Loss of Coolant Accident Analysis (Thermal Hydraulic Analysis) -Japanese Industries Experience-

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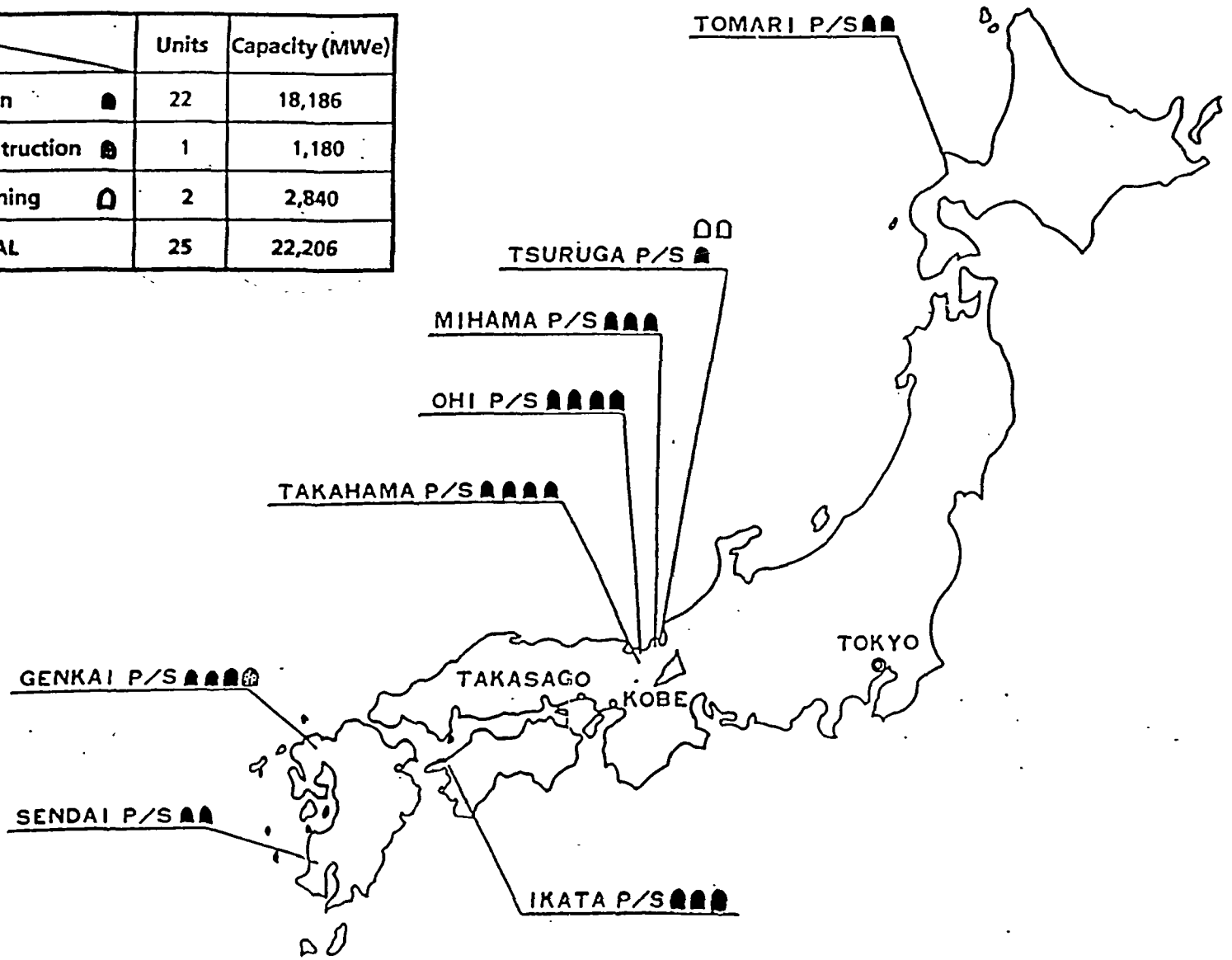
and Thermal Hydraulic Behavior in Accident Conditions
7-9 November 1995 , Sofia

	Units	Capacity (MWe)
In Operation	22	18,186
Under Construction	1	1,180
Under Planning	2	2,840
TOTAL	25	22,206



Status of PWR plants in Japan

Overview of Loss of Coolant Accident Analysis in Japanese Industries

1970s' ○Introduction of computer programs from U.S

1980s' ○These programs are well verified and improved through safety researches of Japan

○Some programs are originally developed

○Application to the operational safety area

1990s' ○Computer programs are utilized in proposals of new PWR safety design concepts

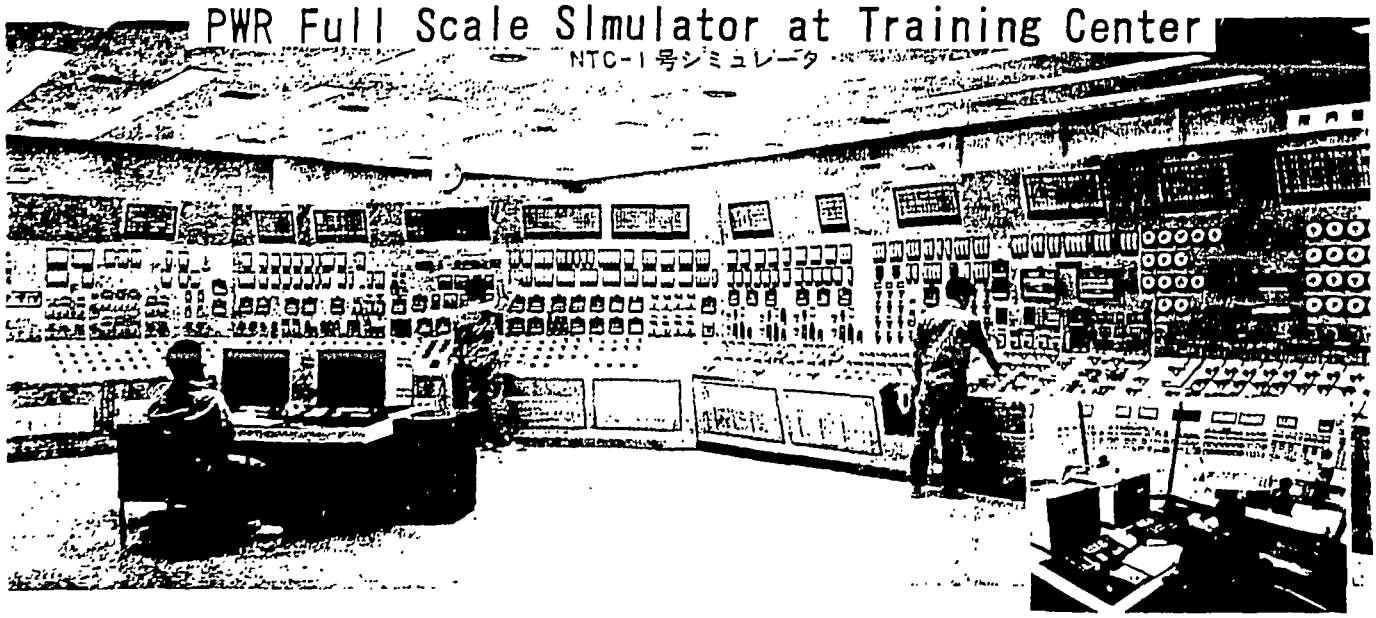
○Further improvement of computational technique

Examples of Application to the operational safety area

- 1D drift flux model base computer program (CANAC) was developed by Mitsubishi
- Advanced trainning simulater based on CANAC and other programs was developed
  It can simulate well PWR behavior in accident conditions and widely used for the education and trainnings of PWR operators
- Emergency operating procedures were also developed based on the thermal -hydraulic analysis capabilities

