IWGFR SPECIALISTS MEETING ON FLOW

INDUCED VIBRATIONS, 21–24 OCT 1986

DEVELOPMENT OF 3–D FLUID–STRUCTURE INTERACTION ANALYSIS CODE FOR FBR

150

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1. INTRODUCTION

PROTO TYPE FBR "MONJU" [FIG1.1, FIG1.2]

Reactor and internal components are axisymmetric structure.

Spring and mass model used to performe the seismic analysis of the reactor.

DEMONSTRATION POOL TYPE FBR [FIG1.3]

Reactor and some internal components–UIS, Core support structure –are axisymmetric structure. But intermediate heat exchanger (IHX) and primary pump are located unsymmetrically.

And, as the size of a vessel increases, the rigidity of the vessel tends to fall in comparison with its capacity.

Then to make a seismic response analysis it is necessary to consider the flexibility of vessel side wall because the natural frequency the vessel including the liquids becomes low.

Spring and mass models does not consider the effect of unsymmetrically located structure and large vessel with thin wall.

And we developed 3–D (2–D) fluid–structure interaction analysis program.

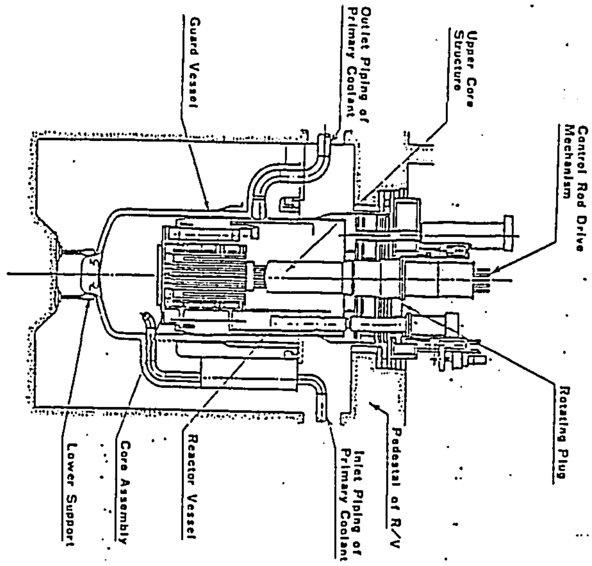

FIG1.1 SCHEMATIC VIEW OF PROTO TYPE REACTOR

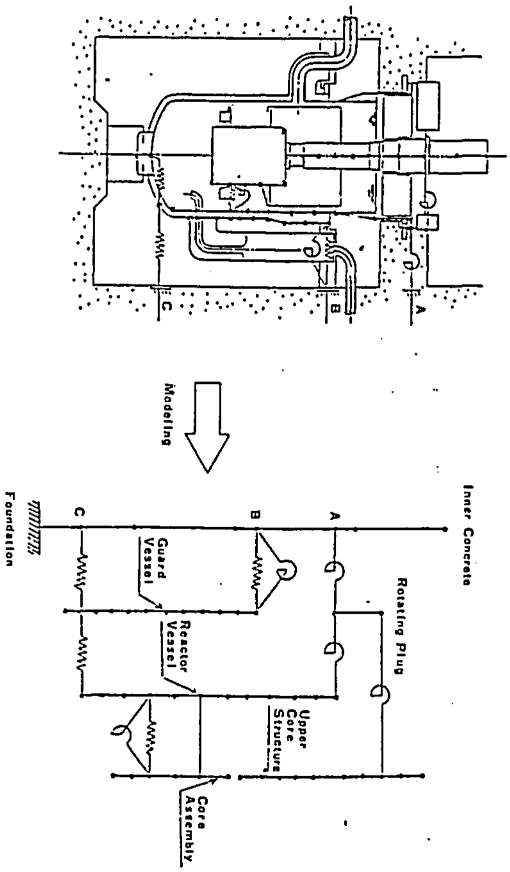

FIG1.2 SEISMIC ANALYSIS MODELISATION

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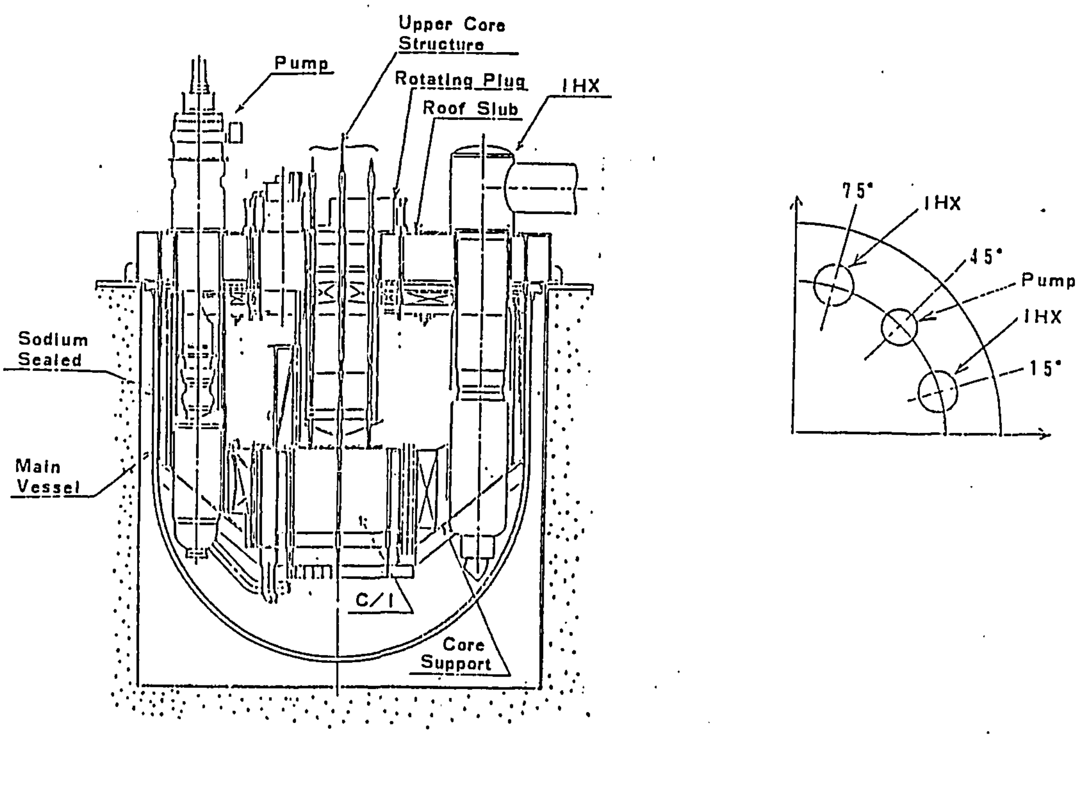


FIG1.3 LMFBR REACTOR STRUCTURE (POOL TYPE)

151

