ATTACHMENT 1

FOR INFORMATION ONLY

Form 01077 (R7-89)

FORM 101.1	REVISION 13

CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER Catawba Nuclear Station Units 1 & 2

TITLE OF CALCULATION

CALCULATION NUMBER CNC - 1150.01 - 00 - 0001

ORIGINALLY CONSISTING OF:

PAGES ________ THROUGH ________

TOTAL ATTACHMENTS ________ TOTAL MICROFICHE ATTACHMENTS ________

TOTAL VOLUMES ________ TYPE I CALCULATION/ANALYSIS YES ☐ NO ☐

TYPE I REVIEW FREQUENCY ________

THESE ENGINEERING CALCULATIONS COVER QA CONDITION ________ ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY ________ DATE ________

CHECKED BY ________ DATE ________

APPROVED BY ________ DATE ________

ISSUED TO TECHNICAL SERVICES DIVISION ________ DATE ________

RECEIVED BY TECHNICAL SERVICES DIVISION ________ DATE ________

MICROFICHE ATTACHMENT LIST: ☐ Yes ☐ No SEE FORM 101.4

REV. NO.	CALCULATION PAGES (VOL)			ATTACHMENTS (VOL)			VOLUMES		ORIG / DATE	CHKD / DATE	APPR / DATE	ISSUE DATE / REC'D DATE
	REVISED	DELETED	ADDED	REVISED	DELETED	ADDED	DELETED	ADDED				
4	-	-	37.1 - 37.29	—	—	—	—	—	DOMd 8-2-91	TKZ 8-6-91	wjm 8-7-91	PCHaugh 8/09/91 Dgd 8-28-91
5	-	-	61 62	-	-	-	-	-	M Madden 12-9-93	WH 12/20/93	DRF Kutle 12/20/93	MJM 12-20-93 Pgd 1-6-94
6	-	All	1-59	-	All	A1 - A14 B1 - B3 C1 - C3 D1 - D11 E1			REB 5-25-95	TKZ 5/30/95	DOMd 5/30/95	REB 5-30-95 Dgd 6-1-95

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FOR INFORMATION ONLY

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CNC 1150.01-00000

CERTIFICATION OF ENGINEERING CALCULATION

Station and Unit Number Catawba Nuclear Station, Units 1 & 2

Title of Calculation Standby Nuclear Service Water Pond - Thermal Analysis During One Unit LOCA and One Unit Shutdown. (Total Rewrite)

Calculation Number CNC-1150.01-1 Originally consisting of Pages 1 through 60.

These Engineering Calculations cover QA CONDITION 1 items. In accordance with established procedures, the quality has been assured and I certify that the above calculation has been performed, checked or approved as noted below:

Performed by William J McCabe Date 2-18-81

Checked by David H. Meachum Date 2-19-81

Approved by Robert F Edmonds Jr Date 3/6/81

Issued to General Services Division R F Edmonds Jr Date 3/6/81

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Revision/Addenda Log:

No.	Pages Revised	Pages Deleted	Pages Added	Performed By / Date	Checked By / Date	Approved By / Date	Issue Date / Rec'd Date
1	0	ALL	1-60	WJM 10/26/81	DHM 10/26/81	RFE 10/26/81	10/26/81 / 10-29-81
2	1, 5-9, 15, 26-37		32b, 37b	DHM 5/11/83	MDF 5/11/83	RFE 5/11/83	5/11/83 / DM 8-8-83
3	1,5,16, 17,22	9,11-15, 28-31, 32a, 32b, 33-36, 37a, 37b	1.1, 4.1-4.4, 8.1, 10.1-10.15, 27.1, 28.1-28.15, 32.1, 33.1-33.5	PMC 5/18/90	DEM 5-31-90	[illegible] 3-15-91	

Form 101.1 Revision 6

3997 371

LINE # 4077 LINE # 591501

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Form 101.2 Revision 1
26164 (R9-89)

File/Calculation No. CNC-1150.01-00-0001

REVISION DOCUMENTATION SHEET

Revision Number	Review Frequency Changed Yes/No	Revision Description
6	No	Complete rewrite of calculation. Purpose was to examine the effect of increasing the CNS SNSWP elevation limit from 570 ft msl to 571 ft msl, and to include the effects of changes in: area-volume curve, heat loads, flowrates and worst-case meteorology.

Form 101.2 Revision 0
26164 (12-82)

Calculation No. CNC-01150.01-~~X~~ 00-0001

REVISION DOCUMENTATION SHEET

REVISION NUMBER	REVISION DESCRIPTION
1	Complete re-write of original calculation. Methodology remained the same.
2	Adjustment to heat input curves (Figure 8) and area volume curves (Figure 7). Calculation was rerun for adjustments. DHM 7/15/83 MDT 7/18/83
3	Modified computer program (Figures 1 and 2) and input dataset format (Figures 9 and 11) to specify initial pond thermal stratification and print input dataset as a part of the model output. Methodology was not changed. Calculation was rerun to verify output using the modified CLIST, model code and input data (Figures 10 and 12). Added calculation to identify pond elevations which supply adequate cooling water to meet FSAR requirements for LOCA. PMC 5/18/90 Ck: DEMcL 5-31-90
4	Document proposed Tech. Spec. changes including raising temperature probe to El. 568 ft and raising temperature limit to 91.5° F. New analysis also includes lower heat load and lower flow rates. Computer code was revised to allow direct entry of heat load. By: DEMcL 8-2-91 Ck: TKE 8-6-91
5	TYPE I PERIODIC REVIEW FOR CUMULATIVE EFFECTS OF CHANGES ([illegible] REVIEW)

3997 372

Standby Nuclear Service Water Pond - Thermal Analysis During One Unit LOCA and One Unit Shutdown. (Total Rewrite)

STATEMENT OF PROBLEM

The Standby Nuclear Service Water System at Catawba Nuclear Station is designed to provide emergency cooling water during a one-unit Loss of Coolant Accident (LOCA) plus a one-unit cooldown. This water is supplied by the Standby Nuclear Service Water Pond (SNSWP). The SNSWP was formed by impounding a cove of Lake Wylie, immediately north of the plant area. During normal operation, Lake Wylie is the source of nuclear service water and also dissipates the waste heat from the discharge.

This calculation determines the plant intake temperature from the SNSWP during the cooldown procedure. The nuclear service water system is designed to operate properly within a specific temperature range. This calculation verifies that the SNSWP intake water is within that range, and that there is a sufficient quantity of water to supply the plant for 30 days.

PURPOSE OF REVISION

The purpose of this revision (6) is to examine the effect of a proposed change to the Catawba Technical Specifications on the SNSWP temperature limit. This change includes:

> Changing the Technical Specification SNSWP elevation limit from 570 ft msl to 571 ft msl. (As a result, the pond thermal analysis was run with area-volume values to reflect the more stringent elevation requirement.)

Additionally, this revision includes the effects of changes to the area-volume curve, heat loads, flowrates, and worst-case meteorology.

QA CONDITION

These calculations are QA condition 1 because the RN System is designed to operate properly with a specific temperature range.

FSAR REFERENCES

This calculation is referenced in the Catawba Nuclear Station Final Safety Analysis Report, Section 9.2.5, Ultimate Heat Sink.

DESIGN METHOD

Analytical Model Description

An in-house analytical model was used to determine the warmest plant intake temperature from the Catawba SNSWP during the 30-day cooldown following a one-unit LOCA. The model treats the Catawba SNSWP as a series of stacked horizontal layers of water. Operation of the pond is simulated by removing the bottom slice, adding heat to it and then placing it on top of the stack where it is permitted to cool. Cooling takes place only in the surface layer and at a rate proportional to the water temperature excess above the equilibrium temperature. The heat transfer is simulated by the following equation from Edinger and Geyer (1965):

$$\frac{dT}{dt} = \frac{K(T-E)}{\rho Cd}$$

where: T = water temperature

K = heat exchange coefficient

E = equilibrium temperature

ρ = water density

C = specific heat

d = depth of the upper slice of water

t = length of time cooling takes place

Equations used in Simulation

The following equations are used in the computer simulation to determine the surface temperature after cooling:

The unit volume (V_u) is calculated with the volume of the SNSWP (V) and the number of layers (L) using:

$$V_u = \frac{V}{L}$$

The length of time for surface cooling (t_s) is calculated with the unit volume (V_u) and the flowrate (Q) using:

$$t_s = \frac{V_u}{Q}$$

The discharge temperature (T_{dis}) is calculated using:

$$T_{dis} = T_{int} + \Delta T$$

where:
T_{int} = temperature of SNSWP intake
$$\Delta T = \frac{H}{QC_p\rho}$$
H = heat load (BTU/hour)
Q = flowrate (ft^3/hr)
C_p = specific heat at constant pressure (BTU/lbm °F)
ρ = 62.4 lbm/ ft^3

The heat loss (T_{hl})is calculated using:

$$T_{hl} = (T_{dis} - E)e^{\frac{Kt_s}{\rho hC_p}}$$

where:
E= equilibrium temperature (°F)
K = heat transfer coefficient (°F)
h = depth of cooling layer (top layer), (ft)

The heat loss to the atmosphere (T_{hla}) is calculated using:
$T_{hla} = T_{dis} - \left[E + T_{hl}\right]$

Thus, the surface temperature (T_{sfc}) after cooling (and just before the layer is dropped down to the 2nd layer in the simulation) is using:
$T_{sfc} = T_{dis} - T_{hla}$

The following equations from Ryan and Harleman (1973) and Sill (1976) are used to calculate evaporation during the simulation:

$$W_{e2} = \frac{-f(U_2)(e_s - e_a)A}{24\,\rho H_{vap}}$$,ft^3/hr (Ryan and Harleman, Eq. 2.16)

$$f(U_2) = \left[22.4(\Delta\Theta_v)^{\frac{1}{3}} + 14U_2\right]$$ (Ryan and Harleman, Eq. 2.35)

U_2 = wind speed (mph) measured at 2 m height

$\Delta\Theta_v = T_{sv} - T_{av}$, virtual temperature difference, (Ryan and Harleman, Eq. 2.30 b)

$$T_{sv} = \frac{(T_s + 460)}{1 - \frac{0.378e_s}{760}}$$ virtual temperature difference of a thin vapor layer in contact with the water surface, (Ryan and Harleman, Eq. 2.31 a)

$$T_{av} = \frac{(T_a + 460)}{1 - \frac{0.378e_a}{760}}$$ virtual air temperature, (Ryan and Harleman, Eq. 2.31 b)

$e_s = 25.4e^{\left(17.62 - \frac{9500}{T_s + 460}\right)}$, saturated vapor pressure at T_s, mm Hg, (Sill, Eq. 20)

$e_a = 25.4e^{\left(17.62 - \frac{9500}{T_d + 460}\right)}$, water vapor pressure, mm Hg, (Sill, Eq. 21)

T_a = dry bulb temperature, °F

T_s = water temperature, °F

T_d = dew point temperature, °F

A = effective cooling area, ft^2

24 = 24 hours/day

ρ = density of water, 62.4 lb/ft^3

H_{vap} = heat of vaporization of water, 1030 BTU/lb, (Ryan and Harleman)

Program Operation

After cooling of the surface layer, each of the stacked horizontal layers of water is shifted down one layer, retaining their previously defined temperatures. A check is then made for density instabilities which are averaged out, if necessary. This procedure is repeated over the 30-day simulation. The following figures are included to provide additional information about the computer program:

Figure Number	Title
1	Program listing
2	Flow chart of the model
3	List of program variables
4	Input variables
5	Output variables

The program accepts the inputs (described in the next section, "Model Inputs") as specified by the user in the input dataset, then models the thermal and evaporative response of the SNSWP to the heat load from the one-unit LOCA and associated one-unit cooldown.

MODEL INPUTS

The Catawba SNSWP model simulation uses the following inputs:

- Area-Volume Curve Values
- Initial Pond Temperature (Isothermal)
- Flowrates
- Heat Loads
- Worst-Case Meteorology

In order to bound the potential scenarios, a computer model analysis was performed to take into account the worst case observed conditions occurring simultaneously.

Area-Volume Curve

Values for the SNSWP Area-Volume Curve (which are used in the input file) are described in CNC 1150.04-00-0009 (see Attachment A). A SNSWP volume of 434 ac-ft is used for the 30-day simulation.

This volume was determined by removing the cumulative evaporation, seepage, and system leakage losses which result at the end of the 6th day of an initial model run at the start of the simulation. This initial run (see Attachment A, Model Run with Initial Elevation of 571 ft msl) used a starting elevation of 571 ft msl (proposed Technical Specification limit) along with the updated input values described previously in this section. This is a conservative approach because the peak temperature occurs on the 5th day of the simulation. The losses at the end of the 6th day are as follows:

- Evaporation losses of 11.7 ac-ft (see value in Attachment A model run, page A10)
- Seepage losses of 0.36 ac-ft (see Attachment A)
- System losses of 1.31 ac-ft (from loss values of 225,000 gallons for first 5 hours and an additional loss of 1.01 E6 gallons total loss occurring over the 30-day period at a steady rate (see Attachment B)

- Total of 6-day losses = 13.37 ac-ft (Use value of 13.5)

Using the total volume (447.5 ac-ft) from the starting elevation of the initial run presented in Attachment A, the initial cooling volume can be determined (447.5 - 13.5 = 434 ac-ft). From linear interpolation, (see Attachment A) the associated surface area is 37.9 acres with an elevation of 570.64 ft msl. Thus, the first two volume values in the data input file are 434 and 396.1 ac-ft, respectively.