PWR Full Scale Simulator at Training Center

NTC-1号シミュレータ



インストラクタ室

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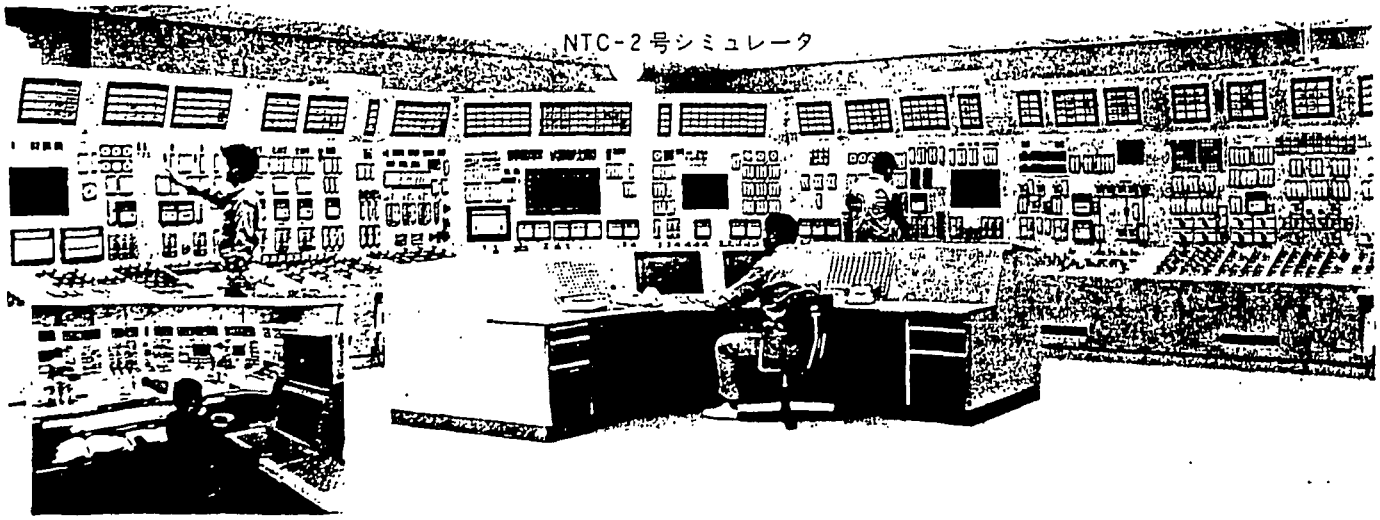

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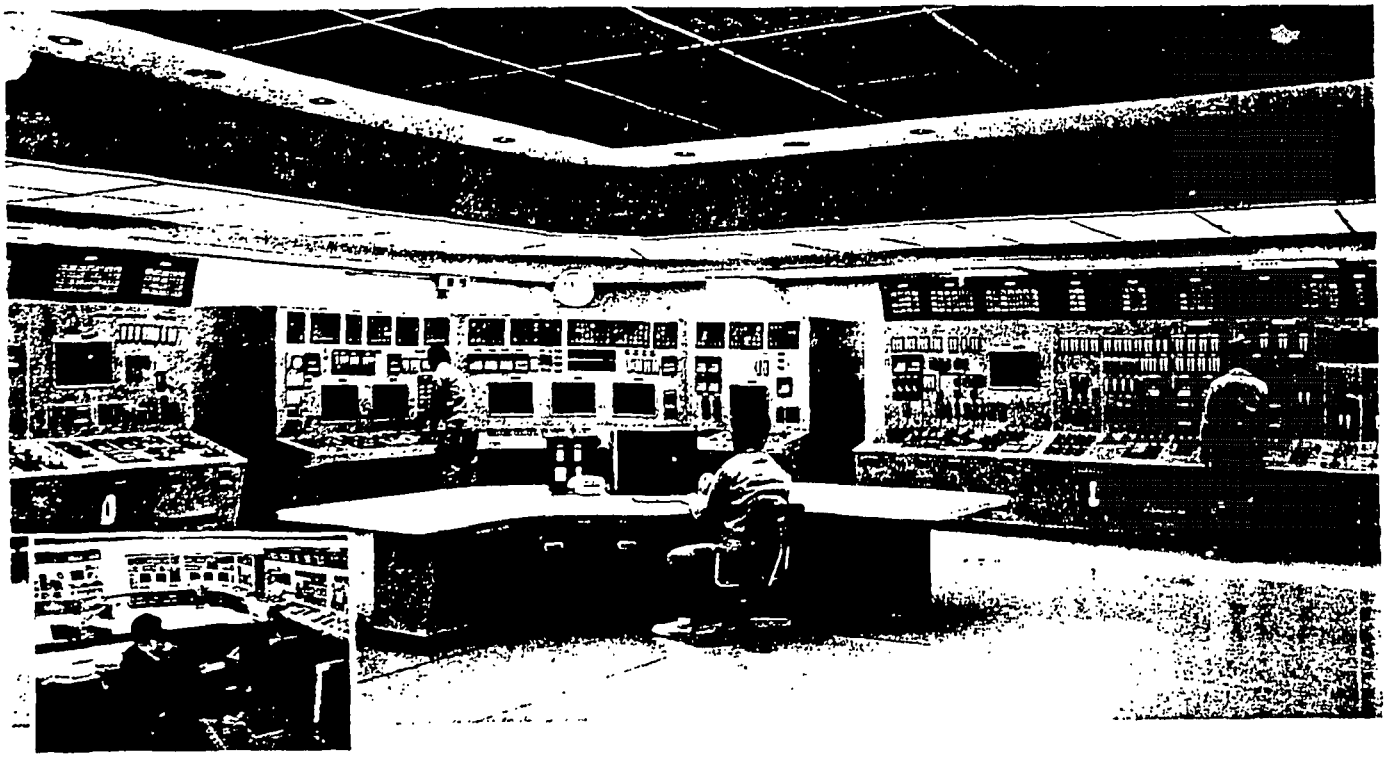

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III. LOCA ANALYSIS WITH COMPUTER CODES

EVALUATION-MODEL (EM) CODES

- CONSERVATIVE, SIMPLIFIED MODELS.
- ACCEPTED FOR DESIGN ASSESSMENT AGAINST DESIGN-BASIS SCENARIOS.
- CONSERVATISM NOT ENSURED FOR ALL POSSIBLE SITUATIONS.
- DO NOT PROVIDE BASIS FOR OPERATOR ACTIONS.

BEST-ESTIMATE (BE) CODES

- MORE REALISTIC, PHYSICALLY-BASED MODELS.
- APPLIED TO BEYOND-DESIGN-BASIS SCENARIOS.
- NEED CAREFUL ASSESSMENT & UNCERTAINTY EVALUATION.
- YET USER SENSITIVE - NEED QUALIFIED USER.

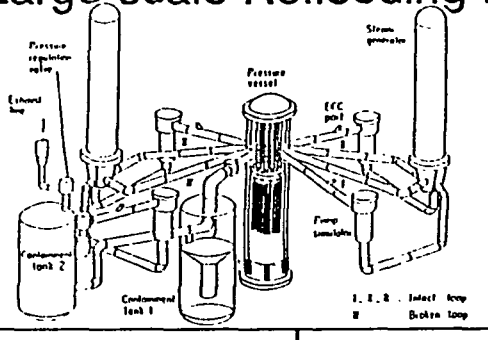
Example of verification and Improvement of U.S Computer programs

BASH

- developed by westinghouse for reflooding analysis at large break LOCA of PWR
- 1D/non-equilibrium two phase flow and quench front propagation are modeled

