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SUBJECT: Provides update to 930611 initial response to NRC Bulletin 93-002.Analysis confirming that subj roughing filters will remain confined within kidney fans in event of LOCA inside containment encl.

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INDIANA
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Donald C. Cook Nuclear Plant Units 1 and 2 AEP:NRC:1188A
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74
BULLETIN NO. 93-02: DEBRIS PLUGGING OF EMERGENCY
CORE COOLING SUCTION STRAINERS

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

August 6, 1993

Dear Dr. Murley:

The purpose of this letter is to provide an update to our initial response to NRC Bulletin 93-02 dated June 11, 1993. The initial response noted that additional time was required to investigate the capability of ventilation units in the containments of Cook Nuclear Plant to contain fibrous filters following a Loss of Coolant Accident (LOCA). Specifically, the Containment Auxiliary Cleanup Ventilation Units (kidney fans) located in the basement of the lower compartment of Cook Nuclear Plant containments needed to be analyzed. As stated in the original letter, these were the only sources of the fibrous material addressed in the bulletin that posed a concern for blocking the containment recirculation sump.

An analysis has been completed that confirms that the subject roughing filters will remain confined within the kidney fans in the event of a LOCA inside containment. As requested by your staff, a copy of the analysis is included as an attachment to this letter. This analysis utilized the leak before break philosophy, developed by Westinghouse as part of the resolution of unresolved safety issue USI-A2. Leak before break is applicable to Cook Nuclear Plant via amendment no. 76 to Unit 2 and an NRC SER dated November 22, 1985.

As indicated in our original response letter referenced above, the filters discussed have been found to be unnecessary for the functionality of the ventilation units. Current plans are to ensure the roughing filters are removed from Unit 1 during the next refueling outage scheduled to begin February 1994. If Unit 1 is forced into an unplanned outage of sufficient duration prior to this date, every effort will be made to ensure the removal of the roughing filters sooner. We verified by inspection that there were no roughing filters in Unit 2 during the forced outage which began August 2, 1993.

100046

JE11

This letter is submitted pursuant to 10 CFR 50.54(f) and, as such, an oath statement is attached.

Sincerely,

E. E. Fitzpatrick
Vice President

eh

Attachment

cc: A. A. Blind - Bridgman
J. R. Padgett
G. Charnoff
NFEM Section Chief
J. B. Martin - Region III
NRC Resident Inspector - Bridgman

STATE OF OHIO)
COUNTY OF FRANKLIN)

E. E. Fitzpatrick, being duly sworn, deposes and says that he is the Vice President of licensee Indiana Michigan Power Company, that he has read the forgoing response to Bulletin 93-02: Debris Plugging of Emergency Core Cooling Suction Strainers and knows the contents thereof; and that said contents are true to the best of his knowledge and belief.

E E Fitzpatrick

Subscribed and sworn to before me this 6th

day of August, 1993.

Rita D. Hill
NOTARY PUBLIC

RITA D. HILL
NOTARY PUBLIC, STATE OF OHIO
MY COMMISSION EXPIRES 6-28-94

ATTACHMENT TO AEP:NRC:1188A

ANALYSIS OF A LOCA ON THE

VENTILATION UNITS

AMERICAN
ELECTRIC
POWER

Date July 29, 1993

Subject Effect of Loss of Coolant Accident on Ventilation Units Housing Fibrous Materials

From T. J. Crawford TJC

To S. A. Hover

Responding to your memo of June 11, 1993, we have analyzed the effects of a LOCA on the ventilation units.

The maximum differential pressure across the ventilation units was calculated to be less than 0.1 psi.

The break of the accumulator line feeding the cold leg was used as the LOCA. Because of the 'Leak-before-break' criteria the double-ended cold-leg break or cross-under leg break were not considered as the LOCA scenario. Direct impingement or dynamic effects were not included since the accumulator line enters the cold leg near elevation 615 and the number 2 steam generator and its four support columns are between the break location and the ventilation unit.

Attached for your information and record retention is a copy of the calculation. If you need additional information please do not hesitate to contact me at 1284.

cc: S.J. Brewer / J.B. Kingseed / S.A. Hover	w	attachment
E.E. Fitzpatrick	w/o	"
G.R. Burris Jr.	w/o	"
M.K. Guha / C.D. Olsen / File N930601	w/o	"

May 1980
Jan 1984, Rev 1
Dec 1988, Rev 2

Calculation Cover Sheet
Technical Assessment Section

Job No.: N930601

Title: Effect of Loss of Coolant Accident on Ventilation Units Housing Fibrous Materials or Filters

System: Emergency Core Cooling

Plant: D.C. Cook   File No.: ___   Unit: 1 & 2

Design Basis: N/A

By: T. J. Crawford   Date: 7/26/93

Review: C. P. Lin   Method: 4.3.1, 4.3.2, 4.3.4   Date: 7/29/93

Approval: M. K. Guha   Date: 7/30/93

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TECHNICAL ASSESSMENT CALCULATION VERIFICATION CHECKLIST

Page 0 of 30

Reviewer: Chao P. Lin / Chao P. L. Date: 7/29/93

Section Manager: Manoj K. Guha Date: 7/30/93

Review of the calculation shall include evaluation against the following questions:

	YES	NO	Basis for Determination
1. Was an appropriate method used?	X		Checked methodology in the calculation
2. Are the results reasonable compared to the input?	X		Compared to an independent check results.
3. Are the results numerically correct?	X		Compared to an independent check results
4. Are the equations used correct and the reference documented?	X		Checked the equations and references in the calculation
5. Were the correct inputs used and their sources documented?	X		Checked the input information and references in the calculation
6. Are the assumptions reasonable and properly documented (including appropriate references and adequate justification)?	X		Checked the assumptions in the calculation.
7. Is the calculation acceptable?	X		Based on all above.

EFFECT OF L.O.C.A. ON VENTILATION UNITS

1. PROBLEM

In a memo of June 11, 1993(Ref. 1), Mr. S. A. Hover of Nuclear Operations requested Technical Assessment to analyze the effects of the accumulator leg break LOCA blowdown forces on the Containment Auxiliary Cleanup (Ventilation) Unit located in the basement of lower containment at the D.C. Cook Plant. The purpose of the analysis is to determine the differential pressure that may be exerted on the ventilation unit during a LOCA, and would be used by Structural Engineering to determine the ability of units to contain fibrous filter materials.

The analysis would be in response to NRC bulletin 93-02 and would be used to support continued operation until the next refueling outage.

2. CONCLUSION

The maximum differential pressure across the cleanup or ventilation units was calculated to be less than 0.1 psi.

The break of the accumulator line feeding the cold leg was used as the LOCA. Because of the 'Leak-before-break' criteria the double-ended cold-leg break or cross-under leg-break were not considered as the LOCA scenario. Direct impingement or dynamic effects were not included since the accumulator line enters the cold leg near elevation 615 and the number 2 steam generator and its four support columns are between the break location and the ventilation unit(Refs: 8 & 20).
The unit sits on elevation 598 and is about 10 feet high, bringing the top of the unit to elevation 608.

The pressure and temperature were calculated for the various containment compartments. The initial pressure, temperature, and relative humidity were 14.7 psia, 90.0 F, and 100% respectively. The initial temperature of the ice condenser was 27.0 F.

The computer program written for this analysis(LOCA01) was checked for reasonableness by using it to analyze the double-ended cold leg break with the appropriate initial pressure and temperatures, and comparing it with the Westinghouse TMD results and the MPR Associates results displayed on p IV-19 of Ref. 5. The results are tabulated below.

Peak Sub-Compartment Pressure(psia)		
LOCA01	MPR	TMD
29.0	26.0	23.9

Peak Deck Differential Pressure(psi)		
LOCA01	MPR	TMD
8.4	8.3	8.6

The LOCA01 program calculates a slightly more conservative pressure and differential pressure. The relatively close agreement of LOCA01 with TMD and MPR provides additional confidence in the results of the present analysis of the ventilation unit.

3. PROCEDURE

A. Obtain the dimensions of the air filtering unit(Ref. 2), the distances between the unit and the crane wall, the unit and the biological shield, the unit and the ceiling, and the two elevations. Calculate flow area for steam/water mixture around the air unit.

B. Obtain the diameter of the accumulator line and the maximum blowdown flow rate from it(Fig. 2-3, Ref. 3). Use a realistic value of temperature for cold leg water to calculate the density and quality of the steam-water mixture that would be released.

C. Obtain necessary input data. Much of this was taken from Refs. 4, 5, 6, 7, & 8. This included the dimensions of the containment building, sub-compartment volumes, flow areas between compartments, wall surface areas and thicknesses, and mass and area of metal in the compartments.

D. Divide the containment building into twelve sub-compartments or regions. The lower compartment was divided into six regions. The two fan-accumulator rooms, the reactor cavity, and the instrument room were four more regions. The ice condenser and the upper compartment were two more regions.

E. Divide the containment walls into slabs or nodes of increasing thickness from the surface to the interior.

F. Write a computer program to calculate the thermodynamic states and properties in each compartment, and the flow of air and steam among compartments. This was done by incorporating some of the techniques used in the MARCH program(Ref. 9).

G. Make the necessary calculations and tabulate the results.

4. ASSUMPTIONS

A. The containment building may be accurately represented as a lower compartment divided into six regions separated by a steam generator or the filtering unit, the dead ended regions and reactor cavity, the ice condenser and the upper compartment, for a total of twelve regions.

B. The pressure and temperature were uniform throughout each compartment. The air and steam or water vapor formed a homogeneous mixture.

C. The flow rate of air and steam among compartments could be adequately modelled using a form of compressible flow equation(p 3-5, Ref. 10) with an appropriate flow coefficient, flow area opening, specific volumes, and the pressure difference between the compartments. This equation includes an acceleration pressure loss as well as form losses. The flow coefficients were obtained from Refs. 4 & 5. The flow coefficient for the passage formed by the filtering unit was calculated using Ref. 12, p335-335.
As was done in Ref. 6, the flow calculated for each time step was limited somewhat by a restriction factor to eliminate the excessive changes in compartment mass in each time step, and the resulting large pressure oscillations that would be observed without it.

