	-	1·23	42·4	4
				1·0			-	0·95	32·8	4
93·5	18·8	Discs 0·075 to 1·200 in. thick	Beryllium [e] (against core)	0·5	1·84	5·25	-	1·00	34·4	4
			Steel [m]	0·5	7·78					
		Discs 0·075 to 1·200 in. thick	Beryllium [e]	0·5 in. (walls and one end) 1·0 in. (one end)	1·84		-	0·96	33·2	4
			Steel [m]	0·5	7·78					

a. Core reflected on one end only, core and reflector forming a 15·00 in. dia cylinder
b. Core reflected on one end only, core and reflector forming a 21·00 in. dia cylinder
c. Core reflected on ends only, core and reflector forming 15·00 in. dia cylinder
d. Core reflected on ends only, core and reflector forming 15·00 in. dia cylinder
e. Type QMV beryllium (1000 ppm Fe, 300 ppm Si, 400 ppm Mg, 1000 ppm Al, 400 ppm C, 7000 ppm O, 20 ppm halogens)
f. One end of reflector separated from the remainder of the system by 0·019 in. thick stainless steel diaphragm
g. Type CS 312 graphite
h. Core reflected on ends only, core and reflector forming a 10·5 in. dia cylinder
i. 5 in. thick type CS 312 graphite against core, reactor grade outside
j. Pseudospherical reflector
k. Class A concrete: 1548 lb ¾ in. rock, 1563 lb sand, 517 lb Portland cement, 40·3 gal water
l. Unreflected critical core mass = 163 8 kgm; curves of $\frac{1}{m}$ rs. mass paralleled for this series
m. Society of Automotive Engineers Type SAE - 1020 (0·17-0·24 wt% C, 0·30-0·60 wt% Mn, 0·040 wt% P, 0·050 wt% S)
n. 0·015 in. thick cadmium between core and reflector.

Table 1.9

20·32 cm dia Cylinder of Uranium Metal Dilute with Molybdenum

Reference: 16, 28

Core Material, 10 wt% molybdenum alloy of uranium

Uranium enrichment, 93·17 wt%

Average density, 17·08 gm/cc

Reflector: Unreflected

Delayed Critical Parameters: Height, 14·78 cm

Height/Diameter -

Mass, 68·6 kgm

Table 1.10

15·00 in. dia Cylinders of Uranium Metal Diluted with Other Materials

Reference: 15
Uranium enrichment: 93·3 wt%
Reflector: All cores unreflected

In these experiments the cores were assembled from alternate layers of uranium and the diluent, with a diluent layer at the base of the stack. The thicknesses of the repeated layers are noted in the Table as well as the average composition of the core. The uranium layers were built up from 0·3 cm thick discs.

VOLUME % URANIUM	LAYER THICKNESSES (cm)		AVERAGE URANIUM DENSITY (gm/cc)	AVERAGE DILUENT DENSITY (gm/cc)	DELAYED CRITICAL PARAMETERS		
	Uranium	Diluent			Height (in.)	Height/Diameter	Mass (kgm)
ALUMINIUM DILUENT							
78·6	0·3	0·08	14·20	0·555	4·14	0·276	170·4
64·8	0·3	0·16	11·68	0·912	5·22	0·348	176·7
55·2	0·3	0·24	9·97	1·166	6·39	0·426	184·6
48·0	0·3	0·32	8·70	1·358	7·67	0·512	193·4
42·6	0·3	0·40	7·75	1·502	9·23	0·615	207·1
IRON DILUENT							
72·8	2·4	0·95	13·28	2·08	4·33	0·289	166·5
62·3	1·5	0·95	11·36	2·88	5·21	0·347	171·4
49·0	0·9	0·95	8·97	3·91	7·02	0·468	182·2
49·0	0·9 [a]	0·95	8·97	3·91	7·00	0·467	181·8
39·1	0·6	0·95	7·18	4·68	9·84	0·656	204·5
38·4	0·6 [a]	0·95	7·01	4·70	9·96	0·664	202·3

Table 1.10 (Cont'd)

VOLUME % URANIUM	LAYER THICKNESSES (cm)		AVERAGE URANIUM DENSITY (gm/cc)	AVERAGE DILUENT DENSITY (gm/cc)	DELAYED CRITICAL PARAMETERS		
	Uranium	Diluent			Height (in.)	Height / Diameter	Mass (kgm)
NICKEL DILUENT							
72·4	2·4	0·95	13·15	2·35	4·33	0·288	164·7
61·8	1·5	0·95	11·33	3·29	5·14	0·343	168·8
48·1	0·9	0·95	8·82	4·47	6·82	0·455	174·3
39·1	0·6	0·95	7·28	5·26	9·20	0·614	191·6
38·3	0·6 [a]	0·95	7·07	5·34	9·28	0·619	190·0
COPPER DILUENT							
79·4	3·6	0·95	13·96	1·775	3·85	0·256	161·0
72·3	2·4	0·95	12·56	2·40	4·26	0·284	162·7
66·4	1·8	0·95	12·13	2·92	4·68	0·312	164·4
61·2	1·5	0·95	11·21	3·37	5·06	0·338	164·5
57·4	1·2	0·95	10·50	3·70	5·54	0·369	168·4
50·9	0·9	0·95	9·33	4·28	6·39	0·426	172·7
39·2	0·6	0·95	7·22	5·33	8·33	0·555	174·2
31·8	0·9	1·90	5·93	6·03	10·92	0·728	187·6
ZINC DILUENT							
38·5	0·6	0·95	7·09	4·32	9·43	0·629	193·7
ZIRCONIUM DILUENT							
71·3	0·3	0·1	13·18	1·810	4·44	0·296	169·6
56·6	0·3	0·2	10·31	2·70	5·84	0·389	174·2
46·5	0·3	0·3	8·45	3·32	7·42	0·495	181·6
39·6	0·3	0·4	7·18	3·74	9·22	0·614	191·5

Table 1.10 (Cont'd)

VOLUME % URANIUM	LAYER THICKNESSES (cm)		AVERAGE URANIUM DENSITY (gm/cc)	AVERAGE DILUENT DENSITY (gm/cc)	DELAYED CRITICAL PARAMETERS		
	Uranium	Diluent			Height (in.)	Height / Diameter	Mass (kgm)
MOLYBDENUM DILUENT							
89·2	0·6	0·08	16·18	1·080	3·56	0·238	167·0
79·1	0·3	0·08	15·15	2·09	3·96	0·264	166·2
HAFNIUM DILUENT							
97·3	3·9 [b]	0·1	17·55	0·349	3·27	0·218	166·2
93·4	1·5	0·1	16·80	0·837	3·45	0·230	167·8
85·1	0·6	0·1	15·31	1·904	3·82	0·255	169·5
74·1	0·3	0·1	13·30	3·30	4·48	0·299	172·8
TANTALUM DILUENT							
74·5	0·3	0·1	13·43	4·08	4·43	0·295	172·2
59·4	0·3	0·2	10·77	6·52	5·73	0·382	178·7
49·2	0·3	0·3	8·94	8·16	7·31	0·487	189·2
TUNGSTEN DILUENT							
73·1	0·3	0·1	13·21	4·92	4·33	0·288	165·5
57·4	0·3	0·2	10·40	7·83	5·55	0·370	167·0
47·3	0·3	0·3	8·63	9·72	6·74	0·480	168·5
40·2	0·3	0·4	7·29	10·99	8·31	0·554	175·5
35·0	0·3	0·5	6·46	12·15	9·85	0·656	184·2
30·9	0·3	0·6	5·64	12·80	12·23	0·815	199·9

a. U(93·3) plate at base of stack (layers inverted)

b. The two thicknesses of U alternate in successive sandwiches

EXPERIMENTAL RESULTS FOR SINGLE, UNMODERATED U^{235} CORES - HIGHLY ENRICHED

Table 1.11

Unreflected Rectilinear Parallelepipeds of Uranium Metal

ENRICHMENT (wt%)	METAL DENSITY (gm/cc)	GEOMETRY	DELAYED CRITICAL PARAMETERS				REFERENCES
			Area (in.) x (in.)	Thickness (in.)	Thickness / Area	U^{235} Mass (kgm)	
93·15	18·7	-	5·00 x 5·00	9·13	1·826	65·6 [a]	21,22
93·15	18·7	-	8·00 x 10·00	3·74	0·42	85·7 [a]	21,22
93·2	18·72	-	8 x 10	3·624	-	-	23,29,30
93·15	18·7	-	10·00 x 10·00	3·32	0·332	95·1 [a]	21,22
93·15	18·7	-	15·00 x 15·00	2·87	0·192	184·9 + 4% - 2% [a]	21,22
93·15	18·7	-	20·00 x 20·00	2·72	0·136	311·9 + 8% - 4% [a]	21,22

a. In these experiments the aluminium support structure for the uranium was made as light as possible in order to minimise back-scattering of neutrons. For some of the 8 in. x 10 in. slab assemblies, in fact, the uranium on the fixed portion of the split table was suspended by aluminium rods. This arrangement is said to have lacked sturdiness, however, and tended to introduce uncertainties into the results by permitting cracks and voids to remain upon the table closure. In all assemblies the number of individual pieces was held to a minimum to reduce the void content.

Table 1.12

(Approximate) Rectilinear Parallelepipeds of Uranium Metal with a Natural Uranium Reflector

Reference: 9
Core: Uranium enrichment, 94 wt%
Average Density, 18·7 gm/cc
Geometry, ½ cubic units
Reflector: Average Density, 19·0 gm/cc
Geometry, Pseudosphere

REFLECTOR THICKNESS	DELAYED CRITICAL CORE PARAMETERS			
	Area (in.)	Thickness (in.)	$\frac{\text{Thickness}}{\sqrt{\text{Area}}}$	Mass (kgm)
~8·5 in.	3 x 3	7·5	-	20·9
~8·75 in.	3 x 3·5	6	-	19·35
~9 in.	4 x 4	3·5	-	18·0
~8·75 in.	5 x 5	2·5	-	19·4
~8·25 in.	7·5 x 7·5	1·5	-	27·0

Table 1.13

Rectilinear Parallelepipeds of Uranium Metal with Moderating Reflectors

Reference: 21, 22
Core: Uranium enrichment 93·15 wt%
Average density 18·7 gm/cc
Reflector Geometry: Parallelepiped

REFLECTOR THICKNESS (in.)	DELAYED CRITICAL CORE PARAMETERS			
	Area (in.) x (in.)	Thickness (in.)	Thickness / √Area	U^{235} Mass (kgm)
Plexiglas Reflector (Density 1·2 gm/cc)				
1	5·00 x 5·00	4·96	0·992	35·5
	8·00 x 10·00	2·64	0·30	60·5
	10·00 x 10·00	2·32	0·232	65·6
	15·00 x 15·00	1·92	0·128	123·7
	20·00 x 20·00	1·79	0·090	205·5
	24·00 x 25·00	1·77	0·072	304·5
2	5·00 x 5·00	3·70	0·740	26·5
	8·00 x 10·00	1·89	0·21	43·3
	10·00 x 10·00	1·72	0·172	49·3
	15 x 15	1·35	0·090	87·0
3	8 x 10	1·63	0·18	37·4
	20 x 20	0·92	0·046	105·3
4	8 x 10	1·55	0·17	35·5
6	5 x 5	3·05	0·610	21·8
	8 x 10	1·53	0·17	35·0
	10 x 10	1·30	0·130	37·3
	15 x 15	0·95	0·0635	61·3
	20 x 20	0·80	0·040	91·7
	25 x 25	0·71	0·028	127·1
a	8 x 10	2·54		

Table 1.13 (Cont'd)

REFLECTOR THICKNESS (in.)	DELAYED CRITICAL CORE PARAMETERS			
	Area (in.) x (in.)	Thickness (in.)	$\frac{\text{Thickness}}{\sqrt{\text{Area}}}$	U^{235} Mass (kgm)
Graphite Reflector[b]				
1·43	8 x 10	2·52	-	57·7
2·87	8 x 10	2·11	-	48·4
5·75	8 x 10	1·65	-	37·8
12·0	8 x 10	1·32	-	30·3
Beryllium Reflector (Density 1·86 gm/cc)				
12·0	5 x 5	1·40	-	10·1

a. One 8 in. x 10 in. surface of core unreflected

b. Union Carbide Co. Ltd. AGOT graphite, a high purity nuclear grade (0·4 p.p.m. B average, ash 0·07 wt%), density 1·72 gm/cc

EXPERIMENTAL RESULTS FOR SINGLE UNMODERATED U^{235} CORES - HIGHLY ENRICHED

Table 1.14

Spherical Shells of Uranium Metal

Reference: 15

Reflector Geometry: Spherical; the reflector material also filled the central cavity in the core

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS		
Enrichment (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness (in.)	Density (gm/cc)	Outer Diameter	Diameter of Central Cavity (in.)	Mass (kgm)
93·9	18·5	-	Water	14·6	1·00	-	3·60	26·7
93·9	18·5	-		14·4	1·00	-	4·08	28·0
93·8	18·5	-		14·3	1·00	-	4·68	29·5
93·9	18·5	-	98·8% Heavy Water (in 0·2 in. thick stainless steel vessel)	14·9	-	-	3·60	17·5
93·7	18·5	-		14·7	-	-	4·08	18·4
93·7	18·5	-		14·4	-	-	4·97	19·5

Table 1.15

Unreflected Cylindrical Annuli of Uranium Metal

References 25, 26

In these experiments the cores were assembled from 1 in. wide cylindrical annuli, ranging in thickness from $\frac{1}{8}$ to $\frac{1}{2}$ in. These were fabricated with a ±0·0002 in. variation in any dimension and a total variation in flatness of ±0·002 in. so that the gap between nesting pieces was no more than 0·0006 in.

ENRICHMENT (wt%)	AVERAGE DENSITY (gm/cc)	DELAYED CRITICAL PARAMETERS			
		Outer Diameter	Diameter of Central Cavity	Height	Mass (kgm)
Annuli with Void Central Cavity					
93·2	18·76	11 in. [a]	7 in. [a]	7·31 in. [a]	157·9 [a]
93·15	18·705	33·010 cm	17·787 cm	14·608 cm	165·937
93·15	18·693	38·088 cm	17·787 cm	10·779 cm	179·509
93·15	18·705	38·088 cm	22·864 cm	15·158 cm	206·635
Annuli with Beryllium Filled Central Cavity					
93·2	18·76	15 in. [f]	7 in. [f]	3·98 in. [f]	168·6 [f]
Annuli with Central Cavity Walls Reflected by 1 in. Graphite					
93·2	18·76	1·3 in. [b]	9 in. [b]	6·08 in. [b]	128·7 [b]
Annuli with Graphite Filled Central Cavity					
93·2	18·76	13 in. [c]	7 in. [c]	5·26 in. [c]	151·9 [c]
93·2	18·76	15 in. [d]	7 in. [d]	4·10 in. [d]	173·6 [d]
93·2	18·76	15 in. [e]	9 in. [e]	5·35 in. [e]	185·3 [e]

a. A 7 in. diameter, 1·38 in. thick uranium disc was located at the bottom of the central cavity, and a 7 in. diameter, 1·25 in. thick disc at the top of the cavity with its top surface 0·13 in. below the top of the annulus. Reactivity - 16·5 cents

b. Reactivity - 5·3 cents

c. Reactivity + 15·6 cents

d. Reactivity - 24·6 cents

e. Reactivity - 11·5 cents

f. Reactivity - 6·3 cents

Table 1.16

Reflected Cylindrical Annuli of Uranium Metal

Reference: 15

In these experiments the cores were assembled from $\frac{1}{4}$ in. and $\frac{1}{4}$ in. thick rings

CORE		REFLECTOR			DELAYED CRITICAL CORE PARAMETERS			
Enrichment (wt%)	Average Density (gm/cc)	Material	Thickness (in.)	Density (gm/cc)	Outer Diameter (in.)	Diameter of Central Cavity (in.)	Height (in.)	Mass (kgm)
Annuli with Void Central Cavity								
93.4	18.7	Natural Uranium	1.00 3.00	19.0	12.25	6.00	3.01 2.03	82.7
93.4	18.7	Polyethylene	3.00	0.92	12.25	6.00	2.20	60.6
93.4	18.7	Natural Uranium (against core) Polyethylene	1.00 2.00	19.0 0.92	12.25	6.00	1.98	54.5
93.4	18.7	Type CS-312 Graphite	2.00	~1.67	12.25	6.00	2.86	78.5
93.15	18.7		9.5 (ends) 8.9 (walls)	1.67	6.14	3.85	6.36	35.1
93.16	17.9		6.00 [a]	1.7	21.00	15.00	3.44	176.7
Annuli with Water Filled Central Cavity								
93.15	18.75	Water	>12	1.00	6.14	3.85	5.75	31.8

a. Reflector across ends of core only, no radial reflector

Table 1.17

Cylindrical Annuli of Uranium Diluted with Molybdenum

(Includes Cadmium shielded systems)

References: 16, 28

Core:

Material	10 wt% molybdenum alloy of uranium
Uranium enrichment	93·17 wt%
Average density	17·08 gm/cc
Outer diameter	20·32 cm

REFLECTOR			DELAYED CRITICAL CORE PARAMETERS			
Material	Thickness (cm)	Density (gm/cc)	Diameter of Central Cavity (cm)	Height (cm)	Volume	U^{235} Mass (kgm)
Annuli with Void Central Cavity						
← Unreflected →			5·08	19·74	-	85·9
Plexiglas	2·54	1·2	8·89 (lower 12·70 cm); 5·08 (above 12·70 cm)	17·25	-	67·5
	5·08			12·57	-	47·2
	2·54 (top and lower 8·25 cm of walls); 15·27 (base)			19·05	-	75·3
Plexiglas/ Cadmium [a]	2·54	1·2	8·89 (lower 12·70 cm); 5·08 (above 12·70 cm)	17·98	-	70·7
	5·08			15·80	-	61·2
Annuli with Plexiglas filled Central Cavity						
Plexiglas	2·54	1·2	8·89 (lower 12·70 cm); 5·08 (above 12·70 cm)	13·86	-	52·8
	15·2 (base only, no top or radial reflector)			17·68	-	69·4
Plexiglas/ Cadmium [a]	2·54	1·2	8·89 (lower 12·70 cm); 5·08 (above 12·70 cm)	14·65	-	56·2
	5·08			13·18	-	49·8
Annuli with Central Cavity filled with Type 347 Stainless Steel						
← Unreflected →			5·08	18·92	-	82·4

a. 0·025 cm thick cadmium between core and reflector

EXPERIMENTAL RESULTS FOR SINGLE UNMODERATED U^{235} CORES - INTERMEDIATE AND LOW ENRICHMENTS

Table 1.18

Spheres of Uranium Metal

Reflector: Pseudosphere of natural uranium, average density 19·0 gm/cc

In these experiments the cores were pseudospheres of $\frac{1}{2}$ in. cubic units and the average enrichment was obtained by mixing units of 94 wt% enriched and natural uranium

CORE		REFLECTOR THICKNESS (in.)	DELAYED CRITICAL CORE PARAMETERS MASS (kgm)	REFERENCES
Average Enrichment (wt%)	Average Density (gm/cc)			
80·5	18·7	8·75	22·73	6
67·6	18·75	8·5	30·73	5,6
66·6	18·7	8·5	31·84	5,6
47·3	18·8	7·75	57·23	5,6

Table 1.19

Unreflected Cylinders of Uranium Metal

(Note: In this Table U(X) is used to denote uranium containing wt% U^{235})

