PDR

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUN 25 1979

Those On The Attached List

Gentlemen:

Enclosed are the minutes of the Steam Generator Meeting held at the NRC-Willste Building, Silver Spring, Maryland, on June 14, 1979.

Sincerely,

N Zuber

N. Zuber
Analysis Development Branch
Division of Reactor Safety Research

Enclosure: as stated

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7907240480

M

Addressees of Letter Dated JUN 2 5 1979

L. S. Tong, NRC/RES
S. Fabic, NRC/RES
P. Andersen, NRC/RES Consultant
Y. Y. Hsu, NRC/RES
W. Lyon, NRC/RES
L. Shotkin, NRC/RES
Z. Rosztoczy, NRC/NRR
N. Lauben, NRC/NRR
F. Odar, NRC/NRR
L. Phillips, NRC/NRR
R. Curtis, NRC/RES
P. Wood, NRC/RES
W. Kato, BNL
P. Griffith, MIT

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MINUTES OF THE STEAM GENERATOR MEETING

Place and Time: NRC Willste Building, Silver Spring, MD, June 14, 1979

Attendees: See Attachment 1

Purpose:

1) To review and assess BNL's experience in modeling U-tube (UTSG) and once-through steam generators (OTSG)

2) To review available experimental data and phenomena relevant to steam generator transients.

3) To select models for improving present capability of codes to simulate steam generator transients.

Agenda:

The agenda of the meeting is shown in Attachment 2. To facilitate the discussion and selection process the speakers were asked to

1) Review and assess present capability of codes to model steam generators

2) Identify problem areas and rank them according to importance

3) Suggest methods for resolving them

4) Identify and rank needs for further improvements.

Conclusions:

1) Steam generator calculations needed by NRR are enumerated in Attachment 3. These calculations require of codes to have the capability to model:

    A) On the Secondary Side:

        i) Slip

        ii) Phase separation - level calculations

        iii) Various modes of heat transfer with and without phase change

        iv) Recirculation (including natural circulation)

        v) Auxiliary feedwater (including effects on natural circulation in the primary side)
        vi) Flow mixing

        vii) Stability with load changes

        viii) Control, safety and protection system

B) <u>On the Primary Side</u>:

   i) Parallel channel instability

   ii) Interactions during natural circulation

   iii) Effects of noncondensibles

   iv) Critical flow through long tubes for tube rupture.

2) The IRT code under development at BNL, is a fast running code originally intended for calculating single phase flow transients in a PWR. The code is based on the homogeneous, thermal-equilibrium model and solves the continuity and energy equations. The momentum equation is <u>not</u> included in the code.

   Consequently, with exception of items iii) and viii) in Group A), IRT <u>cannot</u> model any of the phenomena and processes listed above.

3) In order to attain high computational speed, IRT uses large control volumes. This introduces numerical instabilities whenever large variations of thermal conditions occur within a single control volume.

   To remove this instability, BNL proposes to use profiles for enthalpy (see Discussion for details). According to present schedule, this modification of the code should be implemented by the end of November 1979.

4) NRR (F. Odar) stressed the need to model the effect of auxiliary feedwater which is introduced around tubes in the upper section. Since IRT does not model phase separation, BNL expressed a concern that numerical instabilities will be experienced if cold water is to be injected in the top control volume.

   To resolve this question it was agreed to introduce water uniformly along the steam generator. If numerical instabilities still appear, then as a "bottom line" simplification, BNL is to introduce the auxiliary feedwater in the bottom control volume.

5) Seven basic problems in modeling steam generators were listed by P. Griffith (see Discussion). Of them, the most important is concerned with modeling flow maldistribution and associated flow instabilities among tubes. These phenomena which occur at gravity dominated flows, are of particular importance to calculations of natural circulation. A need was identified to obtain data on this effect from experiments conducted with a condensing mixture flowing through several U-tubes in parallel.

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Discussion

A. Steam Generator Modeling - NRR Assessment and Needs

The presentation was made by Dr. F. Odar. He informed the participants that NRR uses IRT for fast running calculations of PWR plant transients and LOCA. However, he stressed that the UTSG and OTSG models in IRT are rather crude and emphasized the need for improved code capability to model steam generators. He enumerated the type of calculations that NRR has to carry out and listed code requirements which must be met if these calculations are to be performed satisfactorily. Both the type of calculations and code requirements, are listed in Attachment 2.

B. BNL Presentation

BNL's presentation dealt with the following topics:

1) IRT UTSG model

2) IRT OTSG model

3) OTSG modeling improvements

4) SG Mark II model

5) Experiments for SG model verification

The handouts covering these topics are reproduced in Attachment 3.

1) IRT UTSG Model

M. Levine described briefly the IRT code and its UTSG model. The code is based on the homogeneous, thermal equilibrium model. It solves the continuity and energy equation explicitely and omits the momentum equation. Consequently it cannot model

a) phase separation

b) level tracking

c) natural circulation

d) thermal nonequilibrium phenomena, such as injection of cold water in a vapor superheated region.

On the primary side the code uses Dittus-Boelter correlation for the heat transfer coefficient, whereas on the secondary it uses the Jens-Lottes correlation. The entire secondary side is considered as one control volume. However, the length of the heat transfer area is determined from the intersection of a quality X_B, specified by the user, and the assumed linear quality profile (see illustration in Attachment 3).

2 IRT - OTSG Model

C. Hsu described the present status of the IRT - OTSG model. The basic equations and heat transfer correlations are shown in Attachment 3.

The OTSG model has the same shortcomings as those enumerated above for the UTSG model.

Present problem areas of the OTSG model, identified by C. Hsu were:

a) time step control

b) steady state initialization

c) auxiliary feed water injection

d) steam generator downcomer modeling

e) recirculation through the aspirator.

The last three items stem from the inability of the code to model phase separation, thermal nonequilibrium and to calculate momentum balances along the loop.

The need to improve the steam generator downcomer model was confirmed by comparing calculated pressure changes on the primary side with data. The discrepancy was attributed to the downcomer flow rates which affect thermal conditions on the secondary side. To improve calculations, BNL has introduced an overall momentum equation for computing the flow from the S.G. downcomer to the central section of the secondary side. This improvement will be implemented by the end of July 1979.

W. Lyon observed that thermal conditions on the secondary side are affected not only by the flow rate but also by the enthalpy. Consequently, an improvement is needed in modeling the energy flux from the S.G. downcomer to the secondary side upflow section. This entails the modeling of the steam-water mixing at the aspirator. N. Zuber questioned the method used to calculate the flow rate through the aspirator and observed that the term $\dot{W}_R$, should not appear in the equation used to calculate this flow.

The problem with auxiliary feedwater arises because of the fact that cold water is introduced around tubes in the upper section. Consequently, to model this process correctly, cold water should be injected in a top control volume that is originally filled with steam. Since IRT does not model either phase separation or thermal nonequilibrium, it cannot model this process. BNL expressed great concern that if they were to introduce cold water in a top control volume, the code would experience numerical instabilities. F. Odar suggested that, in the code, the injection of the auxiliary feed water should be distributed uniformly along the steam generator tubing. If numerical instabilities still occur (because there is not enough water to completely fill the control volumes and cold water will be mixed again with steam), then as a "bottom line" simplification, water should be introduced in the bottom control volume.

3. OTSG Modeling Improvements

IRT uses large control volumes in order to achieve high computational speed. This introduces numerical instabilities whenever thermal conditions change drastically within one control volume. Since in the OTSG model, the heat transfer coefficients are flow regime dependent they can vary greatly in magnitude from one regime to another for example, from nucleate to film boiling. Consequently, with large control volumes, the OTSG model can experience large changes of energy removal, from one time step to another which introduces instabilities.

In order to alleviate this difficulty, BNL has proposed to introduce spatially linear profiles of enthalpy. The method is described in Attachment 3, and bears similarity to the concept attempted in the THOR program. According to present schedule, this improvement is to be implemented in IRT by the end of FY 79.

4. S.G. Mark II Modeling

W. Wulff described longer range plans for developing a steam generator model that would meet NRR's requirements. The model is described in Attachment 3.

S. Fabic noted that at the present time, WRSR does not have plans to develop a new steam generator code because the fast running version of TRAC scheduled for completion by the end of CY 79, should meet NRR's requirements.

5) Experimental Data Needed for Model Verification

P. Saha reviewed available data on steam generator steady state and transient performance, and suggested experiments which would provide additional data for code assessment. The details are also given in Attachment 3.