BASIC EQUATION

1. Fluid−Structure interaction method

$$\begin{bmatrix} M_L & \rho S^T \\ 0 & M_S \end{bmatrix} \begin{Bmatrix} \ddot{P} \\ \ddot{X} \end{Bmatrix} + \begin{bmatrix} K_L & 0 \\ -S & K_S \end{bmatrix} \begin{Bmatrix} P \\ X \end{Bmatrix} = \begin{Bmatrix} 0 \\ F \end{Bmatrix}$$

- $[M_L]$: Equivalent mass matrix of the liquid
- $[M_S]$: Equivalent mass matrix of the structure
- $[K_L]$: Equivalent stiffeness matrix of the liquid
- $[K_S]$: Stiffeness matrix of structure
- $[S]$: Coupled matrix between the fluid and the structure
- $[P]$: Pressure vector of the liquid
- $[X]$: Displacement vector of the structure
- $[F]$: Load vector

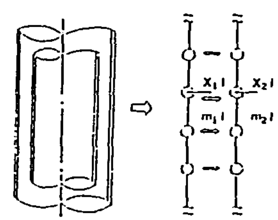
2. Double cylinder

$$([m]+[Mv]) \begin{Bmatrix} \ddot{X}_1+\ddot{Z} \\ \ddot{X}_2+\ddot{Z} \end{Bmatrix} + [K] \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix} = 0$$

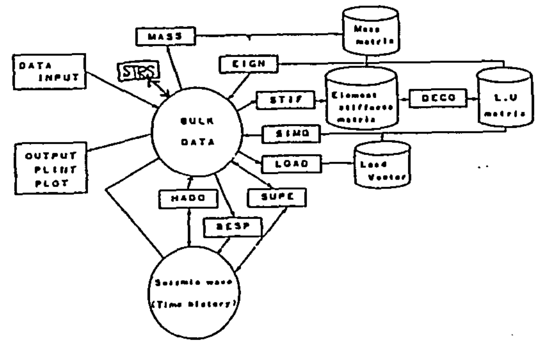
$$[m] = \begin{bmatrix} [m_1] & 0 \\ 0 & [m_2] \end{bmatrix}$$

$$[Mv] = \begin{bmatrix} [M_0+M_H], -[M_1+M_H+M_3] \\ [M_1+M_H], -[M_1+M_2+M_H+M_3] \end{bmatrix}$$

- m_1 ; m_2 : Mass matrix
- $[K]$: Stiffness matrix
- $[\ddot{Z}]$: Seismic acceleration
- $[M]$: Effective mass of liquid



Double cylinder (with fluid) ⇨ Analysis Model



Kinds of Analysis

1. Static Analysis
2. Eigen value Analysis
3. Modal response Analysis
4. Frequency response Analysis

FIG3.1 3−D CODE STRUCTURE AND THE KINDS OF ANALYSIS.

