STATUS OF JUPITER PROGRAM

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To obtain the data necessary for evaluating the nuclear design method of a large-scale fast breeder reactor, criticality tests with a large-scale homogeneous reactor were conducted as part of a joint research program by Japan and the U.S. Analyses of the tests are underway in both countries. The purpose of the present paper is to describe the status of this project.

I. Introduction

The large-scale fast reactor criticality program, which is a joint research program being undertaken by the Power Reactor and Nuclear Fuel Corporation (DONEN) and the Department of Energy of the United States, is called JUPITER (Japan-United States Program of Integral Tests and Experimental Research). The test was conducted with ZPPR (Zero Power Plutonium Reactor)[1, 2] at Argonne National Laboratory (ANL) in the United States from April 1978 to August 1979. Analyses are in progress independently in both the U.S. and Japan. The present test was performed with 2 assemblies called ZPPR-9 and -10 [3, 5] and is called JUPITER Phase I to differentiate it from future JUPITER tests. DONEN sent two technicians** to ANL-Idaho for a period of about 2 years beginning in August, 1978. They participated in planning, executing, and analyzing the criticality test [6] and obtained information concerning these

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activities. In Japan, on the other hand, a FBR reactor core design (JUPITER) committee was established in DONEN in 1978;*** a core design and experimental plan and the direction of analyses have been studied.

1. Significance of JUPITER Phase I

To clarify the significance or the position of JUPITER Phase I, Figure 1 shows those fast reactor simulated criticality tests which have been performed to date in Japan. JOYO simulation tests [7, 8] were conducted as the V assembly series with the use of a fast criticality test unit, FCA, at the Japan Atomic Power Research Institute beginning in February 1970. Following this, the partially simulated MONJU test was performed as the FCA VI and VII assembly series starting in August 1972. Since then simulated tests for specific portions of MONJU have been carried out; these involve core melting, control rod pins, calcndria, the lower structure of the reactor core and fuel storage tanks outside the reactor. A full-size simulated test (MOZART) [9, 10] in conjunction with the joint research project carried out by Japan and England was performed over a period of one and a half years starting in September 1971 with the criticality test unit ZEBRA located at Winfrith Laboratory.

JUPITER Phase I follows these part activities as regards Japan's fast reactor simulated criticality tests. Its meaning or position in relation to these tests is described below.

(1) In this program a reactor core of a verification reactor class has been used for the first time as a subject of simulation. The core volumes of ZPPR-9 and ZPPR -10 of 4,600 - 6,200 ℓ (equivalent to 700 - 900 MWe) are the largest ones ever used in a criticality test for a fast reactor.
(2) This program is the first comprehensive criticality test of a large-scale homogeneous reactor in the world. Data from ZPPR-9 will be especially useful in the future for two-area clean benchmark data for large-scale reactors.

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(3) The property data of the large-scale homogeneous reactor* obtained in the present tests should be able to be compared with the properties of the benchmark reactor core of a large heterogeneous reactor,** which would be subjected to future tests.

(4) The joint Japan-U.S. test can eventually promote mutual exchange of measurement technologies and analytical methods for fast reactor criticality tests and can provide meaningful stimuli for Japan's reactor physics research .