C. MIT's Experiments

P. Griffith briefly described the results of experiments conducted at MIT for the purpose of assessing the effect of flow maldistribution on two phase circulation through inverted U-tubes. The experiments were conducted with air-water mixture flowing through four inverted U-tubes connecting two plena

The most significant result revealed by these experiments was the existance of two regions; one stable, the other unstable. In the stable region, the mixture was flowing through all four inverted U-tubes. Whereas in the unstable region, the mixture was flowing through some of the tubes while the others were starved. This phenomena depended on flow rates and appeared when the flow was gravity dominated. Consequently, it is particularly relevant to modeling steam generators in the natural circulation mode.

On the basis of these experiments, P. Griffith suggested seven basic problems whose solutions should receive top priority; these are:

1) Find the unstable boundary delineating the region of flow maldistribution

2) Determine plenum flow distribution

3) Establish a calculation scheme for connecting plenum flows to tube flows

4) Determine heat transfer coefficients for downflow

5) Determine effects of thermal stratification on heat transfer coefficients

6) Determine the effect of multiple steam generators connected to the vessel

7) Determine heat transfer regimes in tubes during downflow.

Peter Griffith agreed to discuss these topics in more detail together with available experimental data, at the forthcoming Steam Generator Workshop.

Attachment 1

Attendance

S. Fabic, NRC/RES
P. Andersen, NRC/RES
Y. Y. Hsu, NRC/RES
W. Lyon, NRC/RES
L. Shotkin, NRC/RES
R. Curtis, NRC/RES
P. Wood, NRC/RES
N. Lauben, NRC/NRR
F. Odar, NRC/NRR
W. Kato, BNL
M. Levine, BNL
C. Hsu, BNL
J. Jo, BNL
P. Saha, BNL
W. Wulff, BNL

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Attachment 2

Steam Generator Meeting: Agenda

NRC Willste Building
Room 106, 9:00 a.m.
June 14, 1979

9:00 - 9:15 a.m.	Opening Remarks -	S. Fabic, RES
9:15 -10:00 a.m.	Steam Generator Modeling - NRR Assessment and Needs	F. Odar, DSS
10:00 -11:00 a.m.	BNL's Modeling of U-Tube Steam Generators	
11:00 -12:00 a.m.	BNL's Modeling of Once-Through Steam Generators	
12:00 - 1:00 p.m.	Lunch	
1:00 - 2:30 p.m.	Discussion	
2:30 - 5:00 p.m.	Selection of Improved Models and Recommendations	

Attachment 3 F. Odar's Handout

Steam Generator Codes

Type of Steam Generators

a) One Thru Steam Generator

(At least two kinds)

b) U Tube Steam Generators

Westinghouse (at least two kinds)

Combustion Engineering (at least two kinds)

Purpose: Audit Vendor Calculations

a) Audit Demand Heat Curves used by B&W in OTSG for TMI-2 incident and transient calculations

b) Audit Steam Generator Level Calculations in OTSG and U tube generators for transient (loss of feedwater), ATWS and accidents (steam line break accident) analyses

c) Audit Mass and Energy release calculations in steam line break accident - moisture carryover

d) Audit natural circulation capability in the primary. This is dependent on the auxiliary feedwater in OTSG and level calculations in the U tube steam generators

e) Audit parallel channel instability between the tubes in small break LOCA, SLBA and other transients where boiling of primary side occurs.

f) Audit natural circulation capability (or interaction) for different flow rates and heat fluxes in a bundle of tubes

g) Audit the control, engineering safety and protection system

h) Audit steam generator tube rupture analyses (SLBA or LOCA)

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Capabilities Required

Secondary Side

a) Slip

b) Phase separation - level calculations

c) All modes of heat transfer

d) Recirculation

e) Natural circulation

f) Steam Separators - dryers

g) Auxiliary feedwater (Eventually 3-D)

h) Mixing and energy transfer (3-D)

i) Stability (OTSG and U tube) with load changes

j) Control, safety and protection system

k) Effect of non-condensibles

l) Tube recovery - level calculations

Primary Side

a) Parallel channel instability

b) Interaction during natural circulation

c) Effects of noncondensibles

d) Critical flow through long tubes for tube rupture

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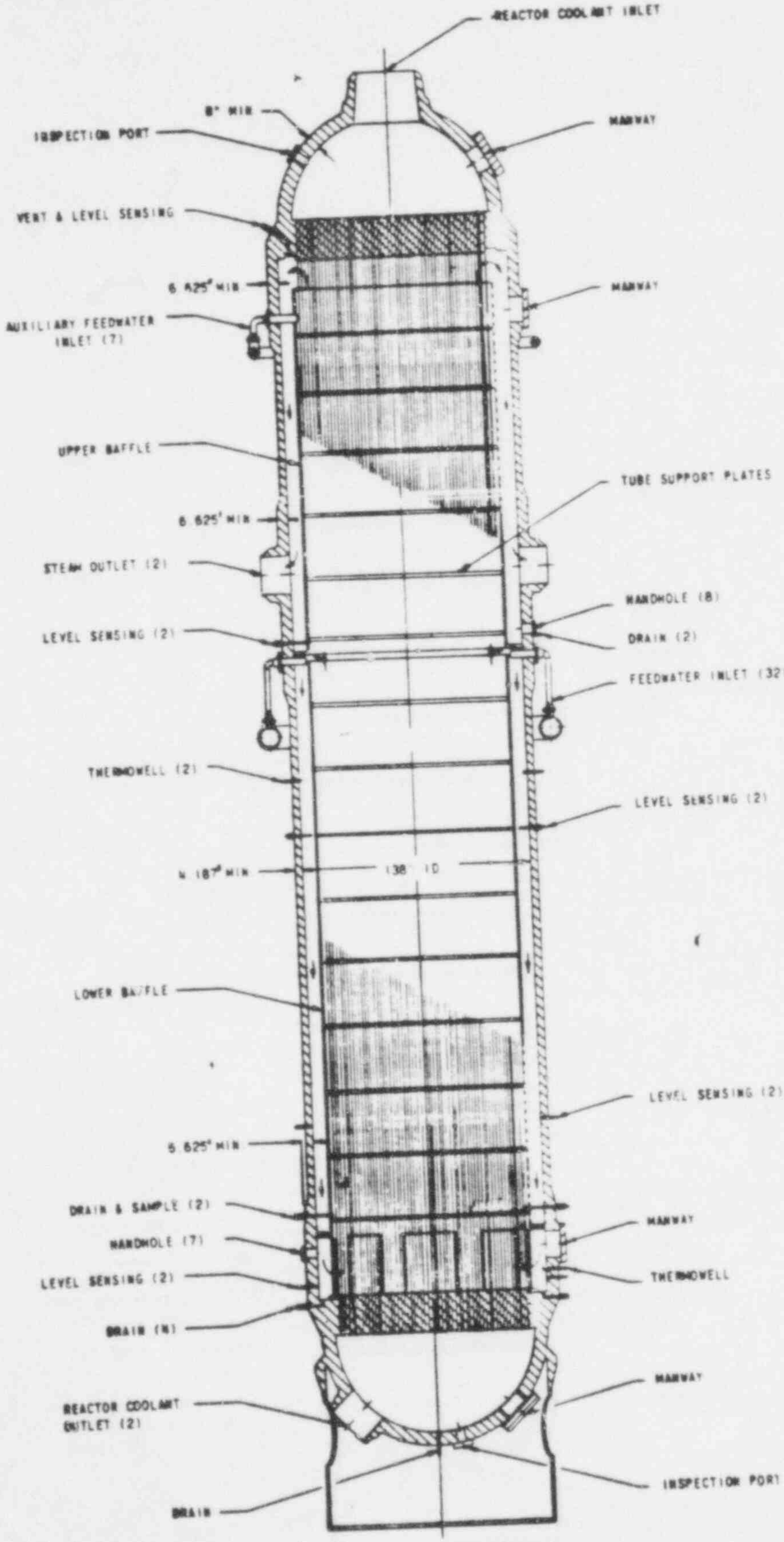
Figure A-1. Full-Scale Once-Through Steam Generator



