A STUDY OF PASSIVE SAFETY CONDITIONS FOR FAST REACTOR CORE

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INTRODUCTION

A study has been made for passive safety conditions of fast reactor cores. Objective of the study is to develope a concept of a core with passive safety as well as a simple safety philosophy. A simple safety philosophy, which is more easy to explain to the public, is needed to enhance the public acceptance for nuclear reactors.

The present paper describes a conceptual plan of the study including the definition of the problem ,a method of approach and identification of tasks to be solved.

METHOD OF APPROACH

Objecive of Study

The objectives of the study are

(1) to develope a fast reactor core , which is safe against ATWS (anticipated transient without scram),

(2) to develope a simple safety philosophy, that can be stated as " the safety of the recator is assured by inherent characteristics of the core , which never fails to act."

Method of Approach

We apply a synthetical method, which is suitable to clarify the overall trends and the macroscopic characteristics of passive safety. The synthetic approach is made as follows (Fig. 1):

(1) Select a small number of parameters as representatives of the passive safety characteristis of core systems,

(2) Define conditions for passive safety quantitatively in terms of the representative parameters ,

(3) Search for cores to meet the conditions.

CONDITIONS FOR PASSIVE SAFETY

The conditions required for passive safety should be defined quantitatively in terms of key parameters.

This work consists of the following tasks :

(1) Define passive safety,

(2) Define safety limits quantitatively,

(3) Define conditions for passive safety in terms of key parameters.

The tasks are described with an example of solutions in Table 1 and 2. The examples in the table are not our final solution, but are described as a help to understand the tasks.

Definition of Pasive Safety

" Pasive safety" must be defined.

Example of definition is :

" transient state is less than a limit without scram."

Definition of Limits

Limits must be defined quantitatively. They include a limit for the maximum state, a limit for the asymptotic state and an allowable duration for the asymptotic state.

The limit for the maximum state is defined so that fuel rapture and coolant boiling do not occur. It is a matter of discussion whether a local fuel rapture due to a lacal power peaking and a local sub-channel coolant boiling are accepted or not.

The limit and allowable duration of the asymptotic state are defined so that the integrity of the coolant boundary is assured.

It is to be noted that the passive safety requires an ultimate shutdown system.

Definition of Conditions for Passive Safety

Conditions required for passive safety should be defined quantitatively in terms of key parameters .

It is a matter of discussion whether is the transient state to be evaluated in the DBE(design base event) or not. If we consider the probability of its occurence ,ATWS shoud be the BDBE (beyond design base event). However, a simple safety phylosophy can be developed if we can treat ATWS as DBE.

Selection of key parameters is of primary importance to the present method of approach. Selection will be made based on trial analysis. Candidates for key parameters are reactivity coeficcients, linear heat

rate and the halving time of the primary pump.

SEARCH FOR CORES WITH PASSIVE SAFETY

The search for cores to meet the conditions consists of the following tasks :

(1) Survey for inherent reactivity

(2) Develop passive reactivity control system

(3) Develop a concept of core with passive safety

(4) Safety evaluations

Tasks are described with some example of solutions in Table 3 and 4.

Survey for Inherent Reactivity

Survey calculatios for reactivity coefficients as functions of the composition and the configuration of cores are planned. The survey calculations cover a wide range of the core composition and configuration as shown in Table 3.

A simplified method of nuclear calculations should be developed to make a large amount of calculations.

A data base will be formed based on the results of calculations.

Evaluation of uncertainty in nuclear calculations is necessary.

Reactivity due to thermal expansion and bowing of core compornents plays impotant role to attain passive safety, and should be evaluated carefully.

Passive Reactivity Control System

Passive reactivity control system, such as gas expansion model, control rod drive with enhanced thermal expansion, has been proposed.

Reliability of such passive systems is subject to study.

Development of Core

A core with passive safety may be developed by combining inherent reactivity with passive reactivity control system.

REFERECES

1. T.Ikegami etal : " A study of enhanced safety fast reactor core concepts using mixed oxide fuels" ,Proc. of International Conference on Fast Reactors and Related Fuel Cycles, Kyoto Japan (1991).