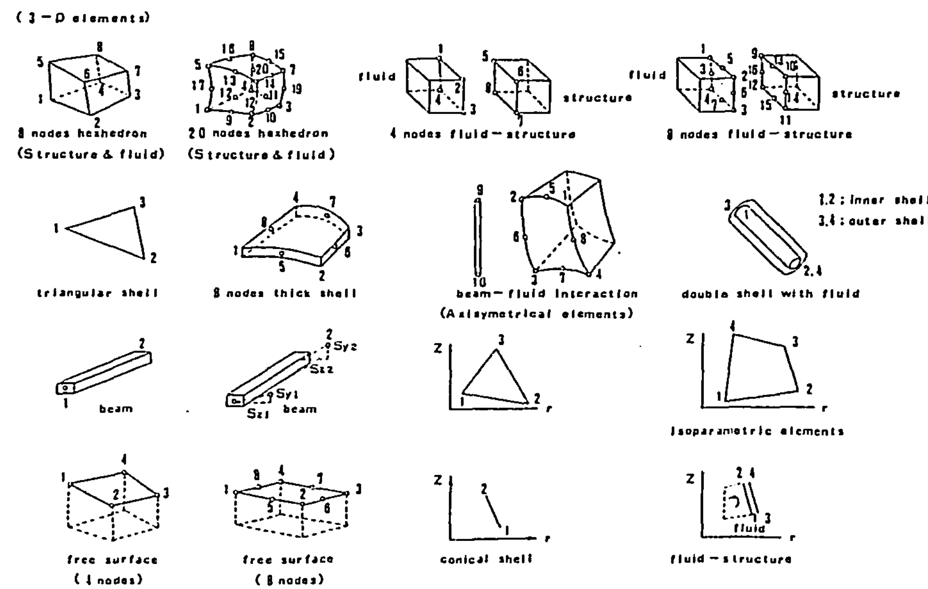
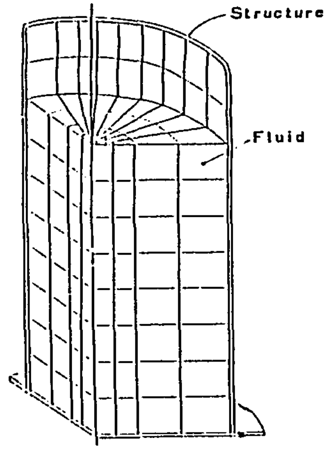
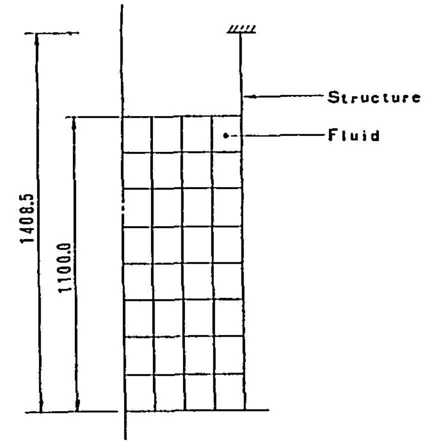


FIG3.2 MAIN ELEMENTS OF THE FLUID STRUCTURE INTERACTION CODE

153



Fluid and structure
3-D MODEL



2-D (Axisymetric) model

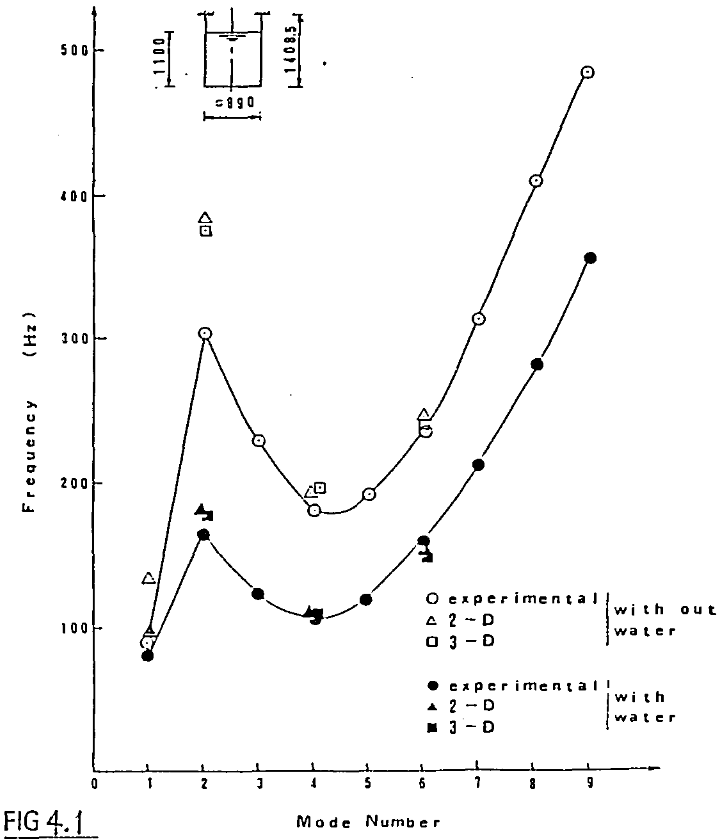
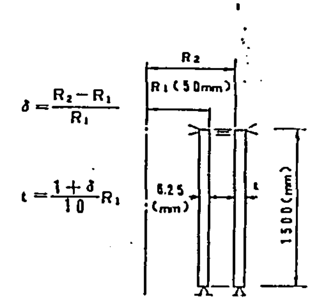


FIG 4.1

NODE NUMBER (CIRCUMFERENCIAL) VS FIREQUENCY
(SIMPLE CYLINDER)



	Diameter (cm)	Thickness (cm)	Length (m)	E (GP)	Density (kg/m³)
Inner cylinder	5 (=R_1)	6.25	1.5	193	7.475×10^3
Outer cylinder	$(1+\delta) R_1$	$\frac{(1+\delta)}{10} R_1$	1.5	193	7.475×10^3

FIG 4.2 (a) DOUBLE SHELL CALCULATION INPUT DATUM
(YEH AND CHEN'S SAMPLE : REF[3])