ENRICHMENT (wt%)	AVERAGE DENSITY (gm/cc)	GEOMETRY	DELAYED CRITICAL PARAMETERS				REFERENCES
			Diameter (in.)	Height (in.)	Height / Diameter	Mass (kgm)	
86·4(ave)	18·08	Repeated layers of 3·6 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	3·36	0·224	176·0	15
83·4(ave)	17·95	Repeated layers of 2·4 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	3·50	0·233	181·8	15
80·5(ave)	17·98	Repeated layers of 1·8 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	3·60	0·240	187·3	15
77·7(ave)	17·98	Repeated layers of 1·5 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	3·70	0·247	192·8	15
75·5(ave)	18·19	Repeated layers of 1·2 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	3·77	0·252	197·5	15
70·5(ave)	18·16	Repeated layers of 0·9 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	4·00	0·266	210·2	15
65·5(ave)	18·33	Repeated layers of 3·6 cm U(93·3) and 1·5 cm U(Natural)[a]	15·00	4·05	0·270	215·0	15
64·4(ave)	18·21	Repeated layers of 0·6 cm U(93·3) and 0·3 cm U(Natural)[a]	15·00	4·34	0·289	229·2	15
56·6(ave)	18·37	Repeated layers of 2·4 cm U(93·3) and 1·5 cm U(Natural)[a]	15·00	4·60	0·306	244·7	15
57·1(ave)	18·34	Repeated layers of 2·1 cm U(93·3) and 1·5 cm U(Natural)[a] with extra U(93·3) at top of stack	15·00	4·66	0·311	247·3	15
53·6(ave)	18·7	Repeated layers of 0·8 cm U(93·4) and 0·6 cm U(Natural)[a]	10·5	~6·10	0·581	91·96 U(93·4) + 70·02 U(Natural) (10·93 layers)	18
50·5(ave)	18·35	Repeated layers of 1·8 cm U(93·3) and 1·5 cm U(Natural)[a]	15·00	5·25	0·350	279·0	15
50·7(ave)	18·44	Repeated layers of 1·5 cm U(93·3) and 1·5 cm U(Natural)[a] with extra U(93·3) at top of stack	15·00	5·25	0·350	280·5	15

Table 1.19 (Cont'd)

ENRICHMENT (wt%)	AVERAGE DENSITY (gm/cc)	GEOMETRY	DELAYED CRITICAL PARAMETERS				REFERENCES
			Diameter (in.)	Height (in.)	Height / Diameter	Mass (kgm)	
47·0(ave)	18·42	Repeated layers of 0·6 cm U(93·3) and 0·6 cm U(Natural) [a]	15·00	5·53	0·369	295·3	15
47·1(ave)	18·25	Repeated layers of 0·3 cm U(93·3) and 0·3 cm U(Natural) [a]	15·00	5·25	0·374	296·8	15
45·5	18·16	Pseudocylinder of hexagonal units 2·75 in. across flats, varying in thickness from 0·2 to 1·2 in. and coated with a protective lacquer (see Figure 1.3) [d,e]	11·58	7·26	-	-	19
			16·92	5·47	-	-	19
44·2(ave)	18·49	Repeated layers of 1·2 cm U(93·3) and 1·5 cm U(Natural) [a]	15·00	5·92	0·394	317·0	15
38·0(ave)	18·49	Repeated layers of 0·9 cm U(93·3) and 1·5 cm U(Natural) [a]	15·00	7·02	0·468	376·1	15
37·7(ave)	18·75	Repeated layers of 0·8 cm U(93·4) and 1·2 cm U(Natural) [b,f]	10·5	~10·04	0·956	105·86 U(93·4) + 161·17 U(Natural) (12·58 layers)	18
31·6(ave)	18·51	Repeated layers of 0·3 cm U(93·3) and 0·6 cm U(Natural) [a]	15·00	8·23	0·548	440·5	15
29·0(ave)	18·8	Psuedocylinder of 10·5 in. dia repeated layers of 0·8 cm U(93·4) and 1·8 cm U(Natural) extended by U(~93·5) and U(Natural) blocks in proper proportion [b,f]	11·42	13·45	1·178	424	18
28·9(ave)	18·32	Repeated layers of 0·6 cm U(93·3) and 1·5 cm U(Natural) [a]	15·00	9·63	0·642	510·4	15
23·9(ave)	18·65	Repeated layers of 0·3 cm U(93·3) and 1·5 cm U(Natural) followed by 0·3 cm U(93·3) and 0·3 cm U(Natural) [a,g]	15·00	11·73	0·782	634·3	15
21·3(ave)	18·62	Repeated layers of 0·3 cm U(93·3) and 1·5 cm U(Natural) followed by 0·3 cm U(93·3) and 0·6 cm U(Natural) [a,g]	15·00	14·15	0·943	763·4	15
19·3(ave)	18·66	Repeated layers of 0·3 cm U(93·3) and 1·5 cm U(Natural) followed by 0·3 cm U(93·3) and 0·9 cm U(Natural) [a,g]	15·00	17·85	1·190	962·7	15

a. Indicated layers assembled from 0·3 cm thick U(93·3) discs and 0·3 cm, 0·6 cm, and 1·5 cm thick U(Natural) discs, starting with U(Natural) at base of stack
b. Indicated layers assembled from 0·8 cm thick U(93·4) discs and 0·6 cm thick U(Natural) discs
c. Starts with U(93·4) at base of stack
d. Mean diameter evaluated on an equivalent area basis
e. Fissile material divided into two approximately equal components. Both upper and lower components were supported on 0·186 cm thick aluminium plates, attached to an aluminium angle framework. This is said to reduce neutron reflection to the practical minimum. The effect of the aluminium interface separating the two fissile components at critical is connected for empirically
f. Starts with 0·6 cm U(Natural) at base of stack
g. Starts with 1·5 cm U(Natural) at base of stack

Table 1.20

Reflected, 45·5 wt% Enriched Cylinders of Uranium Metal

Reference: 19

In these experiments the cores were pseudocylinders assembled from hexagonal and half-hexagonal units ranging in thickness from ~0·2 to ~1·2 in. and measuring ~2·75 in. across the flats (for complete hexagons). All units were coated with a protective lacquer giving an average core density of 18·16 gm/cc. Three sizes of core were used equivalent, on an area basis, to cylinders of diameter 11·58 in., 16·92 in., and 22·1 in.

Two arrangements of side reflector were used with each size of core:

Natural uranium was available in hexagons and half-hexagons similar in size to those in the core; these were placed round the sides of the core (see Figure 1.4) giving a radial reflector 7·05 in. wide and with an average density of 18·26 gm/cc.

The remaining reflector materials were cut in two patterns (see Figure 1.5) enabling the sides of the core to be surrounded by an approximate 6 in. thickness of reflector. The average densities of these reflectors were:

mild steel 7·78 gm/cc, aluminium 2·72 gm/cc, graphite 1·74 gm/cc

The end reflectors are described in the Table:

END REFLECTORS (See notes prefacing Table for details of side reflectors)			DELAYED CRITICAL CORE PARAMETERS			
Geometry	Thickness (in.)	Average Density (gm/cc)	Dia. (in.)	Height (in.)	Height/dia	Mass
NATURAL URANIUM REFLECTOR						
36 in. square pseudoslab assembled from 1 in. thick slabs and 1·2 in. diameter rods of uranium in steel box	~6[a]	-[a]	11·58	3·27	-	-
	a	a	16·92	2·36	-	-
	a	a	22·1	2·01	-	-
MILD STEEL REFLECTOR						
36 in. square slab	6·558 (one end) 6 (one end)	7·24	11·58	4·12	-	-
			16·92	2·98	-	-
			22·1	2·57	-	-

Table 1.20 (Cont'd)

END REFLECTORS (see notes prefacing Table for details of side reflectors)			DELAYED CRITICAL CORE PARAMETERS			
Geometry	Thickness (in.)	Average Density (gm/cc)	Dia. (in.)	Height (in.)	Height/Dia	Mass
ALUMINIUM REFLECTOR						
36 in. square slab	6·377 (one end) 6 (one end)	2·58	11·58	4·40	-	-
			16·92	3·21	-	-
			22·1	2·72	-	-
GRAPHITE REFLECTOR						
36 in. square slab of c blocks in steel box	~6·10	-	11·58	3·00	-	-
			16·92	2·14	-	-
			22·1	1·78	-	-
BORATED GRAPHITE ($Na_{1.62}$, $B_{2.00}$, $O_{4.31}$, $C_{22.6}$) END REFLECTORS, GRAPHITE SIDE REFLECTOR						
40 in. square slab	8	1·55	11·58	3·76	-	-
			16·92	2·80	-	-
			22·1	2·40	-	-

a. The overall composition of the natural uranium end reflectors is given in the following Tables:

LOWER REFLECTOR

LAYER NO.*	THICKNESS (in.)	COMPOSITION	MEAN DENSITY (gm/cc)
1	0·067	Mild Steel	7·78 ± 0·02
2	1·00	Natural Uranium	18·54 ± 0·06
3	5·67	Natural Uranium	16·07 ± 0·13

*Layers with lowest number nearest to fissile components

Table 1.20 (Cont'd)

UPPER REFLECTOR

LAYER NO.*	THICKNESS (in.)	COMPOSITION	MEAN DENSITY (gm/cc)
1	0·130	Mild Steel (1) Natural Uranium 98·0% by volume	7·78 ± 0·02
2	1·00	(2) Mild Steel 2·0% by volume (3) Natural Uranium 83·7% by volume	18·33 ± 0·10
3	5·67	(4) Mild Steel 2·0% by volume	15·91 ± 0·16

*Layers with lowest numbers were nearest to fissile components

Subsidiary experiments showed that the steel interface between the core and these reflectors introduced an error of less than ½% in the critical heights.

(b) The overall composition of the graphite and reflectors is given in the following Table:

UPPER REFLECTOR

LAYER NO.	THICKNESS (in.)	COMPOSITION	MEAN DENSITY (gm/cc)
1*	0·130	Mild Steel (1) Graphite 98·0% by volume	7·78 ± 0·02
2	6·00	(2) Mild Steel 2·0% by volume	1·86 ± 0·04

*Layer No. 1 was next to the fissile components

LOWER REFLECTOR

LAYER NO.	THICKNESS (in.)	COMPOSITION	MEAN DENSITY (gm/cc)
1*	0·067	Mild Steel	7·78
2	6·00	Graphite	1·74 ± 0·03

*Layer No. 1 was next to the fissile components

Subsidiary experiments showed that the steel interface between the core and these reflectors introduced an error of less than ½% in the critical heights.

Table 1.21

16½ wt% (ave) Enriched Cylinder of Uranium Metal with Natural Uranium Reflector

Reference : 20

Core : Average density, 18·75 gm/cc

Geometry, Pairs of 3 mm, 93·4 wt% enriched and 15 mm, natural uranium discs

Reflector : Thickness, 3 in.

Average density, 19·0 gm/cc

Delayed Critical Core Parameters : Diameter, 15 in.

Height, -
Height/Diameter, -
Mass, 692 kgm

The non-homogenity of the core is said to reduce the critical mass by ~1%.

Table 1.22

37·67 wt% Enriched Rectilinear Parallelipipeds of Uranium Metal
(Includes cadmium shielded systems)

References : 24, 33

In these experiments the cores were assemoled from nominal 2 in. x 2 in. x $\frac{1}{8}$ in. plates laid horizontally. Each plate was coated with a 0·0025 cm thick film of protective lacquer of which the chief constituent was aluminium and the remainder carbon, hydrogen and oxygen. Average material densities in the core were 17·84 gm/cc uranium and <0·05 gm/cc aluminium and the average H/U^{235} atomic ratio <0·03.

In one series of experiments only the upper surface of the core was reflected by the reflector specified in the Table, the remaining faces being reflected by an 8 in. thickness of polyethylene, (density 0·919 gm/cc). In another series of experiments all faces of the core were reflected by the specified reflector.

REFLECTOR			DELAYED CRITICAL CORE PARAMETERS					
Material	Thickness (cm)	Average Density (gm/cc)	Area a: Uranium Plates	Area a: cm	Thickness (cm)	Thickness/√Area	Volume	Mass (kgs U^{235})
Cores with Specified Reflector on Upper Surface Only (See notes prefacing Table - this reflector extended across the side reflectors as well as the core)								
Unreflected			4 x 4	20·41 x 20·41	19·16	-	-	-
Water	20	-	4 x 4	20·41 x 20·41	15·45	-	-	-
Polyethylene	2·54	0·919	4 x 4	20·41 x 20·41	17·22	-	-	-
	5·1				16·00	-	-	-
	10·2				15·31	-	-	-
	15·2				15·18	-	-	-
	20				15·11	-	-	42·2
	20		3 x 3	15·31 x 15·31	29·15	-	-	45·8
	20		6 x 6	30·61 x 30·61	9·15	-	-	57·5
	20		4 x 4	20·41 x 20·41	17·45 a	- a	- a	- a
Concrete b	20	2·37	4 x 4	20·41 x 20·41	15·21	-	-	-
Concrete/Cadmium a					16·22	-	-	-
Beechwood b	20	0·693	4 x 4	20·41 x 20·41	16·05	-	-	-
Beechwood/Cadmium a					17·39	-	-	-
Cores with Specified Reflector on all Surfaces (See notes prefacing Table)								
Concrete b	20	2·37	4 x 4	20·38 x 20·38 c	15·17 c	- c	- c	43·1 c
Concrete/Cadmium a				a, c	19·53 c	- c	- c	55·4 c
Beechwood b	20	0·693	4 x 4	20·41 x 20·41	19·63	-	-	54·8
Beechwood/Cadmium a				a	29·85	-	-	83·4

a. 0·06 cm thick cadmium between core and specified reflector. (But not between the core and the 8 in. thick polyethylene reflector on the remaining core surfaces.)

b. The composition of the concrete and beechwood reflectors is given in the following Table, (in wt%).

ELEMENT	CONCRETE	BEECHWOOD
Hydrogen	0·87	6·4
Lithium	<0·001	-
Boron	0·0084	-
Carbon	0·29	45·9
Nitrogen	-	0·076
Oxygen	51·7	47·3
Sodium	0·07	0·015
Magnesium	0·14	0·010
Aluminium	1·57	-
Silicon	32·4	-
Sulphur	0·21	-
Potassium	0·10	0·12
Calcium	11·84	0·08
Manganese	0·018	-
Iron	0·71	-
Cadmium	<0·01	-
Others	0·10	0·30

c. Uranium plates unlacquered; average uranium density in core 18·14 gm/cc.

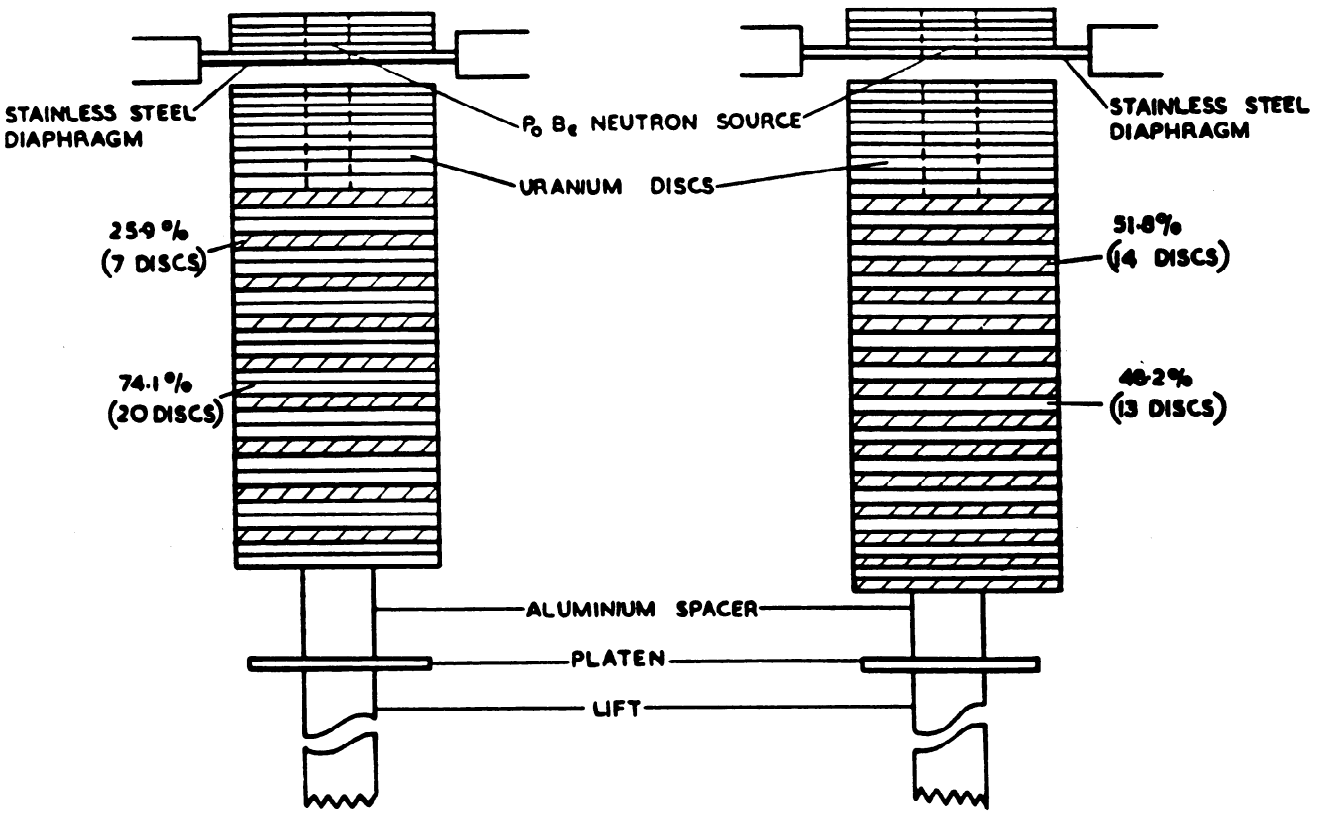


FIG. 1·1. (SEE TABLE 1·6)

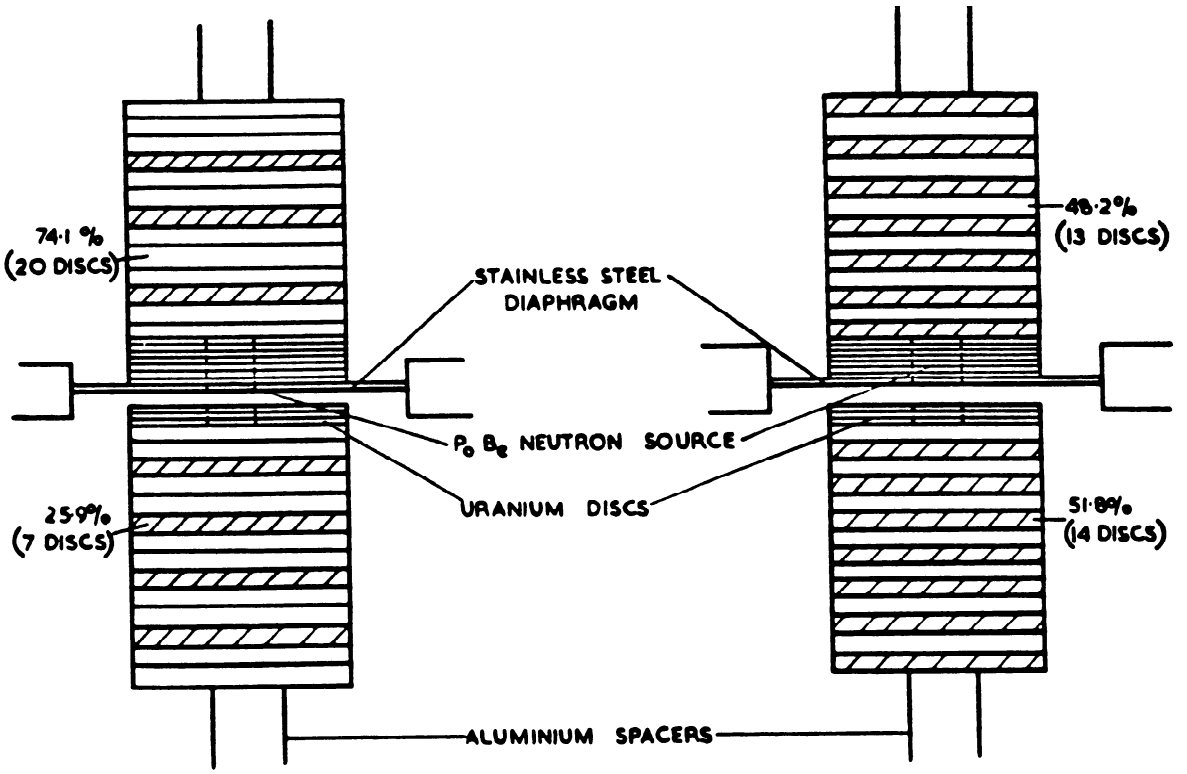
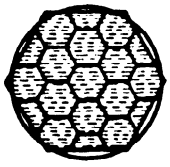
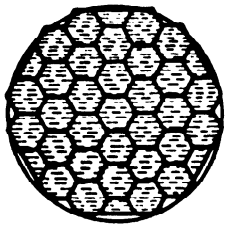