Ref. 6 calculated the number of moles of air and vapor that must be transferred to bring the pressure of two adjacent compartments to an equilibrium pressure. The number of moles to transfer was calculated for the largest flow passage area for a compartment; flow through smaller areas was then based on flow through this largest area. The present calculation used a very small time step(0.0001 sec) to utilize a simple restriction factor (/1.4), and avoid calculating moles transferred and flows based on large and small volumes and flow areas.

D. Flow of liquid or water between adjacent compartment floors was also calculated using a weir flow type equation with the difference in water depth. This method was also used in Ref. 16.

E. The air was treated as an ideal gas. The value of constant pressure specific heat was assumed constant at 0.240 Btu/lbm/F. The value of constant volume specific heat was also assumed constant and was calculated using $Cv = Cp - R/778.16$. The internal energy of air was a function of temperature only.

F. The steam/water vapor was also treated as an ideal gas when calculating the number of moles in a compartment or its average molecular weight. Steam properties were taken from Ref. 11.

G. The containment walls were semi-infinite slabs, and heat transfer only occurred perpendicular to the thickness. The walls were insulated on the outside surface. They could absorb heat from the air/vapor mixture, but could not loose heat to the outside.

[illegible] 7/29/93

H. The floor between the upper and lower compartments was treated as a wall insulated at the center line. Each room could access half the wall thickness. The walls separating the lower compartment from the dead-ended region was treated the same. The walls between the upper compartment and the ice condenser were neglected.

J. The metal equipment in the lower and upper compartments was also modelled as a slab, and heat flow and temperature were calculated similarly to the concrete walls.

K. The temperature of containment air was initially 90 F, the pressure was 14.7 psia, and the relative humidity was 100%.

L. The temperature of the containment walls was initially 90 F.

M. All ice condenser lower plenum inlet doors and outlet intermediate deck doors were assumed to be open.

N. The ice condenser baskets and ice were treated as a wall with heat transfer being calculated as in item F. The heat transferred from the steam/air mixture to the ice was calculated at each time step. The corresponding amount of ice melt was then calculated.

O. Emissivity of the gas mixture to the walls was 0.3 .

P. No credit was allowed for the containment spray system.

OTHER INPUTS/DATA

- The compartment volumes, wall surface areas, thicknesses, physical properties, etc. were taken from Refs 6 and 7. The wall surface areas were re-apportioned for the new volumes based on the amount of perimeter or arc covered by the volume(Ref. 8). These are listed in the computer output. The containment walls are described in the Attachments.

- Only a portion of the floor surface area between the upper compartment and the lower compartment was considered.

- The inside diameter of the accumulator line was 8.75 inches(Ref. 19) and the maximum blowdown flow rate from it was taken as 24400 lb/sec/ft**2 (Fig. 2-3, Ref. 3). This value corresponds to the mass flux at 2250 psia and 540 F, the conditions of cold-leg saturated liquid. It was kept constant for the entire transient to assure a very conservative flow rate. For comparing the LOCA01 program against the Westinghouse TMD results(Ref. 4) and the MPR Associates results(Ref. 5), the cold leg diameter used was 31 inches, the blowdown flow rate used was 9882.777, and the temperature was 534.6 F. These values gave the 103,600 lb/hr and 530 btu/lbm inputs respectively of p IV-2, Ref. 5.

- The number of ice baskets was 1944; their length was 48 feet; their diameter and pitch were 12 and 14 inches respectively (Ref. 18). The surface of the walls and other structures within the ice condenser compartment were neglected.

- Natural convection and condensation heat transfer coefficients between the walls and the steam/air mixture were calculated using the equations of pp 6-13 to 6-16(Ref. 9). Radiation heat transfer was also included. Where steam/air velocities were high enough forced convection heat transfer was included using Ref. 13, p148 for the walls and p176 for the ice baskets.

- Heat transfer through the slab walls was modelled by dividing each wall into adjacent layers of varying thickness, using pp 6-15 and 6-16 (Ref. 9).

- The ice condenser was initially at 27 F, and it contains 2,370,000 lbs of ice also at 27 F. Ice properties were from Ref. 14.

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5. CONTENTS

A. COMPARTMENT ENERGY..

The total internal energy of each compartment was calculated using the First Law of Thermodynamics for an open system. The change in energy equals the mass flow of enthalpy in minus the mass flow of enthalpy out minus the heat transferred to the walls. The new internal energy was calculated in subroutine ENERGY using

$$U2 = \dot{m}i * hi - \dot{m}e * he - Q + U1$$

Each flow rate in and out was averaged over two time steps using

$$\dot{m}i = (mi(2) + mi(1)) / 2.0$$

B. INITIAL COMPARTMENT MASSES

The initial volume of the ice was calculated using Ref. 14 with the initial ice mass. The volume of air and vapor in the ice condenser was provided in Refs. 6 or 7. The total volume of the ice condenser was calculated by adding the volumes of ice and air.

VTOT(1,7) = W(1,5) * VICE

where
- W(1,7) = Ice mass
- VICE = specific volume of ice

VTOT(3,7) = VTOT(2,7) + VTOT(1,7)

where
- VTOT(3,7) = total ice condenser volume
- VTOT(2,7) = air and vapor volume
- VTOT(1,7) = ice volume
- 7 = the ice condenser compartment identification no.

The initial water vapor mass in each compartment, including the ice condenser, was calculated using the steam tables with initial pressure, temperature, relative humidity, and open or void compartment volume.

W(2,NC) = VTOT(2,NC) / VGT(T(NC)) * (RH(NC) / 100.)

where
- VTOT(2,NC) = open volume
- VGT(T(NC)) = specific volume of vapor at temperature T(NC)
- RH(NC) = relative humidity

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The initial air mass in each compartment was calculated using the ideal gas law with partial pressure of air, temperature, and open volume.

```
W(4,NC) = P(2,NC) * 144. * VTOT(2,NC) / R / ( T(NC) + 460. )
```

where

```
P(2,NC) = partial pressure of air
        = total pressure - partial pressure of water vapor
R       = ideal gas constant for air
```

C. FLOW RATES BETWEEN COMPARTMENTS

The flow rate of gas or vapor between adjacent compartments was calculated using p 3-5, Ref. 10

```
F() =   ( ( 2.0 * gc * 144. * DP() * AREA()**2 ) /
          ( 2.0 * dv() + KLS() * v() ) )**1/2
```

where

```
DP()   = pressure difference between compartments
AREA() = flow area
KLS()  = flow loss coefficient
v()    = average specific volume of mixture
dv()   = difference between v() between compartments
```

The amount of air and vapor mass transferred in each time step was calculated using

```
DF() =  F() * TS  / DPDFS
```

where

```
TS     = time step
DPDFS  = a flow limiting factor(1.4) for multiple flow paths through
         each compartment to help avoid pressure oscillations and which
         helped benchmark the program against the TMD and MPR results.
```

The flow of liquid water between adjacent compartments was calculated using a version of the weir flow equation of p 479, Ref. 15.

```
F(1,NP,) = Cflw * rho * Width * ( Z(NF(NP)) - Z(NT(NP)) ) / 12.
```

where

```
Cflw    = weir flow coeff; taken large to accommodate inertia.
 rho    = density of water.
Width   = a characteristic width between adjacent compartments.
Z(NF,)  = depth of water in 'from' compartment, larger than Z(NT,)
Z(NT,)  =   "     "    "   "  'to'      "          "       "    "
```

The flow of enthalpy per time step from a compartment was calculated using

```
DH(j,NP) = DF(j,NP) * H(j,NC)
```

where

```
 H(j,NC) = the enthalpy of fluid type j in compartment NC
DF(j,NP) = mass flow per time step along flow path NP
   j     = liquid, vapor, and air
```

D. NEW COMPARTMENT MASSES..

The new masses of liquid, vapor, and air were calculated using the amounts of mass transferred averaged over the last two time steps using,

```
W(j,NC) = W(j,NC)  +  ( DF(j,in, 1) + DF(j,in, 2) ) / 2.0 )
                   -  ( DF(j,out,1) + DF(j,out,2) ) / 2.0 )
```

where

```
DF() = mass flow per time step
j    = liquid, vapor, and air
in   = flow path into the compartment
out  = flow path from the compartment
1,2  = previous, present time step
```

For gas flow the 'flow from' compartment was always at a pressure greater than the 'flow into' compartment. Pressure in each compartment was checked each time step to identify from and to numbers. For liquid flow the 'flow from' compartment had a greater depth of liquid than the 'flow into' compartment.

E. NEW THERMODYNAMIC STATE OF SUPERHEATED COMPARTMENTS

The new pressure, temperature, etc., of each superheated compartment following the additions or removals of mass and energy was calculated by balancing the total volume with component(vapor and air) volumes, and balancing total energy with component energy. This gave two equations(volume and energy) and two unknowns(total pressure and temperature). The system was solved by iteration with a Newton-Raphson technique for non-linear equations,
(pp 37-39, Ref. 17) The two equations were expressed as the following two functions,

```
G1(P2,T2) = VTOT(3,NC) - ( Mg*Vg(Pg,T2) + Ma*Va(Pa,T2) ) / 2.0
G2(P2,T2) = U(4,NC)    - ( Mg*Ug(Pg,T2) + Ma*Ua(T2) )
```

where

```
VTOT(3,NC) = compartment total volume
U(4,NC)    = compartment total energy
P2,T2      = new total pressure and temperature
Pg,Pa      = partial pressure of vapor, air
Mg,Vg,Ug   = mass, specific volume, and specific energy of vapor
Ma,Va,Ua   = mass, specific volume, and specific energy of air
```

Additional properties such as specific enthalpy, relative humidity, etc. were then calculated using the new P2 and T2.