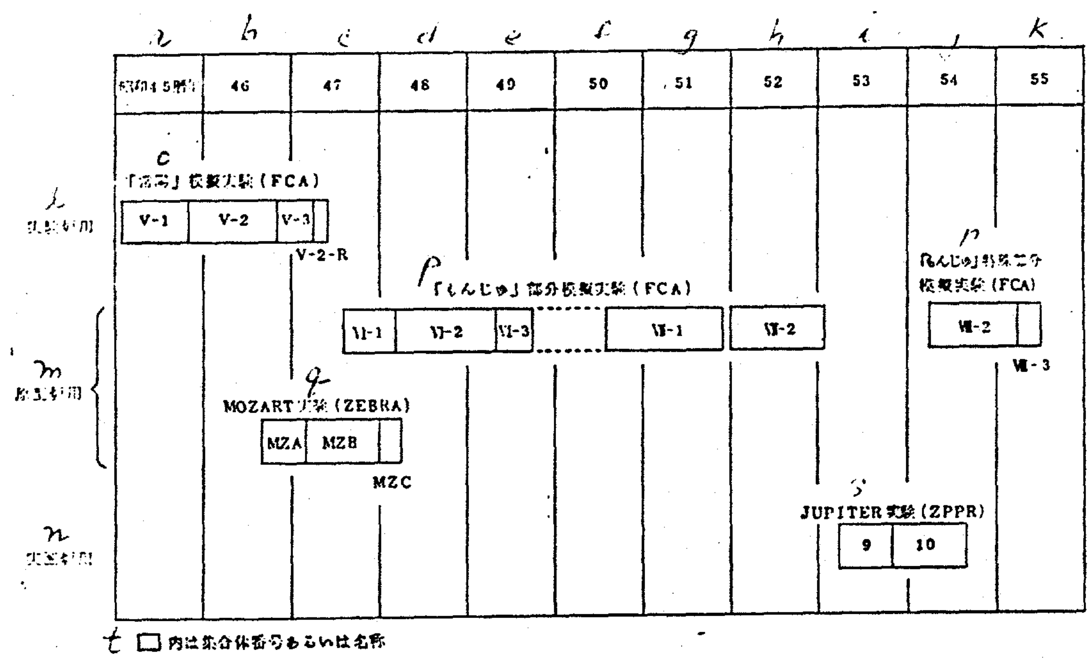

Figure 1. Implementation Procedure for Fast Reactor Simulated Criticality Tests.

Key:

a. 1970 b. 1971 c. 1972 d. 1973 e. 1974 f. 1975

g. 1976 h. 1977 i. 1978 j. 1979 k. 1980

l. for experimental reactor m. for prototype reactor

n. for verification reactor o. JOYO simulated test (FCA)

p. MONJU partial simulated test (FCA) q. MOZART test (ZEBRA)

r. MONJU special portion simulated test (FCA) s. JUPITER test (ZPPR)

Numbers in ☐ indicate an assembly number or name.

*[see key]

**A type of reactor which has a blanket in the core area in the shape of a ring or an island.

2. Purposes of JUPITER Phase I

JUPITER Phase I is a benchmark test whose purpose is to obtain necessary information for the initial stage of the reactor core design of a verification reactor class. Its objectives can be summarized as follows.

(1) The data on basic nuclear properties of two-area homogeneous reactors of the 700 - 900 MWe class are to be obtained by measuring a clean core, EOC (end of cycle cores) and BOC (beginning of cycle) reactor cores.

(2) the size effect of the homogeneous reactor properties is to be investigated by comparing the above data with those of the conventional small to medium-size reactors.

(3) The accuracy of the present analytical method utilized for a large-scale homogeneous reactor is to be evaluated.

3. Implementation Procedure of JUPITER Phase I

The implementation procedure of JUPITER Phase I is shown in Figure 2.

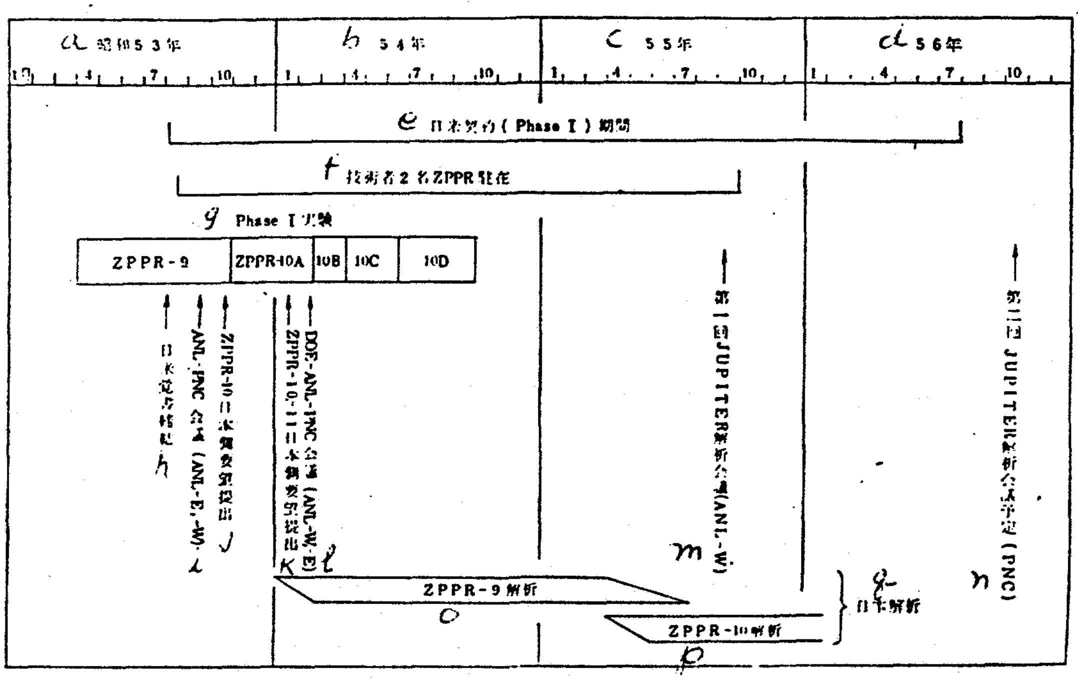

Figure 2. Implementation history of the JUPITER program.