FIG. 1·2 (SEE TABLE 1·7)



(a) EQUIVALENT CYLINDER DIAMETER 11·58 INS



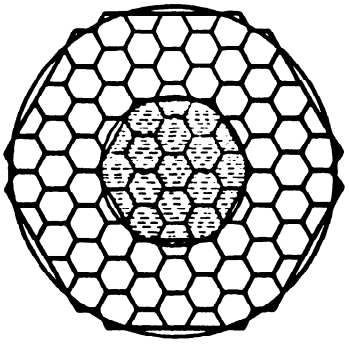
(b) EQUIVALENT CYLINDER DIAMETER 16·92 INS

FIG. 1.3 (SEE TABLE 1·19)

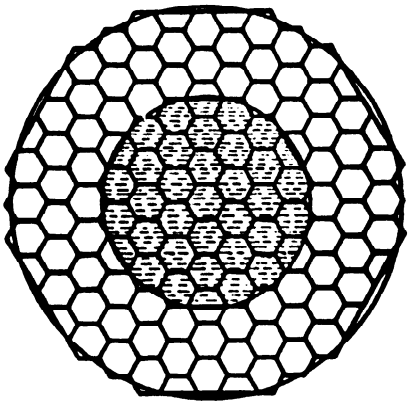
45·5% ENRICHED URANIUM

NATURAL URANIUM

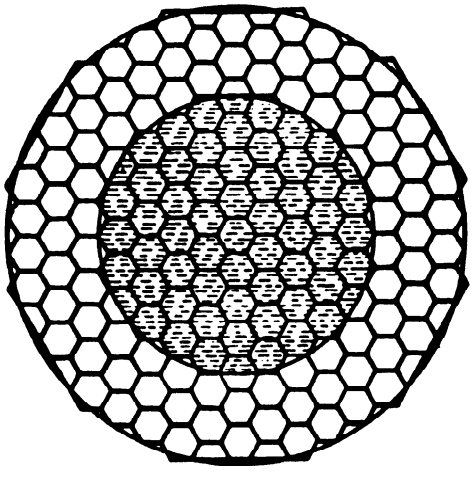
CIRCLES SHOW EQUIVALENT CYLINDERS



(a) EQUIVALENT CYLINDER DIAMETER 11·58 INS

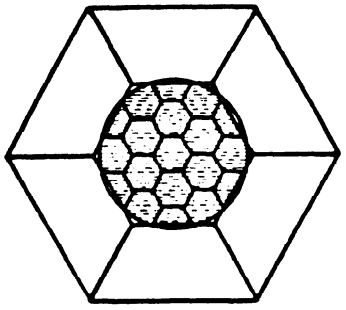


(b) EQUIVALENT CYLINDER DIAMETER 16·92 INS

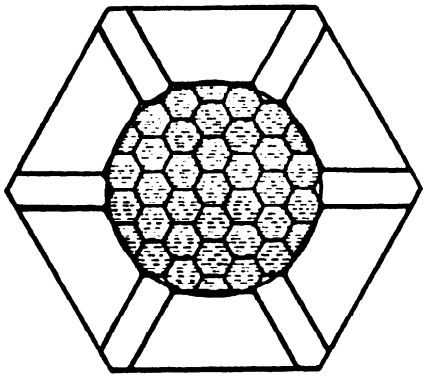


(c) EQUIVALENT CYLINDER DIAMETER 22·10 INS

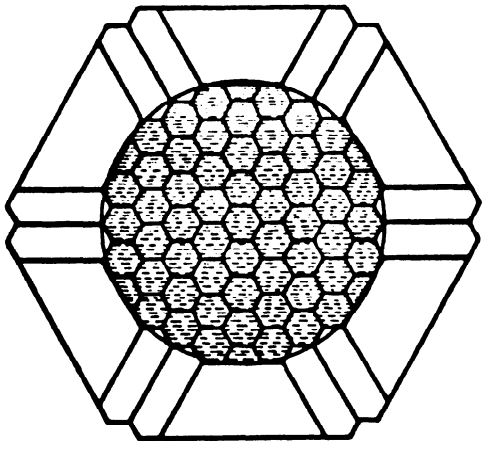
FIG. 1·4 (SEE TABLE 1·20)



(a) EQUIVALENT CYLINDER DIAMETER 11·58 INS



(b) EQUIVALENT CYLINDER DIAMETER 16·92 INS



45·5% ENRICHED URANIUM

STEEL, GRAPHITE OR ALUMINIUM

CIRCLES SHOW EQUIVALENT CYLINDERS

(c) EQUIVALENT CYLINDER DIAMETER 22·10 INS

FIG. 1·5 (SEE TABLE 1·20)

CHAPTER 2 - SINGLE UNMODERATED PLUTONIUM CORES

CHAPTER 2 - CONTENTS

CHAPTER 2 - REFERENCES

1. JARVIS, G.A., LINENBERGER, G.A., ORNDOFF, J.D., and PAXTON, H.C. Two Plutonium-Metal Critical Assemblies, Nucl. Sci. Eng., 8 : 525-531 (1960)

2. McENHILL, J.J., and WEALE, J.W. Integral Experiments on Fast Systems of Pu, U and Th, in Physics of Fast and Intermediate Reactors, I.A.E.A., Vienna (1962)

3. KLOVERSTROM, F.A. Spherical and Cylindrical Plutonium Critical Masses, U.S.A.E.C. Report UCRL-4957, University of California Radiation Laboratory, Livermore, 1957

4. PLAISMAN, E.A., and WOOD, D.P. Critical Reflector Thicknesses for Spherical U^{233} and Pu^{239} Systems, Nucl. Sci. Eng. 8 : 615-20 (1960)

5. HANSEN, G.E., and WOOD, D.P. Precision Critical-Mass Determinations for Oralloy and Plutonium in Spherical Tuballoy Tampers, U.S.A.E.C. Report LA-1356 Revised, Los Alamos Scientific Laboratory, May 6, to be issued

6. PAXTON, H.C. Los Alamos Critical-Mass Data, U.S.A.E.C. Report LAMS 3067, Los Alamos Scientific Laboratory, May 6, 1964

7. BOURGEOIS, P., CLAIR, C., COMTE, R., and LONG, J.J. Description de l'Assemblage Critique Rachel, and CLAIR, C., Proprietes Neutroniques de l'Assemblage Critique Rachel, in Physics of Fast and Intermediate Reactors, I.A.E.A., Vienna (1962)

8. WOOD, D.P., and PENA, B. Critical Mass Measurements of Dy and Pu Cores in Spherical Aluminium Reflectors, U.S.A.E.C. Report LAMS-2579, Los Alamos Scientific Laboratory, June, 1961

9. U.K.A.E.A. Internal Document

10. RALSTON, H.R. Critical Parameters of Spherical Systems of Alpha-Phase Plutonium Reflected by Beryllium, U.S.A.E.C. Report UCRL-5349, University of California Radiation Laboratory, Livermore, Sept. 10, 1958

11. HANSEN, G.E., PAXTON, H.C., and WOOD, D.P. Critical Plutonium and Enriched-Uranium-Metal Cylinders of Extreme Shape, Nucl. Sci. Eng. 8 : 570-577 (1960)

12. WOOD, D.P., BYERS, C.C., and OSBORN, L.C. Critical Masses of Plutonium Diluted with Other Metals, Nucl. Sci. Eng. 8 : 578-587 (1960)

Table 2.1

Unreflected Spheres of Plutonium Metal

Pu^{240} CONTENT (wt%)	AVERAGE DENSITY (gm/cc)	GEOMETRY	DELAYED CRITICAL MASS (kgm)	REFERENCES
4·5	15·66	Three main parts clad in ~0·005 in. thick nickel	16·28 [a]	1
-	15·64	Hemispheres clad in copper 0·01 in. thick on spherical surfaces and 0·005 in. thick on plane surfaces. 2·16 cm dia. central source cavity	16·8	2

a. Plutonium contains 1·0 wt% gallium. Critical mass corrected empirically for effect of nickel cavities, incidental reflection and asphericity; uncorrected value 16·574 kgm. Subsidiary experiments show critical mass of a bare sphere of pure Pu^{239} to be 16·28 kgm at a density of 15·44 gm/cc

Table 2.2

Spheres of Plutonium Metal with Non-moderating Reflectors

CORE			REFLECTOR			DELAYED CRITICAL CORE MASS (kgm)	REFERENCES
Pu^{240} Content (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)		
-	15·8[k]	Four segments clad in 0·005 in. thick nickel	Natural Uranium	1·93 cm[a]	18·8	10·79	3
4·90	15·62	Hemispheres		1·625 in.	18·92	8·386[b]	4
-	15·64	Hemispheres clad in copper 0·01 in. thick on spherical surfaces and 0·005 in. thick on plane surfaces. 2·16 cm dia central source cavity		2 in.	18·7	8·5	2
-	15·8[k]	Hemispheres clad in 0·005 in. thick nickel		6·74 cm[c]	18·8	7·366	3
-	15·64	Hemispheres clad in copper 0·01 in. thick on spherical surfaces and 0·005 in. thick on plane surfaces. 2·16 cm dia central source cavity		3 in.	18·7	7·4	2
-	15·6	Hemispheres separated by discs. All components clad		9·3 cm	18·7	6·820[d]	7
1·35	15·58	Hemispheres clad in ~ 0·005 in. thick nickel		4·60 in.	19·0	6·22[b]	5
-	15·64	Hemispheres clad in copper 0·01 in. thick on spherical surfaces and 0·005 in. thick on plane surfaces. 2·16 cm dia central source cavity		6 in.	18·7	6·3	2
4·8	15·36	Hemispheres		7·72 in.	19·0	5·91[b]	6
1½	15·63	Hemispheres clad in 0·0065 in. thick nickel		9½ in.	19·0	5·73[be]	1
4·9	15·9	Hemispheres clad in 0·005 in. thick nickel	Aluminium[b]	3·12 in.	2·82	11·154[b]	8
-	15·64	↑	Iron	2 in.	7·87	10·9	2
-	15·64	Hemispheres clad in copper 0·01 in. thick on spherical surfaces and 0·005 in. thick on plane surfaces. 2·16 cm dia central source cavity		4 in.	7·87	9·6	2
-	15·64	↓		6 in.	7·87	9·1	2
1·35	15·58	Hemispheres clad in ~ 0·005 in. thick nickel 0·41 in. dia central source cavity	Copper	5·00 in.	8·88	6·88[b]	6
4·90	15·62	Hemispheres	Tungsten Alloy ($W_{62.6}$ $Ni_{11.9}$ Cu_5 Z_r)	1·850 in.	17·21	8·386[b]	4
4·5	15·25	Three main parts clad in ~ 0·005 in. thick nickel	Thorium[g]	8·4 in. minimum.	11·9	9·24[b]	6
1·0	15·6	Hemispheres clad in ~ 0·005 in. thick nickel 0·83 in. dia central source cavity	Natural Uranium[h] (against core)	-	19·0	6·46[b]	6
			Aluminium	4·25 in.	2·7		
1·35	15·58	Hemispheres clad in ~ 0·005 in. thick nickel 0·83 in. dia central source cavity	Natural Uranium[i] (against core)	0·45 in.	19·0	6·13[b]	6
			Tungsten Carbide[j]	-	~ 14·7		

a. Corrected empirically for effects of nickel coating and 0·01 in. thick stainless steel diaphragm separating hemispheres. Uncorrected value 2·08 cm
b. Plutonium contains 1·0 wt % gallium
c. Corrected empirically for effects of nickel coating and 0·01 in. thick stainless steel diaphragm separating hemispheres. Uncorrected value 7·16 cm
d. Corrected for effects of cladding on plane surfaces of core components but uncorrected for cladding on spherical surfaces and for slight asphericity of core
e. Corrected empirically for effects of nickel and cavities. Uncorrected values 5·75 kgm without central cavity, 5·78 kgm with 0·41 in. dia central cavity and 5·84 kgm with 0·84 in. dia central cavity. Subsidiary experiments show critical mass of a sphere of pure Pu^{239} reflected by 9½ in. natural uranium to be 5·73 kgm at 15·54 gm/cc
f. USAA Type 2014 aluminium (3·9-5·0 wt % Cu, 1 wt % Fe, 0·5-1·2 wt % Si, 0·40-1·2 wt % Mn)
g. 21 in. dia x 21 in. cylinder reflector
h. 9·0 in. OD sphere
i. Sphere
j. 12·75 in. x 12·75 in. x 10·62 in. parallelepiped
k. Component density not average core density

TABLE 2.3

Spheres of Plutonium Metal with Moderating Reflectors

CORE			REFLECTOR			DELAYED CRITICAL CORE MASS (kgm)	REFERENCES
Pu^{240} Content (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)		
-	15·64	2·18 cm dia central cavity	Water	12·649 cm	-	-	9
1·35	15·58	Hemispheres clad in ~ 0·005 in. thick nickel, 0·83 in. central source cavity		> 12 in.	1·00	7·9[a]	6
-	15·8[j]	4 segments clad in 0·005 in. thick nickel	Beryllium[b] [d]	1·77 cm[c]	1·86	10·79	3
4·90	15·62	Hemispheres		1·452 in.	1·83	8·386[a]	4
-	15·8[j]	Hemispheres clad in 0·005 in. thick nickel	[b]	5·25 cm[e]	1·86	7·366	3
-	19·25	Complete sphere clad in 0·005 in. thick nickel		5·22 cm[g]	1·84[f]	5·426	10
-	19·25	Complete sphere clad in 0·005 in. thick nickel		8·17 cm[g]	1·84[f]	4·664	10
-	19·25	↑		13·0 cm[gh]	1·84[f]	3·933	10
-	19·25	Hemispheres clad in nickel 0·005 in. thick on spherical surfaces and 0·003 in. thick on plane surfaces		21·0±1 cm[gh]	1·84[f]	3·217	10
-	19·25	↓		32·0±4 cm[gh]	1·84[f]	2·472	10
-	15·8[j]	4 segments clad in 0·005 in. thick nickel	Graphite	3·83 cm	1·632	10·79	3
-	15·64	↑		2 in.	1·61	11·2	2
-	15·64	Hemispheres clad in copper 0·01 in. thick on spherical surfaces and 0·005 in. thick on plane surfaces 2·16 cm dia central source cavity		4 in.	1·61	9·2	2
-	15·64	↓		6 in.	1·61	8·2	2

a. Plutonium contains 1% gallium
b. Contains 2% BeO
c. Corrected empirically for effects of nickel coating and 0·01 in. thick stainless steel diaphragm separating hemispheres. Uncorrected value 1·96 cm
d. 98 wt %
e. Corrected empirically for effects of nickel coating and 0·01 in. thick stainless steel diaphragm separating hemispheres. Uncorrected value 5·50 cm
f. Computed using the plutonium/nickel interface as the inner reflector diameter
g. Uncorrected for effect of nickel (but see note f)
h. Effect of nickel on plane surfaces of core components shown empirically to increase the critical reflector thickness by ~ 0·25%
i. National Carbon Co. of America Type C-18 graphite, 1·0 ppm B
j. Component density, not average core density

Table 2.4

Unreflected Cylinders of Plutonium Metal
(See also Table 2.7)

Reference : 3

In these experiments the cores were assembled from 0·25–1·50 in. thick plutonium discs each clad in 0·005 in. thick nickel or copper. The cladding was neglected in computing the core dimensions and average density (15·8 gm/cc). Two sets of results are given, an "as measured" set and a corrected set. The corrections were determined experimentally and take account of the cladding and of a 0·01 in. thick stainless steel diaphragm supporting the upper section of the core. The lower section of the core rested on an ~$\frac{1}{8}$ in. thick table attached to the top of a thin walled tube. The table was perforated to reduce incidental reflection

GEOMETRY	DELAYED CRITICAL PARAMETERS				
	Diameter (cm)	Height		Height / Diameter	Corrected Mass (kgm)
		Measured (cm)	Corrected (cm)		
Components Nickel clad	9·87	18·2	17·3	1·75	20·6
Components Copper clad	13·85	8·30	8·00	0·577	18·72

Table 2.5

Cylinders of Plutonium Metal with Non-moderating Reflectors
(See also Tables 2.8, 2.9)

CORE			REFLECTOR			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Pu^{240} Content (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height / Diameter	Mass (kgm)	
~ 5	15·44	Discs 0·5 to 3·0 in. thick clad in 0·005 in. thick nickel	Depleted Uranium (~0·3 wt% U^{235})	3 in.	18·7	2·25 in.	19·77 in.	8·75	20·0[a]	11
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	Natural Uranium	2 cm	18·8	8·23 cm[c]	15·5 cm[b,c]	1·88[b]	12·9	3
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel			18·8	9·87 cm[b]	9·14 cm[b,d]	0·926[b]	10·90	3
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick copper			18·8	13·85 cm[b]	5·545cm[b,e]	0·400[b]	12·98	3
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel		5 cm	18·8	8·23 cm[b]	10·0 cm[b,f]	1·22 [b]	8·33	3
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel			18·8	9·87 cm[b]	6·91 cm[b,g]	0·700[b]	8·24	3
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick copper			18·6	13·85 cm[b]	4·38 cm[b,h]	0·316[b]	10·25	3
~ 5	14·3	5·934 in. dia x 0·123 in. discs in nickel cans with outside dimensions 5·967 in. x 0·135 in.		3 in.	18·7	6·0 in.	1·54 in.	0·258	10·14[a]	11
~ 6	15·34	Components clad in 0·005 in. thick nickel. 0·06 cm. in. central source cavity		Thick[f]	19·0	4·315 in.	-	0·44	6·91[a]	6
-	15·8[k]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	Steel	10 cm	18·8	9·87 cm[b]	7·92cm±4%[b,j]	0·802[b]	9·45	3

a. Plutonium contains 1·0 wt% gallium. No correction for nickel cladding
b. Core dimensions computed neglecting the nickel or copper cladding
c. Corrected empirically for effects of nickel or copper cladding and 0·01 in. thick stainless steel diaphragm separating upper and Lower parts of assembly. Uncorrected value 16·06 cm
d. As c but uncorrected value 9·38 cm
e. As c but uncorrected value 5·685 cm
f. As c but uncorrected value 10·28 cm
g. As c but uncorrected value 7·02 cm
h. As d but uncorrected value 4·45 cm
i. Core approximately central in 18·0 in. dia x 10 in. cylinder of natural uranium
j. As d but uncorrected value 7·98 cm

In the original document, Table 2.6 appeared on a single foldout page. It is reproduced on the next three pages. The column headings appear on each page for convenience and the notes appear on the third page.