Initial Pond Temperature (Isothermal)

The SNSWP temperature values do not include the 2.13°F instrument inaccuracy correction for the permanent temperature monitoring system.

The limiting value of SNSWP temperature which allows compliance with the nuclear service water intake temperature requirements of the Catawba FSAR was determined by varying the initial temperature for different model runs (30-day simulations). The FSAR requirements are:

- no increase in intake temperature above 92°F over the first 12.5 hours following a one-unit LOCA, and
- no intake temperature over 97.6° F during the 30-day one-unit cooldown period following a one-unit LOCA.

Stratification conditions often exist in the SNSWP during the critical summer months (June, July, August). However, the temperature inputs in these model runs (see Figures 6 and 7) conservatively assume isothermal conditions in the SNSWP at the start of the simulation.

Flowrates

Two sets of flow rates described in CNC-1223.24-00-0041, "Design Basis Heat Load and Flow Demands on SNSWP" are used in the simulations (see Attachment B).

Flowrate Set	Flowrate (gpm) for first 4 hours of simulation	Flowrate (gpm) for hours 5 - 720 of simulation.
Low	38,000	19,000
High	46,000	23,000

Heat Loads

The heat loads calculated in CNC-1223.24-00-0041, "Design Basis Heat Load and Flow Demands on SNSWP" are used in the simulations (see table in Attachment B).

The computer program (see Figures 1 and 2) reads 52 heat load values directly from the input data sets (see Figures 6 and 7). These values are assigned as follows:

•	Hours	1 - 29	One value is read for each hour .
•	Hours	30 - 190	One value is read for each 10-hour period. This value is then assigned to each of the 10 hours in the period.
•	Hours	200 - 720	One value is read for each 100-hour period. This value is then assigned to each of the 100 hours in the period.

Worst-Case Meteorology

The meteorological inputs to the Catawba SNSWP computer model consist of dry bulb temperature, dew point temperature, wind speed, heat transfer coefficient (computed) and the equilibrium temperature (computed). As suggested in Regulatory Guide 1.27, Revision 2, the worst-case meteorology was determined based on the critical (5-day) cooling period (see description of review process in Attachment C). As a result of the meteorological review, the 30-day period from 6/23/52 - 7/22/52 (with 6/23/52 - 6/27/52 being the worst 5-day period) is used as an input to the model (see Figure C2).

WATER SUPPLY

The full pond elevation for the SNSWP is 572 feet msl and the minimum level for the pond is 571 feet msl. The water supply in the SNSWP may be decreased due to:

- evaporation
- seepage
- system losses.

The drainage basin for the SNSWP has an area of approximately 410 acres. Run-off and groundwater flow from the basin are the sources of water for the pond. A typical drainage basin yield for this area is 1 cfs/mi^2, which for the SNSWP basin equates to 0.6 cfs. Average lake evaporation for this area is about 41 inches/ year, which for a pond area of 40.6 acres (Area at elevation 572 msl), is about 0.2 cfs. If needed, makeup water to the pond can be provided by aligning the nuclear service water discharge to the SNSWP.

During a 30-day LOCA period, there would be increased water loss from the pond by forced evaporation due to elevated surface temperatures. Evaporation is calculated for each iteration time step of the computer simulation. The cumulative evaporation through that time step is then printed.

Seepage from the SNSWP is analyzed in CNC-1150.01-00-0004, "Standby Nuclear Service Water Pond- Seepage Loss Analysis" (see Attachment A). The worst-case loss at the end of six days is 15,547 ft^3. An additional 10.75 ft^3/day is lost through seepage through the SNSWP dam embankment. A 6-day seepage total of 15,612 ft^3 (0.36 ac-ft) results from these values.

The system losses are determined in CNC-1223.24-00-0041 (see Attachment B) are as follows:

- 225,000 gallons for first 5 hours
- 1.01 E6 gallons total loss occurring at a steady rate over the 30-day period

A inventory loss value of 13.5 ac-ft is applied at the start of the simulation by subtracting this volume from the available area and volume at 571 ft msl (see Input section describing Area-Volume values and Attachment A).

SNSWP HYDRAULICS

The Catawba SNSWP is designed to prevent short circuiting of the heated water, and to effectively utilize the full pond surface for cooling. The plant intake is located at the bottom of the pond and the discharge at the surface. The stacked layer concept assumes warm water surface layers cannot be pulled into the intake. Harleman and Elder (1965) analyzed the potential for pulling an upper, warm buoyant layer of water down into a submerged intake (see Attachment D). If a computed withdrawal depth (H) is less than the depth from the warm water interface to the intake (D), then less than 5% of the intake will be pulled down from the surface layer.

$$H = \frac{3}{2}\left[\frac{(Q/B)^2}{g'}\right]^{\frac{1}{3}}$$

where:

H = computed depth of water above lowest point of intake opening, feet

Q = intake flow, cfs

B = width of intake opening, feet

g' = g Δd/d, ft/sec^2

g = acceleration of gravity, 32.17 ft/sec^2

d = density of bottom water layer, slug/ft^3

Δd = density difference between surface and bottom water layers, slug/ft^3

Assuming a surface heated layer temperature of 95°F and a temperature difference between the intake and surface layers of 8°F:

d = 1.932 slug/ft^3, from Weast, 1973

Δd = 0.003 slug/ft^3, from Weast, 1973

g' = .05.

Using B=28 ft (see Figure 8, and Figure D1 in Attachment D) and g' with the flowrates from the high flow conditions (see Model Inputs, Flowrates section), the following withdrawal depths can be calculated.

Hours of Simulation	*Q* Flowrate (cfs)	*H* Computed Withdrawal Depth (ft)
0-4	102.50	9.7
5-720	51.25	6.1

The minimum depth of the SNSWP surface (570.64 ft msl) to the intake structure opening (542.5 ft msl) is 28.14 feet. Thus, significant recirculation of the heated surface layer will not occur until the depth of the heated layer exceeds 18.5 feet. Therefore, a stacked layer model analysis is appropriate for the simulation.

To ensure maximum pond efficiency in dissipating waste heat, it is important to minimize mixing of the discharged heated plume as it spreads over the SNSWP surface. The densimetric Froude number F (calculated using the following equation), which represents the ratio of inertial forces to buoyant forces, is used to determine the extent of mixing in the SNSWP.

$$F = \frac{V}{\sqrt{g \frac{\Delta d}{d} h}}$$

where: F = densimetric Froude number, dimensionless

V = mean velocity, ft/sec

h = depth of the heated layer, feet

When $F < 1$:

- buoyant forces are larger than inertial forces
- vertical mixing of the heated plume is minimized (Ryan and Harleman, 1973)
- heated plume will remain on the pond surface.

There are two discharge structures located at opposite ends of the SNSWP each of which conveys a portion of the discharge flow.

Assuming a 15 degree (from the vertical) discharge angle, a plume 65 ft wide and 4 ft deep results 100 ft downstream from the discharge structure. At these conditions, and assuming the previously discussed temperature difference of 8°F between layers, the densimetric Froude number is 0.66 for the high flow conditions during the first 4 hours of the simulation. A conservative estimate of 75% of the flow (102.5 cfs) going out the short-arm discharge is made in this calculation (see Attachment E for additional information). Thus, mixing will be minimized except in the immediate vicinity of the discharge structures and pond stratification will be preserved.

The Catawba SNSWP is a stratified pond, and as mentioned previously, has a bottom intake, surface discharge configuration with minimal discharge mixing. Ryan and Harleman (1973) have shown a pond designed in this manner will effectively utilize the total pond surface area in dissipating heat to the atmosphere regardless of pond shape. Physical testing performed during February 1994 verified stratification conditions exist in the SNSWP with an associated complete surface spread of the heated layer.

In summary, model assumptions of no direct recirculation of the heated plume and utilization of the total lake surface area and volume are valid for the Catawba SNSWP application and have been supported by physical testing and theoretical analysis.

VERIFICATION OF SUFFICIENT COOLING WATER IN FIRST 12.5 HOURS

An analysis was completed to determine the pond elevation which provides sufficient cooling water to meet the FSAR-required condition of no temperature rise above 92°F at the nuclear service water intake in the first 12.5 hr following a one-unit LOCA, and to ensure that the 768 ft msl elevation is adequate to monitor the SNSWP temperature.

Inputs

High-flow conditions (from Attachment B)

- 46,000 gpm (Hours 0-4)
- 23,000 gpm (Hours 5-720)

Total Volume of SNSWP Circulated during first 12.5 hours of simulation

[46,000 gpm * (60 min/hr) * (4 hr)] + [23,000 gpm * (60 min/hr) * (12.5 - 4 hr)]

- 22.8 MG (70 ac-ft)

Maximum withdrawal height (from SNSWP Hydraulics section using the first four hours of simulation high-flow conditions).

- 9.7 ft

Area-Volume Curve values are shown in Attachment A.

Analysis

- The quantity of 92°F cooling water required in the first 12.5 hours of the simulation, 22.8 MG (70 ac-ft), is provided between pond elevation 542.5 and approximately 557 ft msl (determined from Attachment A - SNSWP Volume Curve).
- The highest elevation from which water could be entrained was calculated as

  542.5 + 9.7 = 552.2 ft msl in the previous section, "SNSWP Hydraulics".
- The 22.8 MG (70 ac-ft) circulated during the first 12.5 hours of the simulation will displace (approximately) the top 2 ft (571 to 569 ft msl) of the SNSWP.

The significant difference in elevation between the lower depth of the heated layer (569 ft msl) and the availability of water at 92°F at all elevations below 557 ft msl ensures that no water in excess of 92°F will be withdrawn during the first 12.5 hours following a one-unit LOCA. Additionally, the probe elevation of 568 ft MSL is high enough to ensure an adequate supply of "cool" water (< 92°F) fduring the first 12.5 hours of the accident .

RESULTS

The effect of the proposed change to the Catawba Technical Specifications (SNSWP elevation limit increase from 570 ft msl to 571 ft msl) was examined with a set of computer simulations. The pond thermal analysis was run with area-volume values (corrected for cumulative inventory losses occurring at the simulated peak temperature) to reflect the more stringent elevation requirement. Additionally, the runs include the effects of recent changes to the area-volume curve, heat loads, flowrates, and assumed worst-case meteorology.

Maximum pond intake temperatures resulted (shown in the following table) from the computer simulations. See Figures 6 and 7 for the inputs and results of the computer simulations.

Flowrate Set	Initial SNSWP Temperature (°F.)	Maximum SNSWP Intake Temperature (°F)
Low (38,000 gpm for hours 0-4 and 19,000 gpm for hours 5-720)	91.5	96.87
High (46,000 gpm for hours 0-4 and 23,000 gpm for hours 5-720)	91.5	97.52

The high flow case results in a temperature maximum of 97.52°F at 10[illegible].6 hours (5th day) while the low flow case results in a temperature maximum of 96.87°F at 130.3 hours (6th day). Both cases (high and low flow) maintain temperatures of 91.5°F at the SNSWP for the first 12.5 hours of the simulation.

CONCLUSION

This calculation simulates operation of the Catawba SNSWP during a one-unit LOCA and subsequent 30-day one-unit cooldown with extreme meteorology and conservative assumptions regarding SNSWP heat content when the LOCA occurs. Based on this computer analysis, the maximum SNSWP intake temperatures were determined to be below 97.6°F for an initial SNSWP temperature of 91.5°F. Additionally, there are no SNSWP intake temperatures greater than 91.5°F during the first 12.5 hours of the simulated accidents.

The pond analysis was conducted utilizing updated values for:

- Area-Volume Curve Values
- Heat Loads
- Flowrates
- Worst-Case Meteorology.

An initial SNSWP temperature of 91.5°F results in a peak of 97.52°F on days 5 and 6 of the high flow simulation. Therefore, the SNSWP is operable for initial SNSWP temperatures up to 91.5°F with a SNSWP elevation of 571 ft msl.

REFERENCES

CNC-1150.01-00-0004, Standby Nuclear Service Water Pond - Seepage Loss Analysis, Revision 0.

CNC-1150.04-00-0009, Area and Volume of Standby Nuclear Service Water Pond, Revision 3.

CNC-1223.24-00-0041, Design Basis Heat Load and Flow Demands on SNSWP, Revision 0.

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Harleman, D. R. F., and R. A. Elder, "Withdrawal from Two Layer Stratified Flows," Proc. ASCE, HY4, Volume 91, July 1965.

Ryan, R. J., and D. R. F. Harleman, "An Analytical and Experimental Study of Transient Cooling Pond Behavior," Ralph M. Parson Laboratory, Department of Civil Engineering, Report No. 161, Massachusetts Institute of Technology, Cambridge, Massachusetts, January 1973.

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Weast, R.., Handbook of Chemistry and Physics, Chemical Rubber Company Press, Cleveland, Ohio, 1973.