F. NEW THERMODYNAMIC STATE OF SATURATED COMPARTMENTS

The new pressure, temperature, etc., of each saturated compartment following the additions or removals of mass and energy was calculated by balancing the total energy with component energy. This gave one equation(energy) and one unknown(temperature). The system was solved by iteration with the bisection technique.(p 18, Ref. 17)
The energy balance equation was expressed as the following function,

```
G1(T2) = U(4,NC) - ( Mf(T2)*Uf(T2) + Mg(T2)*Ug(T2) + Ma*Ua(T2) )
```

where

```
U(4,NC)    = compartment total energy
T2         = new temperature
Mf,Mg,Ma   = mass of liquid, vapor, and air
Uf,Ug,Ua   = internal energy of liquid, vapor, air
```

Additional properties such as pressure, specific enthalpy, relative humidity, etc. were then calculated using the new T2 and the saturated properties.

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G. HEAT TRANSFER TO CONTAINMENT WALLS(SLAB)

Heat transfer to the slab walls by natural convection and condensation was calculated based on the methods of Ref. 9, pp 6-13, 6-15. A radiation heat transfer coefficient and a forced convection coefficient were also included for this calculation. A total heat transfer coefficient was calculated by summing the individual heat flows.

$$qt = qc + qn + qr + qf$$

$$ht*(Tb - Tw) = hc*(Tsat - Tw) + hn*(Tb - Tw) + hr*(Tb - Tw) + hf*(Tb - Tw)$$

Solving for ht gives,

$$ht = hc*(Tsat - Tw)/(Tb - Tw) + hn + hr + hf$$

where

qt	=	total heat flux(Btu/hr/ft**2)
qc,qn,qr,qf	=	heat flux due to condensation, natural convection, radiation, and forced convection.
ht	=	total heat transfer coefficient(Btu/hr/ft**2/F)
hc,hn,hr,hf	=	heat transfer coefficients due to condensation, natural convection, radiation, and forced convection.
Tb,Tsat,Tw	=	bulk and saturation temperatures of gas mixture and wall surface temperature.

Condensation was assumed to occur only if the wall temperature was less than the dew point temperature.

H. HEAT TRANSFER WITHIN CONTAINMENT WALLS(SLABS)

The walls were divided into adjacent slabs or nodes of increasing thickness as per Ref. 9. The heat transfer coefficient for conduction heat transfer between adjacent slabs was calculated using

$$ht(n) = k / (x(n) - x(n-1))$$

where
- ht(n) = total heat transfer coefficient(Btu/hr/ft**2/F) node n
- x(n) = location or coordinate of node n
- k = thermal conductivity of concrete(Btu/hr/ft/F)

The conduction heat transfer entering node n from node (n-1) on the left) was calculated using,

$$qw(n) = ht(n) * (Tw(n-1) - Tw(n))$$

And the conduction heat transfer leaving node n to node (n+1) on the right) was calculated using,

$$qw(n+1) = ht(n+1) * (Tw(n) - Tw(n+1))$$

The temperature change of the first node was calculated using a heat balance:

$$DTw(1) = (QWavg - qw(2))*TS / (rho * dx(1) * Cp)$$

where
- QWavg = (qt(TS=1) + qt(TS=2)) / 2.0
  = time averaged heat flux entering surface of node 1.
- qw(2) = conduction heat flux leaving node 1 to node 2
- TS = time step size
- rho,Cp = density and heat capacity of concrete or steel.
- dx(1) = thickness of control volume, node 1

The temperature changes of the other nodes was calculated in a similar manner using:

$$DTw(n) = (qw(n) - qw(n+1))*TS / (rho * dx(n) * Cp)$$

where
- qw(n) = heat flux leaving node n-1 and entering node n
- qw(n+1) = " " " " n " " " n+1
- dx(n) = thickness of control volume, node n

6. REFERENCES

1. Memo of May 27, 1993, from S.A. Hover to T.J. Crawford, titled 'Effect of Fibrous Material on Recirculation Pump Screen'.

2. Drawing No. 107C-890301-H, from American Air Filter Co., Inc., Louisville, Ky., 1972.

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4. Updated F.S.A.R. for D.C. Cook Plant, Tables 14.3.4-15, 14.3.4-16, and Figure 14.3.4-18

5. MPR Associates, Inc., Ice Condenser Containment Independent Analysis Program Final Report, MPR-340, April, 1972.

6. Technical Assessment Section calculation N-921001, Containment Building Pressure and Temperature in Event of DHR Failure While in Mid-Loop Operation, January, 1993.

7. Containment Data Collection Notebook, D.C. Cook Nuclear Plant I.P.E., prepared by Fauske & Associates, Inc., January, 1992.

8. A.E.P. drawings 12-3181-14, 1-5688-10, and 1-5699-10.

9. NUREG/CR-3988, BMI-2115, MARCH 2 Code Description and Users Manual.

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16. Technical Assessment Section calculation N-920101, Fire Protection Water Storage Tanks for Unit 1 & Unit 2 at D.C. Cook Plant, January, 1992.

17. Grove, W.E., Brief Numerical Methods., Prentice-Hall, Inc., 1966.

18. Various written communications between Nuclear Safety Section and Technical Assessment(Attached).

19. Verbal communications between S.A. Hover of Nuclear Operations and T.J. Crawford of Technical Assessment.

20. Tubeco Inc., drawing 1-51-31, isometric pipe drawing.

7. ATTACHMENTS

A. Sketch of Containment with Compartments and Flow Paths

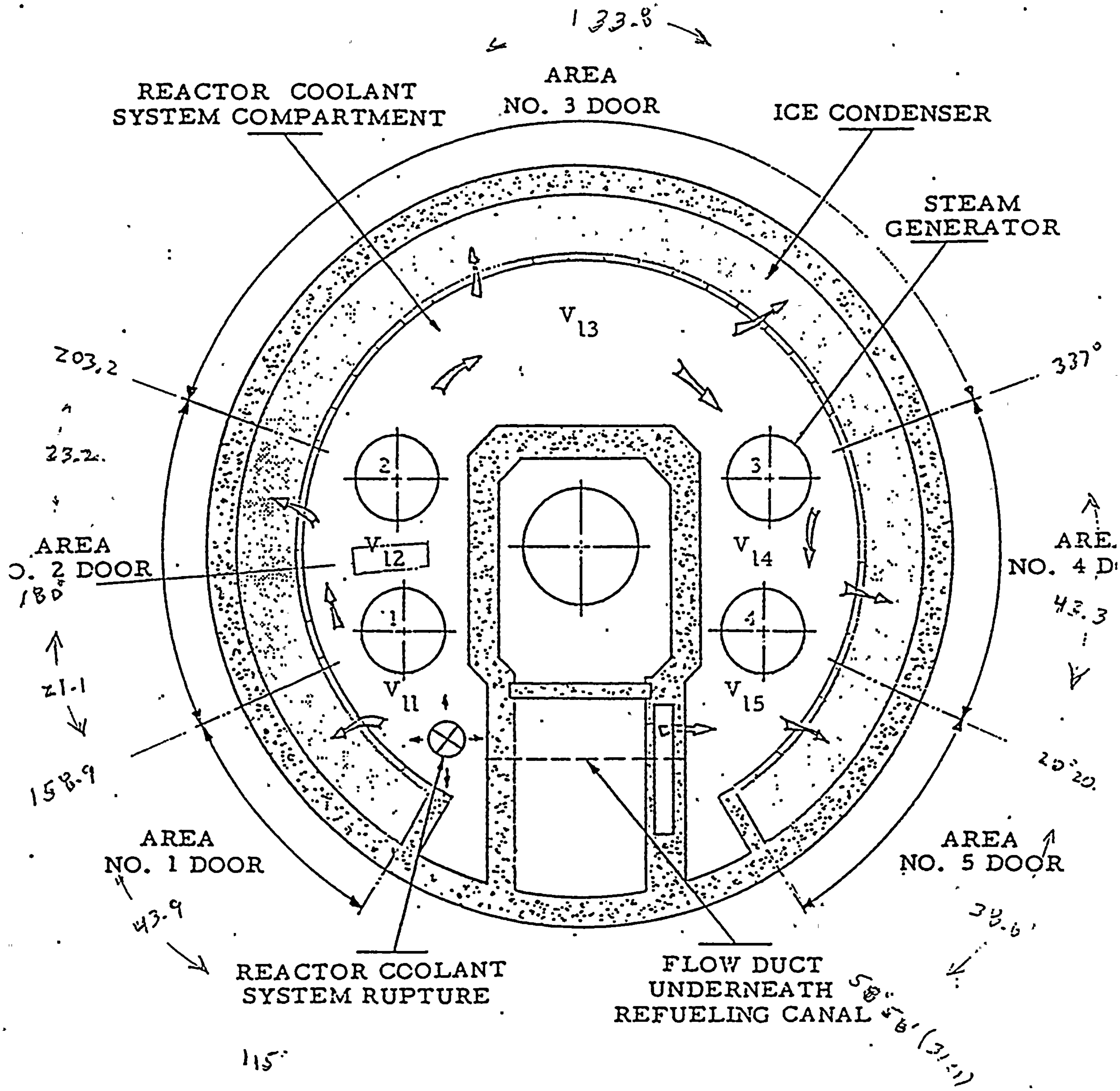
B. Descriptions of Compartment Volumes and Containment Walls or Slabs

C. Flow Diagram of Computer Program LOCA01.

D. Selected References.

E. Program Listing of LOCA01.

F. Program outputs for;
- . accumulator leg break(d=8.75), run time = 0.1112 sec
- . cold leg break(d=31.), run time = 0.2752 sec