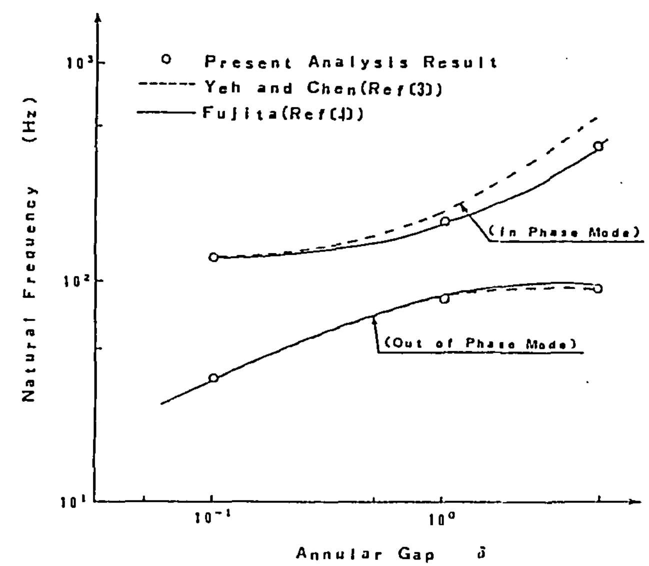
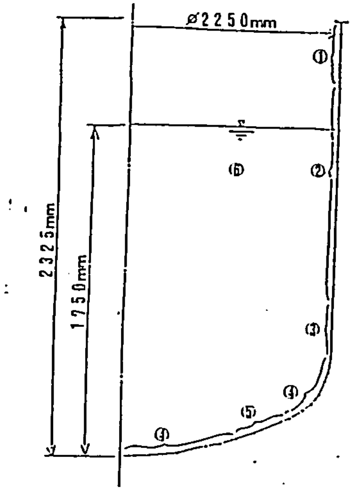
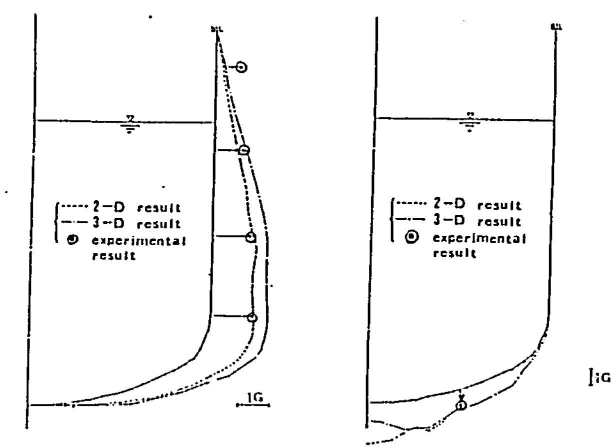


FIG 4.2 (b) COMPARISON OF NATURAL FREQUENCY (DOUBLE CYLINDER)



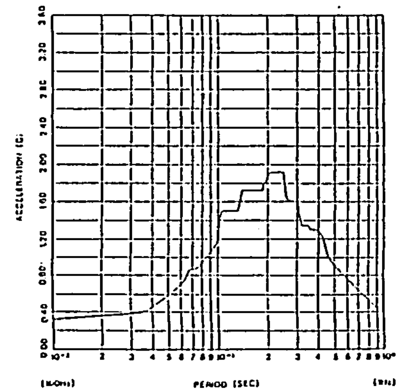
	Thickness (mm)	E (kgf/mm^2)	Density ($kgf \cdot s^2/mm^3$)	Poisson's ratio
①	4.0	0.72E-4	2.75E-10	0.33
②	3.0	↑	↑	↑
③	43.0	↑	↑	↑
④	6.0	↑	↑	↑
⑤	36.0	↑	↑	↑
⑥			1.02E-10	

FIG 4.3[a] PARAMETERS OF ANALYSIS MODEL (VESSEL)



(Horizontal direction) (Vertical direction)

FIG 4.3[b] DISTRIBATION OF ACCELERATION
(RESPONSE ANALYSIS & EXPERIMENTAL RESULTS)



FLOOR RESPONSE SPECTRUM

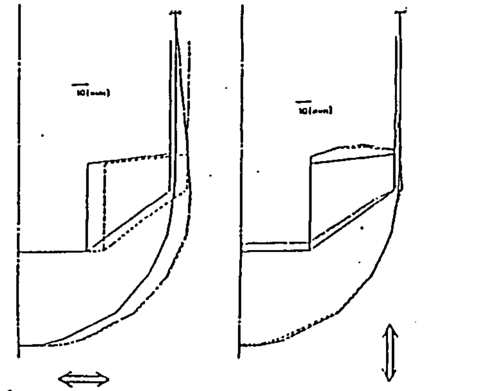
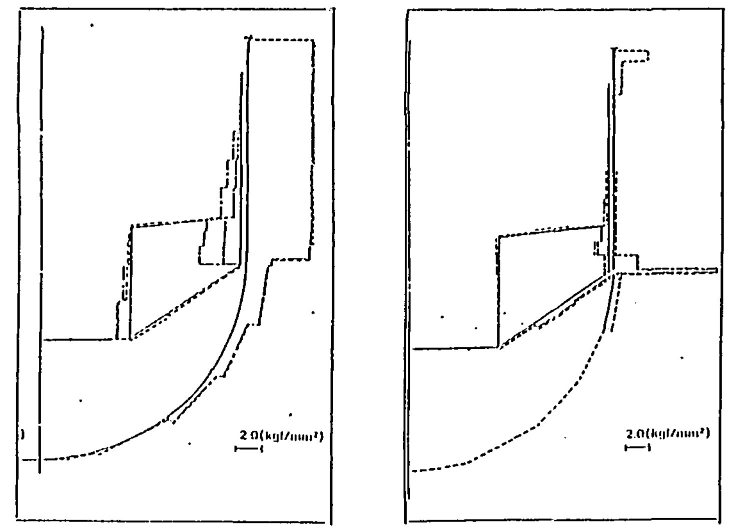