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/* 3) INTERACTIVELY EXECUTES PROGRAM                               *
/* 4) BROWSES OUTPUT DATASET                                       *
/* 5) ALLOWS USER TO PRINT REPORT                                  *
/* 6) ALLOWS USER TO SAVE REPORT                                   *
/* 7) ALLOWS USER TO RE-EXECUTE THE PROGRAM                        *
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/*=================================================================*
/*
  CONTROL NOLIST NOMSG NOSYMLIST NOCONLIST NOFLUSH
/*CONTROL LIST MSG SYMLIST CONLIST NOFLUSH
/*
/*******************************************************************
/* IF ISPF SESSION NOT ACTIVE INVOKE ISPF AND EXECUTE DIALOG       *
/* ELSE CONTINUE TO DIALOG                                         *
/*******************************************************************
/*
  IF &SYSISPF NE ACTIVE THEN +
      ISPF CMD(%CNFEHEAT)
  ELSE CNFEHT2
END
```

Figure 1. Catawba SNSWP Model CLIST and PL1 Program Listing.

```
/*
/***********************************************************************
/* EXIT CODE OF 4 NECESSARY FOR ISPF                                   *
/***********************************************************************
/*
 XIT CODE(4)
```

Figure 1 (Continued)

```
PROC 0  PGMLIB(CERT)
/*
/*CLISTNAME: CNFEHT2
/*=====================================================================*
/*                       JOB DESCRIPTION                               *
/*---------------------------------------------------------------------*
/*DETAILS :  THIS CLIST DOES THE FOLLOWING:                            *
/* 1) PROMPTS FOR INPUT DATASET NAME                                   *
/* 2) ALLOCATES INPUT AND OUTPUT DATASETS                              *
/* 3) INTERACTIVELY EXECUTES PROGRAM                                   *
/* 4) BROWSES OUTPUT DATASET                                           *
/* 5) ALLOWS USER TO PRINT REPORT                                      *
/* 6) ALLOWS USER TO SAVE REPORT                                       *
/* 7) ALLOWS USER TO RE-EXECUTE THE PROGRAM                            *
/*---------------------------------------------------------------------*
/*ADDITIONAL DOCUMENTATION :                                           *
/*  CAN BE VIEWED/OBTAINED BY EXECUTING THE TSO COMMAND                *
/*      PCABENCH F(4)                                                  *
/*  CR CODE = HFE   DOCUMENTATION TYPE = S   VOLUME NUMBER = 055       *
/*---------------------------------------------------------------------*
/*PARMS:                                                               *
/*    NAME            TYPE                 DESCRIPTION                 *
/* &PGMLIB            CHAR         CERT => PROGRAM RUN FROM CERTIFIED  *
/*                                         LIBRARY                     *
/*                                 ACPT => PROGRAM RUN FROM ACCEPTANCE *
/*                                         LIBRARY                     *
/*---------------------------------------------------------------------*
/*VARIABLES:                                                           *
/*                                                                     *
/*    NAME            TYPE                 DESCRIPTION                 *
/*---------------------------------------------------------------------*
/*                                                                     *
/* &LASTCC            NUM         RETURN CODE FROM LAST EXECUTED STATE- *
/*                                MENT                                 *
/* &CHECK             NUM         SAVED RETURN CODE                    *
/* &I                 NUM         LOOP COUNTER                         *
/*                    ----                                             *
/* &ANS               CHAR        Y => USER WANTS TO PRINT/SAVE OUTPUT *
/*                                N => USER DOES NOT                   *
/* &ANS               CHAR        Y => USER WANTS TO RE-EXECUTE PROGRAM *
/*                                N => USER DOES NOT                   *
/* &DEST              CHAR        USER SUPPLIED PRINTER NAME FOR OUTPUT *
/* &MEMBER            CHAR        MEMBER CREATED IN HEATTRAN.SAVED WHEN *
/*                                USER DESIRES TO SAVE REPORT          *
/* &NAME              CHAR        INPUT DATASET NAME                   *
/* &OK                CHAR        FLAG USED TO CHECK VALID PRINTER NAMES *
/* &PGMLIB            CHAR        STEPLIB/LOAD LIBRARY USED            *
/*                                CERT => DK061.CERT.LOAD <- DEFAULT   *
/*                                ACPT => DK061.ACPT.LOAD              *
/*---------------------------------------------------------------------*
/*                                                                     *
/*BUILTIN SUBROUTINES:                                                 *
/*    NAME            TYPE                 DESCRIPTION                 *
/* &STR(A)            CHAR        RETURNS CHARACTER REPRESENTATION OF A *
/*                                                                     *
/*---------------------------------------------------------------------*
/*EXTERNAL REFERENCES:
/*    NAME            TYPE                 DESCRIPTION
/* ISPEXEC                        INVOKES ISPF DIALOG FUNCTIONS
/* BROWSE                         ISPF BROWSE
/*
```

Figure 1 (Continued)

```
/*===================================================================*
/*                        HISTORY OF CHANGES                         *
/*-------------------------------------------------------------------*
/*REQUEST # |   DATE   |           DESCRIPTION          | PROGRAMMER*
/*-------------------------------------------------------------------*
 * 13951921 | 03/08/89 | INITIAL PROGRAMMING            |W.D. CONWAY*
/*===================================================================*
/*                        FILE DESCRIPTIONS                          *
/*-------------------------------------------------------------------*
/*DDNAME   |I/O|       DATASET NAME              DESCRIPTIONS        *
/*-------------------------------------------------------------------*
/* CARDIN  | I | ????????????????????????????? | USER INPUT TO       *
/*         |   |                               | PROGRAM RUN07067    *
/*-------------------------------------------------------------------*
/* PRINTER | O | TSOID.HEATTRAN.OUTPUT         | REPORT/ANALYSIS FROM*
/*         |   |                               | PROGRAM RUN07067    *
/*-------------------------------------------------------------------*
/*         | O |&TSOID.HEATTRAN.SAVED(&MEMBER) | PREVIOUS REPORTS/   *
/*         |   |                               | ANALYSIS FROM       *
/*         |   |                               | PROGRAM RUN07067    *
/*===================================================================*
/*CONTROL LIST MSG SYMLIST CONLIST NOFLUSH NOPROMPT
 CONTROL NOLIST NOMSG NOSYMLIST NOCONLIST NOFLUSH NOPROMPT
/*
/*********************************************************************
/* CHECK EXISTANCE OF HEATTRAN.SAVED                                 *
/* IF DOES NOT EXIST CREATE IT                                       *
/*********************************************************************
/*
  ALLOC DA(HEATTRAN.SAVED) SHR
  IF &LASTCC ¬= 0 THEN +
    DO
      ATTR XXX RECFM(V B A) LRECL(125) BLKSIZE(129) DSORG(PO)
      ALLOC DA(HEATTRAN.SAVED) NEW USING(XXX) CATALOG SPACE (1,1) +
        CYLINDERS DIR(5)
      FREE ATTR(XXX)
      IF &LASTCC ¬= 0 THEN +
        DO
          WRITE
          WRITE CANNOT ALLOCATE HEATTRAN.SAVED ON YOUR ID
          WRITE PLEASE CALL SUPPORT PROGRAMMER
          EXIT
        END
    END
```

Figure 1 (Continued)

```
/*
/************************************************************************
/* CHECK EXISTANCE OF HEATTRAN.OUTPUT                                   *
/* IF DOES NOT EXIST CREATE IT                                          *
/************************************************************************
/*
  ALLOC DA(HEATTRAN.OUTPUT) SHR
  IF &LASTCC ¬= 0 THEN +
    DO
      ATTR XXX RECFM(V B A) LRECL(125) BLKSIZE(129) DSORG(PS)
      ALLOC DA(HEATTRAN.OUTPUT) NEW USING(XXX) CATALOG SPACE (1,1) +
        CYLINDERS
      FREE ATTR(XXX)
      IF &LASTCC ¬= 0 THEN +
        DO
          WRITE
          WRITE CANNOT ALLOCATE OUTPUT DATASET ON YOUR ID
          WRITE PLEASE CALL SUPPORT PROGRAMMER
          EXIT
        END
    END
/*
/************************************************************************
/* ALLOCATE PROGRAM FILES                                               *
/************************************************************************
/*
TOP: +
  FREE F(CARDIN,PRINTER)
  FREE DA(HEATTRAN.DATA)
  ALLOC F(PRINTER) DA(HEATTRAN.OUTPUT) SHR
/*
/************************************************************************
/* PROMPT FOR INPUT DATASET NAME                                        *
/************************************************************************
/*
  SET &I = 0
ENTER: +
  SET &I = &I + 1
  WRITE
  WRITE ENTER NAME OF INPUT DATASET
/*
/************************************************************************
/* CHECK INPUT DATASET EXISTANCE                                        *
/* IF DOES NOT EXIST FORCE REENTRY OF NAME                              *
/************************************************************************
/*
  READ &NAME
  WRITE &STR(&NAME)
/*
/************************************************************************
/* CHECK ON ID                                                          *
/************************************************************************
/*
  ALLOC F(CARDIN) DA(&NAME) SHR
  SET &CHECK = &LASTCC
```

Figure 1 (Continued)

```
/*
/**********************************************************************
/* IF NOT ON ID CHECK QUALIFIED NAME                                  *
/**********************************************************************
/*
  IF &CHECK ¬= 0 && &I < 3 THEN +
    DO
      ALLOC F(CARDIN) DA('&NAME') SHR
      SET &CHECK = &LASTCC
      IF &CHECK ¬= 0 && &I < 3 THEN +
        DO
          WRITE
          WRITE INPUT DATASET DOES NOT EXIST
          GOTO ENTER
        END
    END
  IF &CHECK ¬= 0 && &I = 3 THEN +
    DO
      WRITE
      WRITE INPUT DATASET DOES NOT EXIST
      WRITE PLEASE CREATE INPUT DATASET AN TRY AGAIN
      EXIT
    END
/*
/**********************************************************************
/* EXECUTE PROGRAM FROM SPECIFIED LIBRARY                             *
/**********************************************************************
/*
  CALL '&PGMLIB' '/&NAME'
  FREE F(PRINTER,CARDIN)
/*
/**********************************************************************
/* VIEW OUTPUT DATASET                                                *
/**********************************************************************
/*
  ISPEXEC BROWSE DATASET(HEATTRAN.OUTPUT)
/*
```

Figure 1 (Continued)

```
/************************************************************************
/* QUERY FOR DESIRE TO PRINT REPORT, DESTINATION                        *
/************************************************************************
/*
PRINT: +
  WRITE
  WRITENR DO YOU WANT TO PRINT OUTPUT (Y/N)?
  READ &ANS
  IF &ANS = &STR(Y) THEN +
    DO
      OPTION: +
      WRITE
      WRITE PRINTER OPTIONS (DEFAULT CHURCH)
      WRITE   DESENG1
      READ &DEST
      IF &DEST = &STR() THEN +
        RP HEATTRAN.OUTPUT DEST(CHURCH)
      ELSE +
        DO
          SET &OK = &STR(N)
          IF &STR(&DEST) = &STR(DESENG1) THEN +
            SET &OK = &STR(Y)
          IF &STR(&DEST) = &STR(COMSER1)THEN +
            SET &OK = &STR(Y)
          IF &STR(&DEST) = &STR(COMSER3)THEN +
            SET &OK = &STR(Y)
          IF &OK = &STR(Y) THEN +
            RP HEATTRAN.OUTPUT DEST(&STR(&DEST))
          ELSE +
            DO
              WRITE
              WRITE INVALID PRINTER NAME SUPPLIED
              GOTO OPTION
            END
        END
    END
   ELSE +
    DO
      IF &ANS ¬= &STR(N) THEN +
        DO
          WRITE
          WRITE CORRECT ANSWERS ARE Y (YES) OR N (NO)
          GOTO PRINT
        END
    END
```

Figure 1 (Continued)

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```
/*
/**********************************************************************
/* QUERY FOR DESIRE TO SAVE REPORT                                    *
/**********************************************************************
/*
SAVE: +
  WRITE
  WRITENR DO YOU WANT TO SAVE OUTPUT(Y/N)?
  READ &ANS
  IF &ANS = &STR(Y) THEN +
    DO
      SET &I = 0
    RECOPY: +
      SET &I = &I + 1
      WRITE
      WRITENR ENTER MEMBER NAME FOR HEATTRAN.SAVED
      READ &MEMBER
      COPY HEATTRAN.OUTPUT   HEATTRAN.SAVED(&STR(&MEMBER)) NON
      SET &CHECK = &LASTCC
      IF &CHECK ¬= 0 && &I = 1 THEN +
        DO
          WRITE
          WRITE COPY WAS UNSUCCESSFUL, TRY AGAIN, PLEASE
          GOTO RECOPY
        END
      IF &CHECK ¬= 0 && &I = 2 THEN +
        DO
          WRITE
          WRITE COPY WAS UNSUCCESSFUL, PLEASE CALL SUPPORT PROGRAMMER
        END
    END
  ELSE +
    DO
     IF &ANS ¬= &STR(N) THEN +
       DO
         WRITE
         WRITE CORRECT ANSWERS ARE Y (YES) OR N (NO)
         GOTO SAVE
       END
    END
/*
/**********************************************************************
/* QUERY FOR DESIRE TO RUN PROGRAM AGAIN                              *
/**********************************************************************
/*
RUN: +
  WRITE
  WRITENR DO YOU WANT TO RUN PROGRAM AGAIN(Y/N)?
  READ &ANS
  IF &ANS = &STR(Y) THEN GOTO TOP
  ELSE +
    DO
     IF &ANS ¬= &STR(N) THEN +
       DO
         WRITE
         WRITE CORRECT ANSWERS ARE Y (YES) OR N (NO)
         GOTO RUN
       END
    END
END
```