JAERI

- Large scale Reflooding Experiment

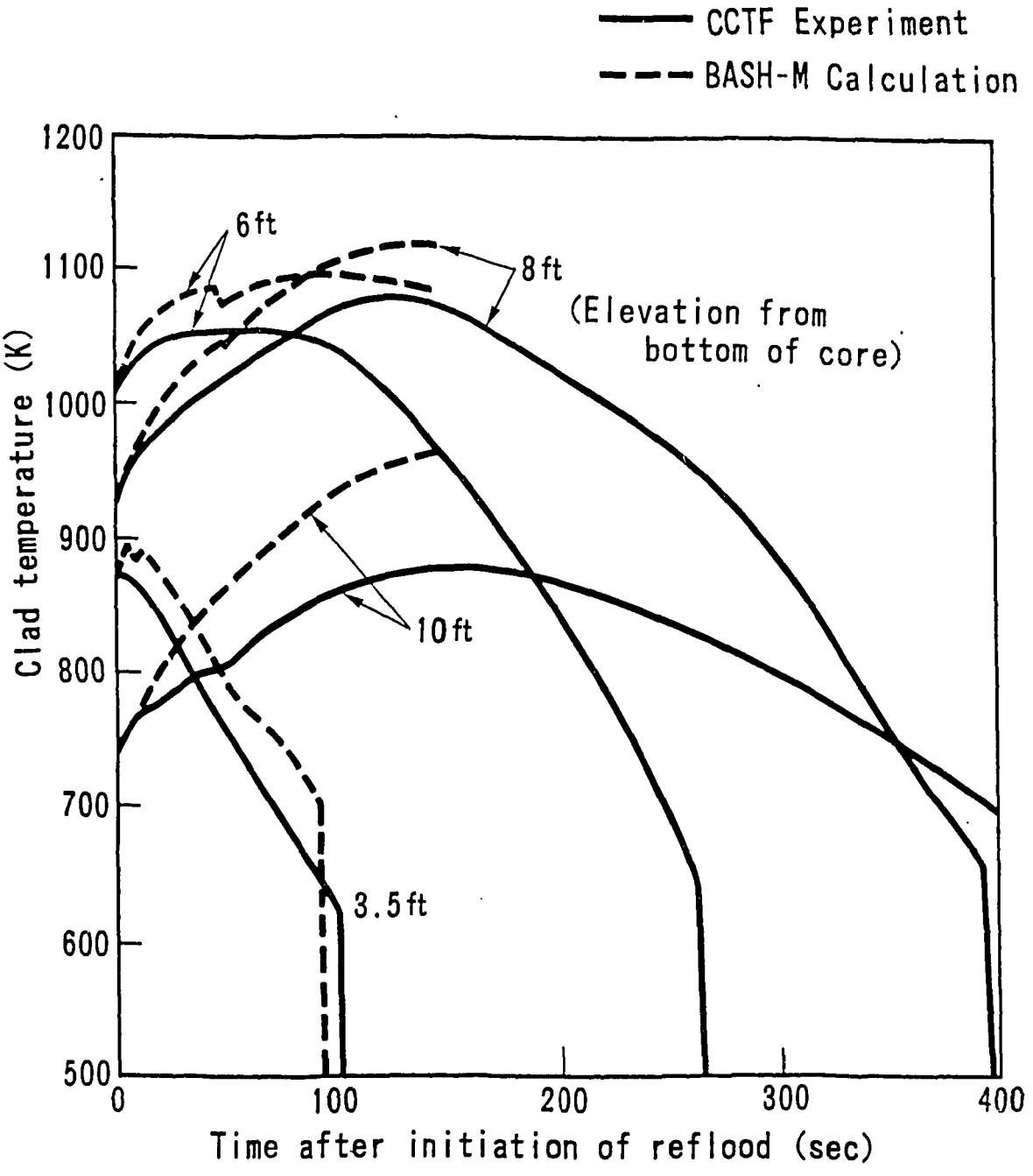


improved by Mitsubishi

(Data on droplet behavior / void fraction in large core et.al)

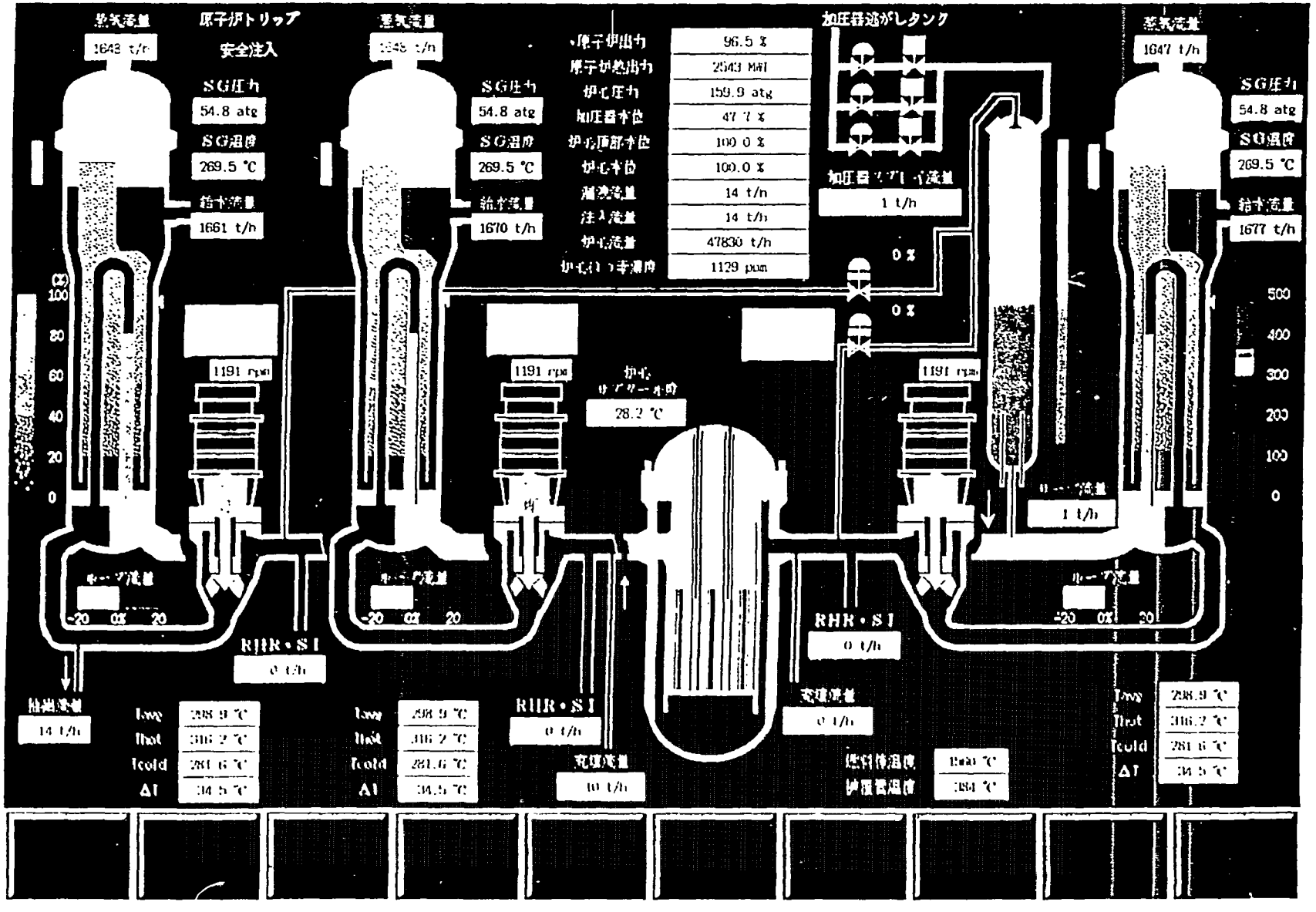
BASH-M

- used for licensing calculation in Japan
  new plant , plant modification (SG replace et.al)