OHP-1

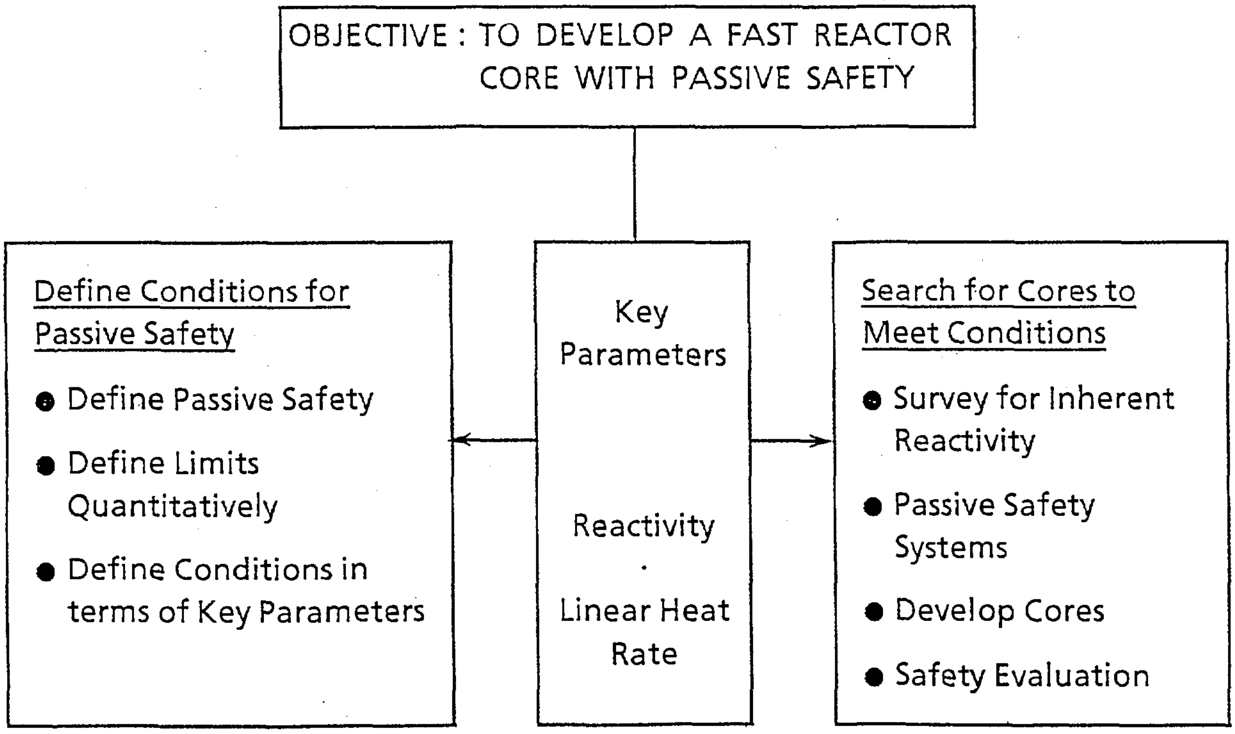
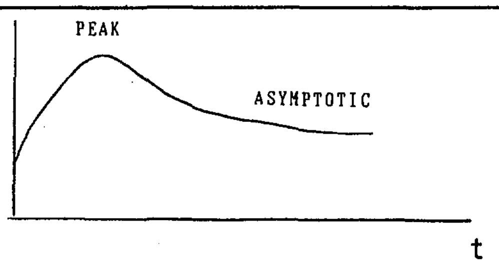


Fig. 1 A Synthetic Approach

OHP-2

Table 1 Conditions for Passive Safety-1

T A S K	E X A M P L E
<u>Conditions for Passive Safety</u> 1. Define Passive Safety ○ Definition is multi level 2. Define Limits Quantitatively ○ Limit for maximum state ○ Limit for asymptotic state ○ Allowable duration for asymptotic state	SYSTEM VARIABLE (POWER · TEMP.)  Transient state is less than limit without scram ○ no coolant boiling ○ fuel pin center melting ≦ 25% ○ coolant temp.≦ 650℃ ○ 1 hour require ultimate shutdown system

OHP-3

Table 2 Conditions for Passive Safety-2

T A S K	E X A M P L E
Conditions for Passive Safety	
3. Define Conditions in Terms of Key Parameters	
○ DBE or BDBE	DBE
○ Selection of Key Parameters	Feedback reactivity, linear heat rate
○ Method of Analysis	Flow coast-down characteristics
(1) Parametric Survey by Kinetics Calculations	Model ○ Kinetics ○ Thermal··· ← Set key parameters; → transient state → judgment
(2) Inverse Method	Model ○ Kinetics ○ Thermal··· ← Set transient state to meet the condition; → Key parameters to meet the condition