Figure 1 (Continued)

```
/*    NAME: RUN07067   TITLE: HEATTRAN                                */

/*************************************************************
*-----------------------------------------------------------*
*|                                                         |*
*|          REQUIRED DOCUMENTATION CHECK OFF LIST          |*
*|                                                         |*
*|---------------------------------------------------------|*
*|                                  |COMPLETED | DATE      |*
*|                                  |   BY:    |COMPLETED:|*
*|---------------------------------------------------------|*
*|  PROJECT LEADER APPROVAL         |          |           |*
*|---------------------------------------------------------|*
*|  SYSTEM DESCRIPTION              |          |           |*
*|---------------------------------------------------------|*
*|  RECORD INFORMATION              |          |           |*
*|---------------------------------------------------------|*
*|  FILE DESCRIPTION                | JLJORDAN | 10/07/83  |*
*|---------------------------------------------------------|*
*|  CONTINGENCY RECOVERY INFORMATION|          |           |*
*|---------------------------------------------------------|*
*|  HISTORY OF CHANGES              | JLJORDAN | 10/07/83  |*
*|---------------------------------------------------------|*
*|  PROGRAM DESCRIPTION             |          |           |*
*|---------------------------------------------------------|*
*|  PROGRAM LISTING                 | JLJORDAN | 10/07/83  |*
*************************************************************/
/************************************************************
|                                                           |
|                   HISTORY OF CHANGES                      |
|                                                           |
|-----------------------------------------------------------|
| REQUEST #  | DATE  |       DESCRIPTION        | PROGRAMMER |
|-----------------------------------------------------------|
| 423549     |10/83  | ORIG - INITIAL LOAD      | JORDAN     |
|            |       | TO CERTIFICATION AND     |            |
|            |       | ACCEPTANCE LIBRARY       |            |
|-----------------------------------------------------------|
| 13951921   | 03/90 | REVISE ALGORITHM TO ACCEPT | W. D. COWAY |
|            |       | TEMPERATURE PROFILE VALUES |            |
|            |       | FROM INPUT FILE INSTEAD OF |            |
|            |       | CALCULATING AVERAGE TEMP.  |            |
|            |       | PRINT INPUT AND PROFILE IN |            |
|            |       | SAME REPORT AS ANALYSIS.   |            |
|***********************************************************/
/***********************************************************
|                                                          |
|                  SYSTEM DESCRIPTION                      |
|                                                          |
|**********************************************************|
|     SUMMARY:                                             |
|                                                          |
|  REV,MOD,LEVEL  : ORIG                                   |
|  REV-DATE       : 11-12-81                               |
|  SPONSOR        : D H MEACHAN                            |
|  DIV-SECTION    : CENV                                   |
|  QA COND        : 1
|  SYSTEM USED    : I
|  VERIF METH     : A
```

Figure 1 (Continued)

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```
|  DUKE CALC FILE : C-16.17-15                                        |
|  STATUS         : A                                                 |
|                                                                     |
 ********************************************************************/
/********************************************************************
|                                                                     |
| CATAWBA SNSWP THERMAL ANALYSIS PROGRAM, REVISED 3/1990              |
|                                                                     |
| THIS PROGRAM CALCULATES SNSWP TEMPERATURES IN RESPONSE TO A         |
| ONE-UNIT LOCA AND AN ACCOMPANYING ONE-UNIT NORMAL SHUTDOWN.         |
|                                                                     |
| THE TECHNICAL BASIS FOR THE CALCULATION IS PRESENTED IN             |
|   CATAWBA NS CALCULATION NO. CNS-1150.01-00-0001.                   |
|                                                                     |
| THIS PROGRAM WAS REVISED IN MARCH 1990 TO INCORPORATE THE           |
|    FOLLOWING CHANGES:                                               |
|    1) THE INITIAL POND TEMPERATURE PROFILE  IS READ FROM THE        |
|       INPUT DATASET, RATHER THAN CALCULATED AS A UNIFORM            |
|       PROFILE FROM INPUT EQUILIBRIUM TEMPERATURES IN                |
|       METEORLOGICAL DATA.                                           |
|    2) OUTPUT FORMAT WAS MODIFIED AS TO TITLES, ETC.                 |
|    3) OUTPUT FORMAT WAS MODIFIED TO INCLUDE A PRINTOUT OF THE       |
|       INPUT DATASET AND THE INITIAL POND THERMAL PROFILE.           |
|    4) CALUCLATING PROCEDURES IN THE PROGRAM WERE NOT MODIFIED.      |
|                                                                     |
 ********************************************************************/
RUN7067:
  PROC (INDSN) OPTIONS (MAIN);
    DCL INDSN CHAR (100) VAR;
    DCL CARDIN FILE STREAM INPUT;
    DCL PRINTER FILE PRINT;
    OPEN FILE (CARDIN);
    OPEN FILE (PRINTER) PAGESIZE(55) LINESIZE(120);
     DCL CDATE CHAR(20);
     %DCL TIME ENTRY;
     %TIME:  PROC RETURNS(CHAR);
        DCL COMPILETIME  BUILTIN;
        RETURN(''''||COMPILETIME||'''');
     %END TIME;
     CDATE = TIME;
     %DEACTIVATE TIME;
    DCL (EXP,ABS)       BUILTIN;
    DCL (DATE,TIME)     BUILTIN;
    DCL SYSDATE         CHAR(6);
    DCL SYSTIME         CHAR(9);
    DCL PLANT CHAR(8);
    DCL TITLE CHAR (32);
    DCL V8          DEC(6);
    DCL K1          DEC(6);
    DCL (I,J,K,INDEX)    FIXED BIN(15);
    DCL (S1,T1,L1,K2)    FIXED BIN(15);
    DCL PAGE FIXED DEC(3,0) INIT (0);
    DCL B     FIXED  BIN(15)    INIT(0);
    DCL J1    FIXED  BIN(15)    INIT(0);
    DCL K4    FIXED  BIN(15)    INIT(0);
    DCL J3    FIXED  BIN(15)    INIT(0);
    DCL L2    FIXED  BIN(15)    INIT(0);
    DCL K9    FIXED  BIN(15)    INIT(0);
    DCL S (40,2)         DEC(12)  INIT((80)0);
    DCL FLOW             DEC(12);
```

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Figure 1 (Continued)

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```
DCL T (720,5)      DEC(12)  INIT((3600)0);
DCL T9             DEC(12)  INIT(0);
DCL T2             DEC(12)  INIT(0);
DCL H3             DEC(12)  INIT(0);
DCL A (30)         DEC(12);
DCL E (30)         DEC(12);
DCL P (30)         DEC(12);
DCL L (100,2)      DEC(12)  INIT((200)0);
DCL W (30)         DEC(12);
DCL Y (30)         DEC(12);
DCL Y1             DEC(12)  INIT(0);
DCL V1             DEC(12)  INIT(0);
DCL V2             DEC(12)  INIT(0);
DCL S2             DEC(12)  INIT(0);
DCL T5             DEC(12)  INIT(0);
DCL T3             DEC(12)  INIT(0);
DCL X              DEC(12)  INIT(0);
DCL T7             DEC(12)  INIT(0);
DCL P3             DEC(12)  INIT(0);
DCL P2             DEC(12)  INIT(0);
DCL T6             DEC(12)  INIT(0);
DCL P1             DEC(12)  INIT(0);
DCL T4             DEC(12)  INIT(0);
DCL V9             DEC(12)  INIT(0);
DCL EOF_CARDIN     BIT (1)  INIT('0'B);
DCL PRT_HDRS       BIT (1)  INIT('0'B);
DCL LINE           CHAR(80);
ON ERROR
  BEGIN;
    ON ERROR STOP;
    PUT FILE (PRINTER) SKIP DATA;
  END;
ON ENDFILE (CARDIN) EOF_CARDIN = '1'B;
ON ENDPAGE(PRINTER) BEGIN;
   PAGE=PAGE+1;
   IF -PRT_HDRS THEN
     DO;
       PAGE = PAGE - 1;
       GOTO NOPRT;
     END;
  PUT FILE(PRINTER)
     EDIT(PLANT,TITLE,'PAGE ',PAGE,
'TIME  REAL   DISC   HEAT   COOL   UN  MIXED  INTAKE  EVAP   E    K',
     '  TEMP',
'TIME   TEMP   LOSS   DOWN  MIX   TEMP   TEMP   AC-FT','TCFH')
(PAGE,X(25),A(9),A(32),X(6),A(5),F(3,0),
 SKIP(2),X(4),A(66),A(6),
 SKIP,X(10),A(52),X(10),A(4));
   PUT FILE(PRINTER) SKIP(2);
 NOPRT:
   END; /* ON ENDPAGE(PRINTER) */
    PUT FILE (PRINTER) SKIP EDIT
    ('THIS PROGRAM(RUN07067) WAS LAST CHANGED ON: ',
       CDATE)  (A,A);
   PUT FILE(PRINTER)
   EDIT('PROGRAM NAME','REV,MODEL,LEVEL/','SPONSOR:          ','QA',
   'SYSTEM','VERIF.','DUKE','STATUS')
   (COL(2),A,COL(22),A,COL(42),A,COL(65),A,COL(73),A,COL(84),A,
    COL(95),A,COL(109),A);
```

Figure 1 (Continued)

```
PUT FILE(PRINTER)
EDIT('REV DATE','DES ENG DEPT','COND','USED','METH','CALC')
(COL(25),A,COL(42),A,COL(64),A,COL(74),A,COL(84),A,COL(95),A);
PUT FILE(PRINTER)
EDIT('ENG SUPP DIVN','CODE','FILE')
(COL(42),A,COL(84),A,COL(95),A);
PUT FILE(PRINTER)
EDIT('HEATTRAN RUN07067','REVISED ','ENV ENG GROUP    ','1','I',
'A','C-6.17-15','A')
(COL(2),A,COL(23),A,COL(42),A,COL(65),A,COL(75),A,COL(85),A,
 COL(94),A,COL(111),A);
PUT FILE(PRINTER)
EDIT('04-1990') (COL(23),A);
GET FILE(CARDIN)
    EDIT(PLANT,TITLE,T1,L1,K2,S1)
        (X(2),A(8),SKIP,X(2),A(32),
         3 (SKIP,X(1),F(4)),SKIP(2),X(1),F(4));
SYSDATE = DATE;
SYSTIME = TIME;
PUT FILE (PRINTER) SKIP(10) EDIT
  ('THIS IS A SNSWP THERMAL ANALYSIS FOR ',PLANT,
   'DATE:  ',SYSDATE,'   TIME:  ',SYSTIME,
   'RUN ON IBM/MVS-TSOPRDB')
  (X(10),A(38),A(8),SKIP,
   X(10),A(7),A(6),A(10),A(9),SKIP,
   X(10),A(22));
CLOSE FILE(CARDIN);
OPEN  FILE(CARDIN);
GET FILE (CARDIN) SKIP EDIT (LINE) (A(80));
DO WHILE (¬EOF_CARDIN);
  PUT FILE (PRINTER) PAGE EDIT ('INPUT DATASET: ',INDSN)
    (X(10),A,A);
  PUT FILE (PRINTER) SKIP(2);
  DO I = 1 TO 55 WHILE (¬EOF_CARDIN);
    PUT FILE (PRINTER) SKIP LIST(LINE);
    GET FILE (CARDIN) SKIP EDIT (LINE) (A(80));
  END;
END;
CLOSE FILE(CARDIN);
PRT_HDRS = '1'B;
EOF_CARDIN = '0'B;
OPEN  FILE(CARDIN);
GET FILE(CARDIN) SKIP(11)                        /* READ PAST LINES*/
    LIST((S(I,1) DO I=1 TO S1)) ;               /* ALREADY PROCESSED*/
DO I=1 TO S1;
    S(I,1)=S(I,1)*43.56;
END;
GET FILE (CARDIN)
    LIST ((S(I,2) DO I=1 TO S1))
    SKIP (4);
GET FILE (CARDIN) SKIP (4) EDIT (INDEX,FLOW)
                              (X(1),F(4),X(1),F(7,2));
DO I=1 TO INDEX;
   T(I,3)=FLOW;
END;
DO WHILE(INDEX<T1);
   GET FILE(CARDIN)
       EDIT(INDEX,FLOW)
           (SKIP,X(1),F(4),X(1),F(7,2));
   IF INDEX<I THEN SIGNAL ERROR;
```