Table 2.6

Cylinders of Plutonium Metal with Moderating Reflectors

(See also Table 4.1 for graphite reflected rectangular parallelepiped of Plutonium metal)

CORE			REFLECTION			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Pu^{240} Content (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height / Diameter	Mass (kgm)	
~ 5	15·44	Discs 0·5 to 3·0 in. thick clad in 0·005 in. thick nickel	Water	> 12 in.	1·00	2·21 in.	27·8 in.	12·52	27·1[a]	11
~ 5	14·3	5·934 in. dia x 0·123 in. discs in nickel cans with outside dimensions 5·967 in. x 0·135 in. Core sealed in close fitting Lucite cylinder				6·0 in.	1·67 in.	0·280	11·1[a]	11
~ 5	13·1	As previous experiment but core assembled from overlapping layers of 3 close-packed discs. See Figure 2.1				11·0 in.	1·05 in.	0·095	21·4[a]	11
~ 5	13·1	As previous experiment but 7 discs per Layer. See Figure 2.2				16·0 in.	0·79 in.	0·049	34·1[a]	11
-	15·8[n]	Discs 0·2-1·50 in. thick clad in 0·005 in. thick nickel	Polyethylene	10 cm	-	9·87 cm[b]	7·01cm±4%[bc]	0·710[b]	8·36	3
~ 5	15·44	Discs 0·5 to 3·0 in. thick clad in 0·005 in. thick nickel		4 in.	0·92	2·21 in.	33·0in.±2	-	32·2[a]	11
~ 5	15·44	Discs 0·5 to 3·0 in. thick clad in 0·005 in. thick nickel	Polyethylene (against core) water	4 in. eff. inf.	-	2·21 in.	29·4in.±2	-	28·6[a]	11

Table 2.6

Cylinders of Plutonium Metal with Moderating Reflectors

(See also Table 4.1 for graphite reflected rectangular parallelepiped of Plutonium metal)

CORE			REFLECTION			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Pu^{240} Content (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height / Diameter	Mass (kgm)	
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	Beryllium[d]	2 cm	1·86	8·23 cm[b]	15·0 cm[be]	1·82[b]	12·5	3
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	[d]			9·87 cm[b]	8·91 cm[bf]	0·903[b]	10·63	3
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick copper	[d]			13·85 cm[b]	5·428 cm[bg]	0·392[b]	12·70	3
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	[d]	5 cm	1·86	8·23 cm[b]	9·14 cm[bh]	1·11[b]	7·62	3
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	[d]			9·87 cm[b]	6·35 cm[bi]	0·643[b]	7·58	3
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick copper	[d]			13·85 cm[b]	3·94 cm[bj]	0·284[b]	9·22	3

Table 2.6

Cylinders of Plutonium Metal with Moderating Reflectors

(See also Table 4.1 for graphite reflected rectangular parallelepiped of Plutonium metal)

CORE			REFLECTION			DELAYED CRITICAL CORE PARAMETERS				REFERENCES
Pu^{240} Content (wt%)	Average Density (gm/cc)	Geometry	Material	Thickness	Average Density (gm/cc)	Diameter	Height	Height / Diameter	Mass (kgm)	
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	Graphite [k]	2 cm	1·632	9·87 cm[b]	10·63 cm[bl]	1·077[b]	12·68	3
-	15·8[n]	Discs 0·25-1·50 in. thick clad in 0·005 in. thick nickel	[k]	5 cm	1·632	9·87 cm[b]	8·46 cm[bm]	0·857[b]	10·09	3
~ 5	14·3	5·934 in. dia x 0·123 in. discs in nickel cans with outside dimensions 5·967 in. x 0·135 in.		1·0 in.	1·60	6·0 in.	2·33 in.	0·390	15·44[a]	11
~ 5	15·44	Discs 0·5-3·0 in. thick clad in 0·005 in. thick nickel		7·0 in.	1·60	2·25 in.	16·11 in.	7·13	16·3[a]	11
~ 5	14·3	5·934 in. dia x 0·123 in. discs in nickel cans with outside dimensions 5·967 in. x 0·135 in.		7·0 in.	1·60	6·0 in.	1·63 in.	0·273	10·8[a]	11

a. Plutonium contains 1 wt% gallium. No correction for nickel cladding
b. Core dimensions computed neglecting the nickel or copper cladding
c. Corrected empirically for effects of nickel or copper cladding and 0·01 in. thick stainless steel diaphragm separating upper and lower parts of assembly. Uncorrected value 7·06 cm
d. Contains 2% BeO
e. As c but uncorrected value 15·63 cm
f. As c but uncorrected value 9·09 cm
g. As c but uncorrected value 5·57 cm
h. As c but uncorrected value 9·37 cm
i. As c but uncorrected value 6·43 cm
j. As c but uncorrected value 4·04 cm
k. National Carbon Co. of America Type C-18 graphite, 1·0 ppm B
l. As c but uncorrected value 10·90 cm
m. Component density not average core density.

Table 2.7

Unreflected Cylinders of Plutonium Metal Diluted with other Materials

References: 6·12

Plutonium: Pu^{240} content ~5 wt%
Also contained ~1·0 wt% gallium

In these experiments the cores were assembled from alternate layers of plutonium and the diluent. The thicknesses of the repeated layers are noted in the Table as well as the average composition of the core. The plutonium layers were built up from 5·934 in. dia. x 0·123 in. discs each enclosed in a nickel can of outside dimensions 5·967 in. x 0·135 in. The diluent layers were built up from 5·967 in. dia. discs nominally $\frac{1}{8}$ in. or $\frac{1}{4}$ in. thick. For ease of comparison with the experiments noted in Tables 2.8, 2.9 the material average densities and the height/diameter ratio computed for the core were based on a core diameter of 6·00 in.

All cores were divided into two halves by a 0·015 in. thick stainless steel diaphragm which supported the upper half. The lower half rested on a light aluminium support to minimise incidental reflection.

DILUENT	VOLUME % PLUTONIUM	NOMINAL LAYER THICKNESSES		AVERAGE MATERIAL DENSITIES (gm/cc)			DEALYED CRITICAL PARAMETERS		
		Plutonium	Diluent	Plutonium	Diluent	Nickel Cladding (See notes prefacing Table)	Height (in.)	Height / Diameter	Mass (kgm)
None	91·4	-	-	14·27	-	0·65	3·23	0·54	21·4
Depleted Uranium (0·28 wt% U^{235})	63·0	$\frac{1}{4}$	$\frac{1}{8}$	9·83	5·97	0·45	6·07	1·01	27·3
Type 304 Stainless Steel	62·7	$\frac{1}{4}$	$\frac{1}{8}$	9·78	2·50	0·45	7·32	1·22	32·8
Thorium	62·7	$\frac{1}{4}$	$\frac{1}{8}$	9·78	3·62	0·45	7·85	1·31	35·2

Table 2.8

Cylinders of Plutonium Metal Diluted with other Materials and Reflected by Depleted Uranium (0·3 wt% U235)

Reference: 6, 12
Plutonium: Pu^{240} content ~ 5 wt %
Also contained ~ 1·0 wt % gallium

In these experiments the cores were assembled from alternate layers of plutonium and the diluent. The thickness of the repeated layers are noted in the table as well as the average composition of the core. The plutonium layers were built up from 5·934 in. dia x 0·123 in. discs each enclosed in a nickel can of outside dimensions 5·967 in. x 0·137 in. The diluent layers were built up from 5·967 in. dia discs nominally ⅛ in. or ¼ in. thick. All cores were enclosed in a 0·03 in. thick stainless steel guide sleeve and the material average densities and height/diameter ratio computed for the core were based on a core diameter of 6·00 in. to include the reflector clearance.

CORE							DELAYED CRITICAL CORE PARAMETERS		
Diluent	Volume % Plutonium	Nominal Layer Thickness (in)		Average Material Densities (gm/cc)			Height (in)	Height / Diameter	Mass (kgm)
		Plutonium	Diluent	Plutonium	Diluent	Nickel Classing (See notes prefacing Table)			
2 in. Thick Reflector									
None	90·8	-	-	14·18	-	0·65	1·72	0·29	11·15
Void	64·0	¼	⅛	9·97	-	0·45	3·29	0·55	15·05
	48·7	⅛	⅛	7·60	-	0·35	6·43	1·07	22·4
Depleted Uranium (0·28 wt % U^{235})	62·2	¼	⅛	9·71	5·95	0·45	2·92	0·49	13·0
	47·8	⅛	⅛	7·46	9·03	0·34	4·56	0·76	15·6
Type 25 Aluminium	62·3	¼	⅛	9·72	0·84	0·45	3·23	0·54	14·4
	48·0	⅛	⅛	7·49	1·28	0·34	5·78	0·96	19·9
Type 304 Stainless Steel	62·5	¼	⅛	9·75	2·51	0·45	3·15	0·525	14·1
	47·6	⅛	⅛	7·43	3·78	0·34	5·58	0·93	19·0
Thorium	62·4	¼	⅛	9·74	3·63	0·45	3·29	0·55	14·7
	48·0	⅛	⅛	7·49	5·55	0·34	6·02	1·00	20·65
4·5 in. Thick Reflector									
None	91·4	⅛	-	14·26	-	0·65	1·42	0·24	9·3
Void	63·7	¼	⅛	9·95	-	0·45	2·59	0·43	11·8
	49·0	⅛	⅛	7·65	-	0·35	4·46	0·74	15·7
	32·7	⅛	¼	5·11	-	0·23	12·84	2·14	30·1
Depleted Uranium (0·28 wt % U^{235})	61·8	¼	⅛	9·65	5·88	0·44	2·40	0·40	10·6
	47·5	⅛	⅛	7·42	9·08	0·34	3·72	0·62	12·65
	32·4	⅛	¼	5·06	12·28	0·23	7·99	1·33	18·55
Type 25 Aluminium	62·5	¼	⅛	9·75	0·84	0·45	2·58	0·43	11·55
	47·5	⅛	⅛	7·42	1·27	0·34	4·34	0·72	14·8
	32·4	⅛	¼	5·05	1·75	0·23	11·42	1·90	26·4
Type 304 Stainless Steel	60·6	¼	⅛	9·46	2·43	0·44	2·59	0·43	11·2
	47·5	⅛	⅛	7·42	3·81	0·34	4·26	0·71	14·5
	32·3	⅛	¼	5·04	5·14	0·23	10·97	1·83	25·3
Thorium	62·5	¼	⅛	9·75	3·65	0·45	2·62	0·44	11·7
	47·7	⅛	⅛	7·44	5·55	0·34	4·51	0·75	15·4
	32·5	¼	¼	5·07	7·70	0·23	12·90	2·15	30·0

Table 2.8 (Continued)

CORE							DELAYED CRITICAL CORE PARAMETERS		
Diluent	Volume % Plutonium	Nominal Layer Thickness (in)		Average Material Densities (gm/cc)			Height (in)	Height / Diameter	Mass (kgm)
		Plutonium	Diluent	Plutonium	Diluent	Nickel Cladding (See notes prefacing Table)			
7·5 in. Thick Reflector									
None	91·2	1/8	-	14·23	-	0·65	1·37	0·23	8·95
Void	63·5	1/4	1/8	9·92	-	0·45	2·47	0·41	11·25
	48·8	1/8	1/8	7·62	-	0·35	4·18	0·70	14·6
	32·8	1/8	1/4	5·12	-	0·23	10·58	1·76	24·85
Depleted Uranium (0·28 wt % U^{235})	62·6	1/4	1/8	9·77	5·94	0·45	2·31	0·385	10·35
	47·7	1/8	1/8	7·44	9·05	0·34	3·51	0·585	11·95
	32·4	1/8	1/4	5·06	12·27	0·23	7·29	1·22	16·9
	24·4	1/8	3/8	3·81	13·87	0·17	17·24	2·87	30·1
Type 25 Aluminium	62·5	1/4	1/8	9·76	0·84	0·45	2·47	0·41	11·05
	48·0	1/8	1/8	7·50	1·28	0·34	3·98	0·665	13·7
	32·4	1/8	1/4	5·05	1·75	0·23	9·65	1·61	22·35
Type 304 Stainless Steel	62·5	1/4	1/8	9·76	2·51	0·45	2·43	0·405	10·9
	47·7	1/8	1/8	7·45	3·80	0·34	3·97	0·665	13·55
	32·1	1/8	1/4	5·01	5·11	0·23	9·49	1·58	21·8
Thorium	62·5	1/4	1/8	9·76	3·63	0·45	2·49	0·415	11·1
	48·1	1/8	1/8	7·51	5·57	0·34	4·14	0·69	14·25
	32·5	1/8	1/4	5·07	7·49	0·23	10·83	1·80	25·15

Table 2.9

Cylinders of Plutonium Metal Diluted with other Materials and Reflected by Thorium

Reference : 6, 12
Plutonium : Pu^{240} content ~ 5 wt %
Also, contained ~ 1·0 wt % gallium

In these experiments the core were assembled from alternate layers of plutonium and the diluent. The thicknesses of the repeated layers are noted in the table as well as the average composition of the core. The plutonium layers were built up from 5·934 in. dia x 0·123 in. discs each enclosed in a nickel can of outside dimensions 5·967 in. x 0·137 in. The diluent layers were built up from 5·967 in. dia discs nominally ⅛ in. or ¼ in. thick. All cores were enclosed in a 0·03 in. thick stainless steel guide sleeve and the material average densities and height/diameter ratio computed for the core were based on a core diameter of 6·00 in. to include the reflector clearance.

CORE							DELAYED CRITICAL CORE PARAMETERS		
Diluent	Volume % Plutonium	Nominal Layer Thickness (in)		Average Material Densities (gm/cc)			Height (in)	Height/Diameter	Mass (kgm)
		Plutonium	Diluent	Plutonium	Diluent	Nickel Cladding (See notes prefacing Table)			
2 in. Thick Reflector									
None	91·3	⅛	-	14·25	-	0·65	2·25	0·375	14·7
Void	64·0	¼	⅛	9·99	-	0·45	4·80	0·80	22·0
Depleted Uranium (0·28 wt % U^{235})	63·1	¼	⅛	9·85	5·29	0·45	3·90	0·65	17·6
	47·5	⅛	⅛	7·41	9·01	0·34	6·55	1·09	22·25
Type 25 Aluminium	62·8	¼	⅛	9·81	0·84	0·45	4·46	0·74	20·05
	48·1	⅛	⅛	7·51	1·29	0·34	10·15	1·69	34·9
Type 304 Stainless Steel	62·8	¼	⅛	9·81	2·51	0·45	4·32	0·72	19·4
	50·4	⅛	⅛	7·87	4·01	0·36	8·50	1·42	30·6
Thorium	62·8	¼	⅛	9·81	3·63	0·45	4·44	0·74	20·0
	47·9	⅛	⅛	7·48	5·54	0·34	9·78	1·63	33·5
4·5 in. Thick Reflector									
None	91·8	⅛	-	14·33	-	0·66	2·02	0·34	13·25
Void	63·9	¼	⅛	9·97	-	0·45	3·99	0·665	18·2
	43·8	⅛	⅛	7·62	-	0·35	8·36	1·39	29·2
Depleted Uranium (0·28 wt % U^{235})	62·5	¼	⅛	9·75	5·94	0·45	3·42	0·57	15·3
	47·7	⅛	⅛	7·45	9·06	0·34	5·52	0·92	18·9
Type 25 Aluminium	63·1	¼	⅛	9·85	0·84	0·45	3·88	0·645	17·5
	47·8	⅛	⅛	7·46	1·28	0·34	7·35	1·225	25·15
Type 304 Stainless Steel	63·1	¼	⅛	9·85	2·52	0·45	3·74	0·625	16·9
	47·3	⅛	⅛	7·39	3·77	0·34	6·85	1·14	23·5
Thorium	63·0	¼	⅛	9·83	3·67	0·45	3·90	0·65	17·55
	47·9	⅛	⅛	7·47	5·52	0·34	7·35	1·225	25·2
7·5 in. Thick Reflector									
None	92·9	⅛	-	14·50	-	0·66	1·92	0·32	12·75
Void	63·7	¼	⅛	9·95	-	0·45	3·80	0·63	17·35
	49·0	⅛	⅛	7·65	-	0·35	7·34	1·22	25·75

Table 2.9 (Continued)

CORE							DELAYED CRITICAL CORE PARAMETERS		
Diluent	Volume % Plutonium	Nominal Layer Thickness (in)		Average Material Densities (gm/cc)			Height (in)	Height / Diameter	Mass (kgm)
		Plutonium	Diluent	Plutonium	Diluent	Nickel Cladding (See notes prefacing Table)			
7·5 in. Thick Reflector (Continued)									
Depleted Uranium (0·28 wt % U^{235})	63·5	¼	⅛	9·91	5·99	0·45	3·23	0·54	14·65
	47·5	⅛	⅛	7·42	9·04	0·34	5·16	0·86	17·55
	32·4	⅛	¼	5·06	12·27	0·23	13·26	2·21	30·8
Type 25 Aluminium	63·7	¼	⅛	9·95	0·85	0·45	3·61	0·60	16·45
	48·6	⅛	⅛	7·59	1·30	0·35	6·55	1·09	22·8
Type 304 Stainless Steel	62·5	¼	⅛	9·76	2·50	0·45	3·58	0·60	16·0
	47·6	⅛	⅛	7·43	3·80	0·34	6·33	1·06	21·55
Thorium	62·9	¼	⅛	9·82	3·63	0·45	3·69	0·615	16·6
	47·7	⅛	⅛	7·45	5·52	0·34	6·78	1·13	23·2

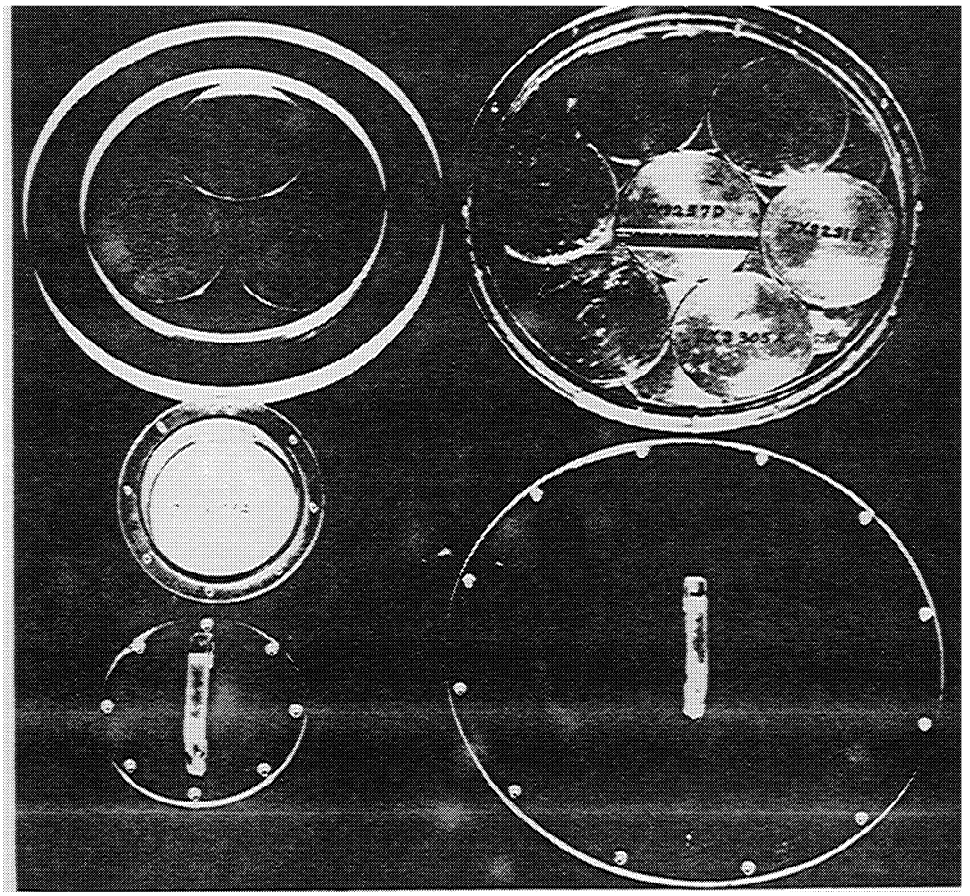


Figure 2.1 Figure 2.2
(See Table 2.6)

CHAPTER 3 - SINGLE U^{235} CORES MODERATED BY DEUTERIUM, BERYLLIUM OR CARBON

CHAPTER 3 - CONTENTS

Parallelepiped Cores (See also Table 5.28-30)

CHAPTER 3 - REFERENCES

1. OLCOTT, R.N. Homogeneous Heavy Water Moderated Critical Assemblies, Part I, Experimental, Nucl. Sci. Eng., 1 : 327-341 (1956)

2. HIROTA, J., KATSURAGI, S., KUROI, H., KOINUMA, R., and ISHIGURO, Y. Analysis of the Enriched Uranium-Heavy Water Homogeneous System, J. At. En. Soc. Japan, 5 : 14-22 (1963)

3. SNELL, A.H. Criticality Studies on Enriched Uranium-Heavy Water Systems, USAEC Report Mon P-454, 1947 (including Addendum 1)

