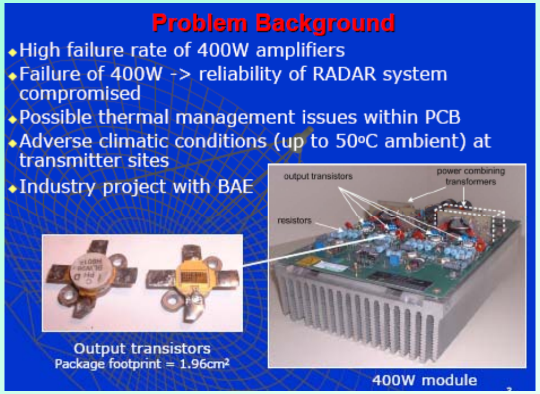
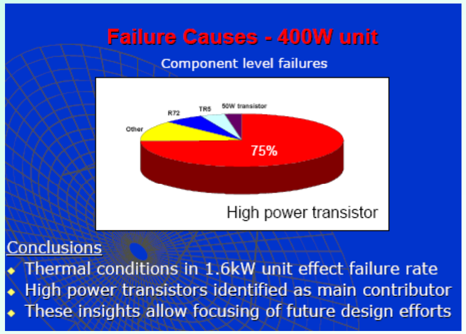
Chapter I. Introduction of Advanced Two-Phase Flow

1. Applications of Two-Phase Flow

a) power and propulsion system
b) process system
c) transport and transmission system
d) environment control system
e) information system
f) biological system and devices
g) geometeological phenomena





2. Characteristics of Two-Phase System

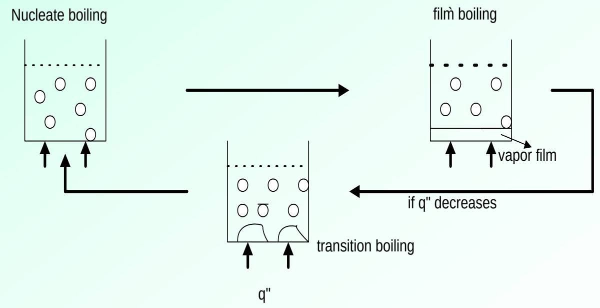
. existence of moving and deformable interface
. internal discontinuities of values
. complicated flow fluid due to interfacial structure
. mathematical difficulties for a local-instant formulation
. difficulties in measurements and scaling problem

3. Methods of Two-Phase Analysis

a) empirical correlations
b) phenomenological models
c) integral analysis
d) differential analysis

4. Classifications of Two-Phase Flow

o # of Phases ; solid, liquid, gas
o composition ; water/steam, air/water, sodium/vapor
o geometry ; upflow, downflow, horizontal
o flow regime
. separated flow regime
. transitional flow regime
. dispersed flow regime



5. Two-Pase Problems in Power Industries

(1) Fossil plants

☞ boiler ; dryout

☞ condenser – heat transfer coefficient, Δp

– flow distribution in inlet and outlet manifold

– direct contact spray condenser

(2) Alternative energy sources

☞ OTEC(Ocean-Thermal Energy Conversion)

– accurate knowledge of evaporating and condensing coefficient

☞ Geothermal energy

– informations for Δp and void fraction

– undesirable flow pattern

☞ Solar power plant – sodium heat transfer

(3) Nuclear power plants

☞ accident analysis like LOCA

– nonequllibrium model to describe two-phase phenomena

– interfacial phenomena between phases

☞ coolant behaviour in core and steam generator

☞ evaporation and condensation within horizontal tube

6. Key issues in two-phase flow

① treatment of gas-liquid interface

- ▶ worse than treatment of turbulence in single-phase flow
- ▶ interfacial area and interfacial drag or heat trransfer

② prediction of local and average void fraction

- ▶ not cover all the flow directions and geometrical variations existing in a complex system