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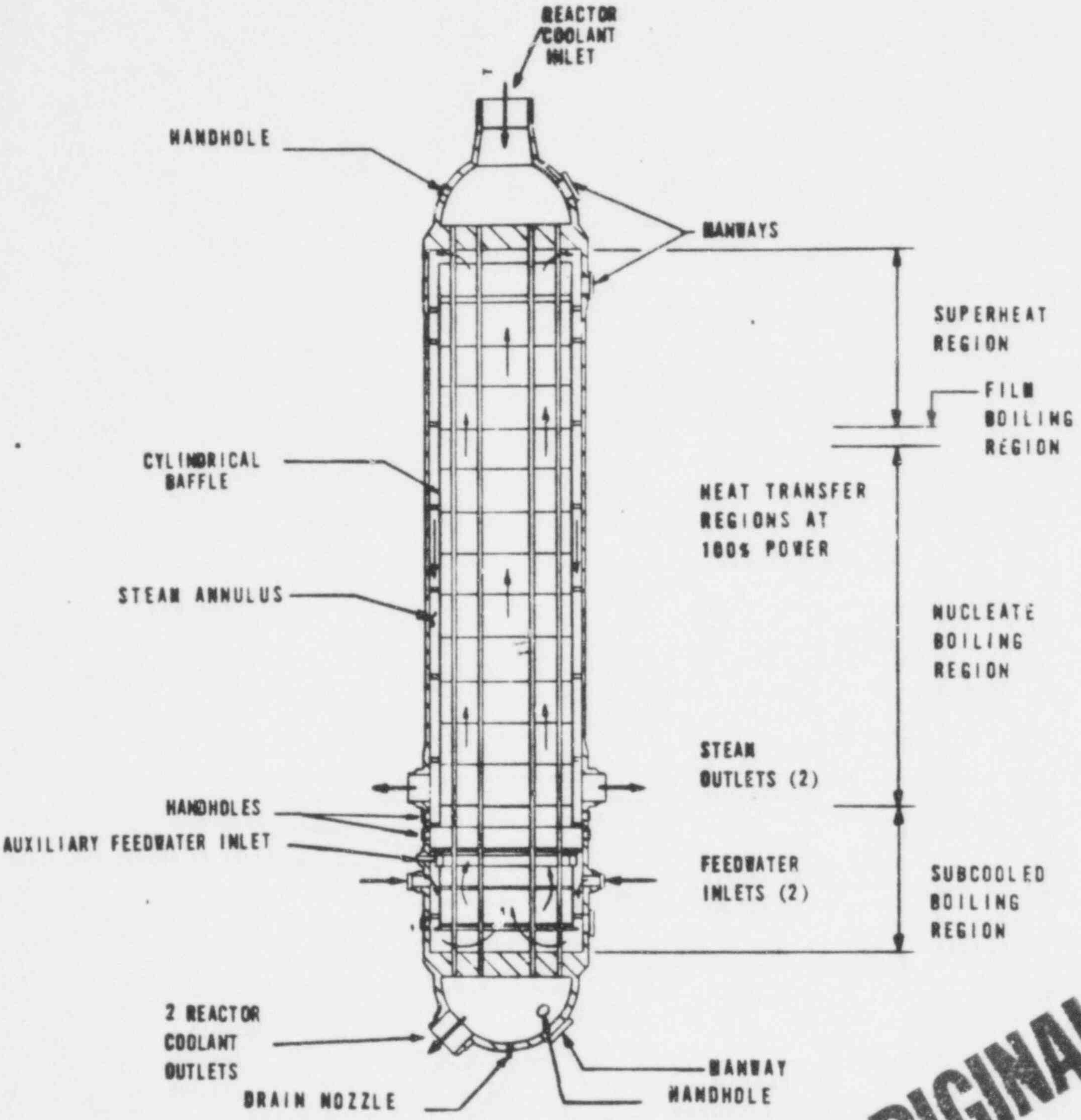

205 BESSAR
(Next B&W design)

POOR ORIGINAL

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ONCE-THROUGH STEAM GENERATOR