a.	1978	e.	Japanese-U.S. contract (Phase I), contract period
b.	1979	f.	two technicians at ZPPR
c.	1980	g.	Phase I test
d.	1981	h.	Japanese-U.S. memorandum signed

Key to Figure 2, continued:

i. ANL-PNC Conference (ANL-E, -W)

j. Japan submitted requests concerning ZPPR-10

k. Japan submitted requests concerning ZPPR-10 and ZPPR-11

l. DOE-ANL-PNC Conference (ANL-W, -E)

m. First JUPITER Analysis Conference (ANL-W)

n. Second JUPITER Analysis Conference scheduled (PNC)

o. ZPPR-9 analysis

p. APPR-10 analysis

q. Japanese analysis

The tests were performed for both ZPPR-9 and ZPPR-10 over a period of one year and five months. The Japanese side requested that an additional 31 rods of the CRP (control rod position) system be tested at a 6,000 ℓ reactor core, and, as a result, the test was later extended to two months under the title, ZPPR-10 Phase D. Based on the requests made by the Japanese research group, additional tests were conducted involving such areas of the multi-control-rod pattern with a one-rod stack, the effect of control rod sizes at off-center, the neutron streaming effect, zones in ZPPR-10 Phase D and Na void effect, and the measurement of the reaction rate distributions at the control rod insertion time in Phase D in the system both before and after criticality.

The test results of JUPITER Phase I were analyzed with ENDR/B-IV at ANL and GE. In Japan ZPPR-9 was analyzed [11, 12] with JENDL-2B [13] by five domestic companies.* In September, 1980, the first JUPITER analysis conference was held at ANL-Idaho, and the analytical results of ZPPR-9 were reported and discussed by both the Japanese and U.S. groups. Since then analyses of ZPPR-10 have been underway in Japan.

II. Summary of Tests

1. Test System

As far as the assemblies are concerned, the scope of the JUPITER Phase I test covers ZPPR-9 and ZPPR-10, and ZPPR-10 is further divided into four phases: A, B, C, and D. The major features of each of these reactor cores are shown in Table 1. In all these assemblies, the cell pattern and composition of the core are basically, with the exception of detail parts, the same. ZPPR-9 and ZPPR-10 are called large scale homogeneous reactor series at ANL. In the core programs for ZPPR, the above two are thus differentiated from those assemblies before ZPPR-8 and after ZPPR-11.

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	ZPPR-9	ZPPR-10A	ZPPR-10B	ZPPR-10C	ZPPR-10D
a 炉心半径(cm)†	119.9	126.6	126.6	144.8	144.8
b 炉心高さ(cm)	101.8	101.8	101.8	101.8	101.8
c 炉心体積(ℓ)††	4,599	4,596	4,596	6,168	6,112
d Fissile Pu量(kg)	1,956	2,071	2,292	2,578	2,612

e † CRP,CR を含む炉心領域の等価半径
f †† CRP,CR を含まない炉心領域の体積

Table I. Major specifications for ZPPR-9 and ZPPR-10 cores.

Key:

a. core radius b. core height c. core volume

d. quantity of fissile Pu

e. equivalent radius of core area including CRP and CR

f. volume of core area excluding CRP and CR

ZPPR-9 is a two-area cylindrical clean reactor core, which is the standard component of this series. Figure 3 shows the core structure of ZPPR-9. A core volume of 4,600 ℓ is equivalent to a design output of 700 MWe in the early stage of the CDS (conceptual design study) [14] in the U.S. A core composition simulating Pu-U oxide fuel has a fuel volume ratio of 41 %.