4. HANSEN, G.E., and ROACH, W.H. Interpretation of Neutron Resonance Detector Activities in Critical Uranyl Fluoride-Heavy Water Solutions, Proc. Brookhaven Conf. on Resonance Absorption of Neutrons in Nuclear Reactors, Upton, New York; USAEC Report BNL 433 (C-24) pp 13-25, September, 1956

5. HARRISON, J.R., SMITH, M.F., CLARKE, W.G., MILLS, A.M., and DYSON, J.A. Critical Assemblies with Heavy Water Solutions of Uranyl Fluoride (H.A.Z.E.L.), Part 2, Physics, UKAEA Report AERE R/R 2703, Atomic Energy Research Establishment, Harwell, November, 1958

6. CARTER, C., LANG, P.K.H., and MYATT, G. Critical Assemblies with Heavy Water Solutions of Uranyl Fluoride (H.A.Z.E.L.), Part III, Theoretical Analysis, UKAEA Report AERE R/R 2731, Atomic Energy Research Establishment, Harwell, July, 1959

7. ZIMMERMAN, E.L. Two Beryllium Moderated Critical Assemblies, in Applied Nuclear Physics Division Progress Report for Period Ending September 10, 1956, USAEC Report ORNL 2081, Oak Ridge National Laboratory, 1958

8. ZIMMERMAN, E.L. Two Beryllium-Moderated Critical Assemblies, USAEC Report ORNL-2201, Oak Ridge National Laboratory, October 20, 1958

9. KLOVERSTROM, F.A., DECK, R.M.R., and RAYENGA, A.J. Critical Measurements on Near-Homogeneous BeO-Moderated, Oralloy-Fuelled Systems, USAEC Report UCRL-5369 Part I, University of California Radiation Laboratory, Livermore, July 1, 1959

10. KLOVERSTROM, F.A., and KRAFT, D.E. Critical Measurements on Near-Homogeneous BeO-Moderated, Oralloy-Fuelled Systems, USAEC Report UCRL 5369 Part II, University of California Radiation Laboratory, Livermore, July 11, 1960

11. KLOVERSTROM, F.A., DECK, R.M.R., and REYENGA, A.J. Critical Measurements on Near-Homogeneous BeO-Moderated, Enriched-Uranium Fuelled Systems, Nucl. Sci. Eng., 8: 221-225 (1960)

12. PAXTON, H.C. Los Alamos Critical Mass Data, USAEC Report LAMS-3067, Los Alamos Scientific Laboratory, May 6, 1964

13. HAUSEN, G.E., WOOD, D.P., and GEER, W.U. Critical Masses of Enriched-Uranium Cylinders with Multiple Reflectors of Medium-2 Elements, Nucl. Sci. Eng. 8: 588-594 (1960)

14. HANSEN, G.E., HOOGTERP, J.C., ORNDOFF, J.D., and PAXTON, H.C. Beryllium-Reflected, Graphite-Moderated Critical Assemblies, USAEC Report LA 2141, Los Alamos Scientific Laboratory, October, 1957

15. REYNOLDS, H.L. Critical Measurements and Calculations for Enriched-Uranium Graphite Moderated Systems, PUAE Geneva, P/2408 (1958)

16. HOOGTERP, J.C. Critical Masses of Graphite-Tamped Heterogeneous Oy-Graphite Systems, USAEC Report LA-1732, Los Alamos Scientific Laboratory, May, 1954

17. REYNOLDS, H.L., and WALTER, C.E. Hot Box A High-Temperature Critical Facility, USAEC Report UCRL-5483, University of California Radiation Laboratory. March 30, 1959

18. GOLDBERG, E., FINKE, R., and REYNOLDS, H.L. High Temperature Graphite Critical Experiments, Trans. Am. Nucl. Soc. 3(1): 71-72 (1960)

19. FINKE, R.G. Preliminary Results of High-temperature Bare U^{235}-C Critical Assembly Measurements, USAEC Report UCRL 6504, University of California Radiation Laboratory, June 6, 1961

20. ZIMMERMAN, E.L. A Graphite Moderated Critical Assembly CA-4, USAEC Report Y-881(DEL), Oak Ridge National Laboratory, 1952

21. KLOVERSTROM, F.A., and GILBERT, W.S. USAEC Report UCRL-5006, University of California Radiation Laboratory, 1957.

Table 3.1

Heavy-water Moderated Spheres - Highly Enriched Uranium

Reference : 1

Fissile Solutions : Fissile material, UO_2F_2 at ~90 wt% enrichment
Heavy water, 99·6-99·8 mole % D_2O

Spheres : 0·04 in. thick stainless steel

Reflector : 99·0-99·8 wt% D_2O in stainless steel vessel

The correction to pure heavy water is said to correspond to ~1% increase in critical volume and mass

CORE			REFLECTOR THICKNESS (in.)	DELAYED CRITICAL CORE PARAMETERS		
Specific Gravity of Solution	Solution Concentration (gm U^{235}/litre)	D/U^{235} Atomic Ratio		Diameter (in.)	Volume (litre)	U^{235} Mass (kgm)
-	679	34·2	10·7	13·5	20·9	14·2
-	443	53·7	10·2	14·5	26·1	11·6
-	302	81·2	9·7	15·5	31·7	9·6
-	185	135·3	9·2	16·5	38·1	7·0
-	104	243	8·7	17·5	45·9	4·8
-	60	431	8·2	18·5	53·8	3·2

Table 3.2

Heavy-water Moderated Spheres - 19·82 wt% Enriched Uranium

Reference : 2

Fissile Solutions : Fissile Material, UO_2SO_4
Heavy water, 99·75 wt% D_2O

Spheres : Type 3S aluminium; fitted with three sleeve tubes for insertion of control rod, neutron source and neutron detectors

Reflector : 99·75 wt% D_2O

CORE			REFLECTOR THICKNESS	DELAYED CRITICAL CORE PARAMETERS		
Specific Gravity of Solution	Solution Concentration (gm U^{235}/litre)	D/U^{235} Atomic Ratio		Diameter	Volume (litre)	U^{235} Mass
-	15·96	-	48·5	_[a,b]	73·0 [a,b]	_[a,b]
-	13·96	-	48·5	_[c]	75·5 [c]	_[c]
-	7·28	-	42·0	_[a,d]	142·1 [a,d]	_[a,d]
-	3·84	-	35·0	_[a,e]	262·1 [a,e]	_[a,e]

a. Sphere lined with polyethylene

b. k eff after empirical correction for sleeve tubes and flange 1·0093 at 15·62 gm U^{235}/litre

c. Sphere lined with epoxy resin

d. k eff after empirical correction for sleeve tubes and flange 1·0108 at 7·06 gm U^{235}/litre

e. k eff after empirical correction for sleeve tubes and flange 1·0105 at 3·60 gm U^{235}/litre

Table 3.3

Unreflected Heavy Water Moderated Cylinders - Highly Enriched Uranium

Reference : 1

Fissile Solution : Fissile Material, UO_2F_2 at ~90 wt% enrichment
Heavy water, ~99 mole % D_2O

Cylinders : $\frac{1}{8}$" in. thick stainless steel; fitted with a central axial "glory hole" tube penetrating the full length of the cylinder

The correction to pure heavy water is said to correspond to 2-3% increase in critical volume and mass.

CORE			REFLECTOR THICKNESS			DELAYED CRITICAL CORE PARAMETERS				
Specific Gravity of Solution	Solution Concentration (gm U^{235}/litre)	D/U^{235} [a] Atomic Ratio	Bottom (in.)	Top (in.)	Walls (in.)	Diameter (in.)	Height (in.)	Height / Diameter	Volume	U^{235} Mass (kgm)
-	1051	19·56	10	8·5 [b]	9·67	12·5	12·1	-	-	25·51
-	595	39·4	10	7 [c]	8·92	14	13·4	-	-	20·11

a. No correction for H_2O in heavy water
b. 0·9 in. thick void above solution
c. 1·1 in. thick void above solution

Table 3.4

Heavy-water Moderated and Reflected Cylinders - Highly Enriched Uranium

Reference : 3

Fissile Solutions : Fissile Material, UO_2F_2 at - gmU^{235}/litre and 95·4% enrichment
Heavy water, 99·7 mole. % D_2O

In these experiments the fissile solution was contained in 1·500 in. OD tubes of Type 2S aluminium, wall thickness 0·035 in., bottom thickness $\frac{1}{8}$ in. These tubes were suspended in a square lattice arrangement from the cover plate of a 142 cm diameter tank filled with heavy water. Reflection to the top surface of the fissile solution was provided by 1·25 in. OD aluminium insert tubes, wall thickness 0·035 in., bottom thickness $\frac{1}{8}$ in., filled to a depth of 9 in. with heavy water.

Also suspended from the cover plate of the reflector tank were a number of void control rod thimbles penetrating the upper reflector and the fissile region of the system but not the lower reflector. These were $2\frac{3}{8}$ in. OD and were fabricated in $\frac{1}{8}$ in. thick aluminium. The 'as measured' results reported in the table were obtained in experiments with a single control rod thimble remaining in the system. The 'corrected' results correspond to situations in which this remaining thimble has been removed and were obtained by extrapolation from series of measurements with varying numbers of thimbles.

CORE				REFLECTOR THICKNESS				DELAYED CRITICAL CORE PARAMETERS						
						WALLS		AS MEASURED					CORRECTED	
U^{235} Mass Per Fuel Tube (gm)	Lattice Pitch (cm)	U^{235} Density Averaged Over A Unit Lattice Cell (gm/litre)	Average D/U^{235} Atomic Ratio (approx.)	Bottom (cm)	Top (cm)	As Measured (cm)	Corrected (cm)	Diameter [a] (cm)	Height [a] (cm)	Height / Diameter	Volume [b] (litre)	U^{235} Mass (kgm)	Diameter [a] (cm)	U^{235} Mass (kgm)
45·45	8·43	10·21	2,500	20	62	49·8	50·2	42·4	62·6	-	88·5	0·904	41·6	0·869
45·45	11·92	5·10	5,000	20	62	40·1	40·6	61·8	62·6	-	187	0·9545	60·8	0·930
73·57	16·86	2·54	10,000	20	62	29·8	30·6	82·4	101·5	-	541	1·374	80·8	1·323

a. Calculated from $2\sqrt{\dfrac{\text{Critical Volume}}{\text{Critical Height} \times \pi}}$

b. Calculated from $\dfrac{\text{Critical Mass of } U^{235}}{U^{235} \text{ density averaged over a unit lattice cell}}$

Table 3.5

Heavy-water Moderated Cylinders with Graphite Reflectors - Highly Enriched Uranium

Reference : 4

Fissile Solutions : Fissile Material, UO_2F_2 at 93·65 wt% enrichment
Heavy water, ~99 mole % D_2O

Cylinders : Stainless Steel; $\frac{1}{16}$ in. wall thickness, $\frac{1}{8}$ in. top and bottom thickness

Reflector : Type CS-312 graphite, density 1·67 gm/cc

SPECIFIC GRAVITY OF SOLUTION	SOLUTION CONCENTRATION (gm U^{235}/litre)	D/U^{235} Atomic Ratio	DELAYED CRITICAL PARAMETERS				
			Diameter (cm)	Height (cm)	Height / Diameter	Volume (litre)	U^{235} Mass
SYSTEMS WITH 1in. O.D. STAINLESS STEEL GLORY HOLE TUBE							
-	109·4	230	31·6	71·45	-	223·8	-
-	61·0	419	31·6	78·74	-	246·6	-
SYSTEMS WITH $1\frac{1}{8}$ in. O.D. ALUMINIUM GLORY HOLE TUBE							
-	30·1	856	38·1	61·09	-	278·0	-
-	30·1	856	38·1	60·83	-	276·8	-
-	124	2081	38·1	84·7	-	385·8	-

Table 3.6

Heavy-water Moderated Cylinders - 45·5 atomic % Enriched Uranium

References : 5, 6

Fissile Solutions : Fissile Material, UO_2F_2.
Heavy water, 99·83 mole % D_2O.

Cylinder : Stainless steel; height 7 ft, wall thickness 0·081 in; resting on a $1\frac{1}{16}$ in. thick steel table and fitted with a central, axial $\frac{3}{4}$ in. O.D. stainless steel tube, wall thickness 0·05 in., penetrating the full height of the cylinder. The top of the cylinder was covered with a $\frac{3}{4}$ in. thick stainless steel plate with fittings for ancillary equipment.

Reflector Geometry : A twelve sided graphite annulus 152·4 cm across outer flats, 18·35 in. thick and of approximately equal height to the fissile solution. Only the core walls were reflected, the top and bottom being unreflected.

CORE			REFLECTOR HEIGHT	DELAYED CRITICAL CORE PARAMETERS				
Solution Concentration (gm U^{235}/litre)	Specific Gravity of Solution	D/U^{235} [a] Atomic Ratio	(cm)	Diameter (cm)	Height (cm)	Height / Diameter	Volume	U^{235} Mass (kgm)
-	1·140	1939	64·5	30·36	69·53	-	203·24	2·699
-	1·133	2515	74·7		74·56	-	217·82	2·234
-	1·130	2984	79·2		81·03	-	236·63	2·048
-	1·126	3580	89·4		89·12	-	260·16	1·877
-	1·123	4146	99·1		99·47	-	290·25	1·808
-	1·120	5183	123·9		121·67	-	354·83	1·769
-	1·119	5658	138·5		137·50	-	400·95	1·832
-	1·119	6035	153·9		152·94	-	445·96	1·911
-	1·117	6549	183·4		179·18	-	521·82	2·059
-	1·117	6722	193·5		192·13	-	560·14	2·154

a. No correction for H_2O in heavy water.

Table 3.7

Beryllium Metal Moderated Cores

Reference : 7, 8

Uranium enrichment : 93·4 wt %

Reflector : All cores nominally unreflected

These systems were assembled at the centre of a 6 ft cube matrix formed by stacking together 3 in. square section Type 2S aluminium tubes, wall thickness 0·047 in. Matrix and core were divided into fixed and movable halves, (see Fig. 3.1)
Core elements were built up from alternate 2·860 in. dia. x 0·01 in. uranium discs and beryllium layers of the thicknesses shown in the table and made up of $2\frac{7}{8}$ in. square x 1 in. blocks (average density 1·86 gm/cc). The elements were held together by a $\frac{3}{16}$ in. dia. aluminium (stainless steel in the case of control and safety elements) skewer passing through a 0·196 in. dia. axial hole.

The Table also shows the average composition of the core.

VOLUME % COMPOSITION					BERYLLIUM LAYER THICKNESS (in.)	Be/U^{235} ATOMIC RATIO	DELAYED CRITICAL PARAMETERS			
Uranium	Beryllium	Aluminium	Stainless Steel	Void			Area (in.)	Thickness [a] (in.)	$\frac{\text{Thickness}}{\sqrt{\text{Area}}}$	U^{235} Mass (kgm)
0·64	90·60	6·10	0·04	2·62	1	390	21·0 x 21·0 [b]	23·3 [b]	- [b]	18·08 [b]
0·16	91·28	6·11	0·03	2·42	4	1560	24·0 x 28·4 [c]	24·1 [c]	- [c]	7·65 [c]

a. i.e., parallel to the length of the core elements

b. keff 1·0054. Critical with control element D (see Fig. 3.1(a)) withdrawn 3·7 in

c. One outer row of elements quarter-sized. i.e., $1\frac{7}{16}$ in. square. keff 1·0020. Critical with control element A (see Fig. 3.1(b)) withdrawn 2·25 ins

Table 3.8

Beryllium Oxide Moderated Cores

References : 9, 10, 11

Uranium Enrichment : 93·2 wt %

In these experiments the cores were assembled from alternate layers of uranium and beryllium oxide. The thicknesses of the repeated layers are noted in the table as well as the average composition of the core, the lowest layer (beryllium oxide) being half the normal thickness.

The uranium layers were built up from foils 5·25 in. square, nominal thickness either 0·001 in. or 0·005 in. each foil being coated with 0·92 gm polytetrafluorethylene (atomic composition CF_2). The beryllium oxide layers were built up from nominal 6 in. square x 1 in. blocks (average weight 1690 gm, density 2·86 gm/cc, thermal neutron absorption cross-section 7 ± 4 mb.)

A reflector of National Carbide Co. type ATJ graphite (density 1·73 gm/cc; 14·4 ppm B) was used, only the top and bottom surfaces of the core parallel to the layer structure being reflected. The nominally unreflected systems were supported on a 4 in. thick aluminium honeycomb (average density 0·37 gm/cc) covered by a 0·02 in. thick layer of cadmium.

CORE				REFLECTOR THICKNESS	DELAYED CRITICAL CORE PARAMETERS			
Layer Thicknesses		Average U^{235} Density	Be/U^{235} Atomic Ratio		Area	Thickness	$\frac{\text{Thickness}}{\sqrt{\text{Area}}}$	Mass
Uranium (in.)	Beryllium Oxide (in.)	(gm/cc)			(in.)	(in.)		
0·008	1	0·109	247	Unreflected	24 x 24	20·2	-	-
0·004	1	0·0545	493		24 x 24	22·0	-	-
0·008	2				24 x 24	22·3	-	-
0·002	1	0·0272	986		24 x 24	25·0	-	-
0·004	2				24 x 24	25·8	-	-
0·006	3				24 x 24	27·5	-	-
0·002	2	0·0140	1920		30 x 24	26·0	-	-
0·003	3				30 x 24	27·3	-	-
0·001	1				30 x 30	21·1	-	-
0·002	2				30 x 30	21·6	-	-
0·001[a]	1	0·00702	3830		36 x 36	22·9	-	-
0·002[a]	2				36 x 36	24·2	-	-
0·001	2				36 x 36	22·7	-	-
0·002	4				36 x 36	24·2	-	-
0·001[b]	1	0·00351	7660		36 x 36	36·2	-	-
0·008	1	0·109	247	6 in	24 x 24	15·8	-	-
				12 in	24 x 24	14·3$_5$	-	-
				18 in	24 x 24	14·2	-	-

a. Half-area foils (triangular)

b. Quarter-area foils (triangular)

Table 3.9

Unreflected Graphite Moderated Cylinders
(See also Table 3.16)

Reference : 12
Uranium Enrichment : 93·3 wt%

In these experiments the cores were assembled from alternate layers of uranium and graphite. The thickness of the repeated layers are noted in the table as well as the average composition of the core. The uranium layers were built up from 0·3 cm thick discs.

VOLUME % URANIUM	LAYER THICKNESSES		AVERAGE MATERIAL DENSITIES (gm/cc)		C/U^{235} ATOMIC RATIO	DELAYED CRITICAL PARAMETERS		
	Uranium (cm)	Graphite (cm)	Uranium	Graphite		Height (in.)	Height / Diameter	U^{235} Mass (kgm)
15 in. dia Cylinders								
86·0	2·4	0·40	15·56	0·222	-	3·67	0·245	154·5
82·2	1·8	0·40	14·78	0·282	-	3·88	0·258	155·0
79·2	1·5	0·40	14·28	0·330	-	4·00	0·267	154·7
75·5	1·2	0·40	13·97	0·399	-	4·14	0·276	156·3
69·7	0·9	0·40	12·70	0·485	-	4·54	0·303	156·0
60·7	0·6	0·40	11·06	0·631	-	5·23	0·349	156·5
53·6	0·9	0·80	9·97	0·758	-	5·86	0·390	157·7
43·5	0·3	0·40	8·07	0·921	-	7·48	0·499	163·1
33·8	0·6	1·20	6·22	1·075	-	10·24	0·683	172·3
28·0	0·3	0·80	5·26	1·188	-	13·61	0·908	193·6
21 in. dia Cylinders								
47·7	0·3	0·32	8·94	0·330	-	5·46	0·260	267
31·8	0·3	0·64	5·97	1·123	-	7·81	0·372	260
23·7	0·3	0·95	4·44	1·248	-	10·48	0·499	258
19·00	0·3	1·27	3·56	1·345	-	13·08	0·623	258
15·79	0·3	1·59	2·96	1·392	-	16·49	0·785	263
13·53	0·3	1·90	2·54	1·434	-	20·1	0·958	274
11·89	0·3	2·22	2·23	1·467	-	23·9	1·138	292
10·47	0·3	2·54	1·965	1·540	-	28·3	1·345	303
9·44	0·3	2·86	1·770	1·551	-	36·4	1·734	350

Table 3.10

Graphite Moderated Cylinders with Non-moderating Reflectors

Reference : 13

Core : Uranium enrichment 93·2 wt %
c/U^{235} atomic ratio = 2·73

These experiments were performed on a vertical approach machine. The cores were assembled from alternate 0·125 in. thick uranium discs and graphite discs and the reflectors from 0·375 in. thick discs, the reflector discs being machined to 0·0005 in. flatness. Core and reflector formed a 15·0 in. dia. cylinder, the core being reflected on the lower end only.