Figure 5.5-3

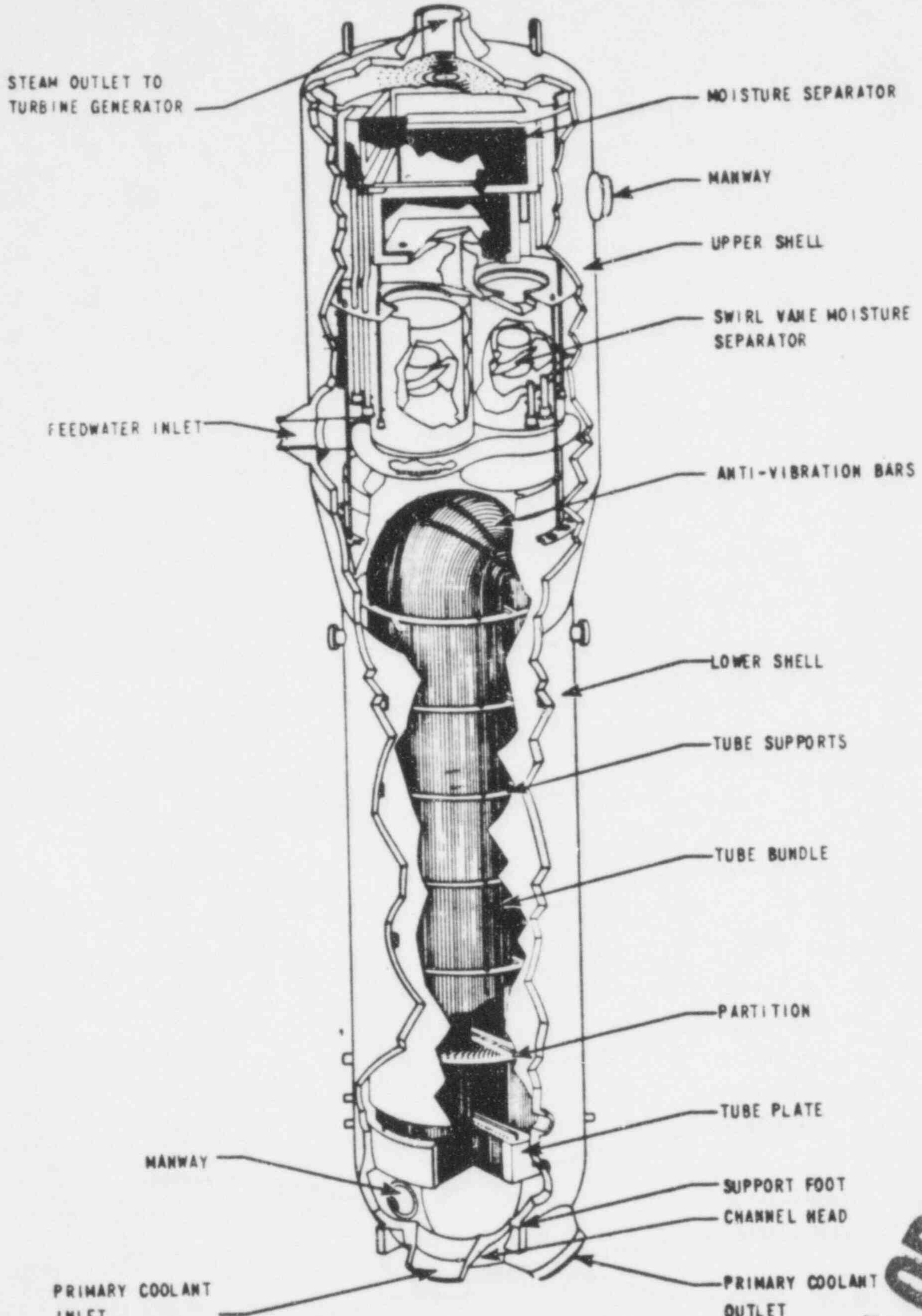

Figure 5.5-4 Steam Generator

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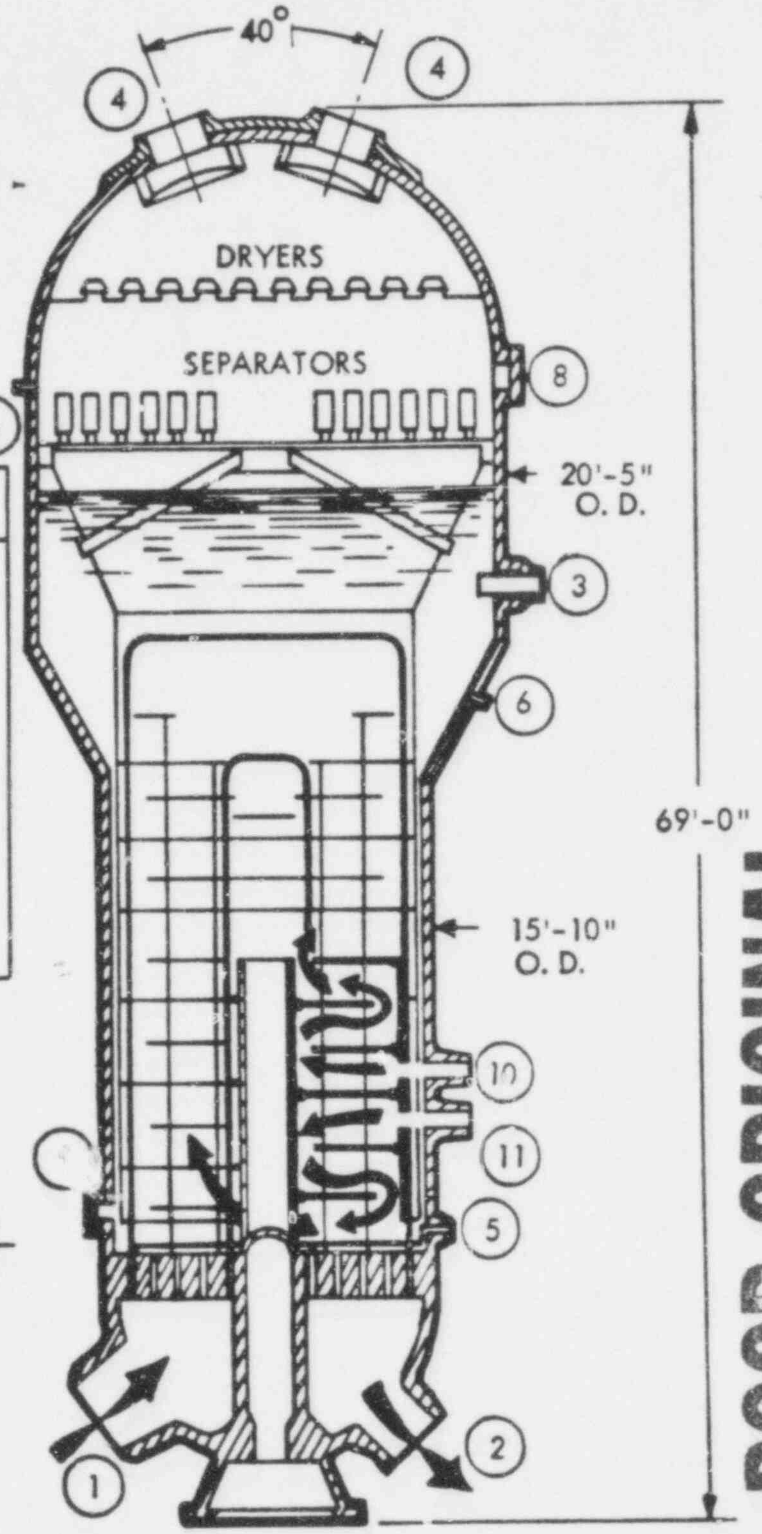
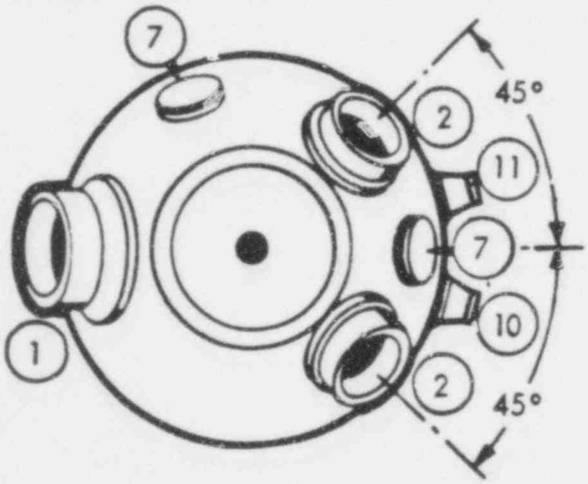


NO.	SERVICE	No. REQ'D
1	PRIMARY INLET	1
2	PRIMARY OUTLET	2
3	DOWNCOMER FEEDWATER	1
4	STEAM OUTLET	2
5	BOTTOM BLOWDOWN	1
6	LIQUID LEVEL	8
7	PRIMARY MANWAY	2
8	SECONDARY MANWAY	2
9	HANDHOLE	2
10	UPPER ECONOMIZER FEEDWATER	1
11	LOWER ECONOMIZER FEEDWATER	1



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DRY WEIGHT	1,428,900 LBS
FLOODED WEIGHT	2,220,000 LBS
NORMAL OPERATING WT.	1,725,000 LBS (FULL LOAD)
SHIPPING WEIGHT	1,570,000 LBS

Amendment No. 28
May 5, 1975

C-E SYSTEM 80

STEAM GENERATOR

Figure 5.5-2

Attachment 4

BNL PRESENTATION AT SG MODELING MEETING

45 min.	Current IRT U-Tube SG Model	M. M. Levine
10 min.	OTSG Model Introduction	M. M. Levine
15 min.	Current IRT OTSG Model	C. J. Hsu
	OTSG Mark I Modeling	
10 min.	Downcomer	C. J. Hsu
15 min.	SG Model	J. H. Jo
	SG Mark II Model	
20 min.	OTSG/UTSG	W. Wulff
15 min.	Experiments for SG Model Verification	P. Saha

BNL/NRC

Meeting on

Steam Generator Modelling

June 14, 1979

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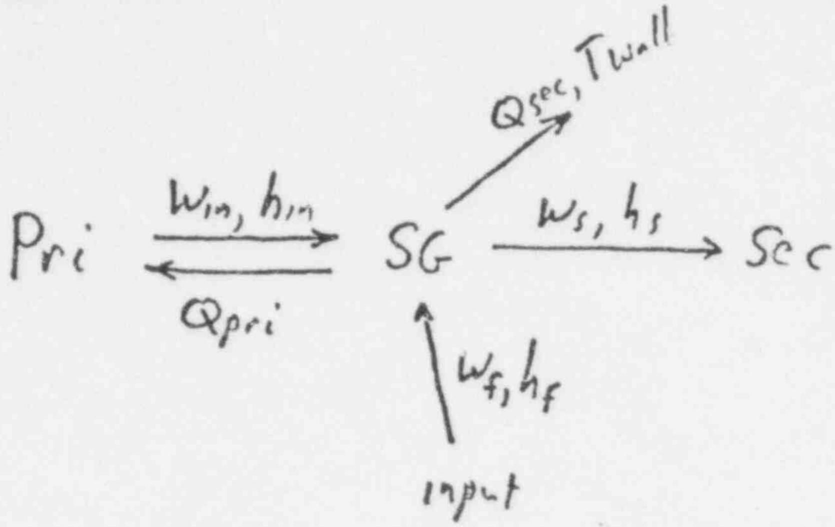
IRT Heat Exchanger



Conservation

mass	$\dot{m} = \sum w$
volume	$(\dot{mv}) = 0$
energy	$(\dot{mh}) = Q + \sum wh + V\dot{p}$

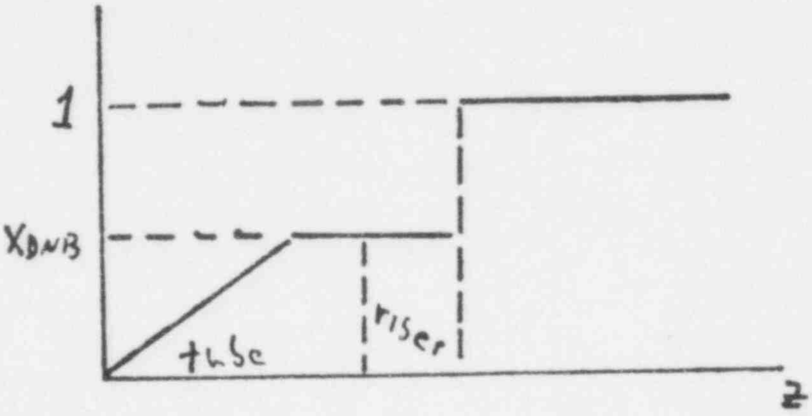
Assume saturated

$$h = h(p,x)$$
$$v = v(p,x)$$

Solve for $\dot{p}, \dot{m}_g, \dot{m}_f$ (or $\dot{p}, \dot{m}, \dot{x}$)

.UTSG-2

DNB



UTSG 4

POOR ORIGINAL

OTSG

Fixed nodes
Homogeneous
Equilibrium
$h_{exit} = h_{avg}$

Pri: Energy balance
Ignore compressibility ($+V\dot{p}$)

Sec: Mass + energy balance

Tubes: Energy balance
Ignore temp. gradient (thru wall)

Ht. Xfr.: 5 nodes

Solver: Explicit

Downcomer:

W_{feed} = tabular
= $f(M_{DC})$ various functions

OTSG in SSC

Fixed nodes

Shell = Na ; Tubes = H_2O

Sec. pressure determined by Steam drum.