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Figure 1 (Continued)

```
   DO I=I TO INDEX;
      T(I,3)=FLOW;
   END;
END;
IF PLANT='CHEROKEE' THEN CALL CHK(T);
ELSE IF PLANT='CATAWBA' THEN CALL CAT(T);
ELSE SIGNAL ERROR;
K=0;
DO I=1 TO T1;
     K=K+1;
     T(I,5)=16.0256*T(I,4)/T(I,3);
     IF K>=K2 THEN K=0;
END;
Y1=0;
GET FILE(CARDIN) SKIP(4);
GET FILE(CARDIN)
     LIST((A(J),P(J),W(J),Y(J),E(J) DO J=1 TO 30));
DO I=1 TO 30;
    Y1=Y1+E(I);
END;
SIGNAL ENDPAGE(PRINTER);
V1=S(S1,1)/L1;
L(1,1)=0;
V2=0;
S2=0;
J1=1;
K=1;
DO I=2 TO L1;
     K=K+1;
     V2=V2+V1;
     DO J=J1 TO S1;
          IF V2<S(J,1) THEN GO TO G04;
     END;
G04: IF J>S1 THEN J=J-1;
     J1=J;
     IF J¬=1 THEN S2=S(J-1,1);
     L(I,1)=J-1+(V2-S2)/(S(J,1)-S2);
     IF K>=K2 THEN K=0;
END;
K=0;
J1=1;
DO I=1 TO L1;
     K=K+1;
     DO J=J1 TO S1;
          IF L(I,1)<J THEN GO TO G05;
     END;
G05: IF J>S1 THEN J=J-1;
     L(I,2)=S(J,2);
     J1=J;
     IF K>=K2 THEN K=0;
END;
V9=0.0;
H3=S1-L(L1,1);
T5=0;
K4=1;
K=0;
J3=1;
DO I=1 TO T1;
   IF T5>(I-.5) THEN GO TO DONE;
   K=K+1;
```

Figure 1 (Continued

```
G03:    T2=V1/T(I,3);
        T5=T5+T2;
        T3=L(1,2)+T(I,5);
        L2=L1-1;
        DO J=1 TO L2;
            L(J,2)=L(J+1,2);
        END;
        J=J-1;
        X=X+T2;
        IF X>24 THEN
            DO;
                J3=J3+1;
                X=X-24;
                IF J3>30 THEN J3=30;
            END;
        K1=Y(J3)/24;
        T9=(T3-E(J3))*EXP(-K1*T2/(62.4*H3));
        T4=T3-(E(J3)+T9);
        IF T4<=0 THEN
            DO;
                V8=0;
                GO TO G01;
            END;
        P1=25.4*EXP(17.62-9500/(P(J3)+460));
        T6=(A(J3)+460)/(1.-0.378*P1/760)-460;
        P2=T3-T4/2;
        P3=25.4*EXP(17.62-9500/(P2+460));
        T7=(P2+460)/(1-0.378*P3/760)-460;
    V8=(22.4*ABS(T6-T7)**0.333+14*W(J3))*(P3-P1)*(S(S1,1)-S(S1-1,1));
        V8=V8*1000/(62.4*1050*43560*24);
        V8=V8*T2;
        L(L1,2)=T3-T4;
G01:    V9=V9+V8;
        L(L1,2)=T3-T4;
        IF L(L1,2)>L(L1-1,2) THEN GO TO G02;
        DO J=L1 TO 1 BY -1;
            IF J=1 THEN B=J;
              ELSE B=J-1;
            IF L(J,2)>L(B,2) THEN GO TO G02;
            L(B,2)=(L(J,2)*(L1+1-J)+L(B,2))/(L1+2-J);
            DO K9=J TO L1;
                L(K9,2)=L(B,2);
            END;
        END;
        IF J<=0 THEN J=1;
G02:    IF K=K4 THEN
    PUT FILE(PRINTER)
        EDIT(I,T5,T3,T4,L(L1,2),J,L(J,2),L(1,2),V9,E(J3),Y(J3),T(I,3))
            (COLUMN(1),X(4),F(4),X(1),F(6,1),X(1),F(6,2),X(1),F(5,2),
             X(1),F(7,2),X(1),F(3),X(1),F(7,2),X(1),F(6,2),
             X(1),F(6,2),X(1),F(3),X(1),F(4),X(1),F(4));
                K=0;
        IF T5<I-.5 THEN GO TO G03;
DONE:  END;
    CLOSE FILE (CARDIN);
    CLOSE FILE (PRINTER);
```

Figure 1 (Continued)

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```
CAT:    PROC(T);
     DCL T(*,*) DEC FLOAT(12);
     GET FILE(CARDIN)
          LIST((T(I,4) DO I=1 TO 4))
          SKIP(4);
     DO I=5 TO 19;
        T(I,4)=527*I**-0.2332;
     END;
     DO I=20 TO 170;
        T(I,4)=527*I**-0.2695;
     END;
     DO I=171 TO 720;
        T(I,4)=1197*I**-0.4995;
     END;

END CAT;


CHK:    PROC(T);

      DCL T(*,*) DEC FLOAT(12);

      GET FILE(CARDIN)
           LIST((T(I,4) DO I=1 TO 10))
           SKIP(4);
      DO I=11 TO 27;
         T(I,4)=600*I**-.22 + 245;
      END;
      DO I=28 TO 120;
         T(I,4)=650*I**-.22 + 157;
      END;
      DO I=121 TO 720;
         T(I,4)=800*I**-.22 + 68;
      END;

 END CHK;