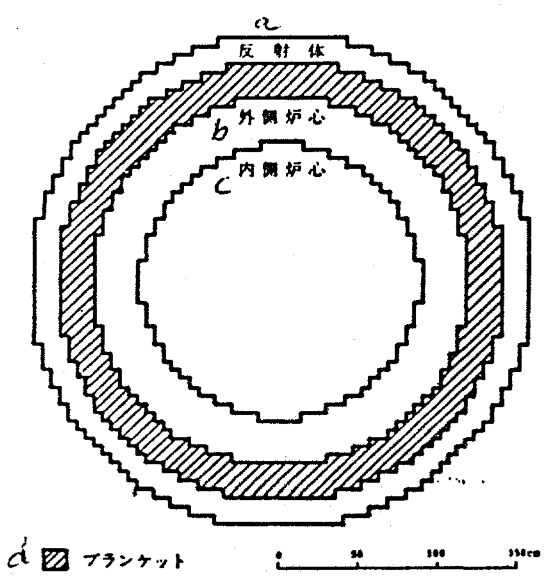

Figure 3. Core structure of ZPPR-9

Key:

a. reflector

b. outer core

c. internal core

d. blanket

The purposes of the tests with ZPPR-9 were to investigate output distributions, control rod values, the effect of Na voids and the core size effect upon external monitoring properties, and to study the basic problems related to the presently employed analytical methods for a core of a large reactor so that they may be improved.

ZPPR-10A is a two-area hexogonal core with the same core volume as that of ZPPR-9 and a system with 19 CRP of Na channels, which is an EOC simulated reactor core. This 10A is the closest system to ZPPR-9 among the phases of ZPPR-10 and is the standard for the ZPPR-10 series.

ZPPR-10B has a structure in which simulated control rods (CR) are inserted into the central CRP and 6 outer CRP of 10A, and it is a simulated core of BOC. The major purpose of 10B is to investigate, by comparing with 10A, the effect of the presence of control rods on each property, especially the variation of neutron flux distributions.

ZPPR-10C is a simulated core of EOC with 19 CRP and a core volume of 6,200 ℓ. The core structure of 10C is shown in Figure 4. The fuel which is normally used for ZPPR is ¼ inch thick 88% fissile Pu depleted U-Mo alloy plate called ZPPR fuel. ZPPR-10C is the largest core capable of being loaded with the ZPPR fuel of the same specification. It has a core larger by about 30% than that of 10A, while its core structure is similar to the latter. The purpose of 10C is to measure the properties of a 900 MWe class core and to investigate the size effect of each property by comparing it with 10A.

ZPPR-10D has the same core shape as that of 10C but has 31 CRP. Photograph 1 shows the radial cross section of 10D.* The main purpose of 10D is to study the control rod values of the 31 CRP system and to obtain the reaction ratio distribution at the time of the control rod insertion. This 10D has to subphases in addition to the above D. One is criticality system D/1, in which a simulated control rod was inserted at the center CRP, and the other is criticality system D/2, in which simulated control rods were inserted at 6 CRP positions at the corners of the second ring. ZPPR-10D/2 is the largest in respect that it is loaded with 2,740 kg fissile Pu.

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* See page 12 of translation.

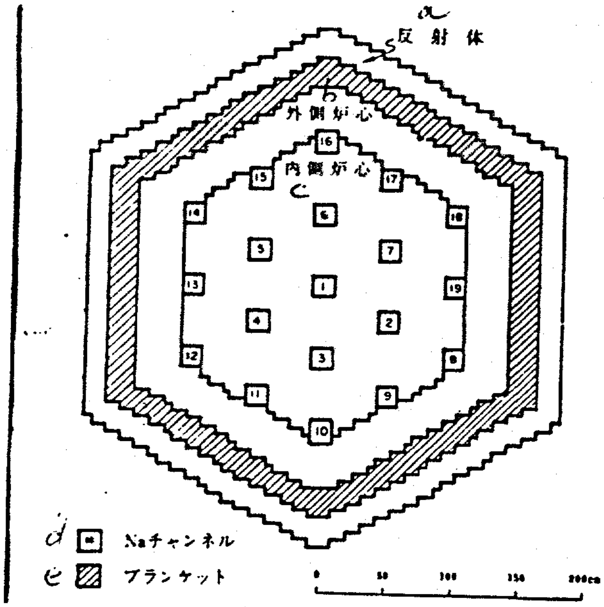

Figure 4. Core structure of ZPPR-10

Key:

a. reflector

b. outer core

c. internal core

d. Na channel

e. blanket

2. Test Items

Table 2 shows those test items which were measured for each assembly of JUPITER Phase I. Important test items in this series were reaction rate distributions, Na void reactivity and control rod values, which are all subjects of study as properties of a large scale reactor. Since ZPPR-9 is the standard core, comprehensive cases for these three items were subjected to measurement. As far as reaction ratio distributions were concerned, both radial and axial measurements were made with ^{239}Pu, ^{235}U and ^{238}U foils three-dimensionally in the assembly, including the blanket. With the use of a micro-fission chamber (MFC), the radial distributions of ^{240}Pu, ^{233}U, ^{234}U, ^{235}U, and ^{236}U were also measured. For the reaction rates, fission ratios of ^{233}U, ^{234}U, ^{236}U, ^{238}U, ^{239}U, ^{240}Pu and ^{241}Pu against ^{235}U were measured with a back-to-back chamber (BTB, which will be discussed later).