Implicit in Twall (iterate if nec.)

DNB point determined by quality
moves within node.

IRT ONCE-THROUGH STEAM GENERATOR

BASIC EQUATIONS

(A) PRIMARY-SIDE:

$$\rho_i V_i C_{p_i} \frac{dT_{p_i}}{dt} = 2 W_i C_{p_i} \left[(T_{in})_i - T_{p_i} \right] - U_{p_i} A_{p_i} (T_{p_i} - T_{m_i})$$

(B) S. G. TUBE

$$\rho_{m_i} V_{m_i} C_{p m_i} \frac{dT_{m_i}}{dt} = U_{p_i} A_{p_i} (T_{p_i} - T_{m_i}) - U_{s_i} A_{s_i} (T_{m_i} - t_{s_i})$$

$$\frac{1}{U_{p_i}} = \frac{1}{h_{p_i}} + \text{PRIMARY-SIDE FOULING RESISTANCE} + \frac{1}{2} \left(\text{TUBE WALL RESISTANCE} \right)$$

$$\frac{1}{U_{s_i}} = \frac{1}{h_{s_i}} + \text{SECONDARY-SIDE FOULING RESISTANCE} + \frac{1}{2} \left(\text{TUBE WALL RESISTANCE} \right)$$

ASSUMPTIONS

(A) $$T_{p_i} = \frac{(T_{p_i})_{in} + (T_{p_i})_{out}}{2}$$

(B) FOR EACH INTEGRATION TIME STEP, W_i IS ASSUMED TO BE CONSTANT FOR ALL THE PRIMARY NODES. THE VOLUMETRIC FLOW RATE, W_i/ρ_i , HOWEVER, IS DIFFERENT FOR EACH NODE.

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HEAT TRANSFER CORRELATIONS

MODE 1 - SUBCOOLED FORCED CONVECTION
SIEDER-TATE CORRELATION

MODE 2 - SUBCOOLED AND NUCLEATE BOILING
THOM'S CORRELATION

MODE 3 - TRANSITION BOILING
MCDONOUGH, MILICH AND KING

MODE 4 - STABLE FILM BOILING
MIROPOL'SKII'S CORRELATION

MODE 5 - SINGLE-PHASE STEAM FLOW
DITTUS-BOELTER CORRELATION FOR STEAM

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$$\dot{P}_s = \frac{-\dot{m}_{DC} + W_f - W_s + \sum_{i=1}^{N} (\sum W_e)_i + (\sum W_e)_{DC} + \sum_{i=1}^{N} \xi_i A_i}{\sum_{i=1}^{N} (\eta_i + \xi_i B_i)}$$

$$\dot{h}_i = A_i - B_i \dot{P}_s \qquad (i = 1 \sim N)$$

WHERE, FOR EXAMPLE,

$$A_i = \frac{K_i - a_i \sum_{1}^{i-1} \xi_i A_i}{m_i} , \qquad B_i = \frac{b_i - a_i \sum_{1}^{i-1} \xi_i B_i}{m_i}$$

$$a_i = h_i - h_{i-1} , \qquad b_i = (h_{i-1} - h_i) \sum_{1}^{i-1} \eta_i - C\overline{V}_i$$

$$K_i = (h_i - h_{i-1}) \dot{m}_{DC} + \dot{Q}_i + (h_{i-1} - h_i) \Big\{ W_f + (\sum W_e)_{DC} + \sum_{1}^{i-1} (\sum W_e)_i \Big\} - h_i (\sum W_e)_i + (\sum h W_e)_i$$

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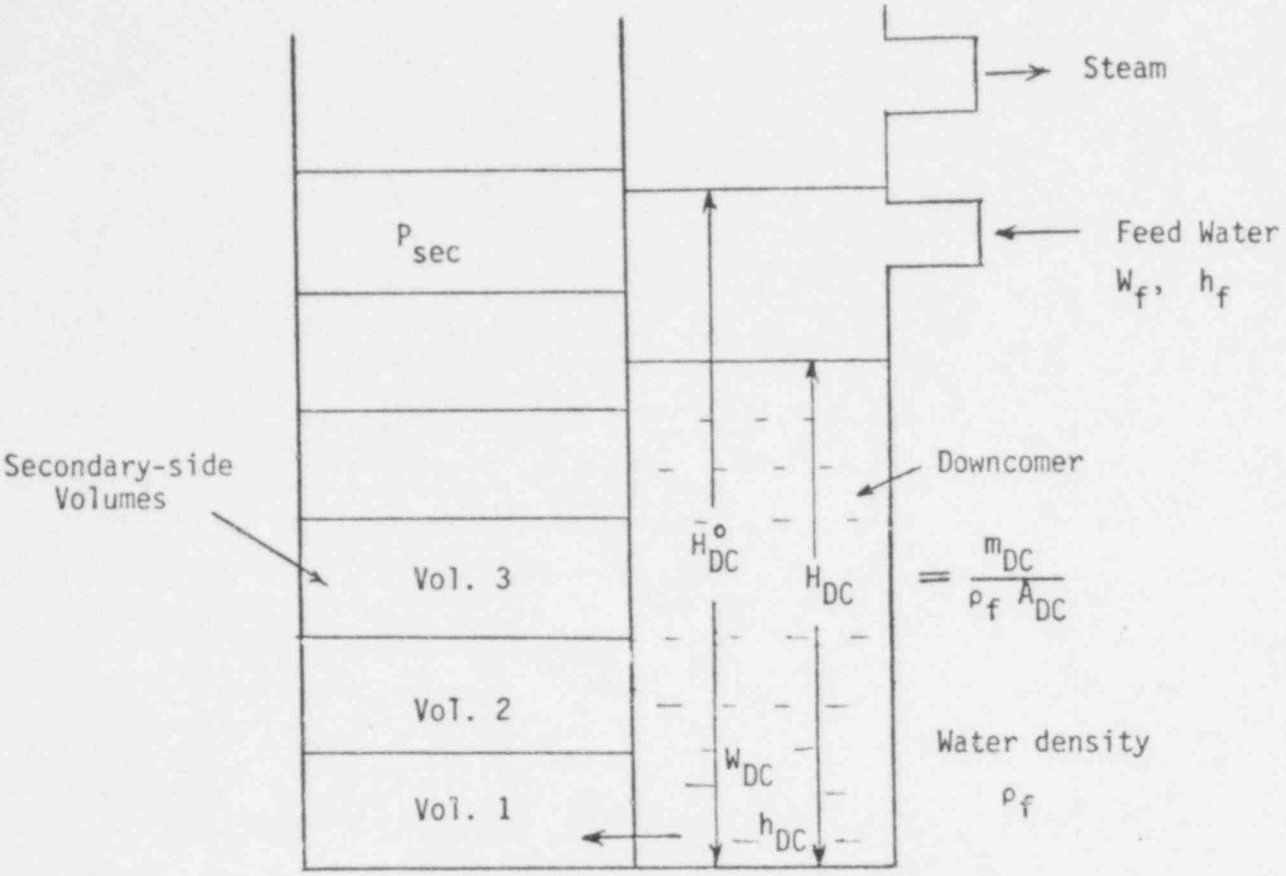