The reflectors contained 27 discs and were supported, together with the lower part of the core containing 9 uranium discs, on a low mass aluminium cylinder attached to the lift. The remainder of the core was supported on a 0·019 in. thick stainless steel diaphragm.

A series of reflectors consisting of a single material or of two materials at ~25 wt % increments was investigated, (see Figure 3.2). Results indicated that any effect introduced by the non-homogeneity of the reflectors was within the total uncertainty of the critical mass measurements (± 0·3 kgm).

REFLECTOR AVERAGE COMPOSITION (vol %)	DELAYED CRITICAL CORE PARAMETERS		
	Height	Height / Diameter	Mass (kgm)
Mild Steel	-	-	138·9
Stainless Steel	-	-	136·0
Nickel	-	-	133·6
Zinc	-	-	137·0
25·9% Mild Steel 74·1% Zinc	-	-	136·0
48·2% Mild Steel 51·8% Zinc	-	-	136·2
74·1% Mild Steel 25·9% Zinc	-	-	137·3
25·9% Stainless Steel 74·1% Nickel	-	-	133·4
51·8% Stainless Steel 48·2% Nickel	-	-	133·7
74·1% Stainless Steel 25·9% Nickel	-	-	134·2

Table 3.11

Graphite Moderated Cylinders with Beryllium Reflectors

References: 14, 15
Uranium Enrichment: 93·2 wt%

These systems were assembled at the centre of a 6 ft. cube matrix formed by stacking together 3 in. square section Type 2S aluminium tubes, wall thickness 0·047 in. Hence, both core and reflector contain 0·165 gm/cc aluminium (average).

Core elements were built up from 2·9 in. x 16 in. plates of Type CS graphite interleaved with uranium foils either 0·002 or 0·005 in. thick. The Table shows the average composition of the core.

The reflectors contained small quantities of graphite as well as beryllium and may be specified as a number of separate regions (see Figure 3·3(a)). Details of each region are given separately in the Table.

CORE		REFLECTOR (See notes, prefacing Table)										DELAYED CRITICAL CORE PARAMETERS			
Average Carbon Density (gm/cc)	C/U Atomic Ratio	(a) BERYLLIUM		(b) CARBON		(c) CARBON		(d) BERYLLIUM		(e) BERYLLIUM		Average Diameter (cm)[a]	Height (cm)	Height Diameter	Mass (kgm)
		Average[a] Thickness (cm)	Average Density (gm/cc)	Thickness (cm)	Average Density (gm/cc)	Thickness (cm)	Average Density (gm/cc)	Thickness (cm)	Average Density (gm/cc)	Thickness (cm)	Average Density (gm/cc)				
1·42	116	12·4	$1·65_9$	2·54	$1·42_1$	1·02	$1·42_1$	10·1	-	20·2	-	62·72[b]	77·7[b]	-[b]	57·5[b]
$1·42_1$		13·7	1·65	2·54	$1·42_1$	1·02	$1·42_1$	10·1	-	10·1	-	62·60[b]	77·7[b]	-[b]	57·5[b]
1·41	351	23·65	1·66	2·54	1·41	2·54	1·41	Nil[b]	-	20·32	-	57·66[d]	76·2[d]	-[d]	12·81[d]
1·42	354	24·71	1·66	2·54	1·42	2·54	1·42	10·16	-	20·32	-	50·50[d]	76·2[d]	-[d]	16·69[d]
$1·42_1$	368	12·9	$1·66_6$	2·54	$1·42_1$	Nil	$1·42_1$	11·47	-	$8·1_2$	-	81·12[b]	78·7[b]	-[b]	30·8[b]
$1·29_0$		14·0	$1·65_3$	2·54	$1·29_0$	Nil	$1·29_0$	7·60 (against core) 3·22 Graphite	- 1·42	7·60 (against core) 3·22 Graphite	- 1·42	92·20[b]	78·7[b]	-[b]	36·0[b]
1·308	371	12·8	$1·66_1$	2·54	1·308	Nil	1·308	8·53	-	8·53	-	97·66[b]	78·74[b]	-[b]	40·4[b]
1·50	384	13·08	1·66	Nil	1·50	Nil	1·50	10·16	-	Nil	-	81·12[e]	81·28[e]	-[e]	32·3[e]
1·50		16·74	1·66	Nil	1·50	Nil	1·50	10·16	-	Nil	-	81·12[e]	81·28[e]	-[e]	32·3[e]
1·50		27·58 (against core) 5·75 Graphite	1·66 1·56	Nil	1·50	Nil	1·50	Nil	-	Nil	-	81·12[e]	81·28[e]	-[e]	32·3[e]
$1·47_7$	952	12·0	1·664	2·54	$1·47_7$	2·54	$1·47_7$	9·76	-	23·03 Graphite	1·47	97·66[b]	76·2[b]	-[b]	17·4
$1·47_7$		12·0	1·664	2·54	$1·47_7$	2·54	$1·47_7$	9·76	-	9·76	-	97·66[b,f]	76·2[b,f]	-[b,f]	17·4[b,f]

a. Evaluated on an equivalent area basis. See Figure 3.3(b) for cross-sectional geometry

b. Uranium foils 0·002 in. thick up to 17·5 kgm, beyond which 0·005 in. thick foils intermixed

c. Peripheral beryllium extends 4 in. beyond core

d. 0·002 in. thick foils only

e. 0·005 in. thick foils only

f. Change in keff of -120 cents estimated for change to 0·005 in. thick foils in this system from subsidiary experiments in which ~ 12% of the foils were charged

Table 3.12

Graphite Moderated and Reflected Cylinders
(See also Table 3.15)

In these experiments the cores were assembled from alternate layers of uranium and graphite. The thicknesses of the repeated layers are noted in the table as well as the average composition of the core.

CORE							REFLECTOR		DELAYED CRITICAL CORE PARAMETERS			REFERENCES
Uranium Enrichment	Volume % Uranium	Layer Thicknesses		Average Material Densities (gm/cc)		C/U^{235} Atomic Ratio	Thickness (in.)	Average Density (gm/cc)	Height (in.)	Height / Diameter	Uranium Mass (kgm)	
		Uranium	Graphite	Uranium	Graphite							
10·50 in. dia Cylinders												
93·4	38·7[a]	0·315 in[a]	0·5 in[a]	7·29[a]	1·04[a]	-	2·00	1·68	7·81	-	80·7±5·0	16
	-[a]	[a]	1·0 in[a]	4·52[a]	1·27[a]	-			-	-	> 67·38	16
	-[a]	[a]	2·0 in[a]	2·57[a]	1·48[a]	-			-	-	> 67·38	16
93·4	-[a]	0·63 in[a]	0·5 in[a]	10·51[a]	0·75[a]	-	2·00	1·68	4·19	0·402	62·5	16
	38·7[a]	[a]	1·0 in[a]	7·29[a]	1·03[a]	-			7·58	-	78·3	16
	-[a]	[a]	2·0 in[a]	4·52[a]	1·30[a]	-			-	-	> 67·38	16
93·4	65·4[a]	0·945 in[a]	0·5 in[a]	12·33[a]	0·59[a]	-	2·00	1·68	3·29	-	> 50·5	16
	48·6[a]	[a]	1·0 in[a]	9·16[a]	0·96[a]	-			4·85	-	> 50·9	16
	32·1[a]	[a]	2·0 in[a]	6·02[a]	1·17[a]	-			9·26	-	> 50·5	16
21·00 in. dia Cylinders												
93·3	47·7	0·30 cm	0·32 cm	8·94	0·83	-	6·00[b]	1·7	-[c]	0·112[c]	112·1[c,d]	12
	31·8		0·64 cm	5·97	1·12	-			-[c]	0·185[c]	123·3[c,d]	12
	19·0		1·27 cm	3·56	1·34	-			-[c]	0·373[c]	148·4[c,d]	12
	13·5		1·91 cm	2·54	1·43	-			-[c]	0·64 [c]	182·7[c,d]	12
	10·47		2·54 cm	1·96	1·54	-			-[c]	1·04 [c]	228·5[c,d]	12
	9·44		2·86 cm	1·77	1·55	-			-[c]	1·39 [c]	276·0[c,d]	12
	8·76		3·18 cm	1·62	1·57	-			-[c]	2·10 [c]	377·6[c,d]	12

a. Type CS-312 graphite. Uranium layers built up from 0·315 in. thick discs. One fewer graphite layers than uranium layers

b. Core reflected on ends only, core and reflector form 21·00 dia cylinders

c. No correction for 0·20 in. thick stainless steel diaphragm across median plane of assembly

d. kgm U^{235}

Table 3.13

Unreflected, Graphite Moderated Rectilinear Parallelepipeds
(At elevated temperatures.)

(See also Table 3.15)

References : 17, 18, 19

Uranium enrichment : 93·2 wt%

In these experiments the systems were assembled from alternate layers of uranium and graphite. The thicknesses of the repeated layers are noted in the table as well as the average composition of the core.
The uranium layers consisted of 0·002 or 0·004 in. thick foils enclosed in a 0·002 in. thick Type 347 stainless steel can, external dimensions 9·25 in. x 23·68 in. x 0·006 in. or 0·008 in. (average mass of uranium per foil 123 gm or 246 gm, average mass of stainless steel per foil 105 gm). The graphite layers were built up from 12 in. square x 1 in. or 2 in. blocks of Type CS-312 graphite (density 1·63 gm/cc). The blocks were machined with a 0·035 in. deep, 9½ in. wide groove on one face to accommodate the uranium foils and were pierced on either side of the groove by a row of six 1 in. dia coolant holes, giving an average graphite density for the system of 1·48 gm/cc. All dimensions given are room-temperature measurements. (The measured thermal expansion properties of the graphite used are given in Figure 3.4). The critical thicknesses include 2·5 in. for the contribution of the floor and a 1½ in. thick base layer of National Carbide Co type ATL graphite (density 1·75 gm/cc) and low mass table on which the systems were supported. Remaining incidental reflection effects are said to be equivalent to less than ~ ½ cm charge in the dimensions of the critical system.
A 1 in. OD stainless steel neutron source tube penetrated the centre of the system along the axis perpendicular to the layer structure.
The effects of neutron streaming is said to be negligible so far as the uranium foil grooves is concerned and equivalent to about a further 3% reduction in graphite density in the coolant holes.

LAYER THICKNESS		C/U^{235} ATOMIC RATIO	DELAYED CRITICAL PARAMETERS				
Uranium	Graphite		Area (ft)	Thickness (in.)	$\frac{\text{Thickness}}{\sqrt{\text{Area}}}$	Mass	Temperature (°F)
{0·004, 0·002}	{2, 1}	1185	4 x 5	50·3	-	-	60
(See Fig. 3.5(a))				52·5	-	-	850
0·004	4	2370	4 x 5	59·2	-	-	45
				65·5	-	-	950
				69·5[a]	-[a]	-[a]	1620[a]
0·002	{4, 8}	7150	6 x 6	61·0[b]	-[b]	-[b]	85[b]
	(See Fig. 3·5(b))			72·5	-	-	1110
0·002	{5, 10}	8940	6 x 6	62·0	-	-	50
	(See Fig. 3.5(c))			74·5	-	-	880
0·002	12	1440	8 x 8	61·5	-	-	79
				69·5	-	-	723
				73·5	-	-	1060
0·002	14	16850	8 x 8	68·8	-	-	52
				84·5	-	-	961
0·002	18	21690	8 x 10	78·8	-	-	46
				89·5	-	-	557

a. Extrapolated from a 1205°F experiment

b. This experiment has, in effect, an extra 2·41 kgm of Type 304 stainless steel per kgm of uranium, not in the uranium flux depression

EXPERIMENTAL RESULTS FOR SINGLE U^{235} CORES MODERATED BY CARBON

Table 3.14(a)

Graphite Moderated and Reflected Rectilinear Parallelepipeds

(See also Tables 3.14(b), 3.15)

References : 12, 15

Uranium enrichment : 93·2 wt %

Reflector : Thickness, 1 ft.

Average carbon density 1·55 gm/cc

These systems were assembled at the centre of a 6 ft cube matrix formed by stacking together 3 in. square section Type 2S aluminium tubes, wall thickness 0·047 in. Hence, both core and reflector contain 0·165 gm/cc aluminium (average).

Core elements were built up from 2·9 in. x 16 in. National Carbon Co. Type CS graphite plates interleaved with uranium foils 0·001 in. thick. The Table shows the average composition of the core.

CORE		DELAYED CRITICAL CORE PARAMETERS			
Average Carbon Density (gm/cc)	C/U^{235} Atomic Ratio	Area (in.) [a]	Thickness (in.)	$\frac{\text{Thickness}}{\sqrt{\text{Area}}}$	U^{235} Mass (kgm)
1·50	2538	40·0 x 33·0	33·0	-	8·24
	3369	40·0 x 36·0	36·0	-	7·38
	5297	48·0 x 42·0 [b]	39·0 [b]	- [b]	7·11 [b]
	7135	48·0 x 48·0 [c]	48·0 [c]	- [c]	7·44 [c]
1·34	2972	42·0 x 40·0 [d]	39·0 [d]	[d]	9·52 [d]
	4685	48·0 x 45·6 [d, e, f]	48·0 [d, e]	[d, e]	9·07 [d, e]

a. i.e., normal to the length of the core elements

b. Effect of self-shielding in the uranium foils estimated to be worth 4·65% in reactivity from subsidiary experiments in which a number of foils were replaced by 0·002 in. thick foils

c. Effect of self-shielding in the uranium foils estimated to be worth 6·66 in. reactivity from subsidiary experiments in which a number of foils were replaced by 0·002 in. thick foils

d. Graphite density reduced by removing one 0·54 in. thick graphite plate from each core element. Subsidiary experiments showed that this produced streaming effects which reduce the reactivity by 0·15%

e. keff for equivalent homogeneous system said to be 1·0480

f. Three extra 3 in. square tubes are averaged into this dimension of the core

Table 3.14(b)

Graphite Moderated and Reflected Rectilinear Parallelepipeds

(See also Tables 3.14(a) and 3.15)

Reference : 20

Uranium enrichment : 93 wt %

These systems were assembled at the centre of a 6 ft cube matrix formed by stacking together 3 in. square section Type 2S aluminium tubes, wall thickness 0·047 in. Matrix and core were divided into fixed and moveable halves (see Fig. 3.5).

Core elements were built up from alternate 0·01 in. thick uranium discs and 4 in. thick layers of Union Carbide Co. Ltd. high purity nuclear grade AGOT graphite (0·4 ppm B average, 0·07 wt % ash, density 1·72 gm/cc), made up of blocks either $\frac{1}{4}$ in., 1 in. or 4 in. thick. In a larger type of element the uranium discs were 2·860 in. dia. (average mass 17·959 gm) and the graphite blocks $2\frac{7}{8}$ in. square and in a smaller type the discs were 1·430 in. dia. (average mass 4·490 gm) and the graphite blocks $1\frac{7}{16}$ in. square. Both types of element were held together by a $\frac{3}{16}$ in. dia. aluminium (stainless steel in the case of control and safety elements) skewer passing through a 0·196 in. dia. axial hole in the centre of each uranium disc or graphite block. At one end the skewers were threaded into a 1 in. dia. x $\frac{1}{8}$ in. aluminium disc recessed into the carbon and a stainless steel clamp was applied at the other end.

The Table shows the average composition of the core.

Only the sides of the core parallel to the length of the elements were reflected; reflector elements were similar to the core elements but with the uranium omitted.

The system specified in the Table was critical with one control element (see Figure 3.6) withdrawn 10·04 in. The upper limit of stray reflection effects is said to be equivalent to an increase of 0·00015 in keff.

CORE						REFLECTOR THICKNESS (in.)	DELAYED CRITICAL CORE PARAMETERS			
	Volume % Composition				C/U^{235} Atomic Ratio		Area[a] (in.)	Thickness (in.)	Thickness / √Area	U^{235} Mass (kgm)
Uranium	Carbon	Aluminium	Stainless Steel	Void						
-	89·48	6·08	0·03126	-	-	3	45 x 45	44·1	-	41·515

a. i.e., normal to length of core elements

In the original document, Table 3.15 appeared on a single foldout page. It is reproduced on the next 2 pages. In copying the first of the next 2 pages, it was necessary to reduce its size so all the text would fit on the long dimension of the page.

EXPERIMENTAL RESULTS FOR SINGLE U^{235} CORES MODERATED BY CARBON

Table 3.15

Miscellaneous Graphite Moderated Cores

References : 15, 21
Uranium Enrichment : 93·2 wt %

In these experiments the cores were assembled from alternate layers of uranium and graphite. The thickness of the repeated layers are noted in the Table as well as average composition of the core.

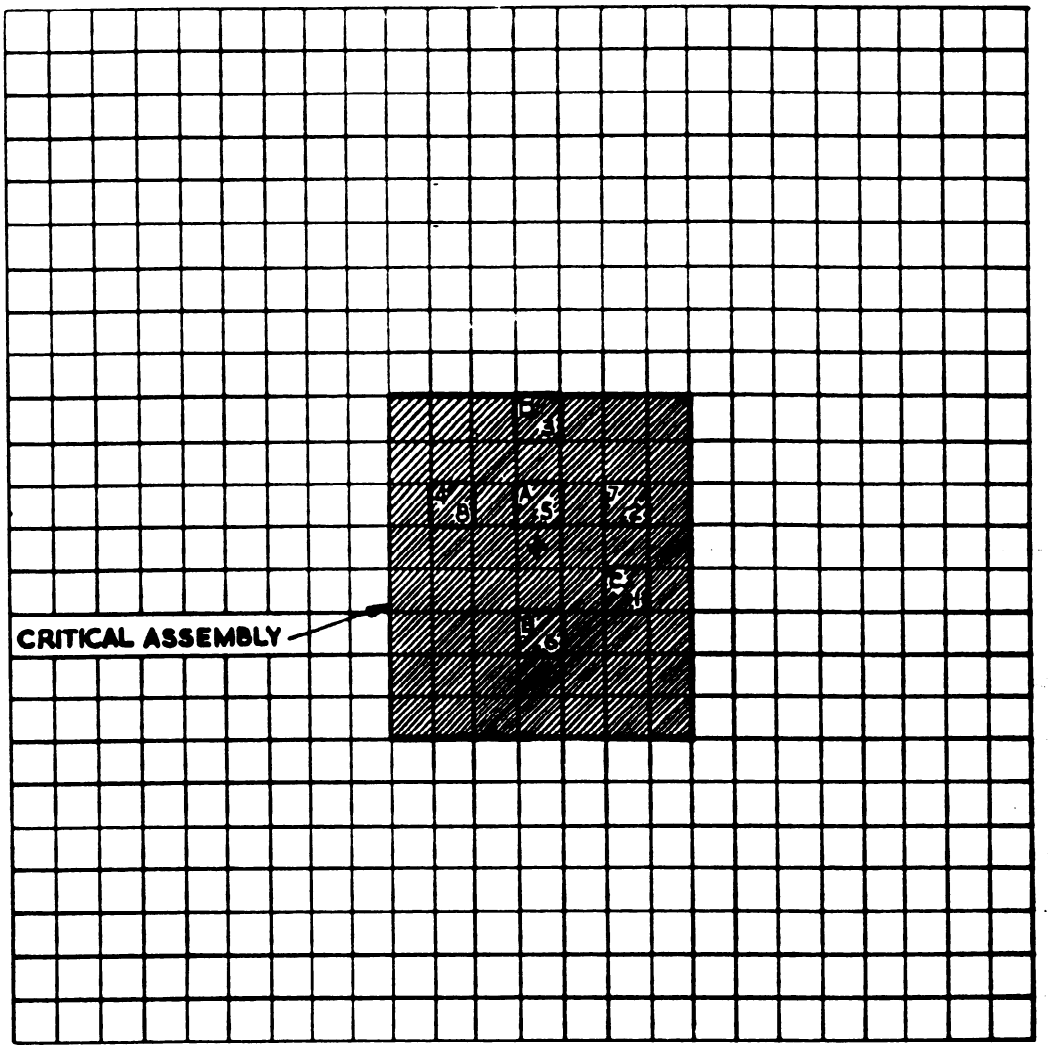
The uranium layers were built up from foils in 5¼ in. squares or isosceles triangles, nominal thickness either 0·001 in. or 0·002 in. thick, each foil being coated with an average of 0·92 gm polytetrafluorethylene, (atomic composition CF_2). The graphite layers were made up from 6 x 6 x ½ in. squares and isosceles triangles of National Carbon Co. A.T.J. graphite (density 1·73 gm/cc) with a 0·01 deep groove on one face to accommodate the uranium. The tablets in the first layer and at subse quent intervals of 6 in. were machined with grooves which reduced the average density over the 6 x 6 x ½ in. profile to 1·03 gm/cc.