PLANT DESIGN - PLAN VIEW SECTION OF
REACTOR COOLANT SYSTEM COMPARTMENT

V_{11} = 27750
V_{12} = 38000
V_{13} = 40000
V_{14} = 39000
V_{15} = 22500

302.9° total

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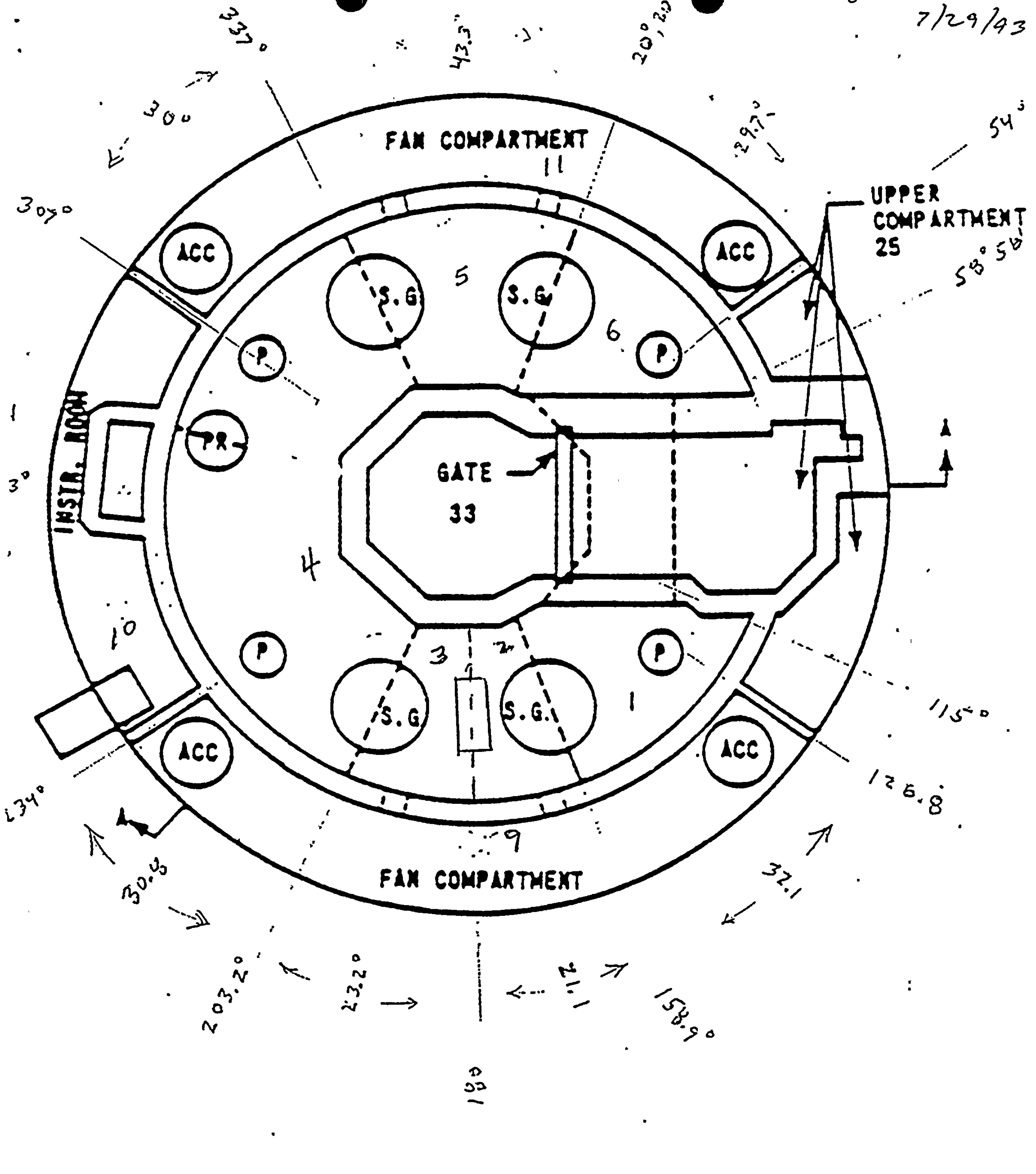
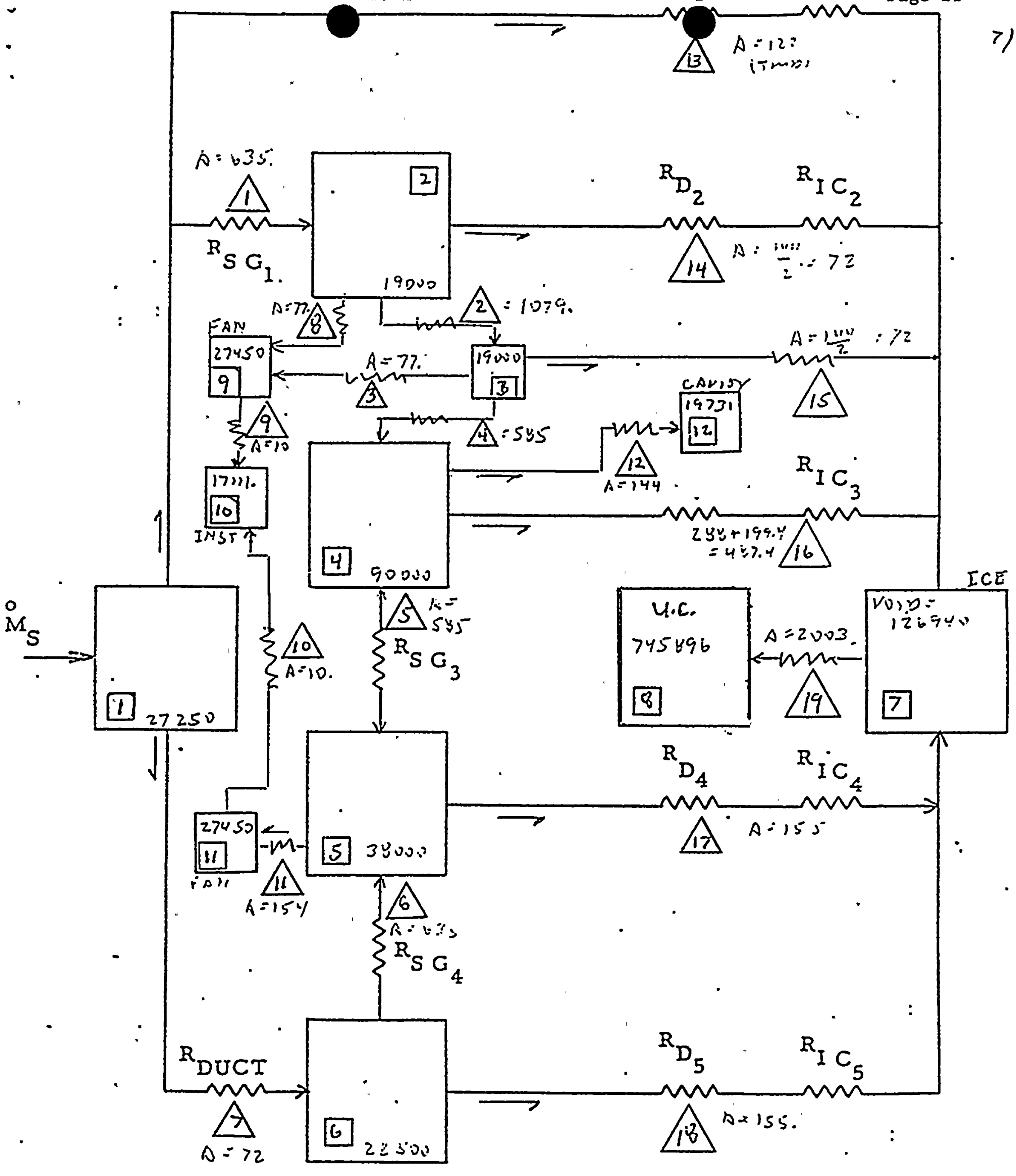

FAN COMPARTMENT
UPPER COMPARTMENT 25
ACC
ACC
ACC
ACC
S.G
S.G
S.G
S.G.
P
P
P
P
PR
INSTR. ROOM
GATE
33
FAN COMPARTMENT
337°
300
309°
54°
58°
115°
126.8
134°
30.5
32.1
203.2°
23.2°
21.1
158.9°



REACTOR CONTAINMENT SUBVOLUMES AND FLOW PATHS

7/29/93

COMPARTMENT NUMBERS AND VOLUMES(Refs. 4 & 5)

No.	Description	Volume (ft**3)
1	Break region in Lower Compartment between Refueling Canal and Steam Generator No. 2 (S/G 2)	27 250.
2	Volume between S/G 2 and Ventilation Unit	19 000.
3	Volume between Ventilation Unit and S/G 3	19 000.
4	Volume between S/G 3 and S/G 4	90 000.
5	Volume between S/G 4 and S/G 1	38 000.
6	Volume between S/G 1 and Refueling Canal	22 500.
7	Ice Condenser(void volume)	126 940.
8	Upper Compartment	745 896.
9	Dead Ended Region Housing Accumulators 2 and 3	27 450.
10	Dead Ended Region Instrument Room	17 111.
11	Dead Ended Region Housing Accumulators 1 and 4	27 450.
12	Reactor Cavity	19 731.