(Mass) $\dot{m}_{DC} = W_f - W_{DC}$

(Energy) $\frac{d(m_{DC}h_{DC})}{dt} - CV_{DC}\dot{P} = W_f h_f - W_{DC}h_{DC}$

At steady-state condition

$$g\left(\rho_f H^o_{DC} - \sum \rho_i H_i\right) = \frac{K\,W^2_{DC}}{\rho_f}$$

from which K is calculated. During transient, since $H_{DC} = \frac{m_{DC}}{\rho_f A_{DC}}$

$$W_{DC} = \sqrt{\frac{\rho_f\ g}{K}\left(m_{DC} - \sum \rho_i H_i\right)}$$

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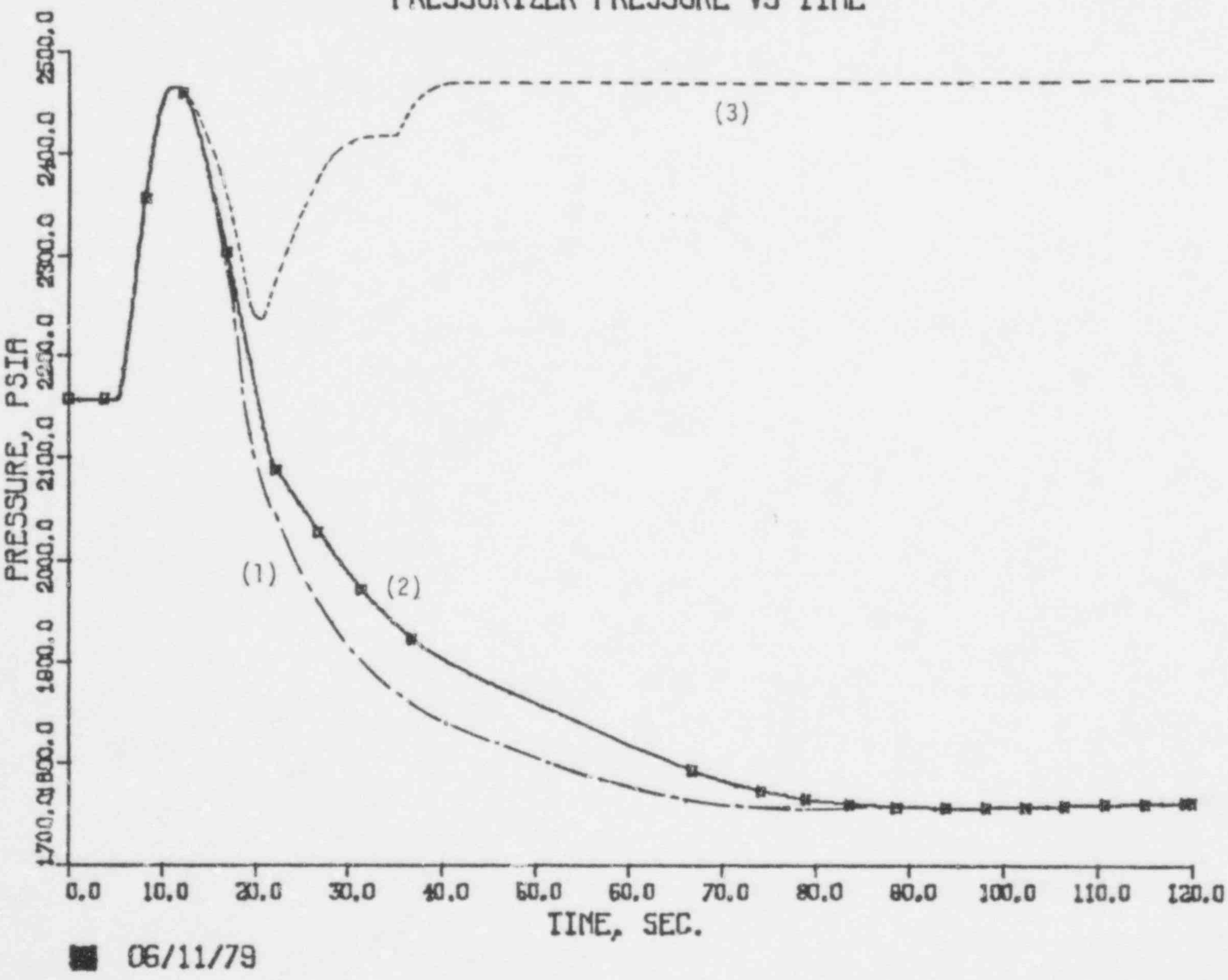
TMI A-1

PRESSURIZER PRESSURE VS TIME



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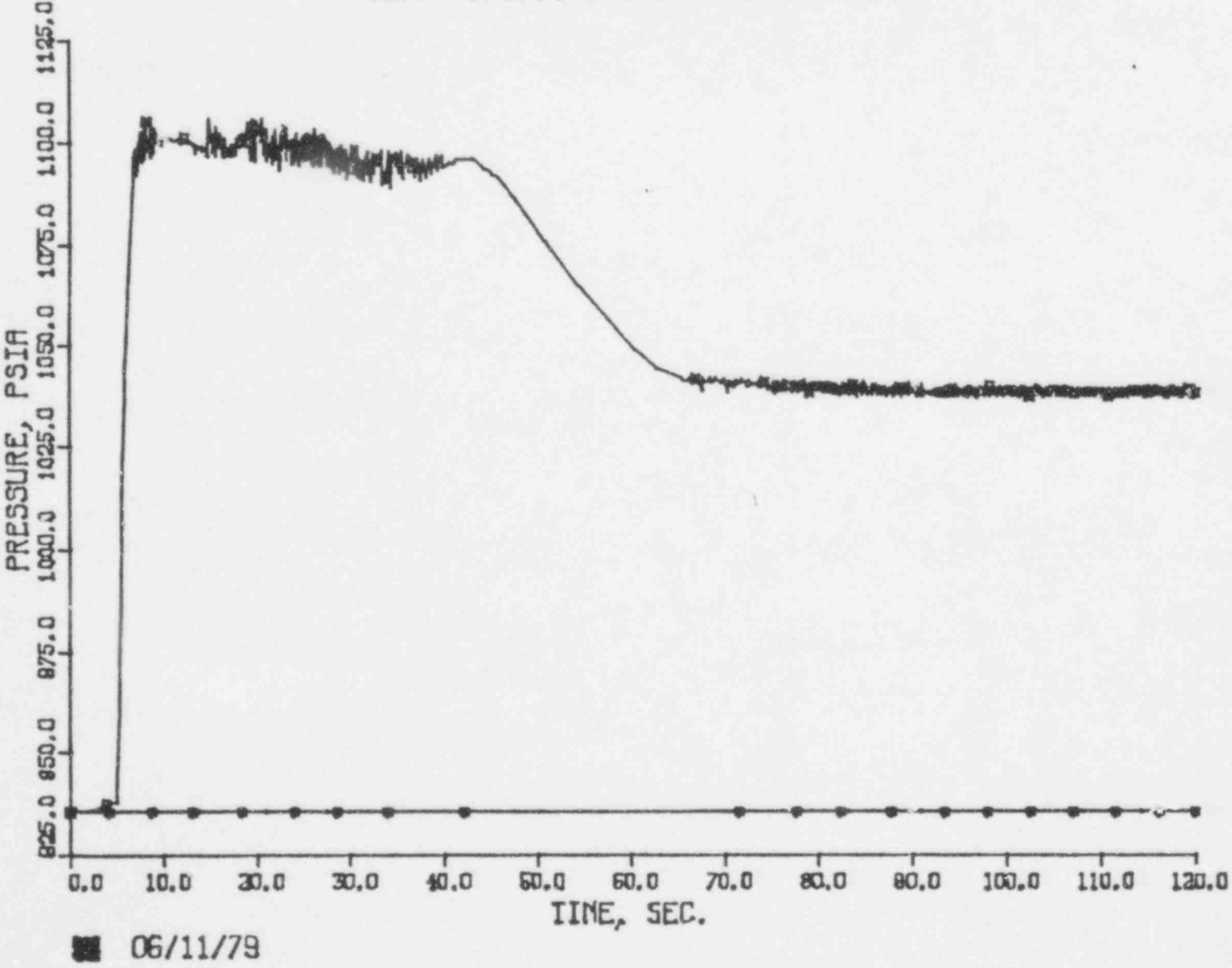
TMI A-1

STEAM GENERATOR PRESSURES VS TIME



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IRT ONCE-THROUGH STEAM GENERATOR

PURPOSE: MODIFY IRT ONCE-THROUGH STEAM GENERATOR TO TRACE BOUNDARIES OF DIFFERENT HEAT TRANSFER REGIMES.

MODEL: 3 TO 5 VARIABLE VOLUMES

2 TO 4 BOUNDARIES

- 2 FIXED
  - POINT OF TUBE RUPTURE
  - POINT OF RECIRCULATION TO DOWNCOMER
- 2 MOVING
  - BOILING POINT
  - CHF POINT (?)