FIG 5.1 (a)
DEFORMATION BY SEISMIC RESPONSE ACCELERATION (WITH INNER STRUCTURE)



(Shear) (Bending)

FIG 5.1(b)
STRESS DISTRIBUTION BY SEISMIC RESPONSE ACCELERATION
(WITH INNER STRCTURE)

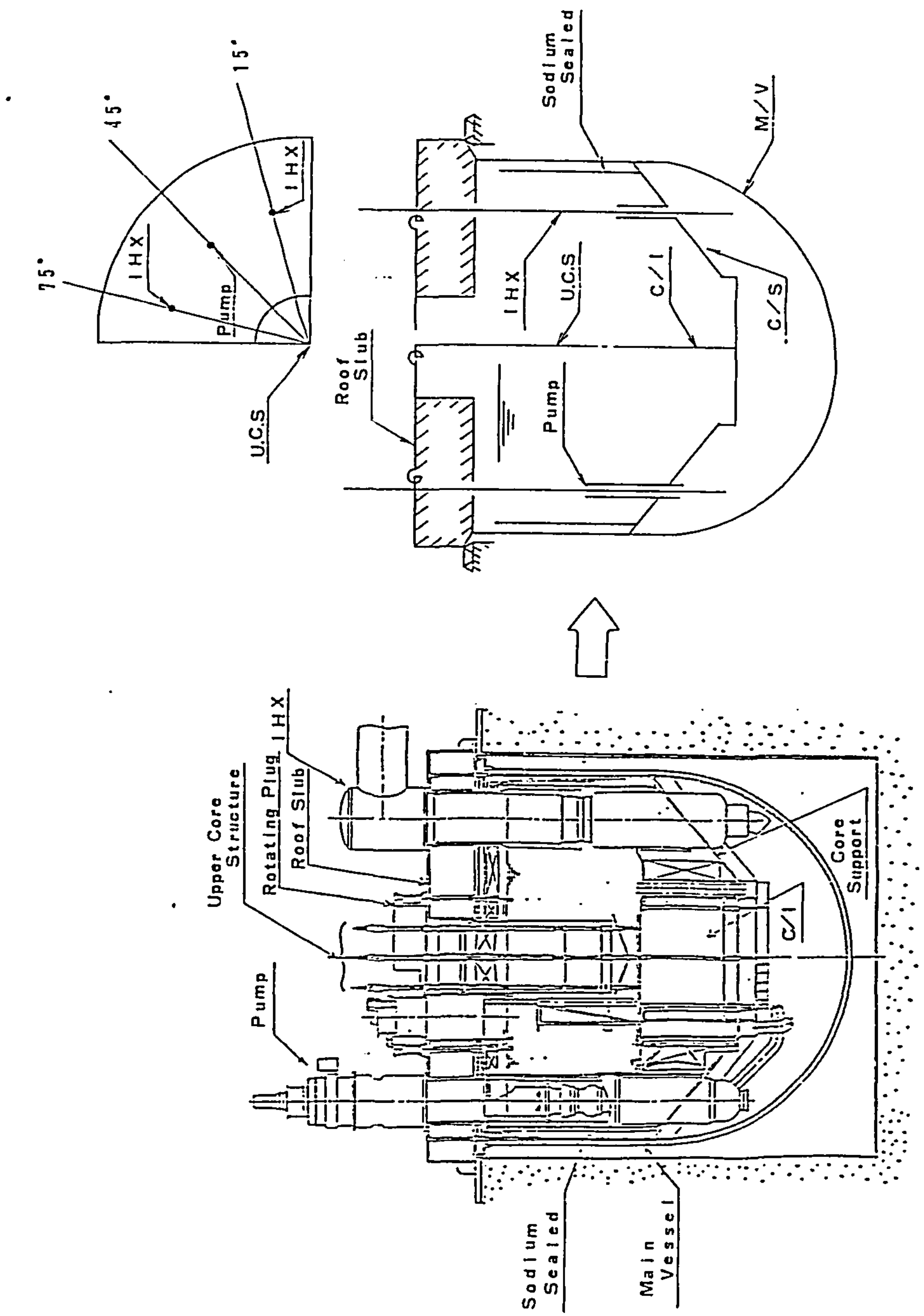


FIG6.1 REACTOR MODELISATION (COMPLETE MODEL)

