**CORE CHARACTERISTICS OF FOUR ARMY PACKAGE POWER
REACTORS**

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ABSTRACT

A brief discussion of the core characteristics of four uranium fuel, pressurized-water type Army Package Power Reactors, the SM-1, SM-1A, PM-2A, and SM-2, is presented. The characteristics discussed are cell geometry, fuel plates, core geometry, flux distributions, core loading, core burnout, and control rods. Tables and illustrations are included.

CORE CHARACTERISTICS OF FOUR ARMY PACKAGE POWER REACTORS

J. G. Gallagher*, M. J. Leibson, B. J. Byrne*

INTRODUCTION

The salient features of the four Army Package Power Reactors under discussion are presented in Table 1. The reactors are all of the pressurized water type and use fully enriched uranium as fuel.

CELL GEOMETRY

The cores for these four systems are characterized by identical cell size (2.9375 in. x 2.9375 in.).¹ The active core length is 21.75 in. Figure 1 shows a view of a fixed element cell and a control rod cell.

The detail geometry of the elements for the SM-1, SM-1A and PM-2A are identical.^{1,2,3} The fixed element consists of eighteen fuel plates 0.030 in. thick brazed into 0.050 in. thick side plates. The meat of the fuel plate is 0.020 in. thick by 2.5 in. wide. The volume fraction water in this cell is 80% (or M/W=0.25). The dead edge and side plates account for 23% of the metal.

The control rods are of the MTR type and consist of a fuel element section and an absorber section which are inserted into a control rod basket. The fuel element consists of sixteen 0.030 in. thick plates brazed into 0.050 in. thick side plates. The fuel plate meat is 0.020 in. thick by 2.28 in. wide. The absorber follower consists of 4 plates, 0.156 in. thick and 2.464 in. wide, welded into a box.

The detail geometry of the SM-2 differs from the other cores in that the fuel plate meat has been increased from

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0.020 in. to 0.030 in. and the fuel plate thickness has been increased from 0.030 in. to 0.040 in.⁴

FUEL PLATE CHARACTERISTICS

The fuel plates for these reactor cores consist of a matrix of stainless steel in which is dispersed UO_2 and burnable poison compound clad with stainless steel. Some of the important characteristics of these plates are given in Table 2. The SM-1 to date (May 1959) has experienced a maximum of 3.0 atom % burnup* in the fuel plate matrix.

CORE GEOMETRY

The fixed and control rod cells are put together in different arrays to form the cores under discussion. Fig. 2 shows the array for each core. The SM-1 and SM-1A arrays are identical. They contain 45 cells of which seven are control rods. The PM-2A array consists of 37 positions of which five are control rods. The SM-2 has 45 elements of which seven are control rods. Equivalent diameter of these cores is approximately 22 in. The SM-2 core is divided into two passes by a flow divider.

FLUX DISTRIBUTIONS

These reactor cores are characterized by lack of large water holes except for the one within the absorber box. However, the absence of fuel in the side plate region causes a local thermal neutron flux peak. Fig. 3 illustrates the magnitude of this peak as calculated and measured for the SM-1⁵ and as calculated for the SM-2. Recent measurements in the SM-2 flexible experiment indicate that the SM-2 prediction may be low.

The axial flux distribution within an SM-1 control rod is shown in Fig. 4. The SM-1 employed 9 Haynes 25 combs to suppress the flux at the tip of the control rod fuel element.⁶ The SM-1A, PM-2A and SM-2 will employ an internal flux suppressor consisting of Eu_2O_3 dispersed in stainless steel at the end of the control rod fuel plates. The calculated distribution for this suppressor⁶ and measured distribution are shown on Fig. 4.

CORE LOADING BREAKDOWN

An insight into the core loading for the SM-1 and SM-2 can be obtained from the breakdown given in Table 3.

CORE BURNOUT CHARACTERISTICS

Core characteristics have been predicted on the basis of modified two group theory. P_3 theory and a hardened neutron temperature are used to evaluate thermal group constants, and the Muft code developed at WAPD is used for the fast group parameters. A comparison of theory and experiment for SM-1 zero power experiments and the ORNL SM-1 critical experiment was presented at the Detroit meeting of the ANS. At that time it was reported that the calculated reactivity was about 2% low for a wide range of experiments in the SM-1 ZPE, but was in good agreement with the ORNL SM-1 experiments. Since that time a re-determination of the actual boron content in SM-1 elements brings the calculations and experiments into closer agreement.