The systems were assembled round a cruciform control and safety rod guide of Type 2S aluminium. This consisted of four mutually perpendicular arms, external dimens 6 x ½ in. penetrating the full height of the core. The total cross-sectional area of void necessary to accommodate this item was 12¼ sq. in., the extensions of the to the core edge being plugged with graphite plates. All the results reported in the Table are for the control rods fully withdrawn from the guide.

Subsidiar, experiments showed that the effects of neutron streaming through the porous carbon layers occurring every 6 in. was to increase the measured critical hei by 0·1 in. Incidental reflection to the nominally unreflected systems reduced the measured critical height by 0·2 in. In some cases two values of the critical hei are given, and 'as measured' value and a 'homogeneous' value corrected for the above effects, for the effects of the control rod guide void and for the effects of s shielding in the uranium foils. Appropriate corrections are again determined from subsidiary experiments. These values will refer to systems with slightly altered C/U^{235} atomic ratios since the control guide void is assumed to be removable by filling with graphite. (The effect of the aluminium guide in the control rod void i shown to be negligible).

CORE							REFLECTOR THICKNESS (in.)	DELAYED CRITICAL CORE PARAMETERS				
Layer Thicknesses		Average Material Densities (gm/cc)			C/U Atomic Ratio	Geometry		Base Dimensions (in.)	'As Measured' Height (in.)	$\frac{\text{Height}}{\sqrt{\text{Area}}}$	U^{235} Mass (kgm)	'Homogeneous' Height (see notes prefacing Table) (in.)
Uranium (in.)	Graphite (in.)	Uranium	Polytetrafluorethylene	Graphite								
No Reflector												
0·002	½	-	-	1·640 [a]	297(C/U^{235})	Parallelipiped	-	42·50 x 42·50	47·1	-	149·7	44·4
0·002	½	0·05345	0·0031	1·645 [a]	600	Psuedo-octagon	-	18½ x 17·0 [b]	~61 [c]	- [c]	~112 [c]	-
		0·05345	0·0031	1·645 [a]			-	24½ x 17·0 [b]	42·3	-	76·5	-
		0·05345	0·0031	1·645 [a]			-	18½ x 25·5 [b]	38·8	-	79·1	-
		0·05345	0·0031	1·645 [a]			-	24½ x 25·5 [b]	33·8	-	89·3	-
		0·05334	0·0031	1·636		Parallelepiped	-	48½ x 48½	40·0 [d]	- [d]	82·3 [d]	37·6
0·002	1	0·02667	0·0015	1·636	1200	Parallelepiped	-	48½ x 48½	42·4 [e]	- [e]	43·5 [e]	40·3
0·001	1	0·01369	0·0011	1·636	2340	Parallelepiped	-	48½ x 48½	47·6 [f]	- [f]	25·1 [f]	44·7
Type QMV Beryllium Reflector (density 1·84 gm/cc)												
0·001	1	0·01369	0·0011	1·645 [a]	2340	Parallelepiped	3·0 [g]	48·50 x 36·50	48·1	-	19·05	45·1
		0·01369	0·0011	1·636			6·0 [h]	36½ x 36½ [i]	36·8 [i]	-	11·0 [i]	34·5
		0·01369	0·0011	1·636			6·0 [g]	48½ x 36½ [i]	40·9 [i]	-	16·2 [i]	38·4
Natural Carbon Co. Type ATJ Graphite Reflector (density 1·73 gm/cc)												
0·002	½	0·05345	0·0031	1·645 [a]	600	Psuedo-octagon	6 [h]	- [b]	44·3	-	40·5	-
0·002	1	0·02667	0·0015	1·636	1200	Parallelepiped	6 [h]	36½ x 36½ [j]	43·5 [j]	- [j]	25·3 [j]	41·3
		0·02667	0·0015	1·636			[g]	48½ x 36½ [k]	42·8 [k]	- [k]	33·0 [k]	40·7

a. Not counting control rod void
b. i.e., dimensions a and b of Figure 3.8
c. Gross extrapolation
d. Critical height with only correction for control rod guide void applied = 37·7 in.
e. Critical height with only correction for control rod guide void applied = 40·4 in.
f. Critical height with only correction for control rod guide void applied = 44·8 in.
g. Core reflected on two larger vertical sides only
h. Core reflected on vertical sides only
i. Control rod guide 6 in. off centre
j. Control rod guide $6\sqrt{2}$ in. off centre
k. Control rod guide off centre



1,2,3,4 = SAFETY ELEMENTS IN MOVABLE HALF

5,6,7,8 = SAFETY ELEMENTS IN FIXED HALF

A,B = CONTROL ELEMENTS IN MOVABLE HALF

C,D = CONTROL ELEMENTS IN FIXED HALF

FUEL ELEMENT DETAIL ($Be / U^{235} = 390$)

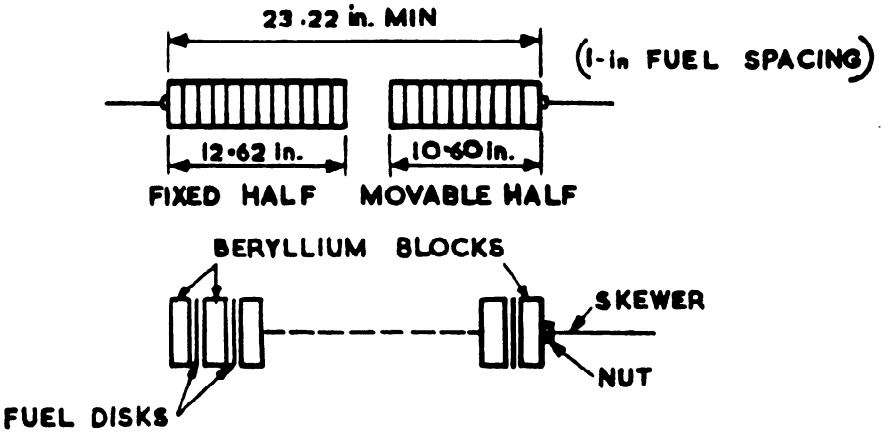
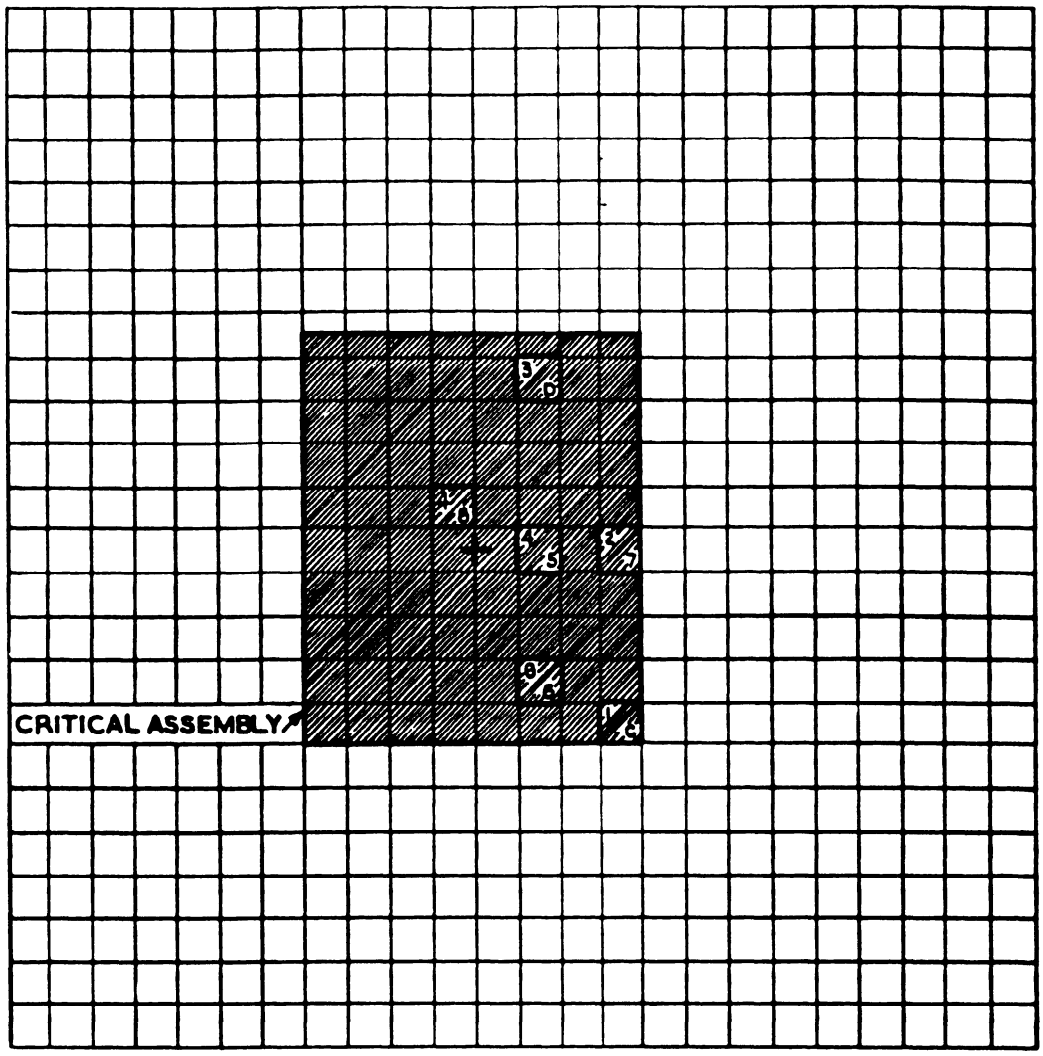


FIG. 3·1 (a) SEE (TABLE 3·7)



1,2,3,4 = SAFETY ELEMENTS IN MOVABLE HALF

5,6,7,8 = SAFETY ELEMENTS IN FIXED HALF

A,B = CONTROL ELEMENTS IN MOVABLE HALF

C,D = CONTROL ELEMENTS IN FIXED HALF

FUEL ELEMENT DETAIL (Be/U^{235} = 1560)

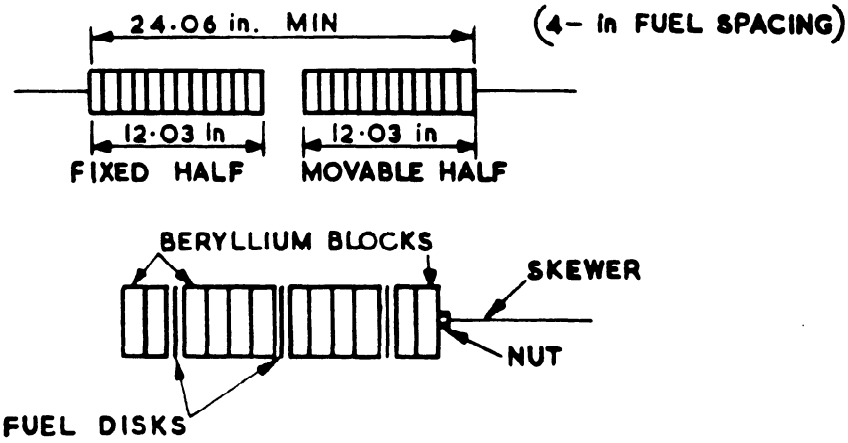


FIG. 3·1(b) (SEE TABLE 3·7)

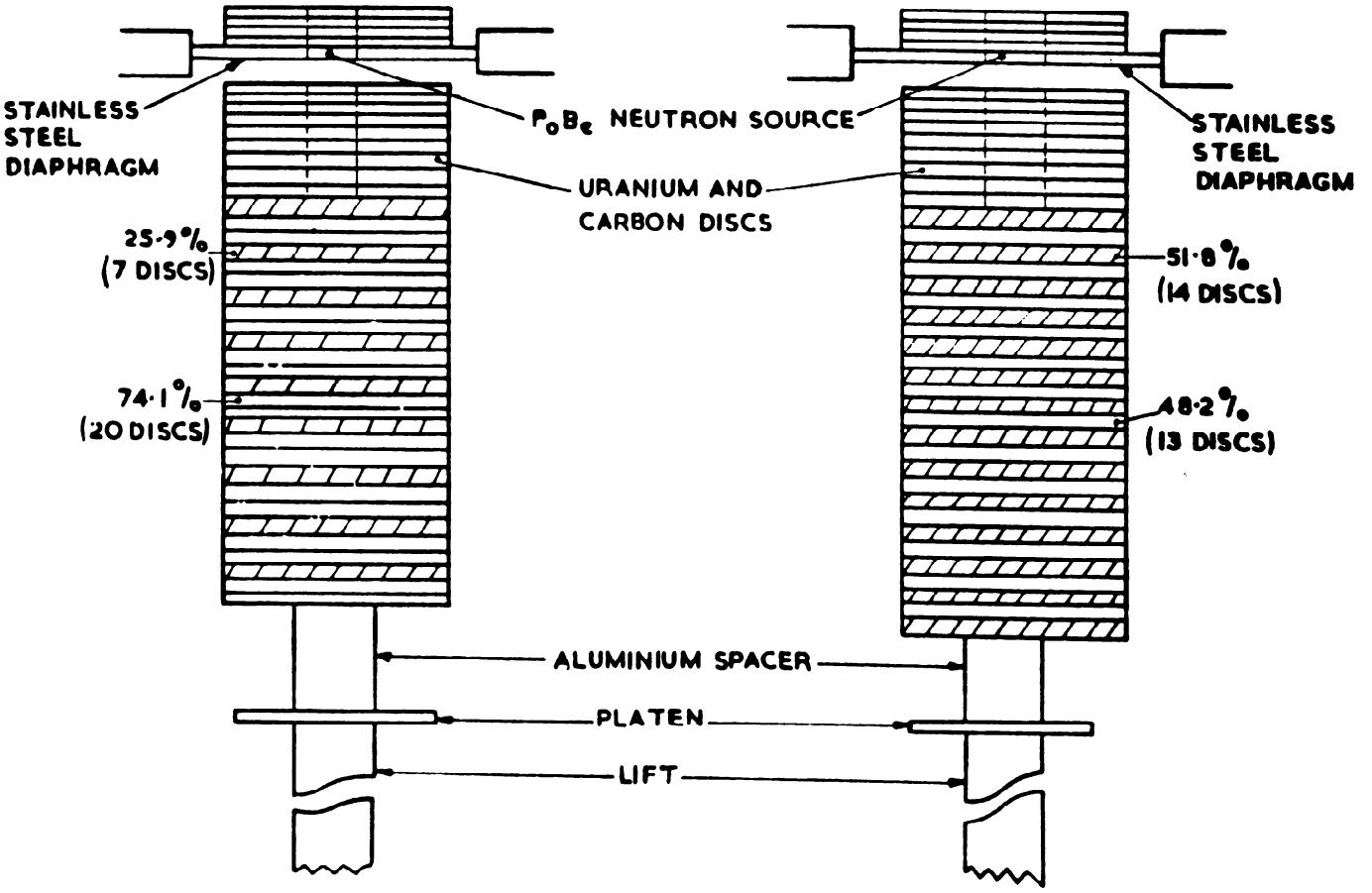
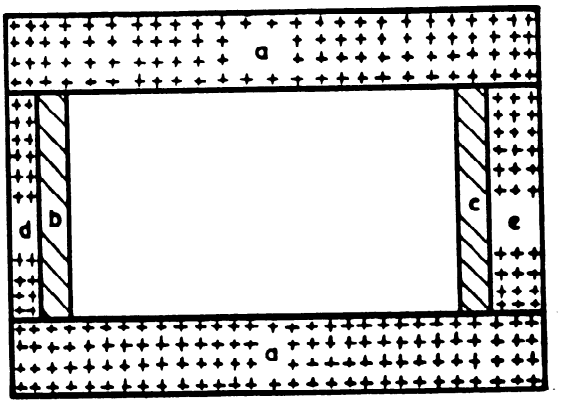
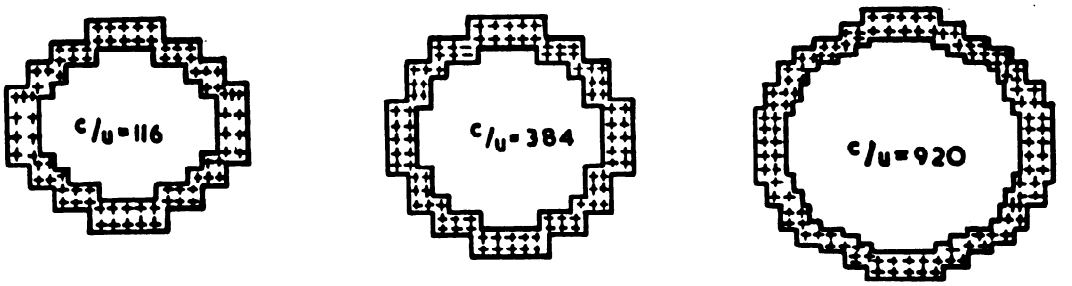


FIG. 3·2 (SEE TABLE 3·10)

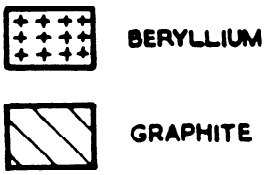


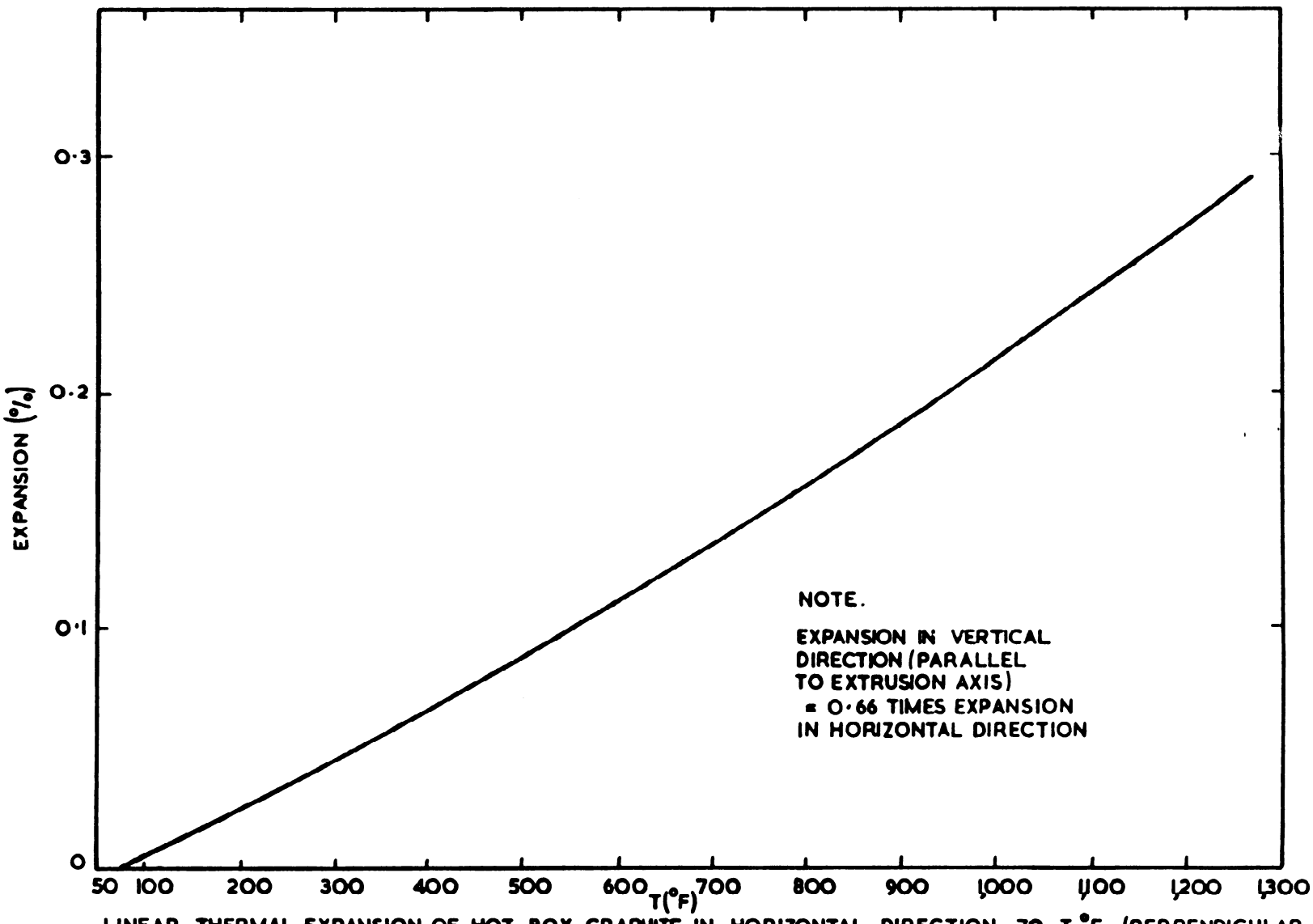
REFLECTOR REGIONS
(a)



CORE CROSS-SECTIONS
(b)

FIG. 3·3 (SEE TABLE 3·11)





LINEAR THERMAL EXPANSION OF HOT BOX GRAPHITE IN HORIZONTAL DIRECTION, 70–T °F, (PERPENDICULAR TO EXTRUSION AXIS)

FIG. 3·4 (SEE TABLE 3·13)

4	4	2	2	4
4	4	2	2	4
4	4	2	2	4
4	4	2	2	4

(a) $^{C}/_{U^{235}} = 1185$. THE NUMBERS IN THE SQUARES GIVE THE THICKNESS OF THE URANIUM LAYERS IN 0·001 IN.