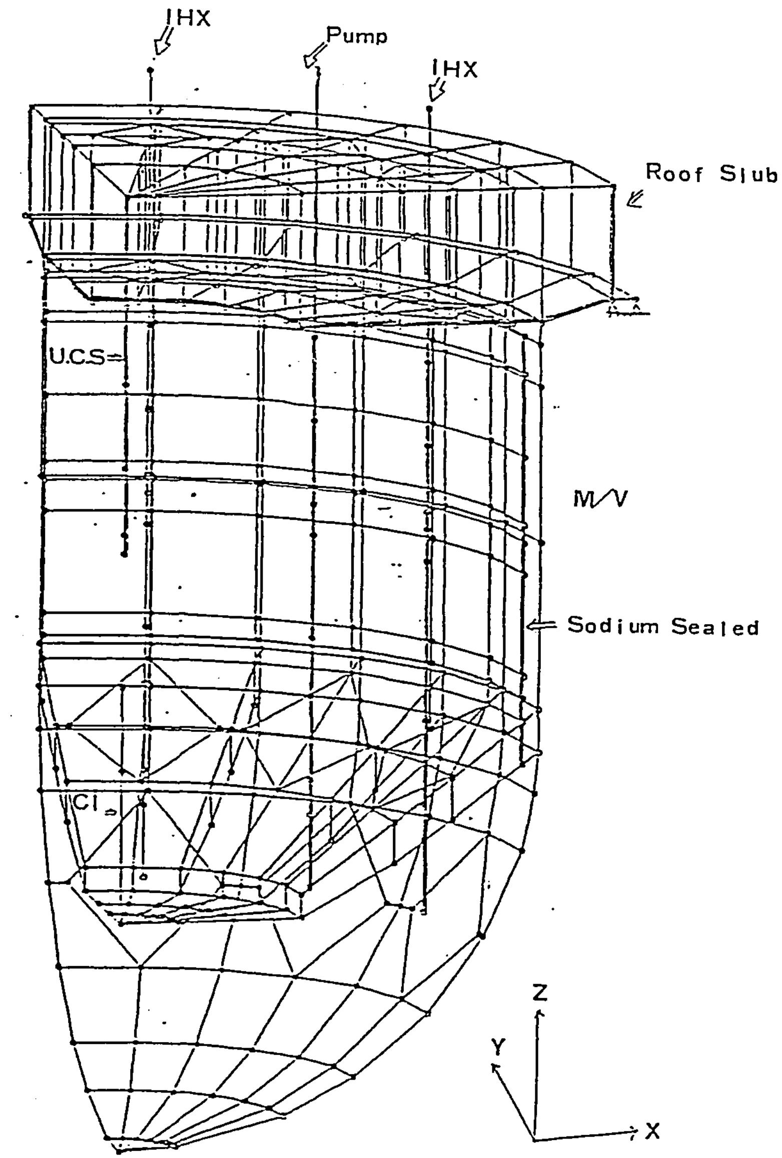


FIG6.2 ANALYSIS MODEL OF STRUCTURE (COMPLETE MODEL)

156

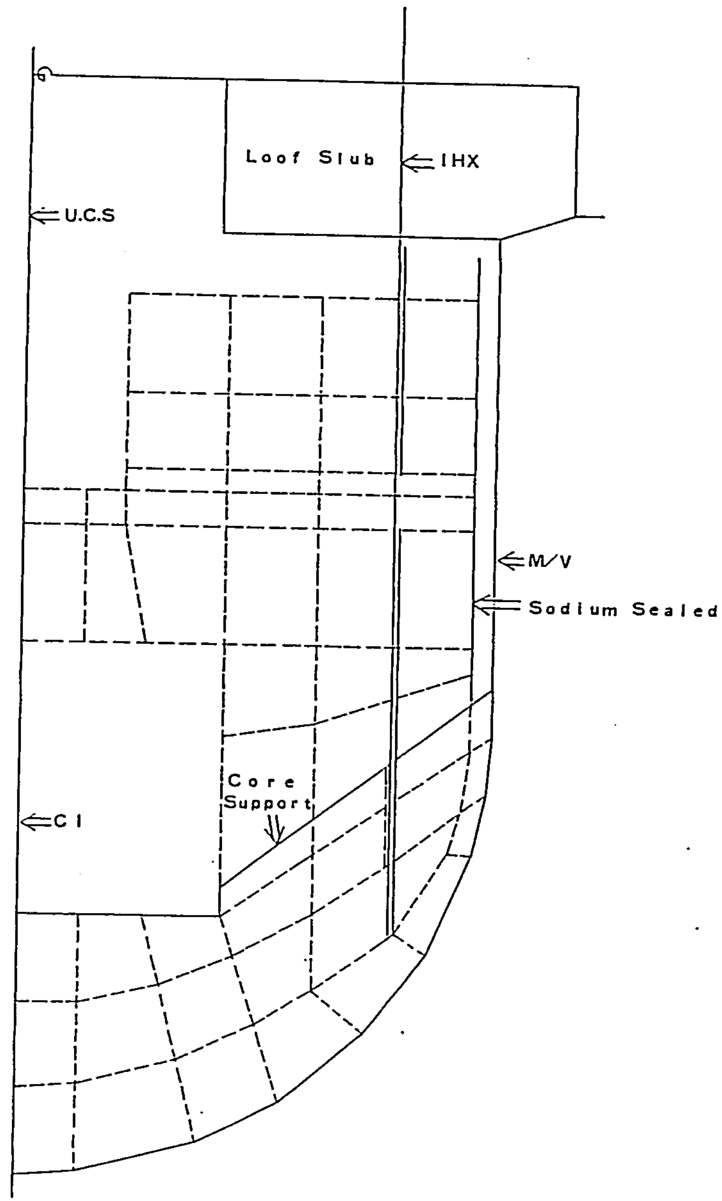


FIG6.3 CROSS SECTION OF FLUID MODEL (COMPLETE MODEL)
(15' OR 75' : IHX'S PLANE)