Comparison between CCTF experiment (C19) and BASH-M calculation

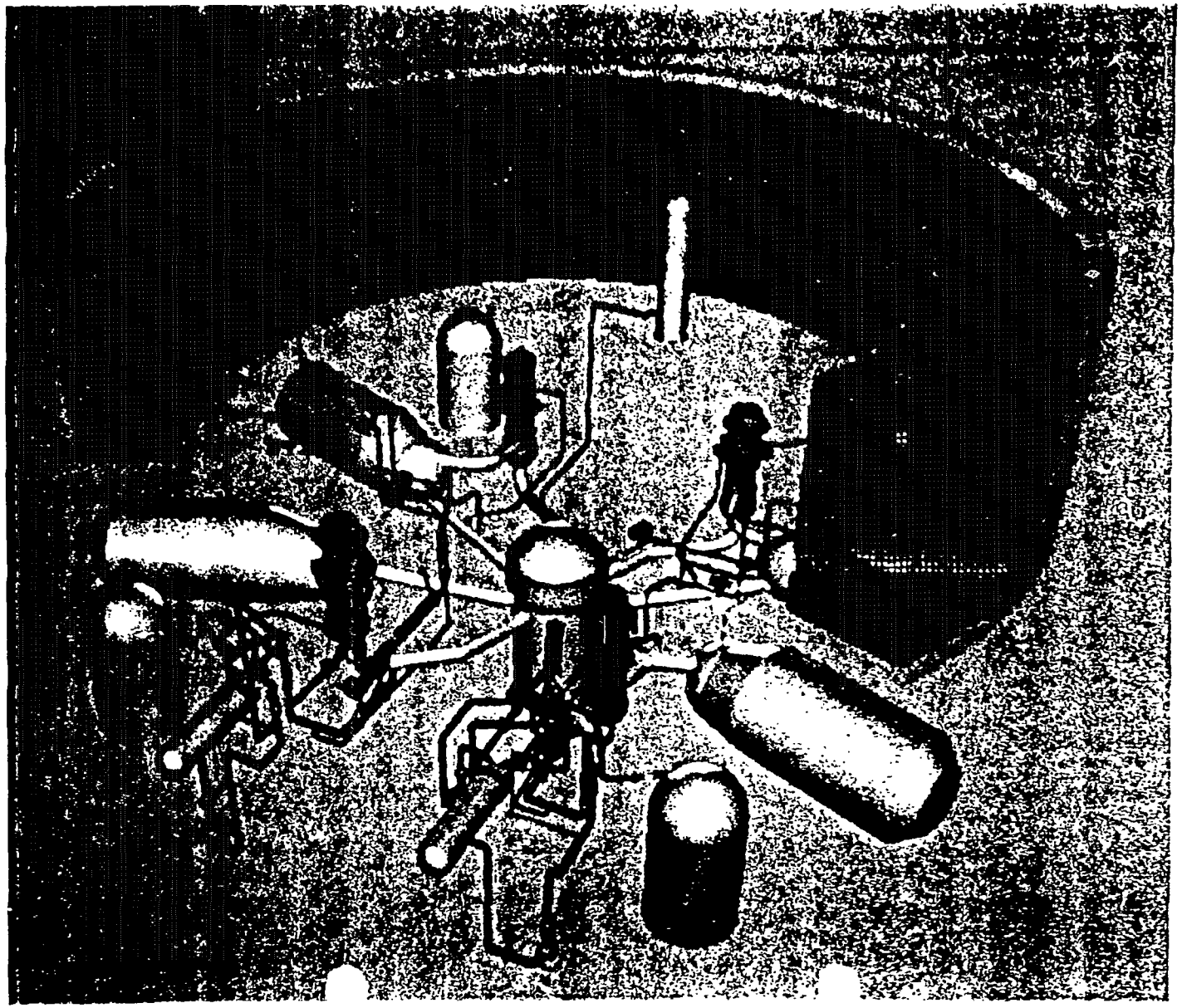
Display for Education at Training Center

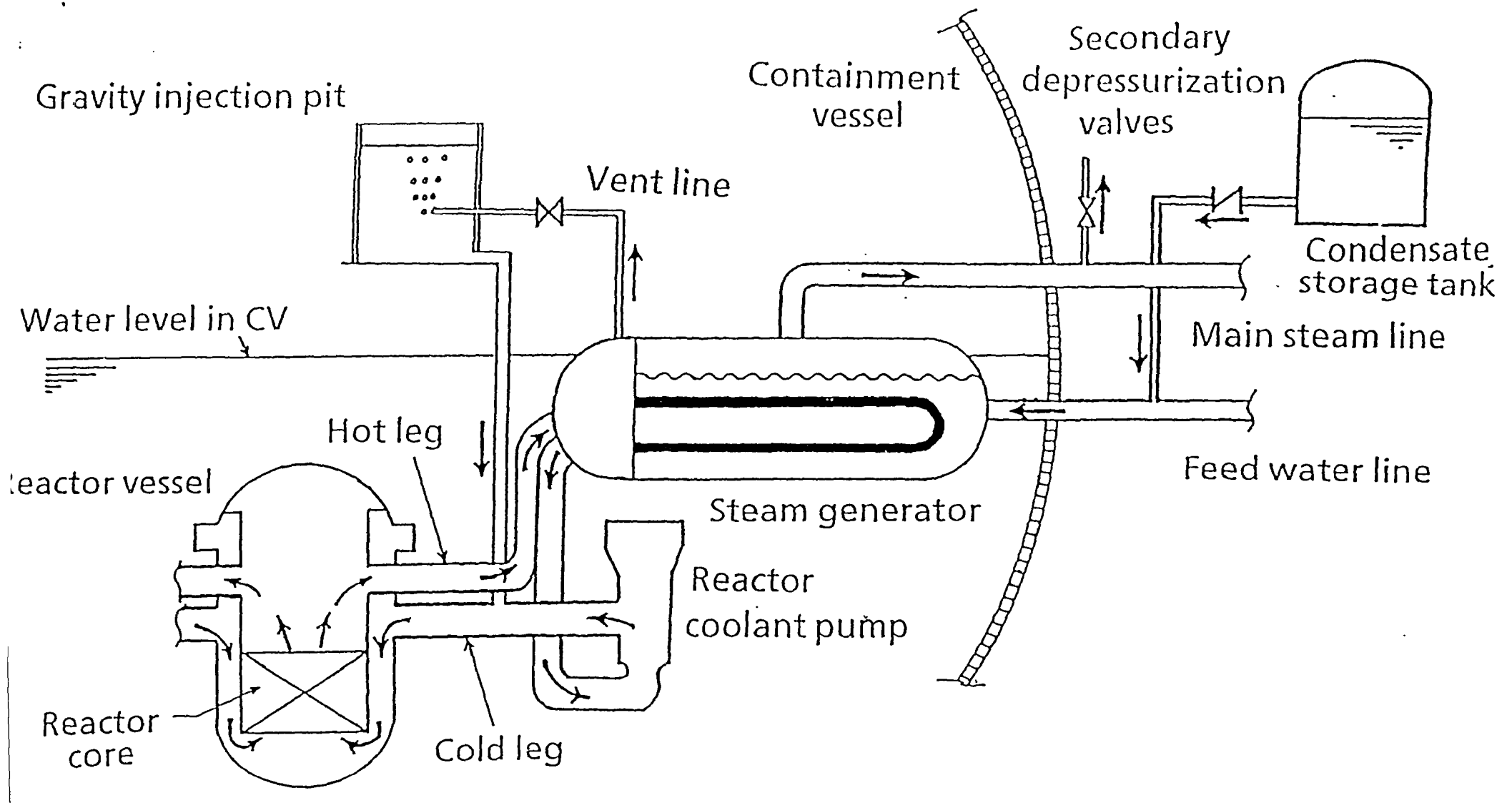


Example of Proposals of New Concepts

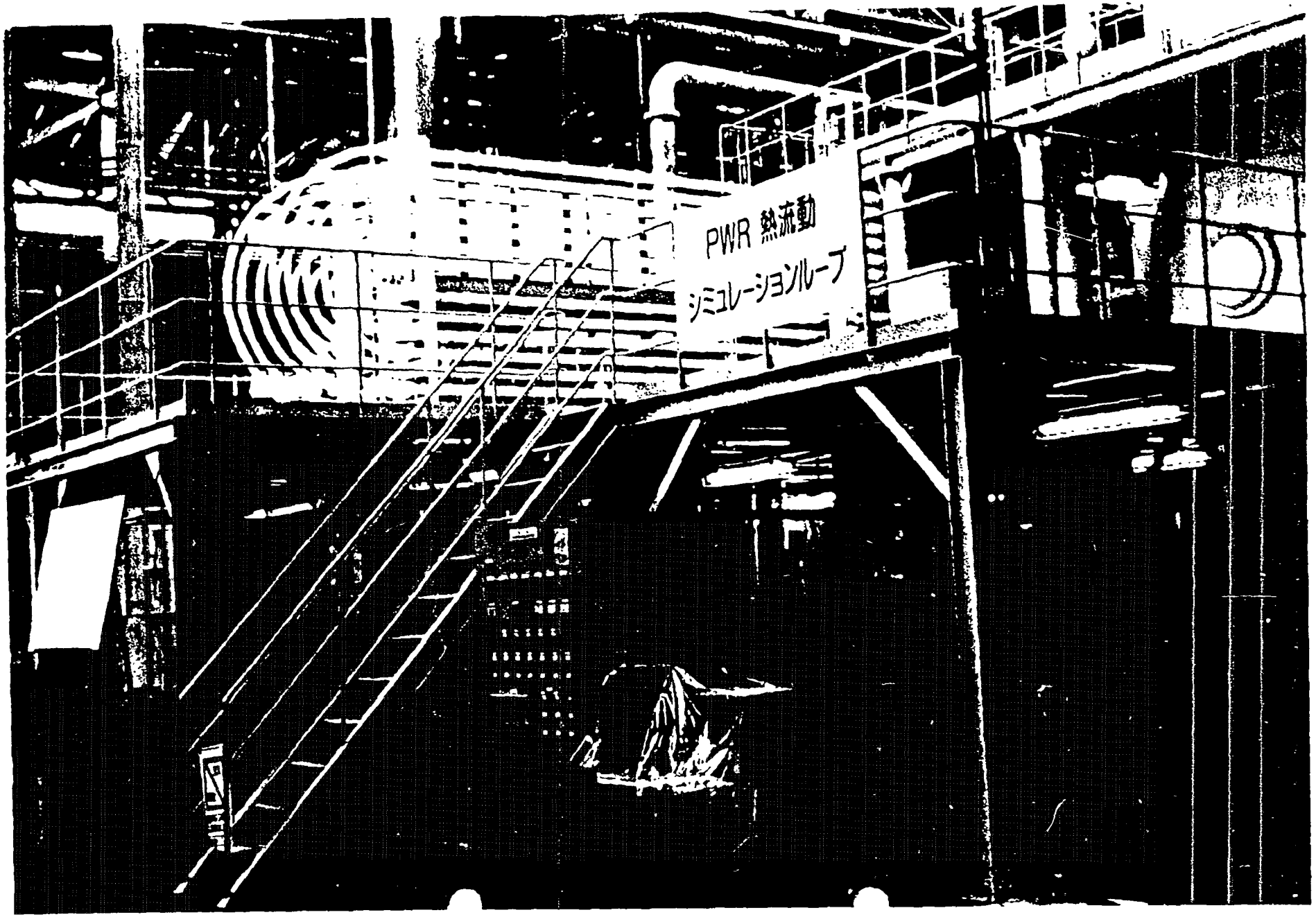
- Various organizations propose new concepts for 21st century
- Example of concepts proposed by Mitsubishi
  - Steam Generators are used for the decay heat removal at LOCA conditions
  - Horizontal type SG is the best to maintain two phase natural circulation under the Reactor Coolant System submerged
- Experiments and analysis are being done