	ZPPR-9	ZPPR-10A	ZPPR-10B	ZPPR-10C	ZPPR-10D	ZPPR-10D/1	ZPPR-10D/2
a 臨界性	○	○	○	○	○	○	○
b 反応率分布							
c 箔	○	○	○	○	○	○	○
d 径方向 MFC	○						
IFC	○	○	○	○	○		
e 軸方向 箔	○	○	○	○	○	○	
f 反応率比	○						
g 制御棒価値	○	○	○	○	○		
h 物質反応度価値	○	○	○				
i Na ボイド反応度							
j 径方向マップ	○	○	○				
k 軸方向マップ	○						
l ゾーン	○	○	○		○		
m ドップラー反応度	○						
n γ線加熱	○				○		
o 中性子スペクトル	○						

Table 2. JUPITER Phase I tests.

Key:

a. criticality
b. reaction rate distribution
c. foil
d. radial direction
e. axial direction foil
f. reaction rate ratio
g. control rod value
h. material reactivity value
i. Na void reactivity value
j. radial map
k. axial map
l. zone
m. Dopplet reactivity
n. gamma-ray heating
o. neutron spectrum

For the void reactivity, the streaming effect of the plate system was measured for the central zone, void, radial and axial maps and void reactivity. Those items which were measured for control rod values included multi-control rod values, the radial distribution of the values of the two symmetrical control rods about the center, interference effect, size effect, composition effect, pin control rod values, and the reactivity values of Ta and Eu_2O_3, which were substitute materials. In addition to the above three major test times for ZPPR-9, measurements were made as shown in Table 2 for criticality, reactivity values of materials, Doppler reactivity, gamma-ray heating, and neutron spectra. Since the reactor composition of each phase of ZPPR-10 is basically the same as that of ZPPR-9, Doppler reactivity and neutron spectra which are the properties dependent upon composition were not measured again for ZPPR-10. The purposes of the ZPPR-10 test were to investigate the effects of shapes such as differences between cylindrical and hexogonal cores, between the presence and absence of CRP, between varied numbers of CRP, between the presence and absence of control rods and varied sizes of cores. For this reason emphasis was placed in the case of ZPPR-10 on the measurements of reaction rate distributions, Na void reactivity, the dependency of control rod values upon shape. Almost the same cases as those for ZPPR-9 were measured for 10A, with emphasis on the above three items. On the other hand, limited cases were studied for 10B to observe the effect of the presence of the control rods, also with emphasis on the three items. Using the foils, 10C was studied in the areas of radial reaction rate distributions, control rod values and the neutron streaming effect of diluting materials. Another activity was the correction of an in-core fission chamber (the IFC, which will be discussed later) by irradiated foils. In the case of 10D, measurements were taken of radial and axial reaction rate distributions, control rod values, zone-void reactivity and gamma-ray heating. As mentioned earlier, the main purpose was to obtain the reaction rate distribution during control rod insertion. With subphase D/1 and D/2, the radial reaction rate distribution was measured with the foils.

3. ZPPR Test Technology

The reactivity with ZPPR was measured by an inverse kinetic method [15] instead of a criticality method. Very small reactivities such as the reactivity values of materials, Doppler reactivity and Na void maps were measured by the oscillation method. The zone-void reactivity and the control rod values were measured by a corrected neutron source multiplying method [16, 17] with the use of 64 IFC installed inside the assemblies.

Reaction rate distributions were measured with irradiated foil and MFC. Gamma-ray heating was measured by TLD (thermoluminescent dosimeter) of

^7LiF and CaF_2:Mn, and the neutron spectra with a proton recoil counter.

The IFC and BTB are independently developed measuring technologies with ZPPR. The IFC is a fission counter designed for measuring pre-criticality systems which was constructed using a Na void tube. It is capable of being mounted without disturbing the original plate cell. The development of the IFC has made it possible to perform measurements with an accuracy of from 1.5 % to about 50 % pre-criticality by the corrected neutron source multiplying method without an inserted control rod pattern. The BTB is constructed of parallel-plate-type fission counters which are put together back to back, and it is capable of measuring the reaction rate of two types of nuclides at the same moment and location.