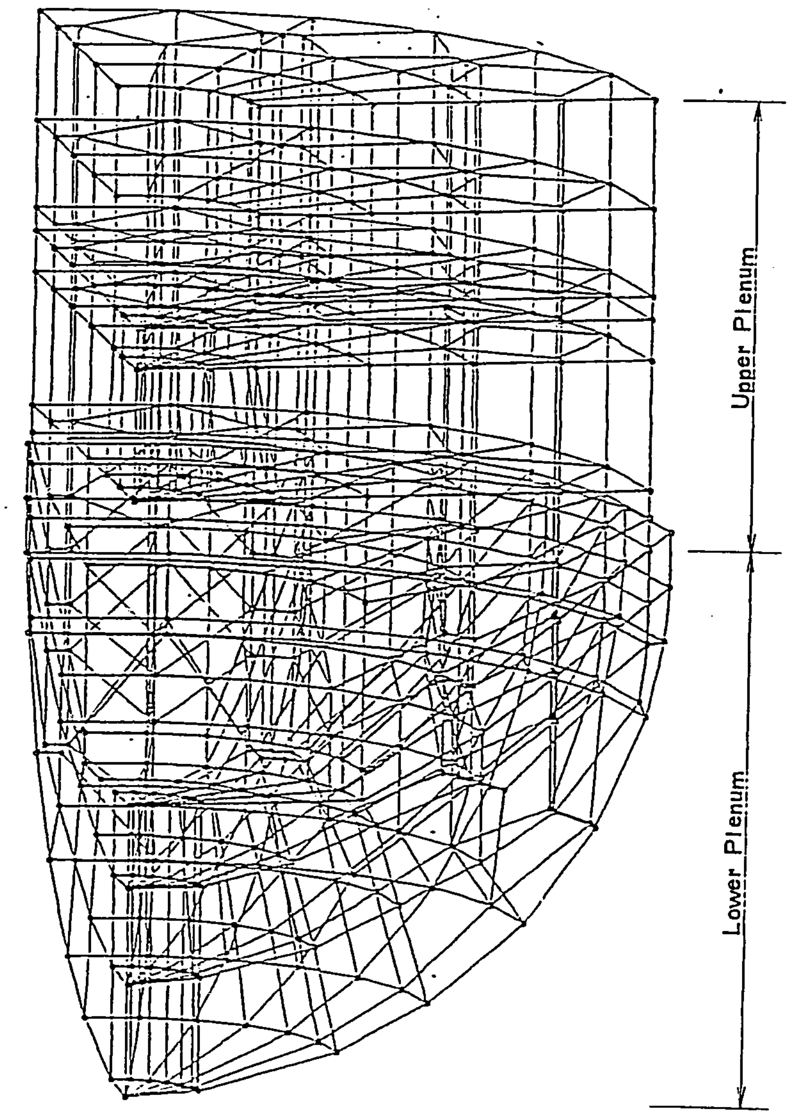


FIG6.4 ANALYSIS MODEL OF FLUID
(COMPLETE MODEL)