DESCRIPTION OF CONTAINMENT WALLS OR HEAT SINK SLABS(Refs. 4 & 5)

No.	Description	Surface Area (ft**2)	Thickness (ft)	Removes Heat From Cmpt
1	Between Cmpts 1 and 9	1 392.	3.0/2	1
2	Between Cmpts 2 and 9	915.	3.0/2	2
3	Between Cmpts 3 and 9	1 006.	3.0/2	3
4	Between Cmpts 4 and 9	1 336.	3.0/2	4
5	Between Cmpts 4 and 10	3 165.	3.0/2	4
6	Between Cmpts 4 and 11	1 301.	3.0/2	4
7	Between Cmpts 7 and 7	293 148.	N/A	7
8	Between Cmpts 5 and 11	1 878.	3.0/2	5
9	Between Cmpts 6 and 11	1 288.	3.0/2	6
10	Between Cmpts 9 and 1	1 392.	3.0/2	9
11	Between Cmpts 9 and 2	915.	3.0/2	9
12	Between Cmpts 9 and 3	1 006.	3.0/2	9
13	Between Cmpts 9 and 4	1 336.	3.0/2	9
14	Between Cmpts 10 and 5	3 165.	3.0/2	10
15	Between Cmpts 11 and 4	1 301.	3.0/2	11
16	Between Cmpts 11 and 5	1 878.	3.0/2	11
17	Between Cmpts 11 and 6	1 288.	3.0/2	11
18	Interior of Cmpt 1	508.	2.25	1
19	Interior of Cmpt 2	244.	2.25	2
20	Interior of Cmpt 3	269.	2.25	3
21	Interior of Cmpt 4	1 549.	2.25	4
22	Interior of Cmpt 5	501.	2.25	5
23	Interior of Cmpt 6	447.	2.25	6
24	Floor of Cmpt 1	539.	5.00	1
25	Floor of Cmpt 2	259.	5.00	2

26	Floor of Cmpt 3	285.	5.00	3
27	Floor of Cmpt 4	1 641.	5.00	4
28	Floor of Cmpt 5	531.	5.00	5
29	Floor of Cmpt 6	474.	5.00	6
30	Between Cmpts 1 and 8	2 511.	2.875/2	1
31	Between Cmpts 2 and 8	1 301.	2.875/2	2
32	Between Cmpts 3 and 8	1 327.	2.875/2	3
33	Between Cmpts 4 and 8	7 654.	2.875/2	4
34	Between Cmpts 5 and 8	2 477.	2.875/2	5
35	Between Cmpts 6 and 8	2 208.	2.875/2	6
36	Between Cmpts 8 and 1	2 511.	2.875/2	8
37	Between Cmpts 8 and 2	1 301.	2.875/2	8
38	Between Cmpts 8 and 3	1 327.	2.875/2	8
39	Between Cmpts 8 and 4	7 654.	2.875/2	8
40	Between Cmpts 8 and 5	2 477.	2.875/2	8
41	Between Cmpts 8 and 6	2 208.	2.875/2	8
42	Between Cmpt 8 and Outside	24 567.	3.5	8
43	Between Cmpt 9 and Outside	4 829.	3.5	9
44	Between Cmpt 10 and Outside	3 288.	3.5	10
45	Between Cmpt 11 and Outside	4 640.	3.5	11
46	Metal in Cmpt 1	9 479.	0.134	1
47	Metal in Cmpt 2	4 556.	0.134	2
48	Metal in Cmpt 3	5 009.	0.134	3
49	Metal in Cmpt 4	28 889.	0.134	4
50	Metal in Cmpt 5	9 349.	0.134	5
51	Metal in Cmpt 6	8 334.	0.134	6
52	Metal in Cmpt 8	38 435.	0.012	8

DESCRIPTION OF FLOW PATHS/AREAS BETWEEN COMPARTMENTS(REFS. 4 & 5)

No.	Description	Flow Area (ft**2)	Loss Coeff
1	From Cmpt 1 to 2	635.0	0.300
2	From Cmpt 2 to 3	1 079.0	0.170
3	From Cmpt 3 to 9	77.0	4.200
4	From Cmpt 3 to 4	585.0	0.340
5	From Cmpt 4 to 5	585.0	0.340
6	From Cmpt 6 to 5	635.0	0.300
7	From Cmpt 1 to 6	72.0	1.450
8	From Cmpt 2 to 9	77.0	4.200
9	From Cmpt 9 to 10	10.0	3.000
10	From Cmpt 11 to 10	10.0	3.000
11	From Cmpt 5 to 11	154.0	4.200
12	From Cmpt 4 to 12	144.0	1.500
13	From Cmpt 1 to 7	122.0	0.890
14	From Cmpt 2 to 7	72.0	0.890
15	From Cmpt 3 to 7	72.0	0.890
16	From Cmpt 4 to 7	487.0	0.890
17	From Cmpt 5 to 7	155.0	0.890
18	From Cmpt 6 to 7	155.0	0.890
19	From Cmpt 7 to 8	2 003.0	1.430
20	From Break Line to 1	0.4	N/A

Walls and Related Compartments; file=LOCA01

Areas are from HALFLP02 & N.O.D. note book

Walls 1: 8 between L.C. and D.E.

ALC := 12280.

NCm = 1 2 3 4 4 4 5 6

Arco := 32.1 + 21.1 + 23.2 + 30.8 + 73.0 + 30.0 + 43.3 + 29.7

9 9 9 9 10 11 11 11

Arco = 283.2

$A_1 := \frac{32.1}{Arco} \cdot ALC$ $A_2 := \frac{21.1}{Arco} \cdot ALC$ $A_3 := \frac{23.2}{Arco} \cdot ALC$

$A_4 := \frac{30.8}{Arco} \cdot ALC$ $A_5 := \frac{73.0}{Arco} \cdot ALC$ $A_6 := \frac{30.0}{Arco} \cdot ALC$

$A_7 := \frac{43.3}{Arco} \cdot ALC$ $A_8 := \frac{29.7}{Arco} \cdot ALC$

Wall 7 is Ice Baskets in Program LOCA01

$A_9 := 293148.$ NCm = 7

Walls 10: 17 between D.E. and L.C.

j2 := 10 .. 17

$A_{j2} := A_{(j2-9)}$ NCm = 9, 9, 9, 9, 10, 11, 11, 11

Walls 18: 23 are Interior of L.C.

NCm = 1 2 3 4 5 6

A18 := 3517.

Arci := 43.9 + 21.1 + 23.2 + 133.8 + 43.3 + 38.6

$A_{18} := \frac{43.9}{Arci} \cdot A18$ $A_{19} := \frac{21.1}{Arci} \cdot A18$ $A_{20} := \frac{23.2}{Arci} \cdot A18$

$A_{21} := \frac{133.8}{Arci} \cdot A18$ $A_{22} := \frac{43.3}{Arci} \cdot A18$ $A_{23} := \frac{38.6}{Arci} \cdot A18$

Walls 24: 29 are Floor of L.C. $A24 := 3728.$

NCM = 1 2 3

$A_{24} := \frac{43.9}{Arci} \cdot A24$ $A_{25} := \frac{21.1}{Arci} \cdot A24$ $A_{26} := \frac{23.2}{Arci} \cdot A24$

$A_{27} := \frac{133.8}{Arci} \cdot A24$ $A_{28} := \frac{43.3}{Arci} \cdot A24$ $A_{29} := \frac{38.6}{Arci} \cdot A24$

4 5 6

Walls 30: 35 are between L.C. and U.C. $A30 := 16246. + 1139.$

NCM = 1 2 3

$A_{30} := \frac{43.9}{Arci} \cdot A30$ $A_{31} := \frac{21.1}{Arci} \cdot A30$ $A_{32} := \frac{23.2}{Arci} \cdot A30$

$A_{33} := \frac{133.8}{Arci} \cdot A30$ $A_{34} := \frac{43.3}{Arci} \cdot A30$ $A_{35} := \frac{38.6}{Arci} \cdot A30$

4 5 6

Walls 36: 41 are between U.C. and L.C.

$j3 := 36 .. 41$ $A_{j3} := A_{(j3-6)}$ NCM = 6 * 8

Wall 42 is between U.C. and Outside

$A_{42} := 24567.$ NCM = 8

Walls 43: 45 are between D.E. and Outside $A43 := 12757.$

$A_{43} := \frac{(234. - 126.8)}{Arco} \cdot A43$ (9) $A_{44} := \frac{73.0}{Arco} \cdot A43$ (10)

$A_{45} := \frac{(30.0 + 43.3 + 29.7)}{Arco} \cdot A43$ (11)

$n := 43 .. 45$ $Sum := \sum_{n} A_n$ $Sum = 12757$

Walls 46: 51 are Metal in L.C. A46 := 65616.

NCM = 1

$A_{46} := \frac{43.9}{Arci}\cdot A46$ $A_{47} := \frac{21.1}{Arci}\cdot A46$ $A_{48} := \frac{23.2}{Arci}\cdot A46$

$A_{49} := \frac{133.8}{Arci}\cdot A46$ $A_{50} := \frac{43.3}{Arci}\cdot A46$ $A_{51} := \frac{38.6}{Arci}\cdot A46$

$n := 46 .. 51$

$Sum := \sum_n A_n$ $Sum = 65616$

Wall 52 is Metal in U.C.