III. Status of Test Analyses

As far as the analysis of the ZPPR-9 and ZPPR-10 tests by the consistent methods (hereafter called a standard analysis) is concerned, the analysis of the former has been practically finished, and the analysis of the latter is now in progress. In conjunction with this, analyses* are also being performed at the Japan Atomic Energy Research Institute by an improved data processing method which uses group constants, and at Osaka University leakage is being evaluated using a unified diffusion coefficient [18]. Another type of analysis is also in progress at this university involving the calculation of control rod group constants, for which a new method has been applied.** Described below is primarily the status of the standard analysis.

1. Procedure of Standard Analysis

Based on experience gained through the MOZART program, the standard analysis is proceeding according to the following guideline.

(1) For efficiency of analytical operations and clarification of evaluating the justification for the nuclear calculation method, basic analytical

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methods are to be standardized for use by those researchers who are involved in the analyses.

(2) To minimize calculational errors and to trace the sources of problematic points, the analytical method must be specified in detail within the scope of a practical calculation method.

(3) In organizing the total analysis, its relationship to a design technique must be clarified.

Photograph 1.

ZPPR-10D at the time of assemblies separating in half.

2. Summary of the Standard Analytical Method

Figure 5 shows a basic analytical procedure. JENDL-2B was used as a nuclear data file, and the resonance data of compound nuclides, TIMS-1 [19] was used. All other nuclear data were processed by PROFGROUCH-G-11 [20], and a ABBN type [21] 70 group constants library* was created. A

*This was created at the Nuclear Data Center and distributed to different institutions.

70 group cell average effective group constant was obtained by one-dimensional cell calculation with the use of a SLAROM [22] code in the library. This was then compacted to 18 groups by 70-group one-dimensional diffusion calculation of SLAROM, and further compacted to 7 groups by rz diffusion calculation. As regards individual nuclear property values, those were obtained which are equivalent to the results of the three-dimensional calculation, in which the correction of the transport factor is taken into account.

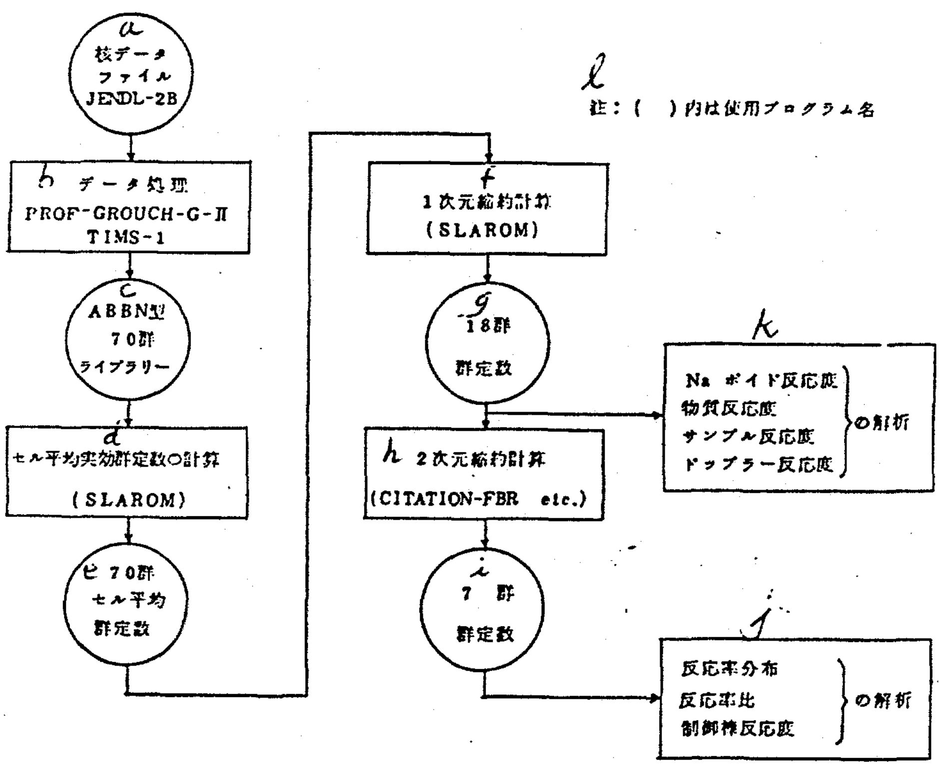

Figure 5. Flow of JUPITER test analysis.