Passive Safety System inside CV



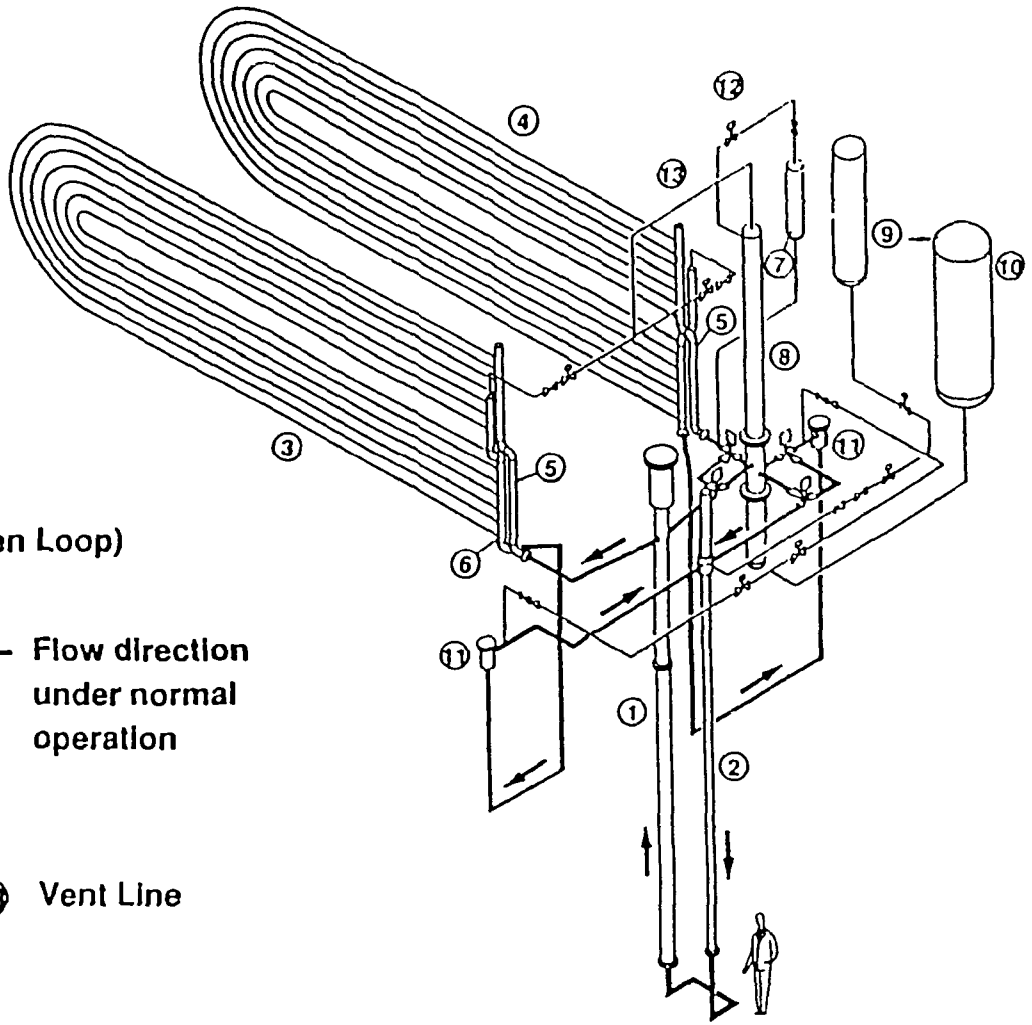


Passive Core Cooling System using Horizontal Steam Generators


PWR 熱流動
シミュレーションループ

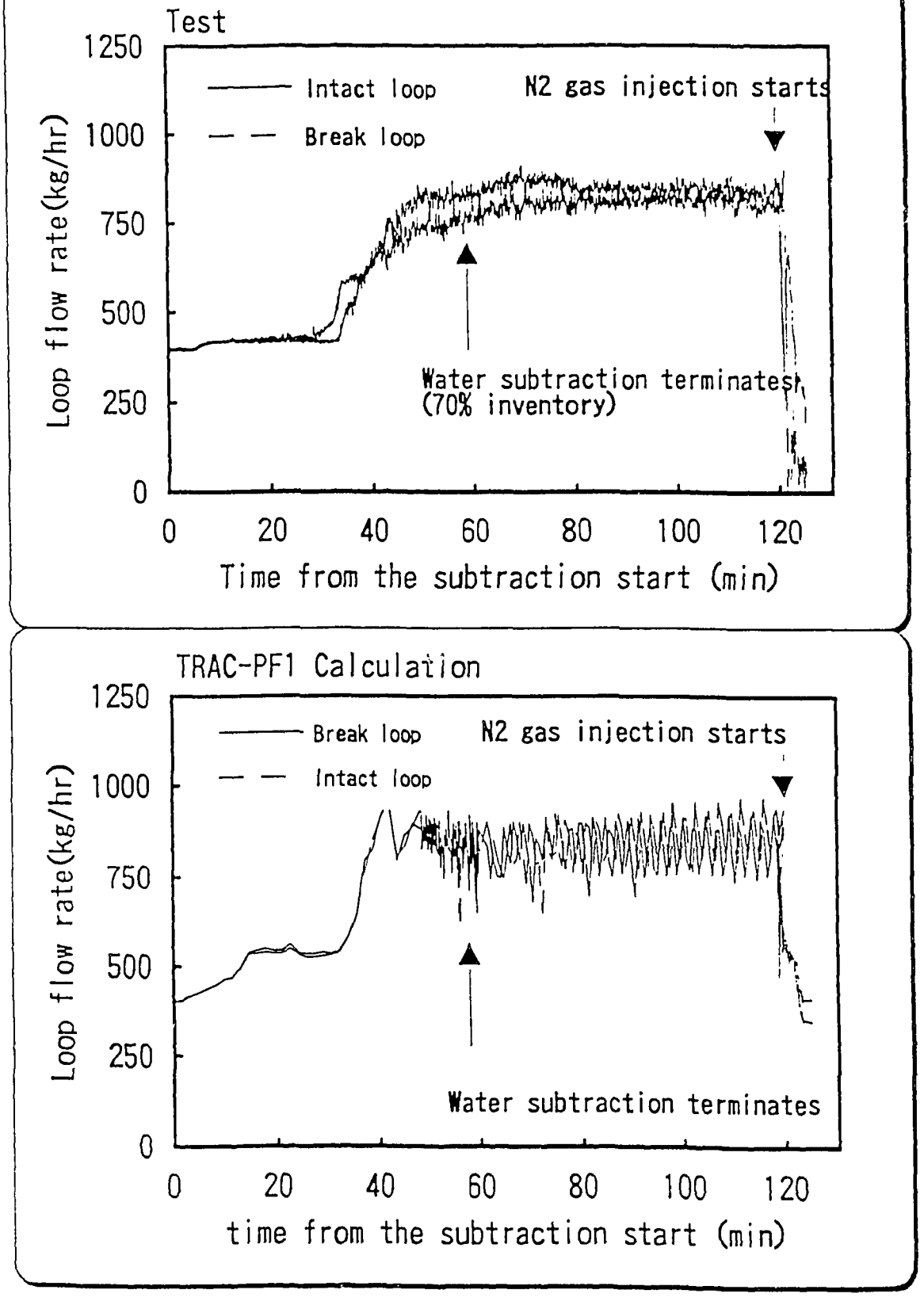
① Reactor Vessel
② Downcomer
③ Horizontal steam Generator (Intact Loop)
④ Horizontal steam Generator (Broken Loop)
⑤ Hot Side Channel Head
⑥ Cold Side Channel Head
⑦ Pressurizer
⑧ Containment Vessel
⑨ Accumulator
⑩ Gravity Injection Pit
⑪ Reactor Coolant Pump
⑫ Primary Depressurization Valve
⑬ Vent Line