OHP-4

Table 3 Search for Cores with Passive Safety-1

T A S K	E X A M P L E
Search for Cores	
1. Survey for Inherent Reactivity	
1) Survey for Nuclear Characteristics	
○ Core Composition, Configuration	fuel system: U-pu, Th-U
○ Simplified Method for Nuclear Calculations	fuel material: MOX, Metal, Carbide, Nitride, Liquid Metal
○ Data Base of Reactivity Coefficients	Coolant: Na, Lead, He Moderator: Be, Graphite
○ Evaluation of Uncertainty	Core Configuration: Cylinder, Modular, Annulus, Axially double layered
2) Evaluation of Reactivity	
○ Expansion, Bowing	
fuel sub-assembly bowing expansion of CRD drive line expansion of RV	negative feedback due to fuel subassembly bowing

OHP-5

Table 4 Search for Cores with Passive Safety-2

T A S K	E X A M P L E
Search for Cores	
2. Passive Reactivity Control System	
○ Use of Core Components Expansion	Enhanced thermal expansion of CRD Bottom Supported RV
○ Use of Coolant Flow Change	Gas Expansion Model
○ Reliability of Passive System	
3. Development of Core	Is a core with passive safety developed by MOX?
4. Safety Evaluation	

OHP-6

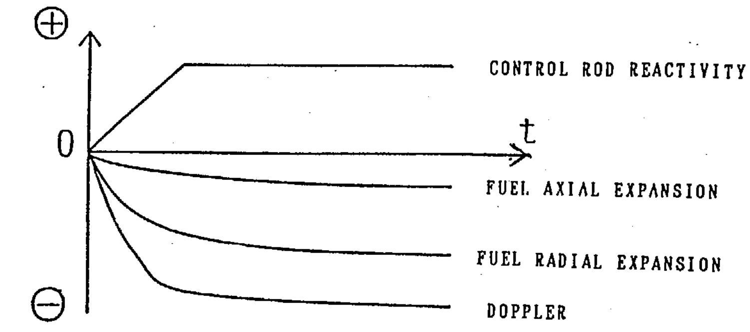
Example of Conditions for Passive Safety

H. Hayashi et al.: Proceedings of 1991 Annual Meeting of the Atomic Energy Society of Japan, B14 (1991).

Reactor: Large FBR with MOX Fuel

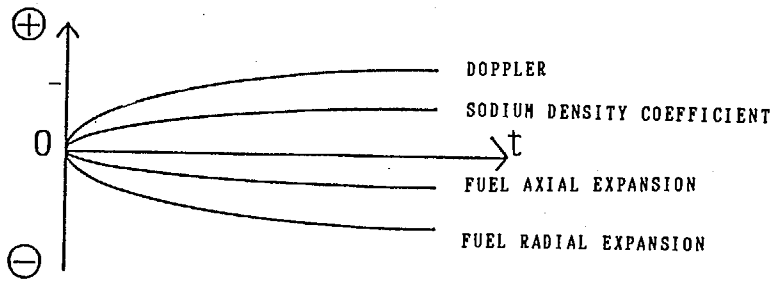
	Condition 1	Condition 2
○ Limits for maximum state	○ no bulk coolant boiling ○ fuel pin center melting less than 25%	○ no subchannel coolant boiling ○ fuel pin center melting less than 25%
○ Limit for asymptotic state	○ coolant temperature ≦ 750℃	○ coolant temperature ≦ 650℃
○ System Parameters		
● Halving time of the primary pump	5~10 sec	30 sec
● Pony motor flow	10%	10%
● Heat removal at equilibrium state	natural circulation	natural circulation