Fig. 5 shows the calculated burnout curves for the SM-1 and SM-2. Also shown are the core burnout measurements for the SM-1.⁸

CONTROL ROD CHARACTERISTICS

The control rod absorber in each of the cores consists of a hollow box made up of four plates, 0.156 in. thick. These plates contain an absorber material dispersed in a matrix clad with stainless steel. The SM-1 used enriched boron dispersed in stainless steel. The other cores will employ Eu_2O_3 dispersed in stainless steel. Table 4 summarizes the worth of these absorbers. The total worth of the various rod arrays is also given. The large reactivity value of these rods is clearly illustrated; as is the contribution of fuel displacement to rod worth.

ACKNOWLEDGEMENTS

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CELL GEOMETRY

FIXED FUEL
ELEMENT

CONTROL ROD
FUEL ELEMENT

CONTROL ROD
ABSORBER

FIGURE 1

CORE GEOMETRY

SM-1 & SM-1A

ONE PASS UP

PM-2A

ONE PASS UP

SM-2

TWO PASS UP-UP

FIGURE 2

FIGURE 3

FIGURE 4

CORE BURNOUT CHARACTERISTICS SM-1 & SM-2

FIGURE 5

TABLE 1
SUMMARY CHARACTERISTICS
FOUR ARMY PACKAGE POWER REACTORS

Designation (old)	APPR-1	APPR-1A Skid	APPR-1B	
(new)	SM-1	SM-1A	PM-2A	SM-2
Thermal Power, MW	10	20	10	28
Mean Coolant Temp, °F	440	434	509	513
Coolant Flow Rate, GPM	3960	7150	4220	8000
System Pressure, psia	1200	1200	1750	2000
Average Power Density, watts/cc	72	144	87	200
Average Heat Flux*, BTU/hr.ft. ² °F	62,000	124,000	72,000	181,000
Core Life, MWYR	15	15	8	28
Fuel Loading, U-235	22.5	22.4	18.5	36.2

* Based on deepest bank insertion

TABLE 2
FUEL PLATE CHARACTERISTICS
FOUR ARMY PACKAGE POWER REACTORS

	<u>SM-1</u>	<u>SM-1A</u>	<u>PM-2A</u>	<u>SM-2</u>
<u>Dimensions</u>				
Plate thickness, in.	0.030	0.030	0.030	0.040
Meat thickness, in.	0.020	0.020	0.020	0.030
<u>Materials</u>				
Matrix	302B	304B	304B	347
Fuel	UO ₂	UO ₂	UO ₂	UO ₂
Burnable Poison	B ₄ C	B ₄ C	B ₄ C	ZrB ₂
Cladding	304L	304L*	304L*	347**
<u>Weight % in Meat</u>				
UO ₂	25.9	25.9	25.9	28.1
Natural Boron	0.11	0.11	0.11	0.24
<u>% Burnup U-235 (fission & capture)</u>				
Average	33	33	22	39
Maximum	73	73	42	77
<u>% Burnup Meat Atoms (all processes)</u>				
Average	1.9	1.9	1.3	1.9
Maximum	4.1	4.1	2.4	3.7
Maximum Fuel Plate Temp. °F	587	595	632	697

* 0.01 w/o Co

** 0.01 w/o Co and Ta

TABLE 3
FUEL INVENTORY BREAKDOWN FOR SM-1 AND SM-2
Kg of U-235

	<u>SM-1</u>	<u>SM-2</u>
Clean Critical Mass (Homogeneous)	8.5	9.4
Clean Critical Mass	9.0	10.9
Hot Clean Critical Mass	10.5	13.0
Hot, eq xe Critical Mass	11.7	14.5
End of Life Critical Mass	12.5	16.7
Fuel for Burnup	10.0	19.5
Initial Fuel Loading	22.5	36.2

TABLE 4
ROD WORTH AS A FUNCTION OF ABSORBER MATERIAL
SM-1 AND SM-1A

	Central Rod (68°F)	5 Rod Bank (68°F)
Normal Boron Rod	4.1%	19%
56.4 gm B-10/element		
Normal Europium Rod	4.0%	18.6%
604 gm Eu/element		
Stainless Steel Rod	2.4%	11.1%