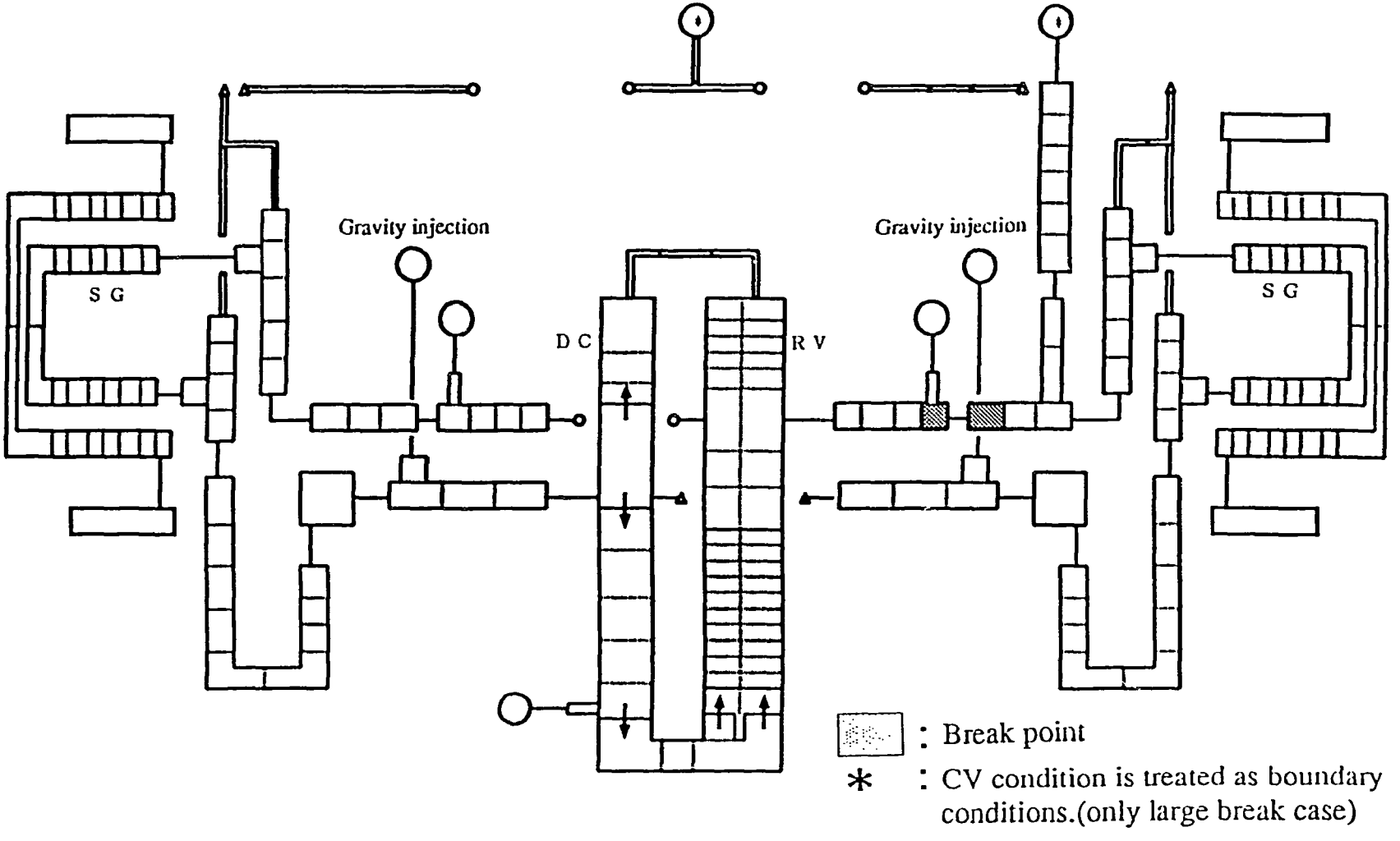
← Flow direction under normal operation



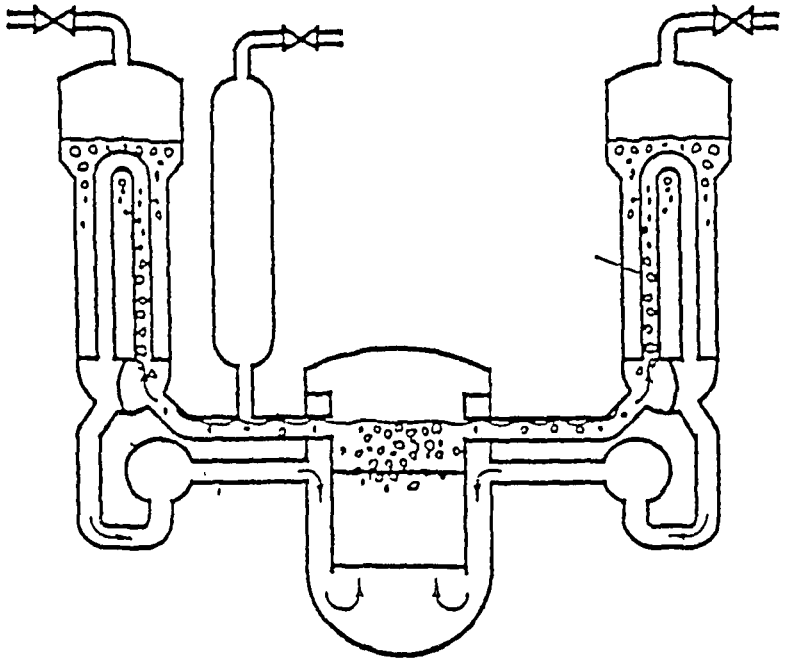
SLIM-facility

Quasi steady state natural circulation test
- comparison of loop flow -

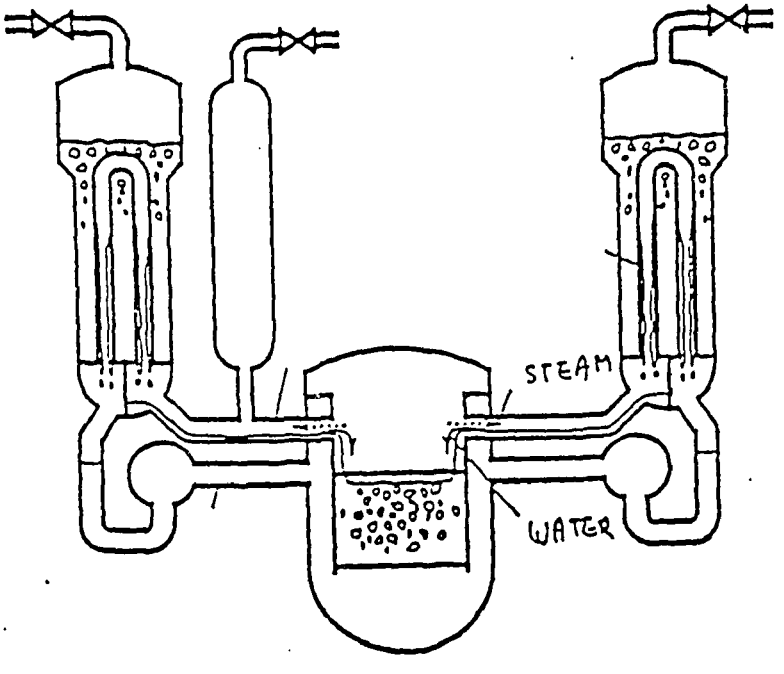




Nodal schematic of TRAC-PF1/mod2 for SLIM test



TWO-PHASE NATURAL CIRCULATION
(TYP. COOLANT INVENTORY = 90 - 50%)