Key:

a. nuclear data file JENDL-2B

b. data processing PROF-GROUCH-G-II, TIMS-1

c. ABBN type, 70 group library

d. calculation of cell average effective group constant (SLAROM)

e. 70 group cell average group constant

f. one-dimensional compacting calculation (SLAROM)

g. 18-group constant

(key to Figure 5 continued):

h. two-dimensional compacting calculation (CITATION-FBR, etc.)

i. 7-group constant

j. analyses of reaction rate distribution, reaction rate ratio, and control rod reactivity

k. analyses of Na void reactivity, material reactivity, sample reactivity, and Doppler reactivity

Note: program name is given in (   ).

3. Results of ZPPR-9 Standard Analysis

The major analytical results from ZPPR-9, along with those obtained in the U.S., are shown in Table 3. The analytical results of ZPPR-9 do not show large discrepancies with those obtained in the past, but they contain several elements which may become problematic in speculating about the properties of a large-scale reactor. Characteristic items of the analytical results are summarized in Table 4.

The analytical result of k_{eff}--which was greatly affected by the accuracy of the nuclear data, reaction rate ratios, and central sample reactivity--indicates that results obtained by JENDL-2B are acceptable at the present stage. However, much greater improvement in the accuracy of the JENDL nuclear data must be made, since problems cited in II-a), VII-b), and d) in Table 4 were all attributed to problems in calculating the neutron flux distributions. The larger the reactor core, the more this effect may tend to become prominent. Therefore, one of the important tasks to be carried out today is to find the cause of this problem.

Items IV-b) and VI-b) are problems related to the diffusion coefficient calculation method of drawer or fuel assemblies. Research underway at Osaka University [18] is expected to provide one promising contribution toward the solution of this problem since it focuses on the effect of surrounding drawers (or fuel assemblies).

a 特性量		b C/E*[2] 日本の解析結果	c 米国の解析結果*[3]
d 臨界性	k_{eff}	0.9930	0.9836
e 反応率比	$\sigma_f^{25}/\sigma_f^{49}$	1.03	1.03
	$\sigma_f^{28}/\sigma_f^{49}$	0.99	0.94
	$\sigma_c^{28}/\sigma_f^{49}$	1.06	1.09
f 反応率分布			
g 径方向分布(σ_f^{25})			
	h 内側炉心	1.008±0.017*[4]	1.009±0.016
	i 外側炉心	1.051±0.009	1.041±0.006
	j 径方向ブランケット	1.041±0.014	1.038±0.007
k 軸方向分布(σ_f^{28})			
	h 内側炉心	1.002±0.003	1.009±0.026
	l 軸方向ブランケット	0.75 ±0.21	0.73 ±0.21
m Na ボイド反応度*[1]			
n ゾーン・ボイド			
	o 中心項	1.22	1.06
	p もれの項	1.02	1.01
q 軸方向ボイド・マップ			
	o 中心項	1.2	1.1
	p もれの項	1.9	1.7
r 制御棒反応度	中心1本	0.907(0.913)*[5]	(0.992)
	s 内側リング6本	0.890(0.884)	(0.963)
	t 外側リング6本	0.985(0.965)	(1.002)
u CRP 反応度	中心1本	0.998(1.205)*[5]	(1.205)
	s 内側リング6本	1.046(1.254)	(1.229)
	t 外側リング6本	1.103(1.332)	(1.269)
v 中心サンプル w 反応度	^{239}Pu	1.05	1.15
	^{235}U	1.06	1.19
	^{238}U	1.15	1.17
	^{10}B	1.12	1.08
	Na	1.03*[6]	0.87*[6]
x ドップラー反応度 $\Delta k/kk'$			
	ΔT=300→ 650K	1.01	0.926
	ΔT=300→1,100K	1.06	0.935

Table 3. Major analytical results for ZPPR-9.

Key:

a. quantity of property
b. analysis results obtained in Japan
c. analysis results obtained in the U.S.*3
d. criticality
e. reaction rate ratio
f. reaction rate distribution
g. radial distribution
h. internal core
i. outer core
j. radial blanket
k. axial distribution
l. axial blanket
m. Na void reactivity*1
n. zone void
o. central term

(key for Table 3 continued):

p. term of leakage

q. axial void map

r. control rod reactivity, one rod in the center

s. 6 internal rings

t. 6 outer rings

u. CRP reactivity, one piece in the center

v. central sample

w. reactivity

x. Doppler reactivity

*1 C/E value of the void reactivity is the reciprocal numbers of a and b when a form z x (calculated value of central term) + b (calculated value of leakage) is matched with a test value.

*2 (calculated value)/(test value)

*3 Analysis by ENDF/B-IV

*4 value of reaction rate distribution of $\overline{(C/E)} \pm \sigma$

*5 control rod reactivity and the value in (   ) of CRP reactivity are the result of xv diffusion calculation at 1 mesh/drawer

*6 This is the analytical result of measuring the axial distribution and has a meaning only for the relative comparison between those obtained in Japan and the U.S.