UTOP

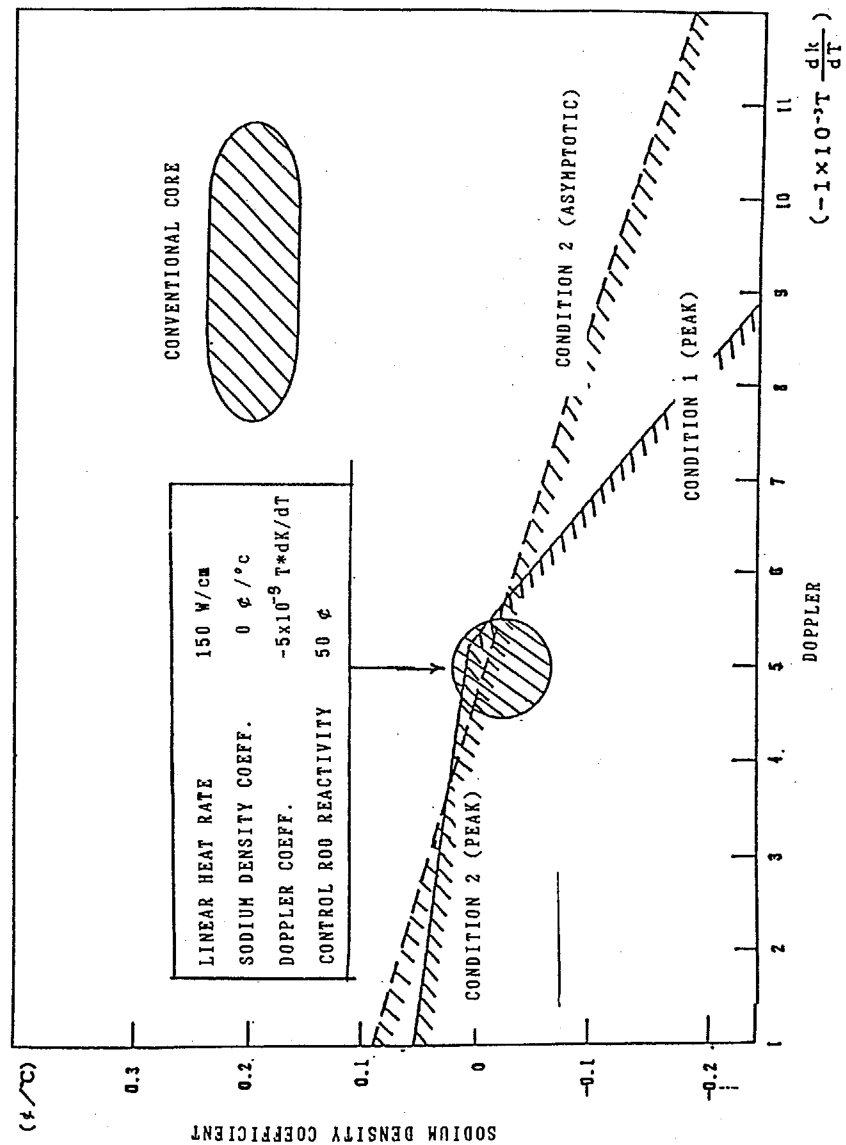


- REDUCE CONTROLL ROD REACTIVITY
- REDUCE LINEAR HEAT RATE

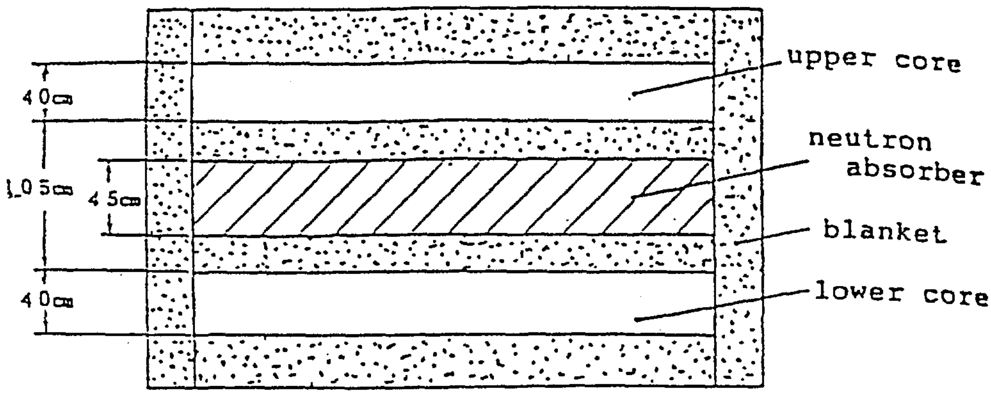
ULOF



- REDUCE DOPPLER COEFF.
- REDUCE SODIUM DENSITY COEFF.
- REDUCE LINEAR HEAT RATE



CONDITIONS FOR PASSIVE SAFETY CORE



thermal output	2,600 MWt	core height	40/40cm
core diameter	442 cm	assembly pitch	154.5mm
average linear heat rating	150 W/cm	assembly length	530cm

AXIALLY DOUBLE LAYERED CORE