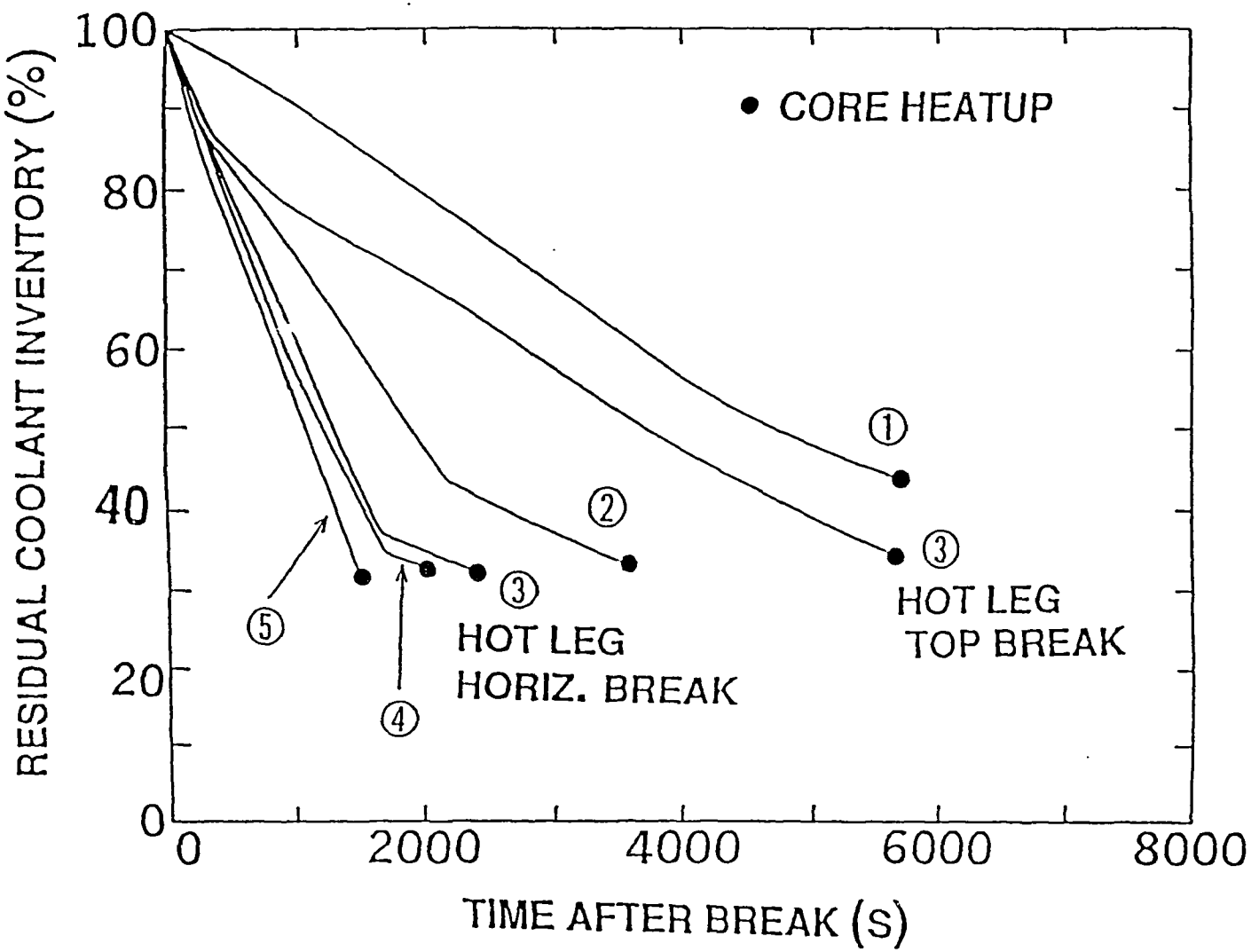


REFLUX CONDENSATION
(TYP. COOLANT INVENTORY = 50 - 30%)

Typical Small-Break LOCA Phenomena

- Natural Circulation & Reflux Condensation
- Stratified Two-phase Flow in Horizontal Legs
- Entrainment from Stratified Flow
- Counter-Current Flow Limiting & Liquid Holdup
- Coexistence of Subcooled Liquid and Steam

BREAK LOCATION EFFECTS ON COOLANT INVENTORY LOSS RATE (SIMULATED 2-IN. BREAK, FAILED HPI)



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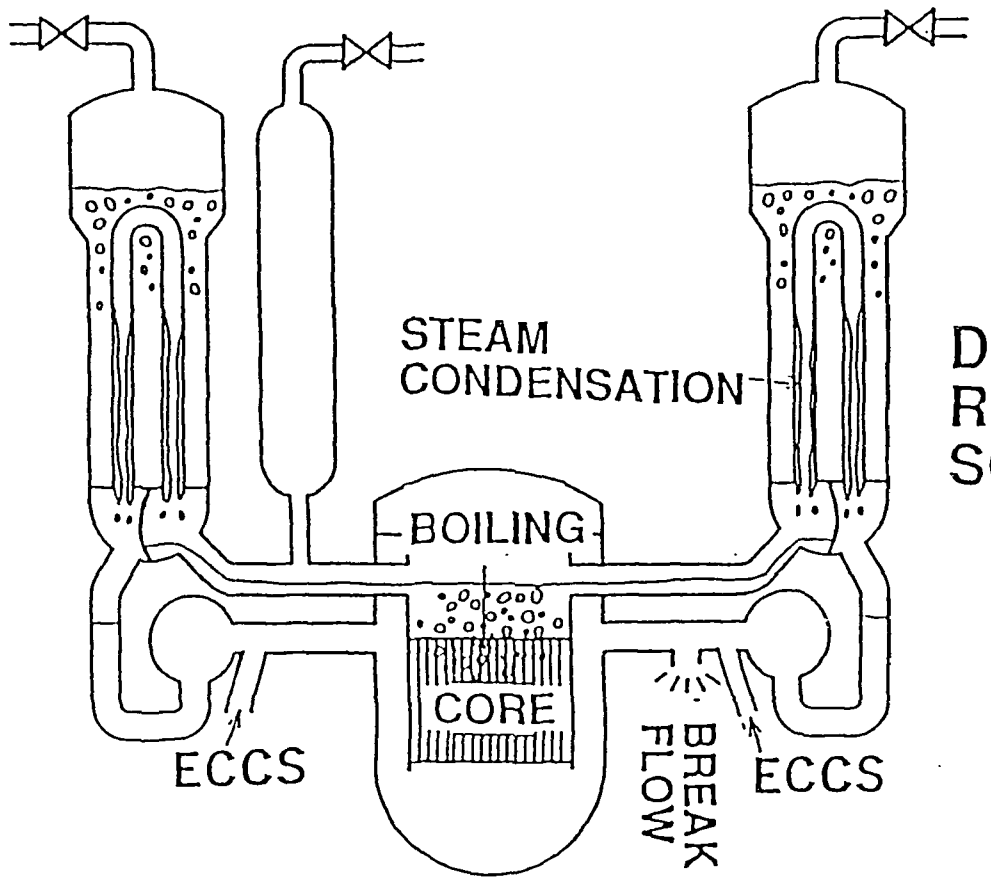
MASS & ENERGY BALANCE DURING A SMALL-BREAK LOCA