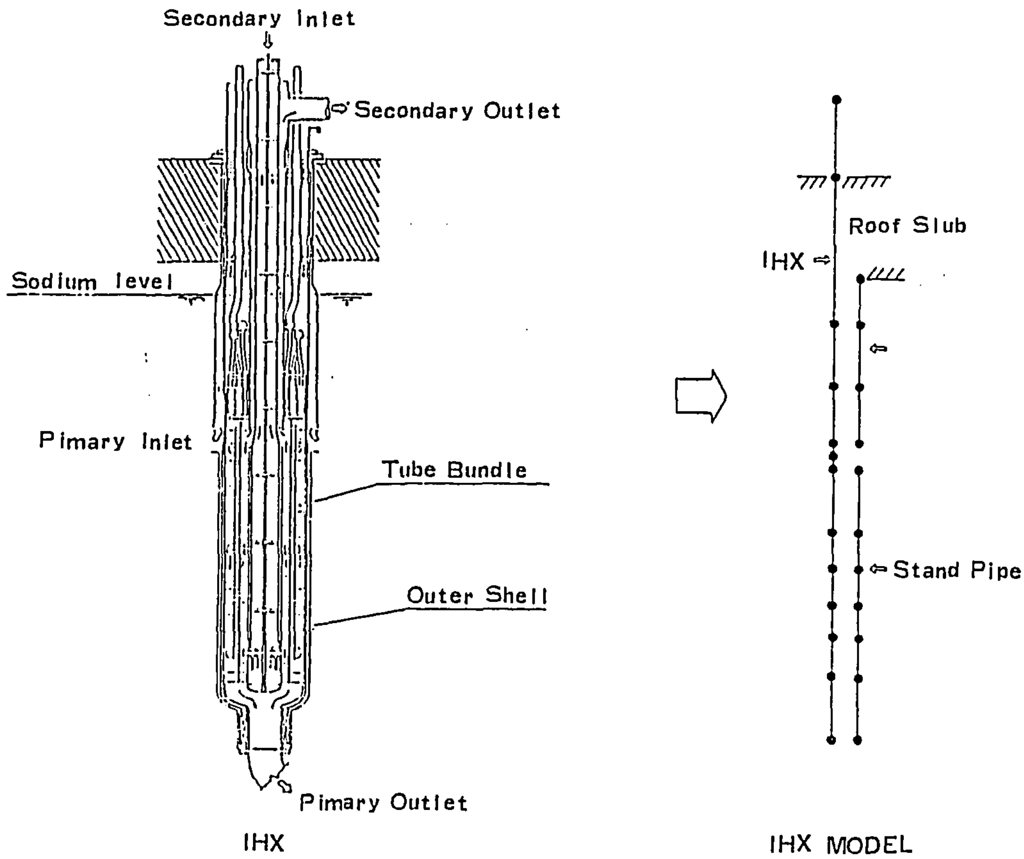


FIG6.5 ANALYSIS MODEL OF IHX

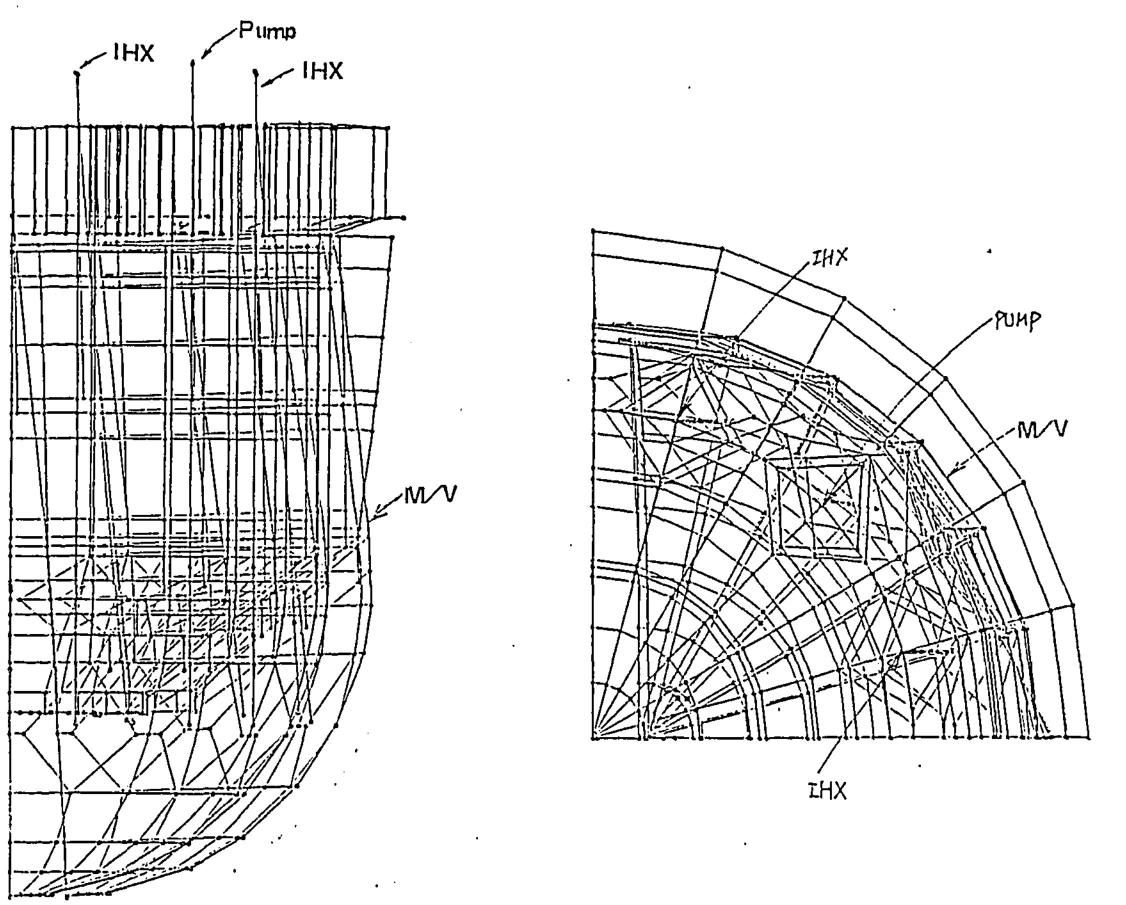


FIG6.6 MAIN VESSEL (N=1) ~~MODEL~~ : f=5.36Hz (COMPLETE MODEL)

7. CONCLUSION

The 3−D code analysis method and its application to the simple structure are presented. The caluculated result by this 3−D ~~wele~~ code and experimental result are in good agreement.

The caluculation of the whole reactor structure is in progress.

And the next plan is as follows.

- Complex structure experiment and analysis by this code.
- Development of this code, (computing time reduction, pre−post processing software)

References

〔1〕 K. FUJITA, T. ITO, M. MORISHITA et al., Nuclear Engineering and Design 83 (1984) 47−61

〔2〕 G. W. Housner, Bull. Seismol. Soc, Am. 47, No1 (1957−1) 15

〔3〕 Yeh. T. T. and Chen S. S, Sound Vibration 59−3 (1978) , P453

〔4〕 K. FUJITA, JSME C−51−466 P1170~1179