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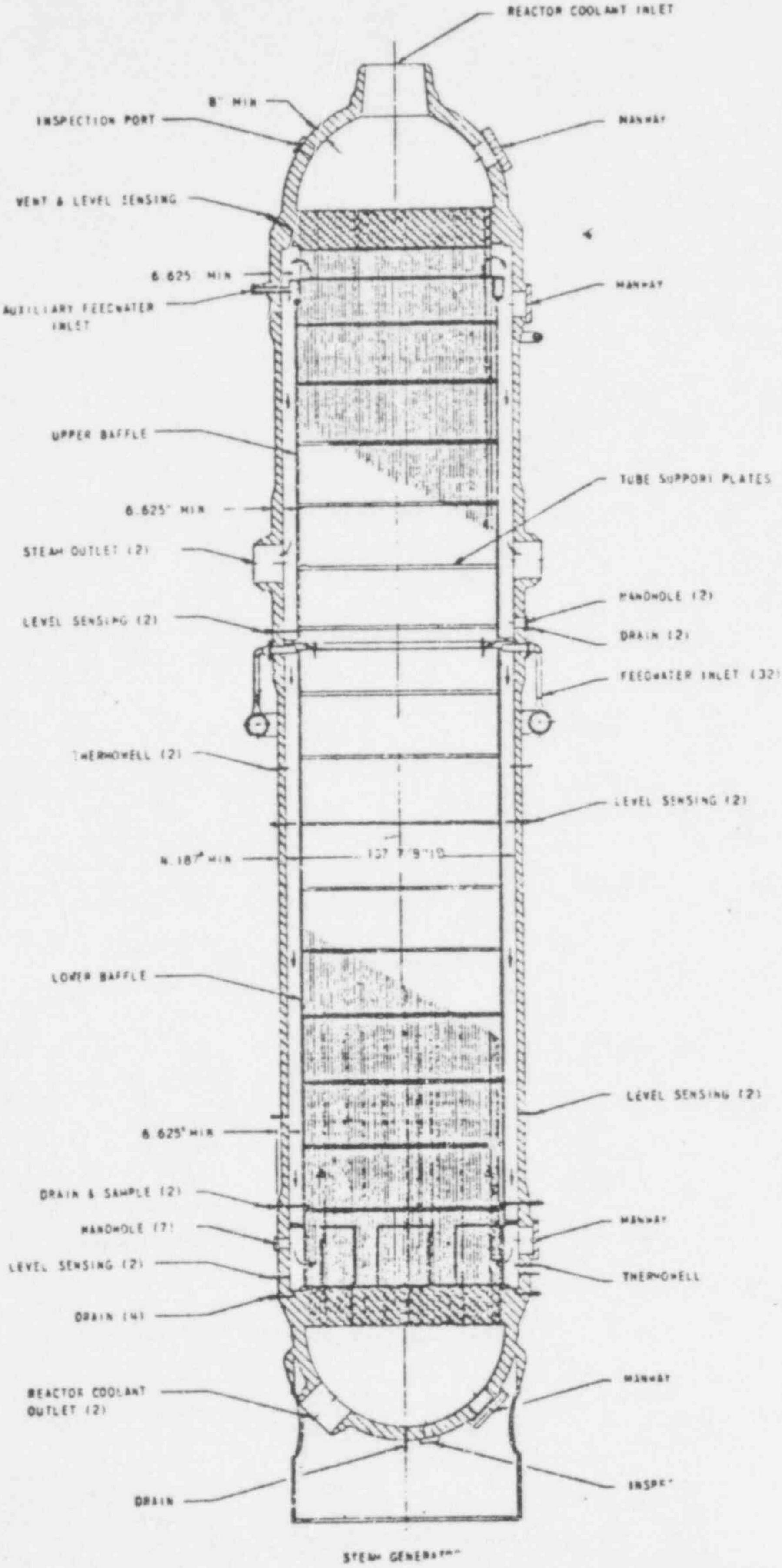
LONG-RANGE PLANS
FOR
STEAM GENERATOR MODELING
OTSG & UTSG

- MODELING NEEDS
    - Primary Side
    - Secondary Side
    - Solid Structures
- PROPOSED MODELING METHODS
    - Fluid Model
    - Solution Method
- REQUIRED PROCESS MODELS
    - Entrainment/Deentrainment
    - Cross Mixing
    - Phase Separation
    - Condensation



POOR ORIGINAL

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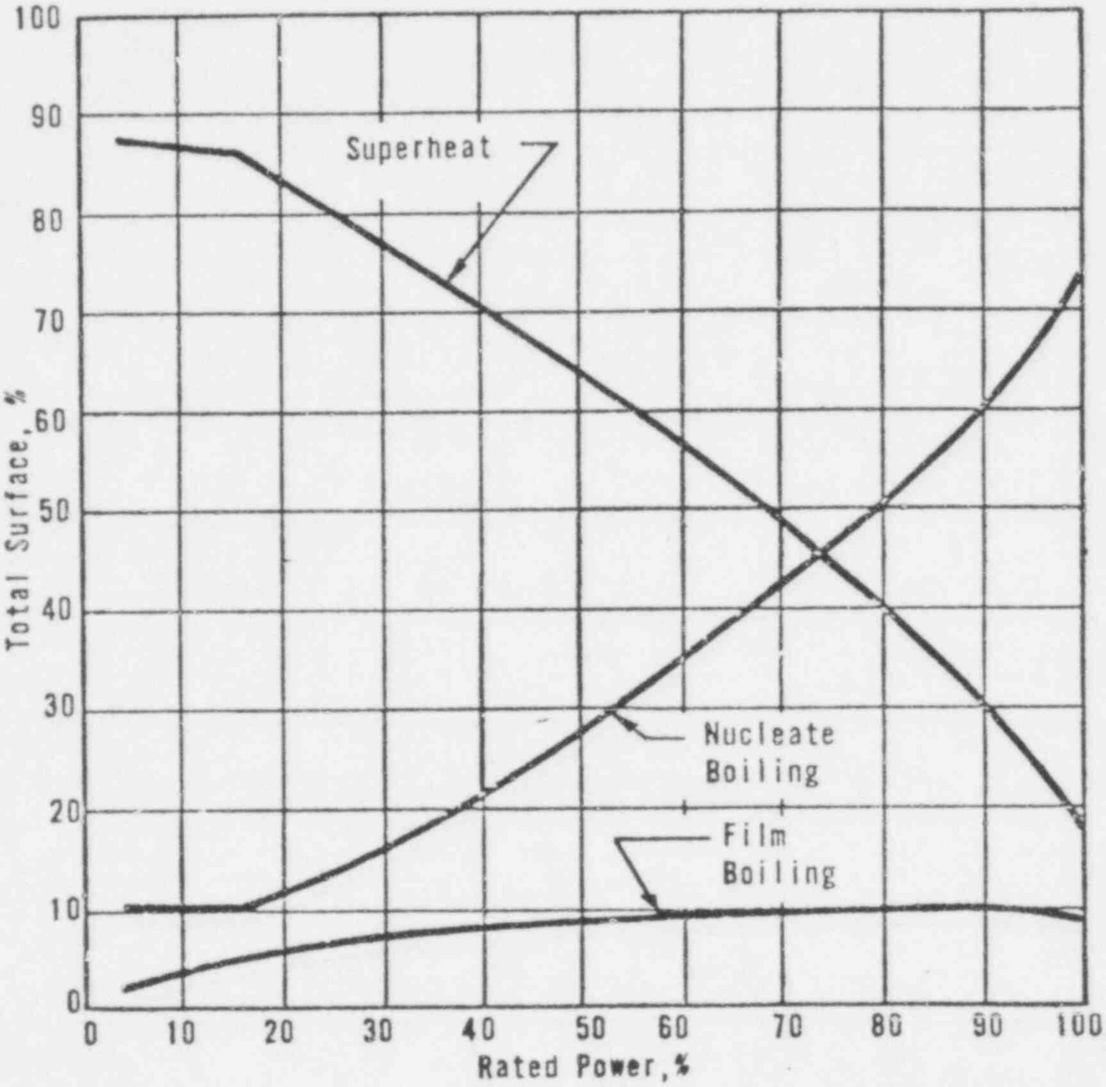
STEAM GENERATOR OUTLINE

THREE MILE ISLAND NUCLEAR STATION UNIT 2

FIGURE 5.5-3



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STEAM GENERATOR HEATING SURFACE VERSUS POWER

THREE MILE ISLAND NUCLEAR STATION UNIT 2

FIGURE 5.5-5

PRIMARY SIDE

FLOW MODEL

Single-Phase Liquid

Two-Component, Two-Phase Flow

(H_2O and N_2)

Nonhomogeneous, Nonequilibrium Flow (slip)