 END RUN7067;
```

Figure 1 (Continued)

CATAWBA NUCLEAR STATION

SNSWP - Model Flow Chart

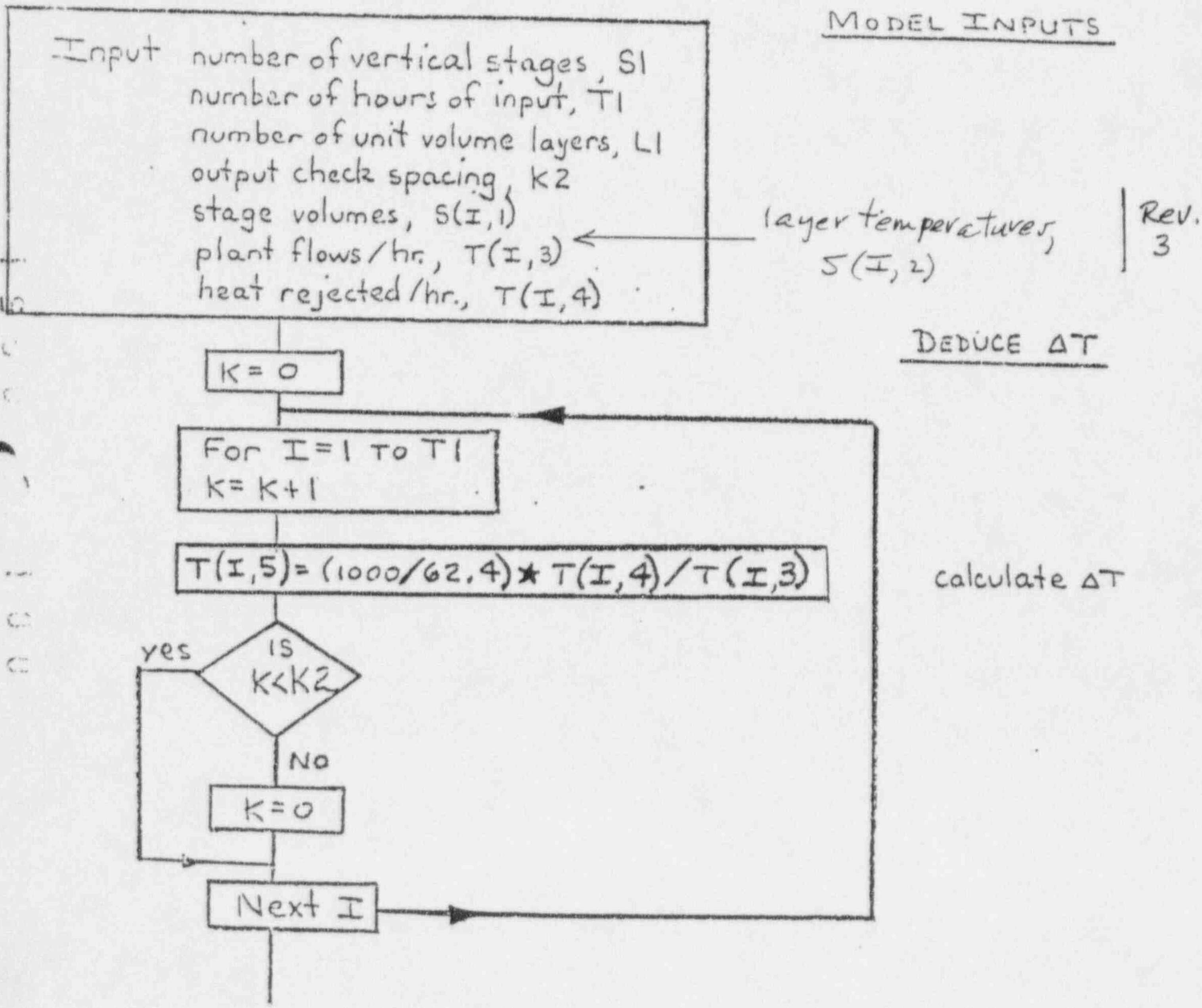
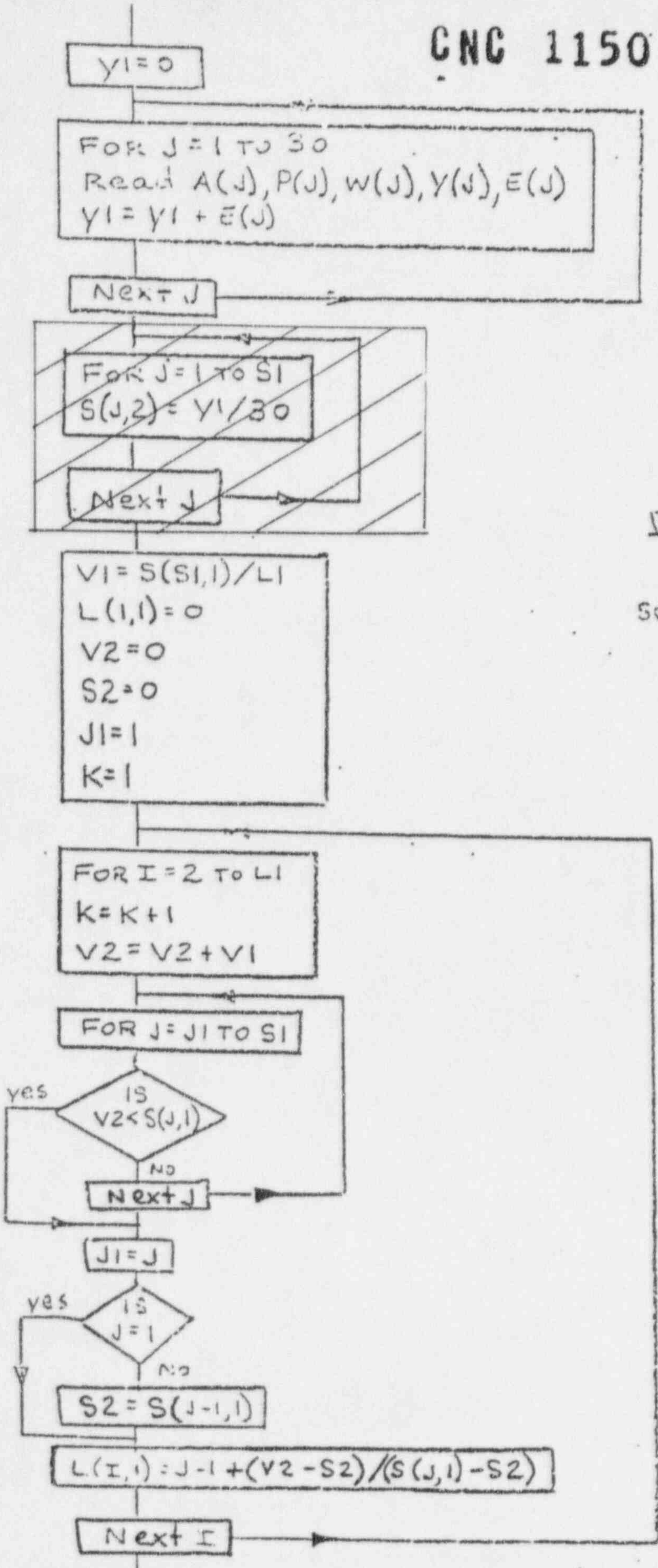


Figure 2. Catawba SNSWP Model Flow Chart



Input meteorological data

Σ equilibrium temp.

~~set initial temp. of pond to average equilibrium temp.~~ Re 3

FORM UNIT VOLUME LAYERS

set bottom of layer 1 at 0 ft.

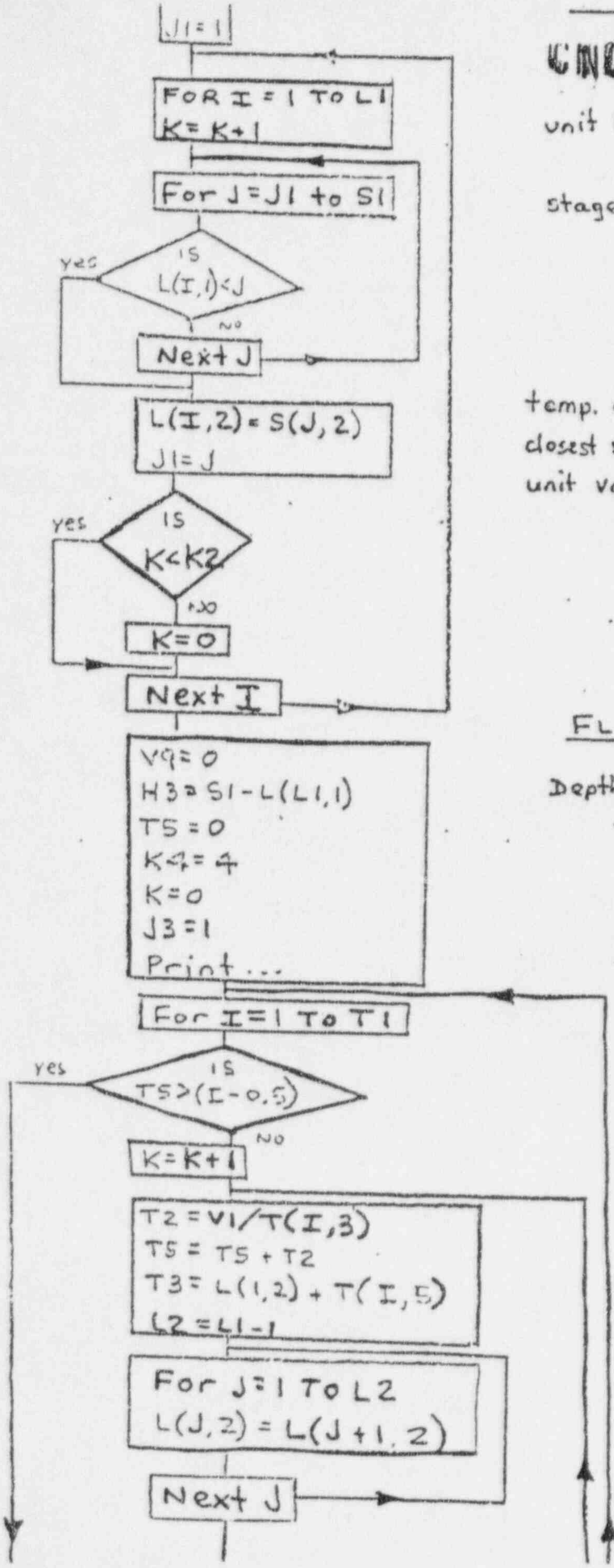
finds nearest whole stage above the bottom boundary of volume I.

finds if unit volume 1 is less than volume at stage 1.

finds nearest whole stage below the bottom boundary of volume I.

assigns bottom of unit volume layer to nearest fraction of stage.

Figure 2 (continued)



unit layers

stages

temp. of the unit volume equals the temp. of the closest stage above the bottom boundary of the unit volume.

FLOW ITERATION

Depth of the top layer.

time required for flow through of 1 unit volume.

discharge temp. from plant.

Sets temp. of each layer to the temp. of the layer above it.

Figure 2 (continued)

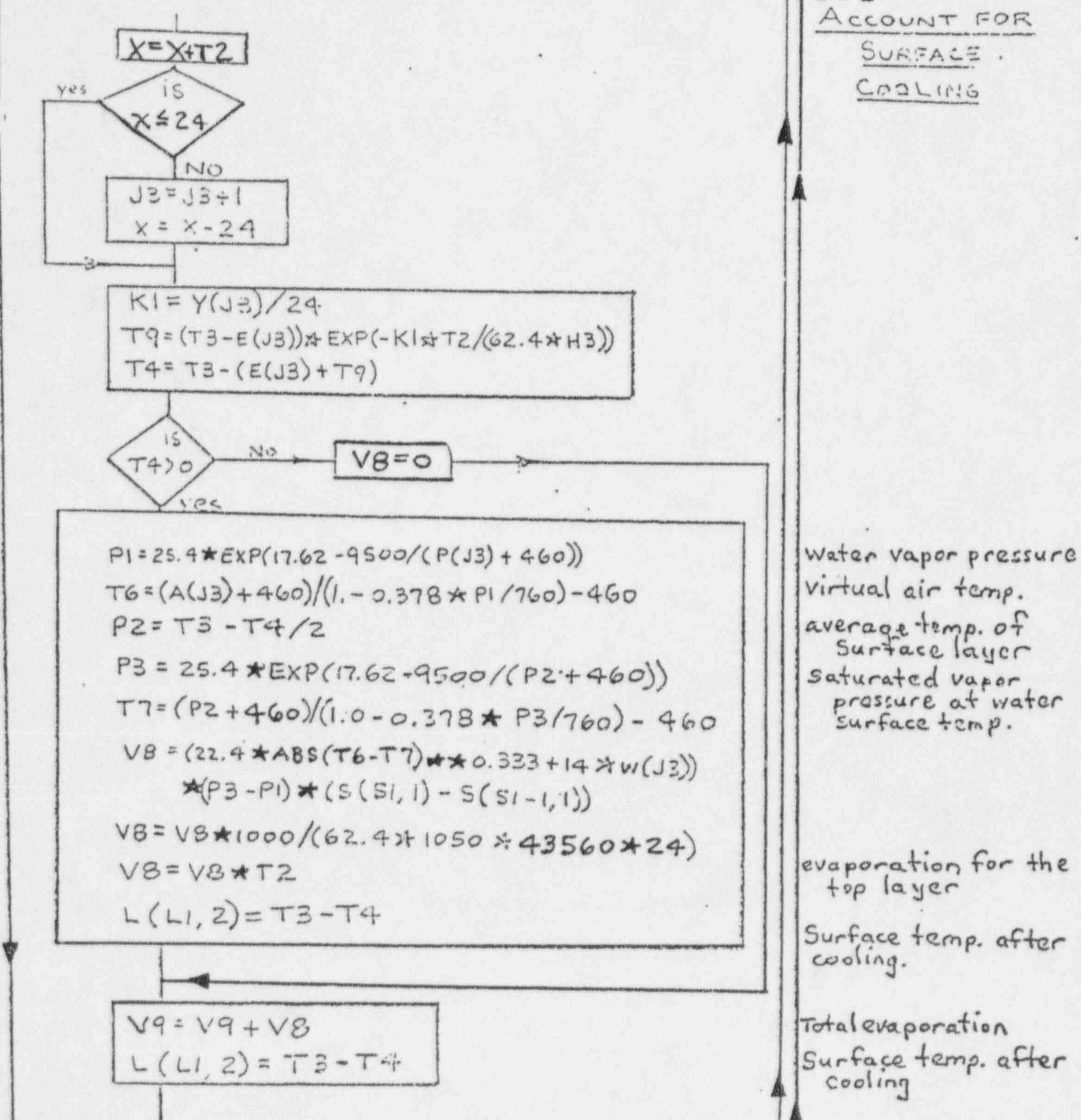
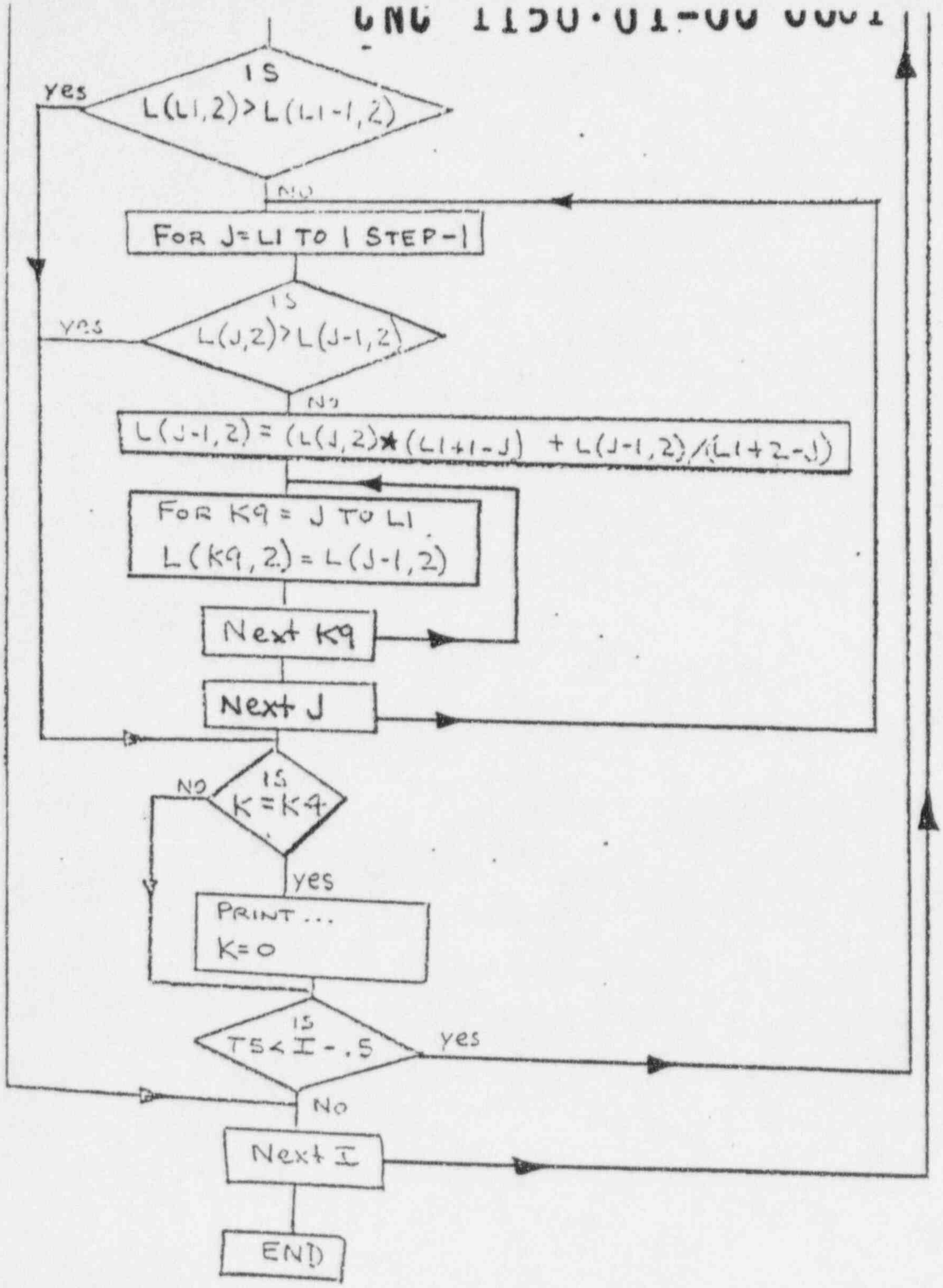


Figure 2 (continued)



INSTABILITY

is the upper layer warmer than the layer below it?

is the upper layer I warmer than the layer below it?

find average temp for mixed region.

Set all temp. of mixed region equal to their average temp.

Figure 2 (continued)

Figure 3. List of Program Variables

A(J)	Daily air temperature
E(J)	Equilibrium temperature
K2	Output check spacing
K4	A counter, determines how often to print
L1	Number of unit volume layers in the pond
L2	Number of unit volume layers minus one
L(I ,1)	Floor depth of each unit volume, from the bottom up
L(I,2)	Temperature of each unit volume layer
P(J)	Daily dew point temperature
S1	Number of vertical stages in pond, in feet
S2	Total volume to nearest stage below I unit layers
S(I,l)	Total volume of pond at each foot of elevation from bottom
S(I,2)	Initial temperature of pond at each stage
T1	Number of hours of input
T2	Time increment for one unit volume to pass through plant
T3	Discharge temperature from plant
T4	Heat loss to atmosphere
T5	Total time elapsed
T9	Heat loss equation
T(I,l)	Equilibrium temperature
T(I,2)	Exchange coefficient
T(I,3)	Flow through plant
T(I,4)	Heat input to pond from the plant
T(I,5)	Calculated ΔT for plant discharge
V1	Volume of a unit volume layer
V2	Volume of pond, up to but not including layer 1.
W(J)	Daily wind speed
Y(J)	Daily surface heat exchange coefficient

Figure 4 Input Variables

S1: S1 is the depth in feet available for use in the SNSWP. The full pond elevation of the SNSWP is 572 feet mean sea level (msl). The pond elevation is set at 570.64 ft msl for the LOCA analysis due to losses (see Model Inputs section). The intake for the nuclear service water system is at elevation 540 feet msl (see Figure 6). This gives a total usable depth of greater than 30 feet for the SNSWP.

Tl: Tl is the number of hours of input and analysis for the LOCA period. From Regulatory Guide 1.27, Revision 2, 720 hours (30 days) is used.

Ll: Ll is the number of unit volume layers. From engineering judgment, 20 unit volume layers are used. The number of layers selected has only a very slight impact on the calculated temperatures, unless a very small number is used, which will have a much greater impact.

K2: K2 is the output check spacing. The number used does not influence the model results at all. K2 is assumed equal to 20.

S(I,1): S(I,l) is the volume of the pond at each foot of elevation. The numbers are from the area volume curve (see Attachment A).

S(I,2): S(I,2) is the initial temperature of pond in degrees F.

T(1,3): T(1,3) is the flow rate from the SNSWP to the plant for hours 1 through 4 and hours 5 through 720 (See Input Section, Reference CNC-1223.24-0041).

Figure 4 (Input Variables, continued)

T(I,4): T(I,4) is the heat rejected to the SNSWP from the plant.

A(J): A(J) is the daily air temperature, °F, for the 30-day LOCA period.

P(J): P(J) is the daily dew point temperature, °F, for the 30-day LOCA period.

W(J): W(J) is the daily wind speed measured at 2m height, mph, for the 30-day LOCA period.

E(J): E(J) is the daily equilibrium temperature, °F, for the 30-day LOCA period.

Y(J): Y(J) is the daily heat exchange coefficient for the 30-day LOCA period, Btu/ft^2/day/°F.

Figure 5 . Model Output Variables

Time: I, Iteration number, approximate time since beginning of LOCA.

Real Time: T5, time in hours from start of LOCA.

Discharge Temperature: T3, discharge temperature from the plant to the pond. It equals the intake temperature plus the plant ΔT, °F.

Heat Loss: T4, heat lost to the atmosphere from the top layer, °F.

Cool Down: L(Ll,2), the surface layer temperature after cooling to the atmosphere and mixing due to water densities, °F.

Un Mix: J, number (from bottom) of the deepest mixed layer.

Mixed Temp: L(J,2) , average temperature of the mixed region, °F. The mixed layers are set equal to this temperature.

Intake Temp: L(1 ,2), intake temperature of the plant, °F. The temperature of unit layer number 1.

Evan Ac-Ft: V9, total evaporation from the pond up to time period I, Acre-feet.

E: E(J3), equilibrium temperature at time I, °F.

K: Y(J3), exchange coefficient at time I, Btu/(ft^{2}day°F).

Flow TCFH: T(I,3), flow rate into the plant at time I, thousands of cubic feet/ hour .