$A_{52} := 38435.$ NCM = 8

Summary of Wall Areas

n1 := 1 .. 9 n2 := 10 .. 17 n3 := 18 .. 23 n4 := 24 .. 29

A_{n1}

1391.907	1
914.929	2
1005.989	3
1335.537	4
3165.395	5
1300.847	6
1877.556	8
1287.839	9
293148	7

A_{n2}

1391.907	10
914.929	11
1005.989	12
1335.537	13
3165.395	14
1300.847	15
1877.556	16
1287.839	17

A_{n3}

508.05	18
244.188	19
268.491	20
1548.452	21
501.106	22
446.713	23

A_{n4}

538.53	24
258.838	25
284.599	26
1641.35	27
531.169	28
473.514	29

n5 := 30 .. 35 n6 := 36 .. 41 n7 := 42 .. 45 n8 := 46 .. 52

A_{n5}

2511.357	30
1207.053	31
1327.187	32
7654.205	33
2477.034	34
2208.164	35

A_{n6}

2511.357	36
1207.053	37
1327.187	38
7654.205	39
2477.034	40
2208.164	41

A_{n7}

24567	42
4828.921	43
3288.351	44
4639.728	45

A_{n8}

9478.586	46
4555.767	47
5009.185	48
28889.177	49
9349.038	50
8334.247	51
38435	52

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7/29/93

COMPUTER PROGRAM LOCA01

```
MAIN

   F, L, LT, N

READ TEND, LEDT

Calc WR, LW

CALL INITL
 "   UHVALS
 "   INITLS
 "   METAL

DO 135 NC = 1, NCMPT
  CALL CLOSE1(NC)
135

CALL CLOSE2
CALL CLOSE3

1234
  CALL ENERGY
   "   SATEST

DO 137 NC = 1, NCMPT
  IF LSPRHT THEN
       CALL TEMP1(NC)
  ELSE IF NC=7 THEN
       CALL TEMP7(NC)
  ELSE
       CALL TEMP2(NC)
137

  CALL SLAB
  CALL FLOWS

IF() GO TO 1234

CALL WRIT1
IF() CALL WRIT2
IF()  "   PLOT1(M)
IF()  "   PLOT2(M)
```

```
DATA

SL, F, LT,
NS, N
```

```
INITL

   F, LT, N

Calc break flow area

CALL SOLID()
CALL FCONVC1(HF())

Calc W(1:4,1:12),
     P(1:3,1:12) and
     MOLES(), MWC()
 for all CMPTS 1:12
Estimate TRCS
```

```
UHVALS

   F, N

Calc v(), h(), u()
   for NCMPTS
```

```
INITLS

   F, SL, NS

Calc DX(), HT()
SET TW(NS)=T(NC)
   DTW(NS)=0.0 for
   all slabs.
```

```
ENERGY

   F, LT, N

Calc U(4,NC=1:12) =
 mi*hi - me*he - Q(NC)
 + U(4,NC)
 for all Cmpts

Set Q(1:12)=0.0,
  will calc in SLAB
```

```
SOLID()
(Ti, vs, hs)

Calc vs, hs of ice
```

```
TEMP1(NC)

F, SL, L, LT, N

Calc new T, P, v, h
  for NCMPT if it
  is superheated.

CALL CLOSE1(NC)
```

```
TEMP2(NC)

B, F, L, LT, N

Calc new T, P, v, h
 for NCMPT if it
 is saturated.

-CLOSE1
  for CLOSE EDITS
```

```
TEMP7(NC)

B, F, LT, N

Calc new T, P, v,
 and WMELT(2)
Calc W(1:3,7), u()
  VTOT(), h, etc.,
  FT7=F(1:,NP,) for
  condensed vapor.

CALL CLOSE1(NC)
```

LOCA01 ..continued...

```
FLOWS

   B, PL, 1, F, SL, LT, L, N

Set NF(N)=NCFT(N,1),  DFRX()=1.0,
Set  F(...,1)= F(...,2),  DF(...,1)=DF(..,2)
    DH(...,1)=DH(...,2)
    F(...,2)=0.0, DF(...,2)=0.0, DH(..,2)=0.

Calc Z(NC), F(1,NP,.) for liquid
Calc F(4,NBK,.), then F(1:2,..), DF(1:2,..),
    DH(1:2,..) for the break flow path.
Calc DP(), DV, VBAR, F(4,NP,.) all flow paths
Calc PLPS(), NSNL(), DN(), DFRX(), all paths.
Calc DF(1,NP,.) & DH(1,NP,.)
Calc DF(4,NP,.) based on DF(4,1,.), various NP

Calc F(2:3,NP,), DF(2:3,NP,.), & DH(2:3,NP,.)

Calc W(3:4,NC), MOLES(), MWC() for all
   compartments NC=1,12

- CLOSE3
   for CLOSE EDITS
```

```
SLAB

A, B, F, SL, LT,
   NS, N

Set QW(NS,1)=QW(,2)
    QW(NS,2)=0.0

Calc ASFR,TDEW,T
CALL FCONVC(HF)

Calc HN, HC, HT, QW
  TW, Q(NC) for
  slabs NS=1,52

- CLOSE2
   for CLOSE EDITS
```

```
METAL

F, SL, LT, NS

Calc WMTL, DXM
  for metal equip
  slabs NS=46,52 as
  DATA in INITLS
```

```
TVOL(NC)

F, LT

Calc cmpt T* using
  VTOT(3,NC) and
  W(2:3,NC); used in
  SBRS SLAB & SATEST
```

```
WRIT1

A, B, NS, LT

Write T, P, U, H, W,
   F, DF, DH, QW, Q,
   TW(ND=1,NS=1:52)
   for all CMPTS
```

```
SATEST

F, L, LT, N
Calc U(NC) above
  saturated;
Is NC saturated?
```

```
PLOT1(M)
PL

Plots P(3,1:12) &
    T(1:12) vs Time
```

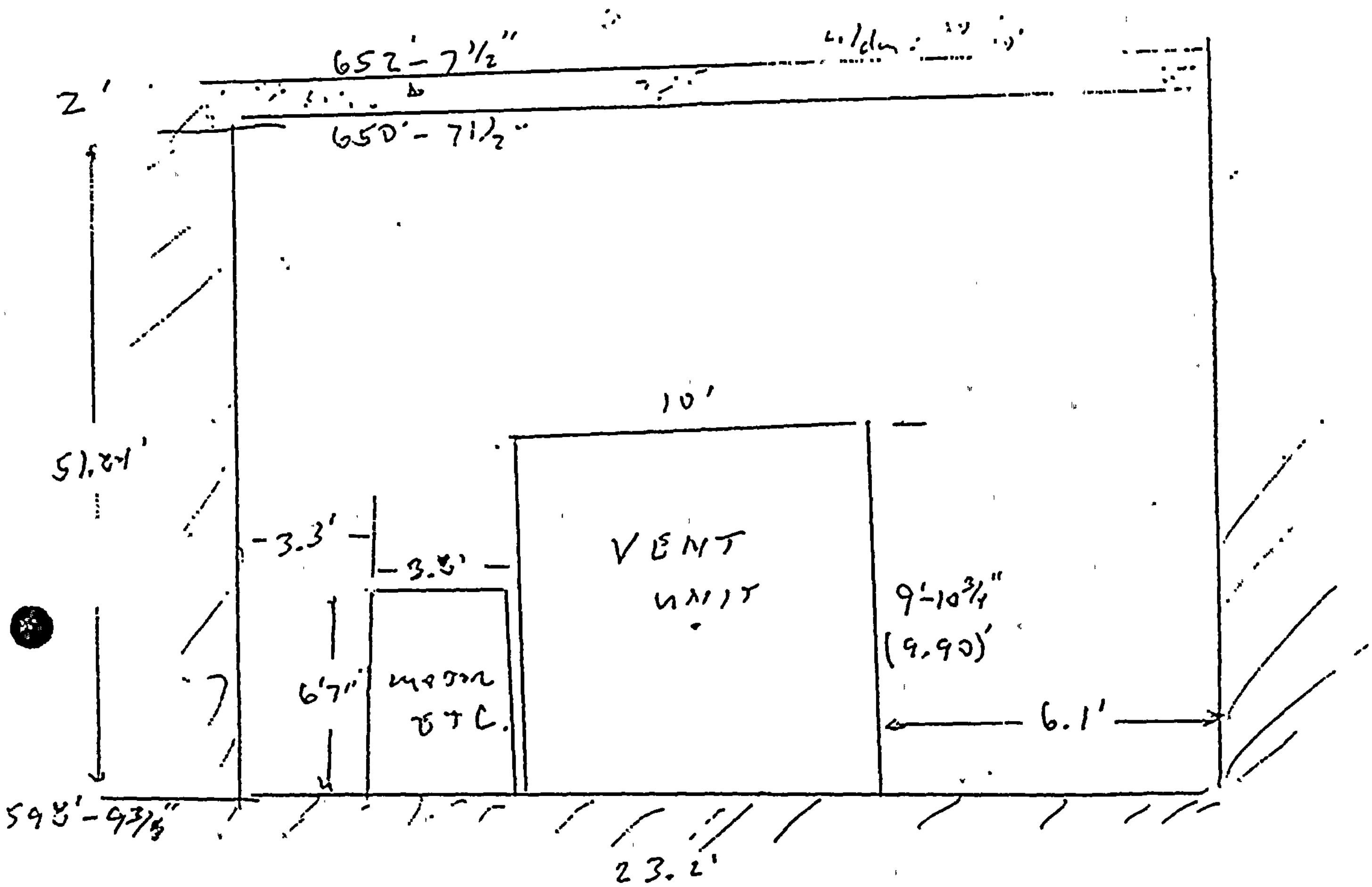
```
FCONVI

F, SL, LT, N, NS

Calc 'cross area of
each cmpt for RE no

-ENTRY FCONVC(HF)
 Calc HF(1:52) for
  each slab.
```

```
WRIT2

A, LT

Write TW(ND=1:8,NS=1:52)
```

```
PLOT2(M)
PL

Plots P(3,1:12) on
  finer scale
```

6/21/93

Tabulate, Volumes, Walls, Floor Area



$A_{blk} = (3.8' * 6.58') + (10' * 9.90') = 124\ ft^2$

$A_{tot} = [(650'-7½") - (598'-9⅜")] * [23.2'] = 1202.8\ ft^2$

650.625 − 598.781

51.84

$A_{open} = A_{tot} - A_{blk} = 1202.8 - 124 = 1078.8\ ft^2$

1.05 0.335

124.