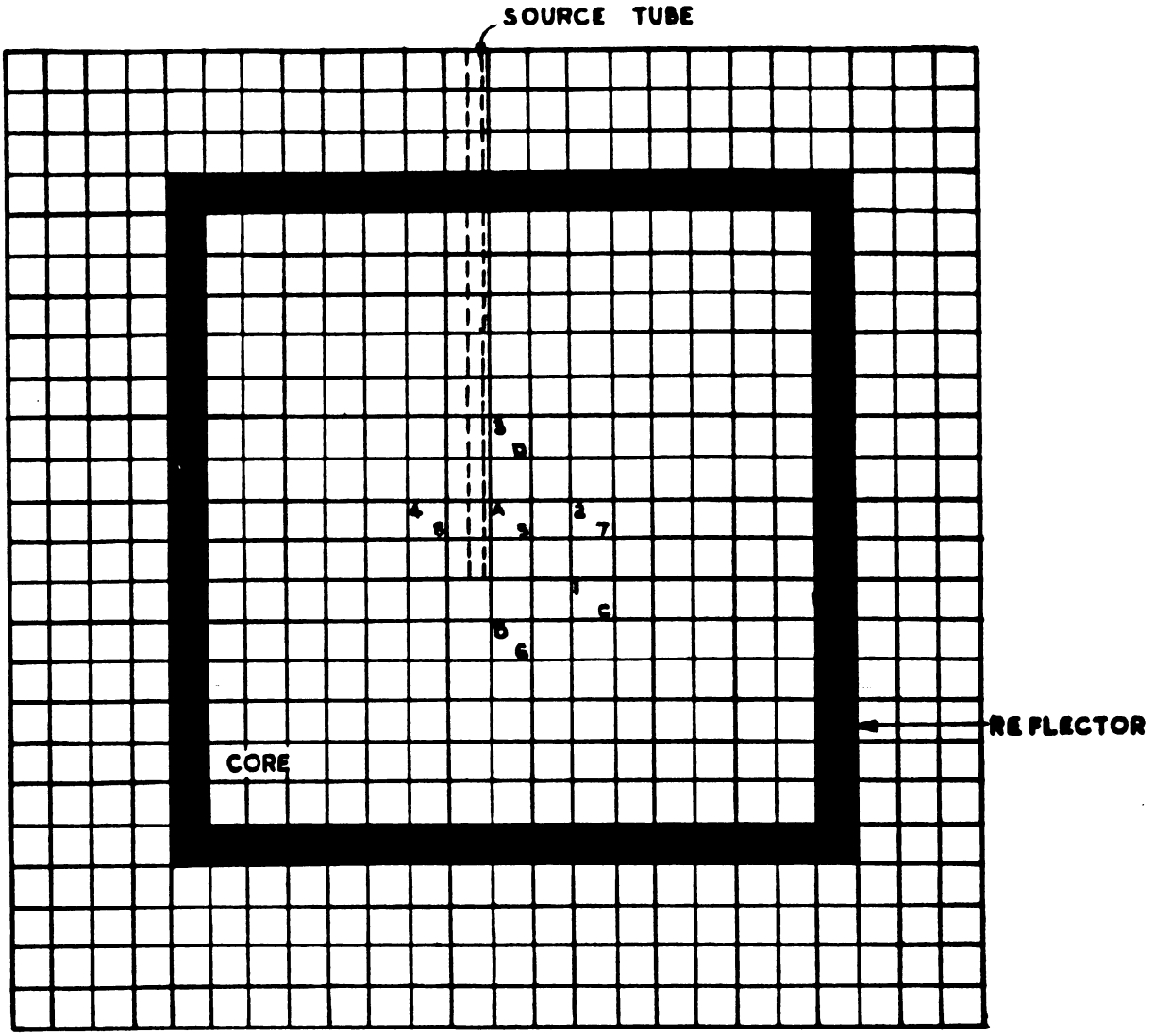
8	8	8	8	8	8
4	4	4	4	4	4
8	8	8	8	8	8
8	8	8	8	8	8
4	4	4	4	4	4
8	8	8	8	8	8

(b) $^{C}/_{U^{235}} = 7150$. THE NUMBERS IN THE SQUARES GIVE THE THICKNESS OF THE URANIUM LAYERS IN 0·001 IN.

10	10	10	10	10	10
5	5	5	5	5	5
10	10	10	10	10	10
10	10	10	10	10	10
5	5	5	5	5	5
10	10	10	10	10	10

(c) $^{C}/_{U^{235}} = 8940$. THE NUMBERS IN THE SQUARES GIVE THE THICKNESSES OF THE GRAPHITE LAYERS IN INCHES

FIG. 3·5 (SEE TABLE 3·13)



1, 3, 5, 7 = SAFETY ELEMENTS IN MOVABLE HALF

2, 4, 6, 8, = SAFETY ELEMENTS IN FIXED HALF

A, C, D, = CONTROL ELEMENTS IN FIXED HALF

B = CONTROL ELEMENTS IN MOVABLE HALF

FIG 3·6 (SEE TABLE 3·14 (b))

CHAPTER 4 - SINGLE Pu CORES MODERATED BY DEUTERIUM, BERYLLIUM OR CARBON

CHAPTER 4 - CONTENTS

CHAPTER 4 - REFERENCES

1. BATES, J. C. A Discussion of Reactor Physics Measurements and Calculations on the Quagga Series of Plutonium - Carbon Critical Assemblies TRG Report 615(D) DERE 1963.

Table 4.1

Graphite Moderated and Reflected Systems

Reference: 1

Plutonium: Pu^{240} content 5·0 wt%

In these experiments the cores were assembled from 2 in. square columns made up of alternate layers of plutonium and graphite (density 1·62 gm/cc). The thicknesses of the repeated layers are noted in the Table as well as the average composition of the core. The plutonium layers were built up from 1·788 in. square x 0·040 in. thick coupons, (weight 32·39 gm) each enclosed in a tin-soldered nickel can of external dimensions 2·0 in. square x 0·0622 in. The disposition of plutonium in the core was chosen to approach as nearly as possible a homogeneous distribution and in particular to avoid continuous planes of fuel. The method of constructing the cores was to lay first a graphite base of variable thickness (recorded in Figure 4·1 for a number of cases) followed by the alternate plutonium and graphite layers. Critical height was then calculated according to the following convention

$$\text{Critical core height} = \frac{4 \times \text{No. of Pu Coupons in Core}}{\text{Plan Area of Core (in.}^2\text{)}} \times \left(\text{Thickness of one Pu layer} + 1 \text{ graphite layer}\right)$$

All assemblies were divided vertically by a gap offset 2 in. from the centre plane of the assembly and containing steel wires occupying ~10% of the gap volume. The critical mass is given in two forms, "as measured" values and values which are corrected experimentally to allow for the effects of the gap.

The reflector was in all cases an octagonal prism of graphite, external dimensions 57 in. across the flats x 52 in. arranged approximately symmetrically about the core. The reflector graphite was of two kinds, UKAEA Reactor Grade B, (thermal cross-section 4·2-4·7 mb, density 1·65 gm/cc) and a material of density 1·78 gm/cc; the former accounts for the majority of the reflector but the two materials were mixed differently in different assemblies, and in some cases core graphite was also used in the reflector. The result of these variations is said to be that the absolute accuracy of the critical masses is ± 3%.

The effect of increasing heterogeneity was checked for C/Pu atomic ratios of 3·94 and 32·6; the results for the former case are given in the Table. In both cases the critical mass of the assembly was measured with the fuel coupons grouped in twos and in fours in addition to a single grouping. Extrapolation of these results to a homogeneous core is said to give critical masses larger than for a single grouping by 0·85% in the C/Pu atomic ratio = 3·94 case and 0·6% in the C/Pu atomic ratio = 32·6 case.

EXPERIMENTAL RESULTS FOR SINGLE Pu CORES MODERATED BY CARBON

Table 4.1 (Cont'd)

CORE									GAP WIDTH (in.)	DELAYED CRITICAL CORE PARAMETERS				
Volume % Composition					Layer Thicknesses (in.)		Average Plutonium Density (gm/cc)	C/Pu Atomic Ratio		Base Dimensions (in.)	Height (in.)	Height / √Base area	Pu Mass (kgm)	
Plutonium	Graphite	Nickel	Tin	Void	Plutonium	Graphite							As Measured	Corrected
50·8	0	38·6	3·2	7·4	0·0622	Nil	7·95	Nil	0·130	4 x 4	6·58	-	13·36	-
									-	4 x 5	-	-	-	12·9
									-	6 x 6	-	-	-	13·5
34·0	33·1	25·8	2·1	5·0	0·1244	0·0625	5·32	1·97	-	6 x 6	-	-	-	16·5
25·6	49·7	19·4	1·6	3·7	0·0622	0·0625	4·01	3·94	0·085	6 x 6 (See Figure 4.1(a))	8·60	-	20·5	19·75
					0·1244	0·125			0·093	6 x 6 (See Figure 4.1(b))	8·59	-	20·02	19·57
					0·2488	0·25			0·114	6 x 6 (See Figure 4.1(c))	8·48	-	19·76	19·13
					0·0622	0·0625			-	8 x 8 (See Figure 4.1(d))	-	-	-	19·8
17·0	66·6	12·9	1·1	2·5	0·0622	0·125	2·66	8·10	0·025	8 x 8 (See Figure 4.1(e))	8·24	-	22·73	22·6
12·8	74·9	9·69	0·80	1·86	0·0622	0·1875	2·00	12·02	0·05	10 x 8	9·59	-	24·86	24·7
10·2	80·0	7·72	0·46	1·48	0·0622	0·25	1·60	16·2	0·018	10 x 10 (See Figure 4.1(f))	9·99	-	25·83	25·3
7·26	85·7	5·52	0·46	1·06	0·0622	0·375	1·14	24·3	0·039	10 x 12	11·99	-	26·57	26·6
5·64	88·9	4·28	0·36	0·82	0·0622	0·5	0·883	32·6	0·065[a]	12 x 12 (See Figure 4.1(g))	13·24[a]	-	27·38[a]	27·3[a]

Table 4.1 (Cont'd)

CORE									GAP WIDTH (in.)	DELAYED CRITICAL CORE PARAMETERS				
Volume % Composition					Layer Thicknesses (in.)		Average Plutonium Density (gm/cc)	C/Pu Atomic Ratio		Base Dimensions (in.)	Height (in.)	Height / √Base area	Pu Mass (kgm)	
Plutonium	Graphite	Nickel	Tin	Void	Plutonium	Graphite							As measured	Corrected
3·00	94·1	2·28	0·19	0·44	0·0622	1·0	0·470	65·2	0·014	16 x 16 (See Figure 4.1(h))	14·27	-	27·77	27·4
1·02	98·0	0·77	0·06	0·15	0·0622	3	0·160	195·5	0·219	24·7 dia[b] pseudo-cylinder (See Figure 4.2)	17·89	-	22·64	22·1
0·51	99·0	0·39	0·03	0·07	0·0622	6	0·080	391	0·145	24·7 dia[b,c] pseudo-cylinder (See Figure 4.2)	27·28	-	17·44	17·1

a. The effect of arranging the core in alternating planes of plutonium and graphite was shown to be within the limits of reproducibility of the assembly, ± 0·0005 in. in measured critical gap

b. Diameter evaluated on an area basis

c. Core assembled from four basic types of column with initial graphite layers $1\frac{1}{2}$ in., 3 in., $4\frac{1}{2}$ in. and 6 in. thick, respectively

0	1/16	0

GAP

1/16	0	1/16
0	1/16	0

(a) C/Pu = 3·94

0	1/8	0

GAP

1/8	0	1/8
0	1/8	0

(b) C/Pu = 3·94

0	1/4	0

GAP

1/4	0	1/4
0	1/4	0

(c) C/Pu = 3·94

0	1/16	0	1/16

GAP

1/16	0	1/16	0
0	1/16	0	1/16
1/16	0	1/16	0

(d) C/Pu = 3·94

0	1/16	1/8	0
1/8	0	1/16	1/8

GAP

1/16	1/8	0	1/8
0	1/16	1/8	0

(e) C/Pu = 8·10

0	1/16	1/8	3/16	1/4
1/16	1/8	3/16	1/4	0

GAP

1/8	3/16	1/4	0	1/16
3/16	1/4	0	1/16	1/8
1/4	0	1/16	1/8	3/16

(f) C/Pu = 16·2

0	3/16	3/8	0	3/16	3/8
1/4	7/16	1/16	1/4	7/16	1/16

GAP

1/2	1/4	5/16	1/2	1/4	5/16
0	3/16	3/8	0	3/16	3/8
1/4	7/16	1/16	1/4	7/16	1/16
1/2	1/4	5/16	1/2	1/4	5/16

(g) C/Pu = 32·6

0	1/2	1	7/16	15/16	3/8	7/8	5/16
1/4	3/4	3/16	11/16	1/8	5/8	1/16	9/16
1/2	1	7/16	15/16	3/8	7/8	5/16	13/16

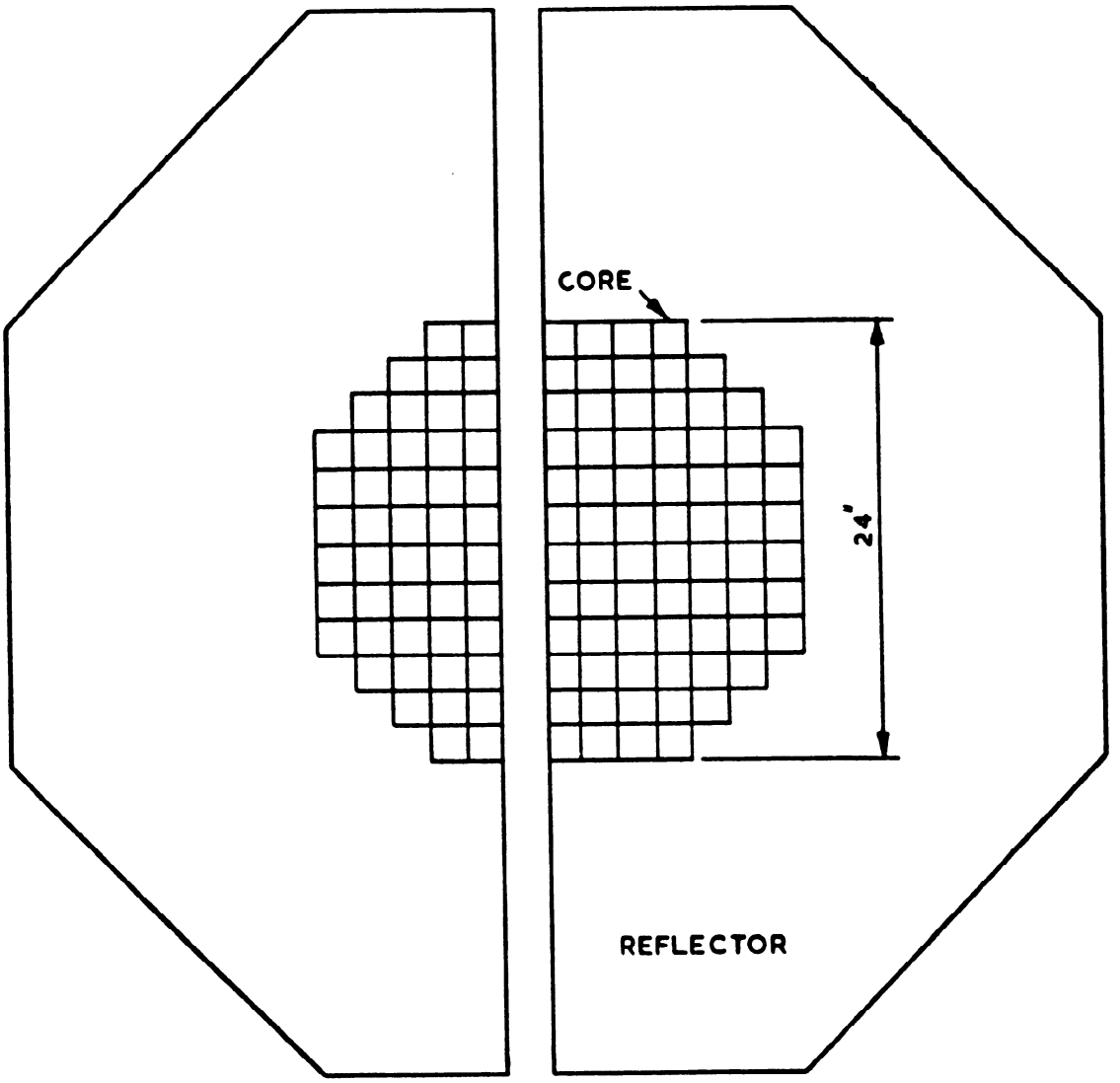
GAP

3/4	3/16	11/16	1/8	5/8	1/16	9/16	0
1	7/16	15/16	3/8	7/8	5/16	13/16	1/4
3/16	11/16	1/8	5/8	1/16	9/16	0	1/2
7/16	15/16	3/8	7/8	5/16	13/16	1/4	3/4
11/16	1/8	5/8	1/16	9/16	0	1/2	1

(h) C/Pu = 65·2

FIG. 4·1 (SEE TABLE 4·1)

THE NUMBERS IN THE SQUARES GIVE THE THICKNESS OF THE INITIAL GRAPHITE LAYER AT THE FOOT OF THE 2in SQUARE COLUMNS IN INCHES



CROSS SECTION OF 24·7in DIAMETER PSEUDOCYLINDER

FIG. 4·2 (SEE TABLE 4·1)