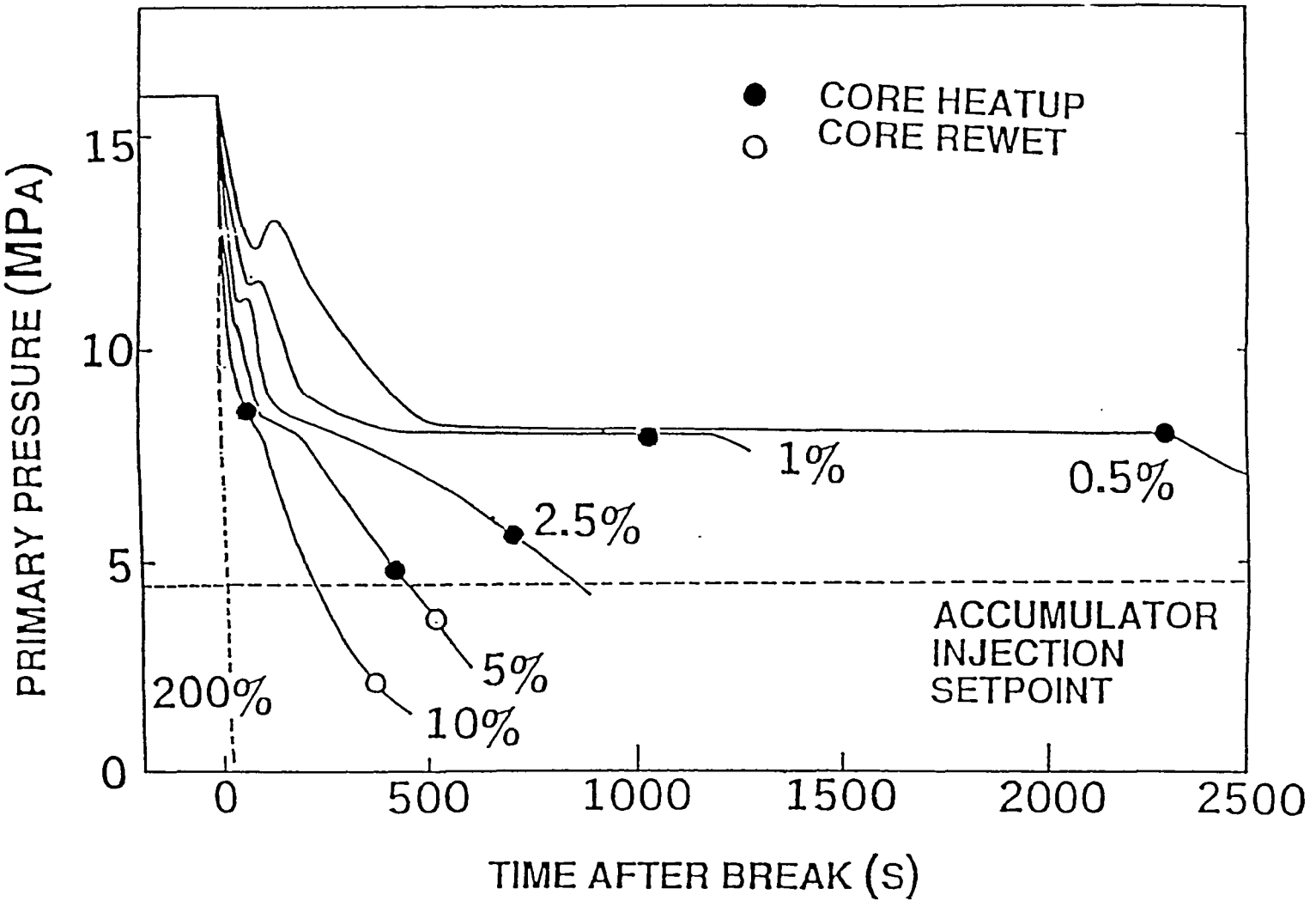


DECAY HEAT REMOVAL BY SGs

CORE COOLING

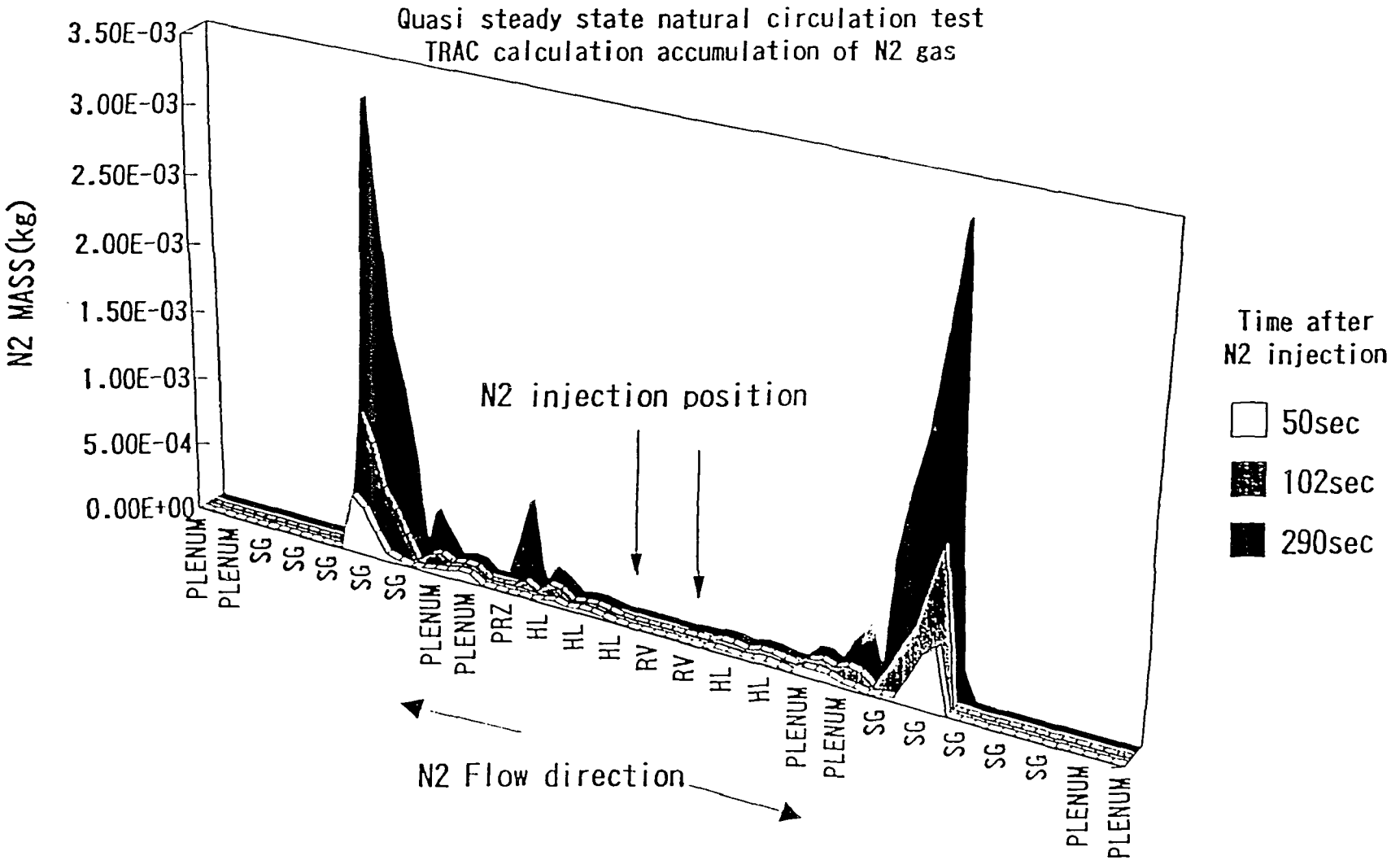
BREAK AHEA EFFECTS ON PRIMARY SYSTEM DEPRESSURIZATION

(SIMULATED COLD LEG BREAK, FAILED HPI)



Summary

- Previous safety researches enable us to
  - propose the reliable safety design for licensing
  - support the education/trainning of operators
- Best analytical model for two phase flow should be selected by the concerned problem characteristics
  - 1D,2D,3D
  - homogeneous , drift-flux , two velocity , three velocity
  - equilibrium , non-equilibrium
- Further improvement of computational technique is required for the efficient problem soluing in some area


Quasi steady state natural circulation test
TRAC calculation accumulation of N2 gas
N2 MASS(kg)
3.50E-03
3.00E-03
2.50E-03
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00
N2 injection position
N2 Flow direction
PLENUM
SG
PRZ
HL
RV
Time after
N2 injection
50sec
102sec
290sec