③ two-phase flow turbulence model

- ▶ interface-induced turbulence

④ three-dimensional and nonthermal equlibrium condition

- ▶ countercurrent flow in downcomer or small-break critical flow
- ▶ subcooled boiling, heat transfer beyond CHF or surface dryout, flashing during critical flow depressurization, direct contact condensation with and without gas
- ▶ empirical adjustment for mixing description among adjacent nodes

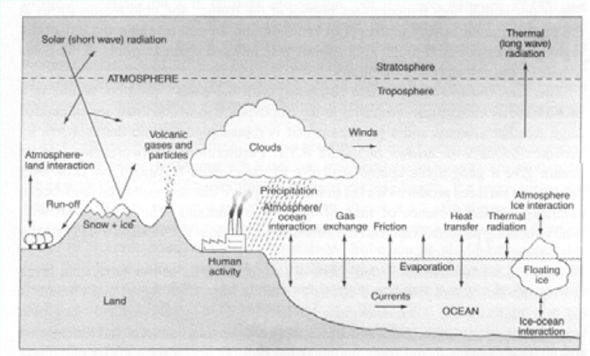
⑤ outside issues

a) microchannel two-phase flow

b) global two-fluid problems

- similarities between global climate and nuclear system
- treatment of vertical movement of air with moisture

- atmosphere general circulation model



7. Multi-scale approach for nuclear thermal-hydraulic research

o CFD scale
o component scale
o system scale

- macro-scale
- multi-field modeling
- transport of interfacial area
- turbulence modeling

(1) CFD scale

- open medium
- turbulence modelling using RANS or LES
- ITM(Interface Tracking Method) and DNS

● In bubbly flow,

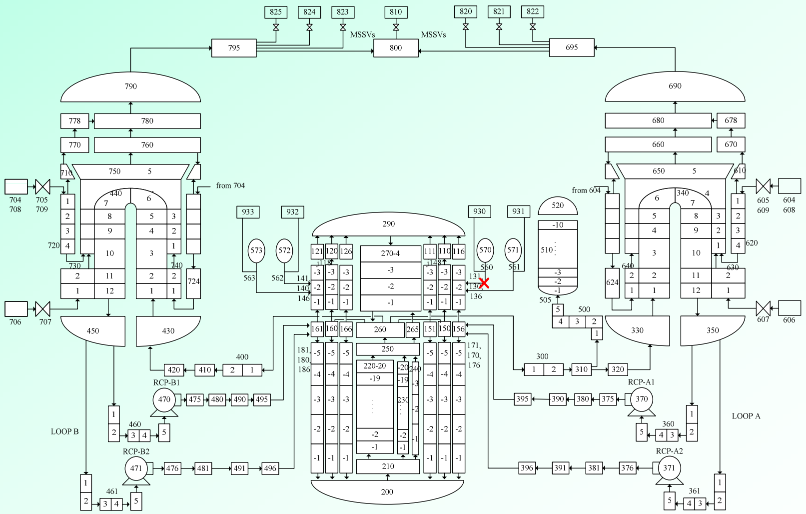
o liquid turbulence by wall shear
o random stirring due to bubble motion
o vortex sheding in wake of bubble
o deformation of interface
⇒ velocity fluctuation in liquid field

● Successive steps to investigate a two-phase flow with CFD

- Identification of important flow processes
- Selecting a basic model
- Filtering turbulent scales : RANS, LES
- Identification of local interface structures
- Use of Interface Tracking Method
- Selecting a turbulence modeling: k-ε, etc
- Modeling Interfacial transfers and validation
- Modeling Turbulent transfers and validation
- Modeling Wall transfers and validation

(2) Component scale

- design, safety and operation studies for reactor core, steam generator or pressurizer, etc
- minimum spatial resolution
  ; subchannel size (~ 1 cm)
- FLICA, COBRA, and THYC



(3) System scale

- RELAP or CATHARE
  - o two-fluid 6-eq. model
  - o 0D, 1D, 3D

Two-Phase Flow,

A Science or An Art ?