Problems VII-c) and VIII-a) in Table 4 are considered to be attributed to the ABBN type group constant library creation method and to interpolation of the f-table. These matters may be clarified when results of analyses by the group constants derived from an improved data processing method now being done at the Japan Atomic Energy Institute are available.

At present, the cause of III-b) is not known. It is it related to a problem inherent to the testing system itself such as the effect of plate heterogeneity, this problem must be solved before any analytical result is applied to the design.

The analysis of gamma-ray heating, one of the test items of ZPPR-9, has not been started. To implement this analysis without delay, it is necessary to prepare a standard gamma-ray library in Japan as soon as possible.

Table 4. Specific items of analytical results for ZPPR-9

Property	Specific Items	Note
I. Criticality	a) Dependency of k_{eff} on C/E system is small [13,22]	To be confirmed by analyzing APPR-10
II. Reaction rate ratio	a) Overestimation of $\sigma_c^{28}/\sigma_f^{49}$	Greatly affect breeding and combustion property
III. Reaction rate	a) C/E increased toward outer core	Could be attributed to errors in calculating neutron distribution or to unique property of testing system
	b) Underestimation of σ_f^{28} reaction rate in axial blanket	
IV. Na void reactivity	a) Overestimation of ~20 % of central term in analysis made in Japan	Could be the property of JENDL-2B
	b) Overestimation of term of leakage in void map	Problem related to cell group constants
V. Control rod reactivity	a) Dependency of C/E upon space, especially prominent in analysis made in Japan	Could be the same reason as III-a)
VI. CRP reactivity	a) Same dependency of C/E on space as control rod reactivity	Could be the same cause as III-a) and V-a)
	b) Overestimation of ~20 % by diffusion approximation	Overestimation of axial neutron streaming; Error of -0.5 % $\Delta k/k$ affecting k_{eff}
VII. Central sample	a) U.S. results overestimated 10-20 % as before for fuel nuclides	Cause not known
	b) Japanese results greatly overestimated only ^{238}U among fuel nuclides	Could be the same reason as II-a) or overestimation of low energy neutron spectrum
	c) Japanese results indicated 12 % overestimation of ^{10}B; Tendency of being different from C/E of control rod reactivity	Could be caused by overestimation of low energy neutron spectrum
	d) Japanese result of Na is larger than that of U.S. 20 %; Similar tendency to void reactivity	Same cause as IV-a)
VIII. Doppler reactivity	a) Japanese analysis showed tendency of C/E on temperature	Could be interpolation error of f-table

IV. Future Plan

1. Evaluation of JUPITER Phase I

The analytical operations of ZPPR-10 now in progress are to be completed in the future and the analytical results of ZPPR-10 obtained in the U.S. and in Japan are to be compared at the second JUPITER analysis conference scheduled to be held in the U.S. in the fall of 1981. Based on the results, comprehensive evaluation of the Phase I program with ZPPR-9 and ZPPR-10 is scheduled to be carried out. It is expected that the accuracy and problems of the present analytical method with respect to application to a large homogeneous reactor will be revealed. Plans are to examine the preliminary accuracy of a nuclear design method for a large-scale homogeneous reactor and to clarify directions for improving data methods.

2. JUPITER Phase II Plan

In addition to the conventional homogeneous reactor, the heterogeneous reactor is being considered by some nations, especially European nations for selection as a large-scale fast reactor since it has the advantages of low Na void reactivity and high breeding ratio. The CRBR (Clinch River Breeder Reactor) in the U.S. and the CDS reactor design of CDS are to involve, at this stage, heterogeneous reactors. In Japan, the heterogeneous reactor type is being considered as a substitute for the verification reactor conceptual design. With this background, both Japan and the U.S. are examining a plan to implement a large scale heterogeneous benchmark test in the future in conjunction with JUPITER Phase II involving joint Japanese and U.S. research.

V. Conclusions

At this stage the standard analysis of ZPPR-9 has been completed, and ZPPR-10 is being analyzed. As a whole, the analysis of ZPPR-9 has shown proper results. However, the results of the reaction rate distribution and the control rod reactivity indicate a problem in the calculational accuracy of the radial neutron flux distribution; this is believed to be a problem uniqùe to large-scale reactor. When ZPPR-10 is analyzed in the future, it is hoped that very valuable data will be obtained for applying the present calculational method to a large-scale reactor in such areas as the dependencies of a core upon sizes and of control rods upon the insertion condition.

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