1202.8

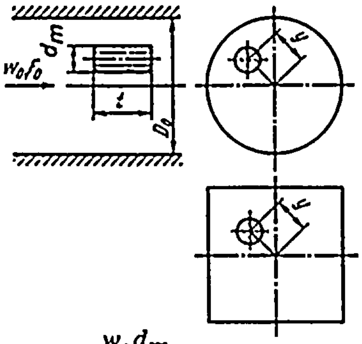
$\frac{A_o}{A_t} = 0.897$

Idelchik $K = 1.15\, C_x' \frac{S_m/F_o}{[1 - \tau S_m/F_o]^3} \left(1 - \frac{2y}{D_t}\right)^{1/3} = 0.119 * \left(\frac{F_o - S_m}{F_o}\right)^2 = $ [illegible]

p333, 335

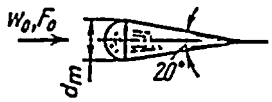
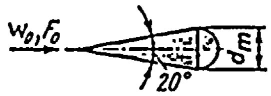
Bodies of different shapes in a tube; three-dimensional flow; $S_m/F_0 < 0.3$ [29, 38]

Diagram 10-9

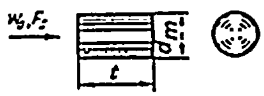


$$\zeta = \frac{\Delta p}{\rho w_0^2/2} \approx 1.15 c_x \frac{S_m/F_0}{(1 - \tau S_m/F_0)^3}\left(1 - \frac{2y}{D_0}\right)^{1/3}$$

$$Re' = \frac{w_0 d_m}{\nu}$$

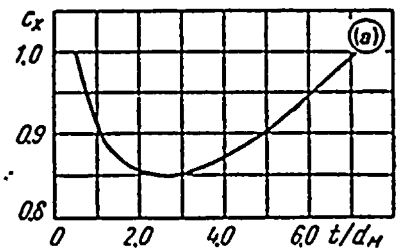
Name of a body and scheme	Drag coefficient c_x
Convex hemisphere-cup (without end plane) $S_m = \frac{\pi d_m^2}{4}$ 	$Re' = 4 \times 10^5$; $c_x = 0.36$; $Re' = 5 \times 10^5$; $c_x = 0.34$; $\tau \approx 0.5$ for τ, see Diagram 10-1
Hemisphere-cone $S_m = \frac{\pi d_m^2}{4}$ 	$Re' = 1.35 \times 10^5$; $c_x = 0.088$; $\tau \approx 0.5$
Concave hemisphere-cup (without end plane) $S_m = \frac{\pi d_m^2}{4}$ 	$Re' = 4 \times 10^5$; $c_x = 1.44$; $Re' = 5 \times 10^5$; $c_x = 1.42$; $\tau \approx 1.5$
Cone-hemisphere $S_m = \frac{4\pi d_m^2}{4}$ 	$Re' = 1.35 \times 10^5$; $c_x = 0.16$; $\tau \approx 0.5$

Circular smooth cylinder in a flow parallel to the axis, $S_m = \frac{\pi d_m^2}{4}$



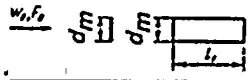
t/d_m	0.5	1	2	3	4	5	6	7
c_x	1.0	0.91	0.85	0.85	0.87	0.90	0.95	0.99

$\tau \approx 1.0$



Bodies of different shapes in a tube; three-dimensional flow; $S_m/F_0 < 0.3$ [29, 38] — Diagram 10-9

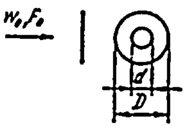
Name of body and scheme	Drag coefficient c_x
Rectangular plate; $S_m = d_m l_1$; Re' = 6 × 10⁵	Curve 2 of graph b ($\tau = 1.5$)



l_1/d_m	1.0	2.0	2.8	4.0	5.0	10	20	∞
c_x	1.16	1.16	1.18	1.19	1.21	1.29	1.40	2.0

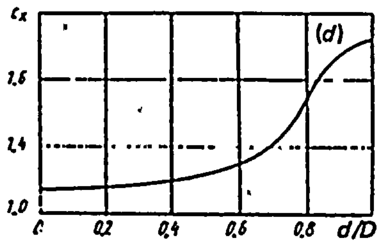
Washer; $S_m = \frac{\pi}{4}(D^2 - d^2)$

Re' = 3.6 × 10⁵

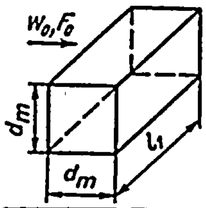


d/D	0	0.1	0.2	0.3	0.4	0.5
c_x	1.16	1.16	1.16	1.18	1.20	1.22
d/D	0.6	0.7	0.8	0.9	1.0	
c_x	1.25	1.40	1.78	1.92	2.00	

$\tau = 1.5$



Prismatic body of square cross section; Re' > 5 × 10⁵

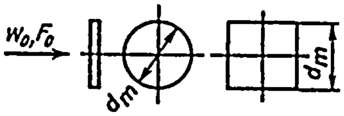


Curve 3 of graph b

l_1/d_m	0.15	0.20	0.3	0.5	1.0	2.0	5.0	∞
c_x	0.57	0.67	0.77	0.90	1.05	1.20	1.40	2.0

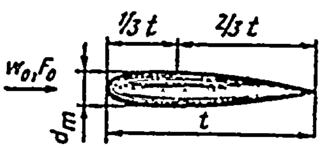
$\tau \approx 1.5$

Circular or square disk; Re' = 6.2 × 10⁵



$c_x = 1.16$; $\tau \approx 1.5$

Body of revolution; Re'' = (5–6) × 10⁵ angle of attack α = 0–20°



$\bar{t} = t/d_m$	3	4	5	6
c_x	0.05–0.10	0.05–0.12	0.06–0.15	0.075–0.18

$\tau \approx 0.5$

```
FDBM043                    DISPLAY COMPONENT DATA                    PAGE 1  OF 21
                        COMPONENT NO.: 1-PP-45-2
COMPONENT TYPE: PUMP - CENTRIFUGAL
SIZE AND UNITS:   88500       GALLONS/MINUTE
PLANT SYSTEM:   REACTOR COOLANT
CABLE SYSTEM:
FUNCTIONAL NAME: REACTOR COOLANT PUMP #2

UNIT: 1 BUILDING: CONTAINMENT    FLOOR ELEVATION: 598  CONTAINMENT AZIMUTH: 130
ROOM: LOWER CONTAINMENT, QUADRANT NO. 2
FEG:                                        FEG BOUNDARY:
 102.02     #12 RCP (REACTOR COOLANT PU


CONTROL PANEL: 1-RCP
OTHER LOCATION      ON SOUTHEAST SIDE OF STEAM GENERATOR #2-OME-3-2
INFORMATION:

ENTER NEXT COMPONENT NO.: ____________________ PRINTER ID: _____ PAGE NO.: __
PF3/15=DISPLAY NEXT COMPONENT  PF4/16=PRINT ALL DATA - WITH M & E NOS.: N
PF5/17=DISPLAY ASSEMBLY DATA   PF6/18=DISPLAY M & E DATA   PF8/20=PAGE FORWARD
PF9/21=SYSTEM MENU             PF12/24=EXIT
B  ==                             LU #4
```

FDBM043 DISPLAY COMPONENT DATA PAGE 1 OF 9

COMPONENT NO.: 1-SI-170-L2

COMPONENT TYPE: VALVE - CHECK
SIZE AND UNITS: 10 INCH
PLANT SYSTEM: RESIDUAL HEAT REMOVAL
CABLE SYSTEM:
FUNCTIONAL NAME: ACCUMULATOR TANK OME-6-2 OUTLET & ECCS TO REACTOR COOLANT LOOP #2 COLD LEG CHECK VALVE
UNIT: 1 BUILDING: CONTAINMENT FLOOR ELEVATION: 617 CONTAINMENT AZIMUTH: 140
ROOM: LOWER CONTAINMENT, QUADRANT NO. 2
FEG: FEG BOUNDARY:
102.00 RCS (REACTOR COOLANT SYSTEM

CONTROL PANEL:
OTHER LOCATION INFORMATION: BETWEEN REACTOR COOLANT PUMP #1-PP-45-2 AND THE SHIELD WALL, 2 FEET BELOW THE 617 ELEVATION PLATFORM

ENTER NEXT COMPONENT NO.: ____________________ PRINTER ID: _____ PAGE NO.: __
PF3/15=DISPLAY NEXT COMPONENT PF4/16=PRINT ALL DATA - WITH M & E NOS.: N
PF5/17=DISPLAY ASSEMBLY DATA PF6/18=DISPLAY M & E DATA PF8/20=PAGE FORWARD
PF9/21=SYSTEM MENU PF12/24=EXIT
B == LU #4

```
***********************************************************
*                   CALCULATION CHECK                     *
* Maximum Differential Pressure across the Ventilation Unit *
*                    by C. P. Lin                         *
***********************************************************
```

A. Input Information : ORIGIN := 1 $i := 1..2$ $j := 1..3$

1. Region 1 - region between refueling canal and steam generator No 2, in which the accumulator line breaks.

   Volume, $V_1 := 27250$ (ft^3)

   Flow path(11) to the region between steam generator No 2 and ventilation unit,

   Area, $A_{1,1} := 635$ (ft^2)

   Flow path(12) through refueling canal,

   Area, $A_{1,2} := 72$ (ft^2)

   Flow path(13) to ice condenser through inlet doors,

   Area, $A_{1,3} := 95$ (ft^2)

2. Region 2 - region betweem steam generator No 2 and ventilation unit,

   Volume, $V_2 := 19000$ (ft^3)

   Flow path(21) to the region between ventilation unit and steam generator No 3,

   Area, $A_{2,1} := 1079$ (ft^2)

   Flow path(22) to ice condenser through inlet doors,

   Area, $A_{2,2} := 64$ (ft^2)

   Flow path(23) to dead end region housing accumulators 2 and 3,

   Area, $A_{2,3} := 77$ (ft^2)

3. Lower Containment Conditions :

   $Plc := 14.7$ (psia) $Tlc := 90$ (F) $RHlc := 100.0$

   Water vapor partial pressure, $Pw := 0.698$

   Air partial pressure, $Pa := Plc - Pw$ $Pa = 14.002$

   Water vapor mass contained in Region 1 and 2,

   $$Mw_i := \frac{Pw \cdot 144 \cdot V_i}{\frac{1545}{18} \cdot (Tlc + 460)} \qquad Mw = \begin{bmatrix} 58.018 \\ 40.453 \end{bmatrix} \text{ (lb)}$$