```
T DATASET: CNAVLOWS.DATA

 CATAWBA    PLANT
      -WORST HEAT TRANSFER-       TITLE
 720        T1:   # OF HOURS INPUT
  20        L1:   # OF UNIT VOLUME LAYERS
  20        K2:   OUTPUT CHECK SPACING
C
  31        S1:   # OF VERTICAL STAGES (FT)
C
C         S(I,1):    VOLUME IN POND AT EACH STAGE (ACFT)
C
0 0 0 0 0 1 1 2 6 10 16 23 32 41
53 66 79 92 113 133 154 176 200 224 251 279 310 341
374 396.1 434
C
C         S(I,2):    INITIAL TEMPERATURE AT EACH STAGE (F)
C
  91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
  91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
  91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
  91.5 91.5 91.5 91.5 91.5 91.5 91.5
C
C         LOOPING VALUES AND PLANT FLOWS FOR T(I,3) (1000*CU.FT/HR)
C
   4  304.8
 720  152.4
C
C         T(I,1):    INPUT HEAT (MBTU/HR)
C
117.4 171.7 182.9 188.2 147.9 262.9 258.5 253.9
249.9 245.9 242.1 238.2 234.2 231.4 227.8 224.2
222.0 219.1 216.0 214.1 211.8 211.8 211.8 211.8
195.0 195.0 195.0 195.0 195.0 186.8 177.9 167.2
159.3 159.3 151.0 151.0 142.0 142.0 142.0 142.0
142.0 142.0 142.0 128.5 128.5 128.5  85.5  77.1
 69.8  63.9  59.6  59.6  59.6
C
C A(J) P(J) W(J) Y(J) E(J)
C
81 72 2 170 90
85 71 2 106 93
89 70 2 184 92
89 72 2 189 94
91 71 2 198 95
83 72 5 197 85
79 71 3 142 81
83 71 3 166 86
72 61 5 154 73
73 58 3 166 82
75 60 2 163 86
77 62 4 187 84
78 63 4 167 80
72 66 3 135 77
73 69 3 133 76
77 70 2 157 86
77 68 4 159 80
```

Figure 6: Low-Flow Conditions Model Run

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Figure 6

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DATASET: CNAVLOH5.DATA

72	55	2	131	77
74	60	3	155	80
77	63	1	153	88
77	65	2	149	84
78	68	3	170	85
76	69	3	149	81
78	71	2	133	82
80	70	3	159	84
80	71	3	164	85
83	72	3	159	84
86	69	3	178	87
88	69	2	190	93
87	70	3	194	90

CATAWBA -WORST HEAT TRANSFER- PA

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
1	3.1	97.67	3.52	94.15	19	91.50	91.50	0.16	90	170	305
4	6.2	101.40	5.23	96.16	19	94.15	91.50	0.35	90	170	305
7	12.4	118.68	20.30	98.39	19	96.16	91.50	1.02	90	170	152
13	18.6	116.13	18.49	98.01	19	98.01	91.50	1.64	90	170	152
20	24.8	114.01	15.54	98.47	19	98.01	91.50	2.23	93	186	152
26	31.0	112.01	14.06	98.21	19	98.21	91.50	2.78	93	186	152
32	37.2	111.14	13.42	98.05	18	98.05	91.50	3.32	93	186	152
38	43.4	111.14	13.42	97.98	15	97.98	91.50	3.85	93	186	152
44	49.6	110.21	13.40	97.82	14	97.82	91.50	4.35	92	184	152
51	55.8	109.08	12.57	97.65	13	97.65	91.50	4.83	92	184	152
57	62.0	109.08	12.57	97.53	12	97.53	91.50	5.30	92	184	152
63	68.2	108.25	11.96	97.40	11	97.40	91.50	5.76	92	184	152
69	74.4	108.25	10.62	97.63	19	97.40	91.50	6.23	94	189	152
75	80.6	108.25	10.62	97.63	19	97.63	91.50	6.69	94	189	152
82	86.8	107.38	9.97	97.56	18	97.56	91.50	7.13	94	189	152
88	93.0	107.38	9.97	97.52	17	97.52	91.50	7.58	94	189	152
94	99.2	107.38	9.42	97.96	19	97.52	91.50	8.03	95	198	152
100	105.4	106.43	8.70	97.84	19	97.84	91.50	8.47	95	198	152
106	111.6	106.43	8.70	97.81	18	97.81	91.50	8.91	95	198	152
113	117.8	106.43	8.70	97.79	17	97.79	94.15	9.35	95	198	152
119	124.0	109.08	18.29	97.16	2	97.14	96.16	9.93	85	197	152
125	130.3	111.09	19.82	96.87	1	96.87	96.87	10.56	85	197	152
131	136.5	111.80	20.35	96.60	1	96.60	96.60	11.21	85	197	152
137	142.7	111.53	20.15	96.33	1	96.33	96.33	11.85	85	197	152
144	148.9	111.27	19.43	96.11	1	96.11	96.11	12.39	81	142	152
150	155.1	111.04	19.29	95.89	1	95.89	95.89	12.92	81	142	152
156	161.3	110.82	19.15	95.68	1	95.68	95.68	13.45	81	142	152
162	167.5	110.61	19.01	95.48	1	95.48	95.48	13.98	81	142	152
168	173.7	110.41	17.06	95.37	1	95.37	95.37	14.51	86	166	152
175	179.9	108.88	16.00	95.25	1	95.25	95.25	15.01	86	166	152
181	186.1	108.76	15.91	95.13	1	95.13	95.13	15.51	86	166	152
187	192.3	108.64	23.94	94.61	1	94.61	94.61	16.16	73	154	152
193	198.5	108.12	23.59	94.10	1	94.10	94.10	16.80	73	154	152
199	204.7	107.61	23.25	93.61	1	93.61	93.61	17.42	73	154	152
206	210.9	102.61	19.89	93.07	1	93.07	93.07	17.94	73	154	152
212	217.1	102.06	14.02	92.82	1	92.82	92.82	18.44	82	166	152
218	223.3	101.81	13.85	92.58	1	92.58	92.58	18.93	82	166	152
224	229.5	101.57	13.68	92.34	1	92.34	92.34	19.42	82	166	152
230	235.7	101.33	13.51	92.11	1	92.11	92.11	19.91	82	166	152
237	241.9	101.11	10.46	92.04	1	92.04	92.04	20.34	86	163	152
243	248.1	101.03	10.41	91.97	1	91.97	91.97	20.77	86	163	152
249	254.3	100.96	10.36	91.90	1	91.90	91.90	21.21	86	163	152
255	260.5	100.89	10.31	91.84	1	91.84	91.84	21.64	86	163	152
262	266.7	100.83	12.48	91.66	1	91.66	91.66	22.13	84	187	152
268	272.9	100.65	12.35	91.49	1	91.49	91.49	22.63	84	187	152
274	279.1	100.48	12.22	91.33	1	91.33	91.33	23.12	84	187	152
280	285.3	100.32	12.10	91.18	1	91.18	91.18	23.60	84	187	152
286	291.5	100.17	14.14	90.92	1	90.92	90.92	24.04	80	167	152
293	297.7	99.91	13.96	90.67	1	90.67	90.67	24.48	80	167	152
299	303.9	99.66	13.79	90.43	1	90.43	90.43	24.92	80	167	152

Figure 6

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TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
305	310.1	98.54	13.00	90.19	1	90.19	90.19	25.33	80	167	152
311	316.3	98.29	13.27	89.93	1	89.93	89.93	25.68	77	135	152
317	322.5	98.04	13.11	89.68	1	89.68	89.68	26.02	77	135	152
324	328.7	97.79	12.96	89.46	1	89.44	89.44	26.36	77	135	152
330	334.9	97.54	12.81	89.20	1	89.20	89.20	26.70	77	135	152
336	341.1	97.31	11.93	89.01	1	89.01	89.01	27.01	78	133	152
342	347.3	97.12	11.81	88.82	1	88.82	88.82	27.31	78	133	152
348	353.5	96.93	11.70	88.64	1	88.64	88.64	27.62	78	133	152
355	359.7	96.75	11.59	88.47	1	88.47	88.47	27.92	78	133	152
361	365.9	96.58	7.18	89.40	19	88.47	88.47	28.20	86	157	152
367	372.1	96.58	7.18	89.40	19	89.40	88.47	28.48	86	157	152
373	378.3	96.58	7.18	89.40	18	89.40	88.47	28.76	86	157	152
379	384.6	96.58	11.33	88.45	1	88.45	88.45	29.10	80	159	152
386	390.8	96.56	11.31	88.29	1	88.29	88.29	29.44	80	159	152
392	397.0	96.40	11.20	88.13	1	88.13	88.13	29.77	80	159	152
398	403.2	96.24	11.10	87.98	1	87.98	87.98	30.10	80	159	152
404	409.4	95.32	11.22	87.79	1	87.79	87.79	30.45	77	131	152
410	415.6	95.13	11.10	87.60	1	87.60	87.60	30.78	77	131	152
417	421.8	94.94	10.99	87.42	1	87.42	87.42	31.12	77	131	152
423	428.0	94.76	10.87	87.24	1	87.24	87.24	31.45	77	131	152
429	434.2	94.58	9.83	87.12	1	87.12	87.12	31.80	80	155	152
435	440.4	94.46	9.75	87.00	1	87.00	87.00	32.15	80	155	152
441	446.6	94.34	9.67	86.88	1	86.88	86.88	32.50	80	155	152
448	452.8	94.22	9.59	86.77	1	86.77	86.77	32.84	80	155	152
454	459.0	94.11	4.09	90.02	19	86.77	86.77	33.11	88	153	152
460	465.2	94.11	4.09	90.02	19	90.02	86.77	33.38	88	153	152
466	471.4	94.11	4.09	90.02	18	90.02	86.77	33.65	88	153	152
472	477.6	94.11	4.09	90.02	19	90.02	86.77	33.92	88	153	152
479	483.8	94.11	6.67	89.50	16	89.50	86.77	34.20	84	149	152
485	490.0	94.11	6.67	89.16	15	89.16	86.77	34.48	84	149	152
491	496.2	94.11	6.67	88.91	14	88.91	86.77	34.76	84	149	152
497	502.4	94.11	6.67	88.73	13	88.73	86.77	35.03	84	149	152
503	508.6	93.49	6.01	88.59	12	88.59	86.77	35.32	85	170	152
510	514.8	93.49	6.01	88.48	11	88.48	86.77	35.61	85	170	152
516	521.0	93.49	6.01	88.39	10	88.39	86.77	35.89	85	170	152
522	527.2	93.49	6.01	88.31	9	88.31	86.77	36.18	85	170	152
528	533.4	93.49	8.24	88.08	8	88.08	86.77	36.44	81	149	152
534	539.6	93.49	8.24	87.88	7	87.88	86.77	36.69	81	149	152
541	545.8	93.49	8.24	87.70	6	87.70	86.77	36.95	81	149	152
547	552.0	93.49	7.10	87.62	5	87.62	86.77	37.16	82	133	152
553	558.2	93.49	7.10	87.55	4	87.55	86.77	37.37	82	133	152
559	564.4	93.49	7.10	87.48	3	87.48	86.77	37.58	82	133	152
565	570.6	93.49	7.10	87.43	2	87.43	86.77	37.79	82	133	152
572	576.8	93.49	6.48	87.40	1	87.40	87.40	38.05	84	159	152
578	583.0	94.12	6.92	87.39	1	87.39	87.39	38.31	84	159	152
584	589.2	94.11	6.91	87.38	1	87.38	87.38	38.58	84	159	152
590	595.4	94.10	6.91	87.38	1	87.38	87.38	38.84	84	159	152
596	601.6	94.09	6.32	87.78	19	87.38	87.38	39.10	85	164	152
603	607.8	93.64	6.00	87.71	19	87.71	87.38	39.35	85	164	152
609	614.0	93.64	6.00	87.69	18	87.69	87.38	39.61	85	164	152

Figure 6

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CATAWBA -WORST HEAT TRANSFER- PA

TIME	TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
615	620.2	93.64	6.00	87.67	17	87.67	87.38	39.86	85	164	152
621	626.4	93.64	6.59	87.55	16	87.55	87.38	40.09	84	159	152
627	632.6	93.64	6.59	87.47	15	87.47	87.38	40.31	84	159	152
634	638.9	93.64	6.59	87.41	14	87.41	87.38	40.54	84	159	152
640	645.1	93.64	6.59	87.37	1	87.37	87.37	40.77	84	159	152
646	651.3	93.64	4.81	88.83	19	87.37	87.37	41.03	87	178	152
652	657.5	93.64	4.81	88.83	19	88.83	87.37	41.29	87	178	152
658	663.7	93.64	4.81	88.83	18	88.83	87.37	41.56	87	178	152
665	669.9	93.64	4.81	88.83	19	88.83	87.37	41.82	87	178	152
671	676.1	93.64	0.48	93.16	19	88.83	87.37	42.08	93	190	152
677	682.3	93.64	0.48	93.16	19	93.16	87.37	42.33	93	190	152
683	688.5	93.64	0.48	93.16	18	93.16	87.37	42.59	93	190	152
689	694.7	93.64	0.48	93.16	19	93.16	87.37	42.85	93	190	152
696	700.9	93.64	2.74	92.71	16	92.71	87.37	43.12	90	194	152
702	707.1	93.64	2.74	92.41	15	92.41	87.37	43.39	90	194	152
708	713.3	93.64	2.74	92.19	14	92.19	87.37	43.67	90	194	152
714	719.5	93.64	2.74	92.03	13	92.03	87.37	43.94	90	194	152
720	725.7	93.64	2.74	91.90	12	91.90	87.37	44.21	90	194	152

Figure 6

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```
T DATASET: CNAV1ST5.DATA

 CATAWBA    PLANT
     -WORST HEAT TRANSFER-       TITLE
  720        T1:   # OF HOURS INPUT
   20        L1:   # OF UNIT VOLUME LAYERS
   20        K2:   OUTPUT CHECK SPACING
C
   31        S1:   # OF VERTICAL STAGES (FT)
C
C        S(I,1):    VOLUME IN POND AT EACH STAGE (ACFT)
C
0 0 0 0 0 1 1 2 6 10 16 23 32 41
53 66 79 92 113 133 154 176 200 224 251 279 310 341
374 396.1 434
C
C        S(I,2):    INITIAL TEMPERATURE AT EACH STAGE (F)
C
   91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
   91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
   91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
   91.5 91.5 91.5 91.5 91.5 91.5 91.5
C
C        LOOPING VALUES AND PLANT FLOWS FOR T(I,3) (1000*CU.FT/HR)
C
    4  369.0
  720  184.5
C
C        T(I,1):    INPUT HEAT (MBTU/HR)
C
117.4 171.7 182.9 188.2 147.9 262.9 258.5 253.9
249.9 245.9 242.1 238.2 234.2 231.4 227.8 224.2
222.0 219.1 216.0 214.1 211.8 211.8 211.8 211.8
195.0 195.0 195.0 195.0 195.0 186.8 177.9 167.2
159.3 159.3 151.0 151.0 142.0 142.0 142.0 142.0
142.0 142.0 142.0 128.5 128.5 128.5  85.5  77.1
 69.8  63.9  59.6  59.6
C
C A(J) P(J) M(J) Y(J) E(J)
C
81 72 2 170 90
85 71 2 186 93
89 70 2 184 92
89 72 2 189 94
91 71 2 198 95
83 72 5 197 85
79 71 3 142 81
83 71 3 166 86
72 61 5 154 73
73 58 3 166 82
75 60 2 163 86
77 62 4 187 84
78 63 4 167 80
72 66 3 135 77
73 69 3 133 78
77 70 2 157 86
77 68 4 159 80
```