Forced and Free Convection

INTERFACE TRACKING

1. Mixture Level
2. Boiling Boundary

(3. Flow and Heat Transfer Regimes)

HEAT TRANSFER

Single Phase, liquid

Two-Phase, liquid water & N_2 & water vapor

Subcooled boiling
Bulk boiling } ($p_1 < 130$ bar)

Condensation (effect of N_2)

LIQUID ENTRAINMENT

Annular - Mist Flow Interface

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SECONDARY SIDE

FLOW MODEL

Single-Phase, liquid and vapor/air

Two-Component, Two-Phase Flow
(water and air)

Nonhomogeneous, Nonequilibrium Flow

Forced and Free Convection

INTERFACE TRACKING

1. Mixture Level
2. Boiling Boundary
(3. Flow and Heat Transfer Regimes)

HEAT TRANSFER

Single Phase, liquid

Two-Phase, liquid water and air

Subcooled Boiling

Bulk Boiling

(Condensation, $P_1 < P_2$)

ENTRAINMENT

Vapor (Downcomer Entrance)

Liquid (Mixture Level)

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PROPOSED MODELING METHOD

FLUID MODEL

- GEOMETRY
- BALANCE EQUATIONS
- INTERFACE EQUATION
- CONSTITUTIVE EQUATIONS

SOLUTION METHOD

- SPATIAL DISCRETIZATION
- TEMPORAL DISCRETIZATION &
  SOLUTION METHOD

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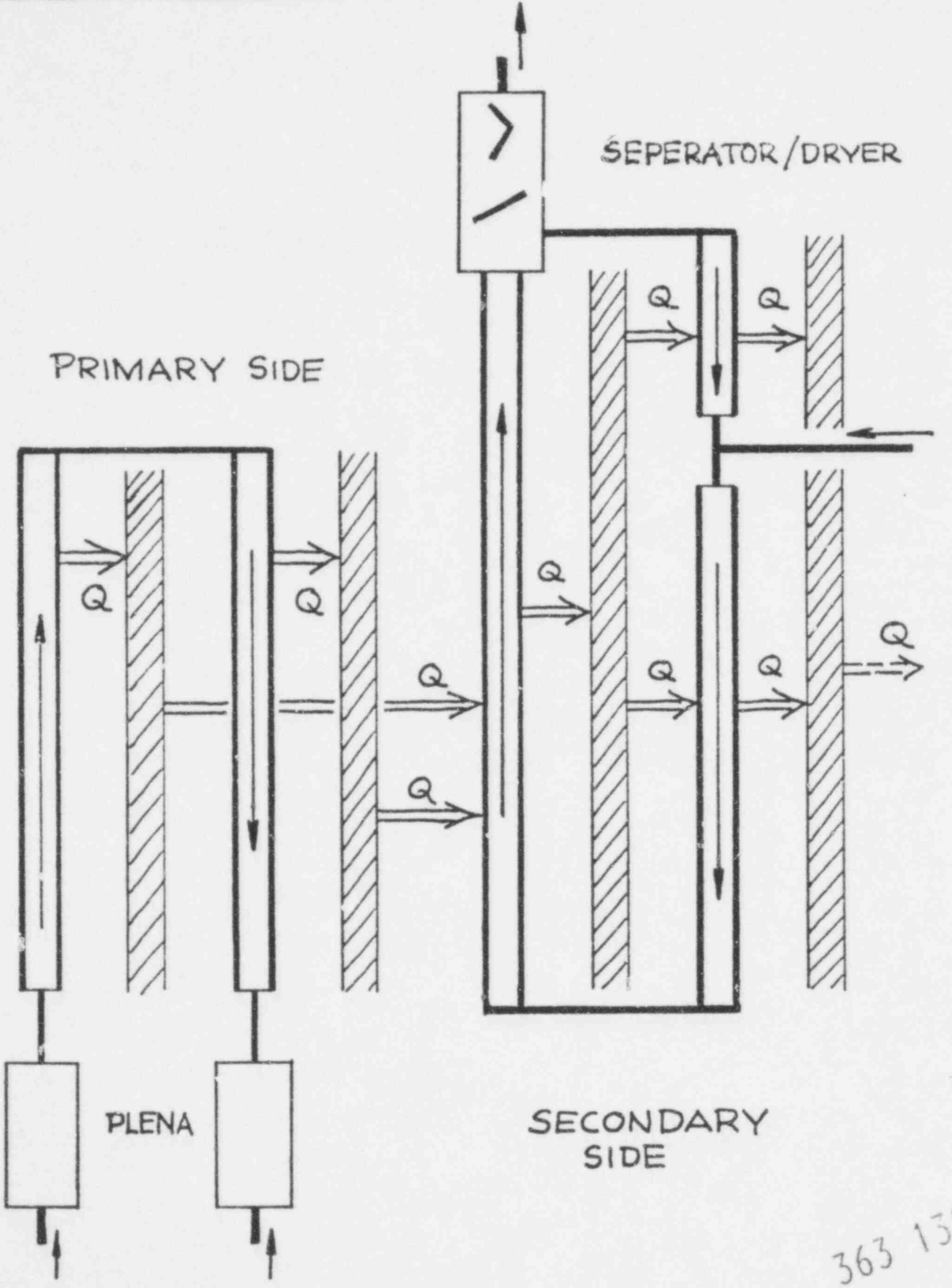
UTSG GEOMETRY



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INTERFACE EQUATIONS

1. INTERFACE WITH CONTINUOUS FLOW VARIABLES

$$\phi\{\underset{\sim}{Y}(Z)\} = 0$$

$$\dot{Z} = -(\partial\phi/\partial\tau)\Big/(\partial\phi/\partial z)$$

EXAMPLE: BOILING BOUNDARY

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2. KINEMATIC JUMPS

MIXTURE AND GAS MASS JUMP CONDITION AND FLOW VARIABLES BELOW AND ABOVE THE INTERFACE.

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SOLUTION METHOD

P.D.E. $AY_T + BY_Z = 0$

SPATIAL DISCRETIZATION

1. CELLS WITHOUT INTERFACE
   - UPWIND DIFFERENCING (BNL, RPI)
2. CELLS WITH MOVING INTERFACE
   - LP MODEL WITH EXTRAPOLATION OF PROPERTIES Y^+, Y^- AT INTERFACE FROM DISCRETE MODEL.

TIME DISCRETIZATION

STAND-ALONE PROGRAM MUST HAVE TIME INTEGRATION SCHEME OF HOST CODE (SYSTEMS CODE).

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REQUIRED PROCESS MODELS

ENTRAINMENT/DEENTRAINMENT

- Droplets at Mixture Level
- Droplet-Tube-Baffel Interaction
- Steam Entrainment at DC Aspirator

CROSS MIXING	UTSG OTSG Baffels
PHASE SEPARATION	Baffel Effects
CONDENSATION	Superheated Steam & Incondensible Gases.

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EXPERIMENTS FOR STEAM GENERATOR MODEL VERIFICATION

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B. U-TUBE S. G.

- STEADY-STATE AND TRANSIENT EXPTS.
- GLOBAL VARIABLES
  (SAME AS OTSG)
- INTERNAL VARIABLES
  - TWO-PHASE/WATER LEVEL IN SECONDARY
  - PERFORMANCE OF SEPARATOR
    (CARRY-OVER AND CARRY-UNDER)
  - PRESSURE, TEMPERATURE, QUALITY AND VOID FRACTION (FOR 2-PHASE) IN PRIMARY AND SECONDARY
  - RADIAL DISTRIBUTION OF PRESSURE, TEMPERATURE, QUALITY AND VOID FRACTION IN SECONDARY

3. SUGGESTIONS FOR ADDITIONAL EXPERIMENTS

A. FULL-SCALE S. G.

- VERIFICATION TESTS IN POWER PLANTS
- TRANSIENT TESTS (E.G., LOAD FOLLOWING)
    - MAINLY TO PROVIDE GLOBAL VARIABLES
    - INTERNAL VARIABLES AS MUCH AS POSSIBLE

B. SMALL-SCALE S. G.

- CONTROLLED, WELL-INSTRUMENTED EXPERIMENTS IN LABORATORY
- SIMULATE ALL POSSIBLE REACTOR CONDITIONS OF INTEREST INCLUDING NATURAL CIRCULATION THROUGH STEADY-STATE AND/OR TRANSIENT TESTS
- SHOULD PROVIDE BOTH THE GLOBAL AND THE INTERNAL VARIABLES

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