   Air mass contained in Region 1 and 2,

   $$Ma_i := \frac{Pa \cdot 144 \cdot V_i}{\frac{1545}{28.97} \cdot (Tlc + 460)} \qquad Ma = \begin{bmatrix} 1873.167 \\ 1306.061 \end{bmatrix} \text{ (lb)}$$

B. Flow Path Resistance :

1. Flow Path through Steam Generator :
   from Idel'Chik P.335,

$F0 := 1203 \quad dm := 11.5 \quad l := 36 \quad Sm := dm \cdot l \quad Sm = 414$

$D0 := 23.2$

$$y := 12.8 - \frac{D0}{2} \qquad y = 1.2$$

Using $\quad Cx := 0.702 \quad \tau := 1.0$

$$RES := 1.15 \cdot Cx \cdot \frac{\frac{Sm}{F0}}{\left[1 - \tau \cdot \frac{Sm}{F0}\right]^{3}} \cdot \left[1 - \frac{2 \cdot y}{D0}\right]^{.3333} \qquad RES = 0.95$$

$$K_{1,1} := RES \cdot \left[\frac{F0 - Sm}{F0}\right]^{2} \qquad K_{1,1} = 0.408$$

2. Flow Path through Ventilation Unit :
   from Idel'Chik P.335,

$F0 := 1203 \quad dm := 9.9 \quad l := 13.8 \quad Sm := dm \cdot l \quad Sm = 136.62$

$D0 := 51.84$

$$y := \frac{D0}{2} - \frac{dm}{2} \qquad y = 20.97$$

Using $\quad Cx := 1.11 \quad \tau := 1.5$

$$RES := 1.15 \cdot Cx \cdot \frac{\frac{Sm}{F0}}{\left[1 - \tau \cdot \frac{Sm}{F0}\right]^{3}} \cdot \left[1 - \frac{2 \cdot y}{D0}\right]^{.3333} \qquad RES = 0.146$$

$$K_{2,1} := RES \cdot \left[\frac{F0 - Sm}{F0}\right]^{2} \qquad K_{2,1} = 0.115$$

3. Flow Path through Refueling Canal :
   Entrance loss and velocity head,

$K_{1,2} := 1 + 0.5$

4. Flow Path through Ice Condenser Inlet Doors :
   Lower inlet door opening, 84"x91.5"
   Hydraulic diameter,

$$Dh := \frac{4 \cdot (84 \cdot 91.5)}{2 \cdot (84 + 91.5)} \cdot \frac{1}{12} \qquad Dh = 7.299$$

Crane wall thickness, $\quad l := 3$

From Idel'Chik, P.144,

$$\frac{l}{Dh} = 0.411 \qquad K_{1,3} := 2.59 \qquad K_{2,2} := K_{1,3}$$

5. Flow Path to Dead Ended Housing Accumulators 2 & 3 :
   From FSAR Table 14.3.4-16,
   $K_{2,3} := 4.2$

C. Assumptions :

1. Pressures in the areas outside of region 1 & 2 are the same.
2. From Tom's calculation results for region 1, air in the region 1 and 2 is depleted in 0.3 sec.
4. All the steam generated in the region 1 is carried out through flow paths.

D. Flow Calculations :

1. Region 1 :
   Critical flow rate from accumulator line break, D := 8.75 (in)
   RCS cold leg conditions,
   Prcs := 2250 (psia) Trcs := 541 (F)
   hrcs := 536.07 (Btu/lb)
   From "System Analysis Handbook", mf := 24400 (lb/sec/ft^2)

$$MFR := mf \cdot \frac{\pi}{4} \cdot \left[\frac{D}{12}\right]^2 \qquad MFR = 1.019 \cdot 10^4 \quad \text{(lb/sec)}$$

   Steam generation,

$$Gs := MFR \cdot \frac{hrcs - 58.018}{1100.8 - 58.018} \qquad Gs = 4.671 \cdot 10^3 \quad \text{(lb/sec)}$$

   Air depletion rate,

$$Sa_1 := \frac{Ma_1}{0.3} \qquad Sa_1 = 6.244 \cdot 10^3 \quad \text{(lb/sec)}$$

   Steam/air mixture density,

$$MW_1 := \frac{Gs + Sa_1}{\frac{Gs}{18} + \frac{Sa_1}{28.97}} \qquad MW_1 = 22.977$$

$$\rho_1 := \frac{Plc \cdot 144}{\frac{1545}{MW_1} \cdot (Tlc + 460)} \qquad \rho_1 = 0.057 \quad \text{(lb/ft^3)}$$

   **** Assume region 1 & 2 pressure ****
   P1 := 0.211 (psi above outside pressure)
   P2 := 0.033 (psi above outside pressure)

Pressure differential across flow paths,

$$DP_{1,1} := P1 - P2$$

$$DP_{1,2} := P1 \qquad DP_{1,3} := P1$$

Steam/air flow through a flow path can be calculated by the following equation,

$$MFR_{1,j} := A_{1,j} \cdot \sqrt{\frac{DP \cdot \rho \cdot 144 \cdot 2 \cdot 32.2}{K_{1,j}}}$$

Flow ratio of path (1,2) and (1,3) to (1,1),

$$FR_{1,j} := \frac{A_{1,j} \cdot \sqrt{\frac{DP_{1,j}}{K_{1,j}}}}{A_{1,1} \cdot \sqrt{\frac{DP_{1,1}}{K_{1,1}}}}$$

$FR_{1,j}$
1
0.064
0.065

Steam/air flow rate through path (1,1),

$$MFR_{1,1} := \frac{Gs + Sa_1}{\sum_j FR_{1,j}} \qquad MFR_{1,1} = 9.667 \cdot 10^3 \quad \text{(lb/sec)}$$

Pressure differential across flow paths,

$$DP_{1,j} := \frac{K_{1,j}}{A_{1,j}^2 \cdot \rho_1} \cdot \frac{\left[MFR_{1,1} \cdot FR_{1,j}\right]^2}{2 \cdot 32.2} \cdot \frac{1}{144}$$

$DP_{1,j}$
0.178
0.211
0.211

2. Region 2 :

Incoming steam flow from Region 1,

$$STi := MFR_{1,1} \cdot \frac{Gs}{Gs + Sa_1} \qquad STi = 4.137 \cdot 10^3 \quad \text{(lb/sec)}$$

Incoming air flow from Region 1,

$$AIRi := MFR_{1,1} - STi \qquad AIRi = 5.53 \cdot 10^3 \quad \text{(lb/sec)}$$

Air depletion rate in Region 2,

$$Sa_2 := \frac{Ma_2}{0.3} + AIRi \qquad Sa_2 = 9.883 \cdot 10^3 \quad \text{(lb/sec)}$$

Steam/air mixture density,

$$MW_2 := \frac{STi + Sa_2}{\frac{STi}{18} + \frac{Sa_2}{28.97}} \qquad MW_2 = 24.554$$

$$\rho_2 := \frac{Plc \cdot 144}{\frac{1545}{MW_2} \cdot (Tlc + 460)} \qquad \rho_2 = 0.061 \quad \text{(lb/ft\^{}3)}$$

Steam/air flow through a flow path can be calculated by the following equation,

$$MFR_{2,j} := A_{2,j} \cdot \sqrt{\frac{DP \cdot \rho \cdot 144 \cdot 2 \cdot 32.2}{K_{2,j}}}$$

Flow ratio of path (2,2)&(2,3) to (2,1),

$$FR_{2,j} := \frac{A_{2,j}}{A_{2,1}} \cdot \sqrt{\frac{K_{2,1}}{K_{2,j}}}$$

$FR_{2,j}$
1
0.012
0.012

Steam/air flow rate through path (2,1),

$$MFR_{2,1} := \frac{STi + Sa_2}{\sum_j FR_{2,j}} \qquad MFR_{2,1} = 1.369 \cdot 10^4 \quad \text{(lb/sec)}$$

Pressure differential across flow paths,

$$DP_{2,j} := \frac{K_{2,j}}{A_{2,j}^2 \cdot \rho_2} \cdot \frac{\left[MFR_{2,1} \cdot FR_{2,j}\right]^2}{2 \cdot 32.2} \cdot \frac{1}{144}$$

$DP_{2,j}$
0.033
0.033
0.033

I Differential pressure across ventilation unit is less than 0.1 psi I

AMERICAN ELECTRIC POWER

Date July 30, 1993

Subject Cook Nuclear Plant
Containment Building, EL. 598'-9 3/8"
HV-CFT Ventilation Units

CES JLB

From C. E. Shute/J. L. Ball

To J. B. Kingseed/S. A. Hover

NEDS has performed a GT-STRUDL finite element analysis of the filter house portion of the HV-CFT ventilation units as requested by S.A. Hover in his June 16, 1993 memo.

The analysis found that the filter house can withstand a jet impingement pressure of 0.25 psi based on the capacity of the floor anchorage and of 1.13 psi based on the capacity of the housing.

The Technical Assessment Section has established that the maximum pressure that the units can be expected to receive is less than 0.10 psi. Therefore, the HEPA filters housed inside the box will not be dislodged in the event of a LOCA or steam line break.

The original design criteria for the filter house required that it be able to withstand a jet impingement pressure of 2 psi. The above findings by NEDS show pressures much less and it should be noted that NEDS did not use a conservative approach in their analysis. During the next refueling outages, a walkdown will be performed by NEDS to gather additional structural data on these filter houses. Recommendations will then be made for modifications necessary to bring these structures up to their original design requirements.

Approved by [signature] for N. Ruccia
N. J. Ruccia - Manager
Nuclear Design - Structural & Analytical

CES/JAR:dm

xc: J. A. Kobyra/R. C. Armstrong

Ref:stru\hv-cft.ces