Figure 7: High-Flow Conditions Model Run

T DATASET: CNAV1ST5.DATA

72	55	2	131	77
74	60	3	155	80
77	63	1	153	88
77	65	2	149	84
78	68	3	170	85
76	69	3	149	81
78	71	2	133	82
80	70	3	159	84
80	71	3	164	85
83	72	3	159	84
86	69	3	178	87
88	69	2	190	93
87	70	3	194	90

CATAWBA -WORST HEAT TRANSFER- P/ L

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
1	2.6	96.60	2.63	93.97	19	91.50	91.50	0.12	90	170	369
4	5.1	99.67	3.85	95.82	19	93.97	91.50	0.27	90	170	369
6	10.2	114.34	15.52	98.81	19	95.82	91.50	0.77	90	170	185
11	15.4	112.53	14.37	98.49	19	98.49	91.50	1.24	90	170	185
16	20.5	110.97	13.38	98.19	18	98.19	91.50	1.68	90	170	185
21	25.6	109.90	11.34	98.56	19	98.19	91.50	2.12	93	186	185
27	30.7	108.44	10.36	98.32	19	98.32	91.50	2.53	93	186	185
32	35.9	107.73	9.88	98.18	15	98.18	91.50	2.93	93	186	185
37	41.0	107.73	9.88	98.13	14	98.13	91.50	3.33	93	186	185
42	46.1	106.95	9.36	98.06	13	98.06	91.50	3.72	93	186	185
47	51.2	106.95	9.97	97.94	12	97.94	91.50	4.09	92	184	185
52	56.4	106.02	9.35	97.81	11	97.81	91.50	4.45	92	184	185
57	61.5	106.02	9.35	97.71	10	97.71	91.50	4.81	92	184	185
62	66.6	105.34	8.09	97.60	9	97.60	91.50	5.16	92	184	185
68	71.7	105.34	8.89	97.52	8	97.52	91.50	5.51	92	184	185
73	76.8	105.34	7.67	97.66	19	97.52	91.50	5.86	94	189	185
78	82.0	105.34	7.67	97.66	19	97.66	91.50	6.21	94	189	185
83	87.1	104.62	7.18	97.59	18	97.59	91.50	6.55	94	189	185
88	92.2	104.62	7.18	97.55	17	97.55	91.50	6.88	94	189	185
93	97.3	104.62	6.67	97.95	19	97.55	93.97	7.23	95	198	185
98	102.5	107.09	8.38	98.70	19	97.95	95.82	7.61	95	198	185
103	107.6	108.16	9.13	99.03	19	98.70	97.52-	8.00	95	198	185
109	112.7	109.85	10.30	99.55	19	99.03	97.52	8.43	95	198	185
114	117.8	109.85	10.30	99.55	19	99.55	97.52	8.85	95	198	185
119	123.0	109.85	17.19	97.91	15	97.91	97.52	9.38	85	197	185
124	128.1	109.85	17.19	97.40	1	97.40	97.40	9.90	85	197	185
129	133.2	109.73	17.11	97.16	1	97.16	97.16	10.42	85	197	185
134	138.3	109.49	16.94	96.93	1	96.93	96.93	10.93	85	197	185
139	143.5	109.26	16.78	96.70	1	96.70	96.70	11.45	85	197	185
144	148.6	109.04	16.04	96.52	1	96.52	96.52	11.88	81	142	185
150	153.7	108.85	15.93	96.34	1	96.34	96.34	12.31	81	142	185
155	158.8	108.67	15.83	96.16	1	96.16	96.16	12.73	81	142	185
160	163.9	108.50	15.73	96.00	1	96.00	96.00	13.15	81	142	185
165	169.1	108.33	14.05	95.91	1	95.91	95.91	13.58	86	166	185
170	174.2	107.07	13.26	95.80	1	95.80	95.80	13.98	86	166	185
175	179.3	106.97	13.19	95.70	1	95.70	95.70	14.39	86	166	185
180	184.4	106.86	13.13	95.61	1	95.61	95.61	14.79	86	166	185
185	189.6	106.77	13.06	95.51	1	95.51	95.51	15.19	86	166	185
191	194.7	106.67	20.25	95.06	1	95.06	95.06	15.72	73	154	185
196	199.8	106.22	19.98	94.61	1	94.61	94.61	16.24	73	154	185
201	204.9	102.04	17.47	94.11	1	94.11	94.11	16.69	73	154	185
206	210.1	101.54	17.17	93.63	1	93.63	93.63	17.13	73	154	185
211	215.2	101.05	16.87	93.15	1	93.15	93.15	17.56	73	154	185
216	220.3	100.58	11.69	92.94	1	92.94	92.94	17.96	82	166	185
221	225.4	100.37	11.55	92.73	1	92.73	92.73	18.36	82	166	185
226	230.5	100.16	11.42	92.53	1	92.53	92.53	18.76	82	166	185
232	235.7	99.96	11.30	92.34	1	92.34	92.34	19.16	82	166	185
237	240.8	99.77	8.57	92.28	1	92.28	92.28	19.51	86	167	185
242	245.9	99.71	8.53	92.23	1	92.23	92.23	19.86	86	165	185
247	251.0	99.65	8.50	92.17	1	92.17	92.17	20.21	86	163	185

Figure 7

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CATAWBA -WORST HEAT TRANSFER- PA

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
252	256.2	99.60	8.46	92.12	1	92.12	92.12	20.55	86	163	185
257	261.3	99.55	8.43	92.07	1	92.07	92.07	20.90	86	163	185
262	266.4	99.50	10.43	91.92	1	91.92	91.92	21.30	84	187	185
267	271.5	99.35	10.33	91.78	1	91.78	91.78	21.70	84	187	185
273	276.7	99.20	10.23	91.64	1	91.64	91.64	22.10	84	187	185
278	281.8	99.06	10.13	91.50	1	91.50	91.50	22.50	84	187	185
283	286.9	98.93	10.04	91.37	1	91.37	91.37	22.89	84	187	185
288	292.0	98.80	11.87	91.15	1	91.15	91.15	23.25	80	167	185
293	297.2	98.57	11.73	90.93	1	90.93	90.93	23.61	80	167	185
298	302.3	98.36	11.59	90.72	1	90.72	90.72	23.96	80	167	185
303	307.4	97.42	11.00	90.51	1	90.51	90.51	24.30	80	167	185
308	312.5	97.21	11.19	90.29	1	90.29	90.29	24.59	77	135	185
314	317.6	96.98	11.06	90.07	1	90.07	90.07	24.87	77	135	185
319	322.8	96.76	10.94	89.85	1	89.85	89.85	25.15	77	135	185
324	327.9	96.55	10.82	89.65	1	89.65	89.65	25.43	77	135	185
329	333.0	96.35	10.71	89.45	1	89.45	89.45	25.71	77	135	185
334	338.1	96.14	9.95	89.29	1	89.29	89.29	25.96	78	133	185
339	343.3	95.98	9.86	89.13	1	89.13	89.13	26.21	78	133	185
344	348.4	95.82	9.77	88.97	1	88.97	88.97	26.45	78	133	185
349	353.5	95.67	9.69	88.82	1	88.82	88.82	26.70	78	133	185
355	358.6	95.52	9.61	88.68	1	88.68	88.68	26.94	78	133	185
360	363.8	95.38	5.71	89.67	19	88.68	88.68	27.17	86	157	185
365	368.9	95.38	5.71	89.67	19	89.67	88.68	27.39	86	157	185
370	374.0	95.38	5.71	89.67	18	89.67	88.68	27.62	86	157	185
375	379.1	95.38	5.71	89.67	19	89.67	88.68	27.84	86	157	185
380	384.2	95.38	9.43	88.92	16	88.92	88.68	28.12	80	159	185
385	389.4	95.38	9.43	88.60	1	88.60	88.60	28.39	80	159	185
390	394.5	95.30	9.38	88.47	1	88.47	88.47	28.66	80	159	185
395	399.6	95.17	9.30	88.34	1	88.34	88.34	28.94	80	159	185
401	404.7	94.40	8.83	88.20	1	88.20	88.20	29.20	80	159	185
406	409.9	94.26	9.37	88.03	1	88.03	88.03	29.48	77	131	185
411	415.0	94.10	9.28	87.87	1	87.87	87.87	29.76	77	131	185
416	420.1	93.94	9.19	87.72	1	87.72	87.72	30.03	77	131	185
421	425.2	93.78	9.11	87.57	1	87.57	87.57	30.30	77	131	185
426	430.4	93.63	9.03	87.42	1	87.42	87.42	30.58	77	131	185
431	435.5	93.48	8.14	87.31	1	87.31	87.31	30.86	80	155	185
436	440.6	93.38	8.08	87.21	1	87.21	87.21	31.14	80	155	185
442	445.7	93.28	8.02	87.11	1	87.11	87.11	31.42	80	155	185
447	450.9	93.18	7.96	87.02	1	87.02	87.02	31.70	80	155	185
452	456.0	93.08	7.90	86.93	1	86.93	86.93	31.98	80	155	185
457	461.1	92.99	2.99	90.00	19	86.93	86.93	32.20	88	153	185
462	466.2	92.99	2.99	90.00	19	90.00	86.93	32.41	88	153	185
467	471.3	92.99	2.99	90.00	18	90.00	86.93	32.63	88	153	185
472	476.5	92.99	2.99	90.00	19	90.00	86.93	32.84	88	153	185
477	481.6	92.99	5.30	89.54	16	89.54	86.93	33.07	84	149	185
483	486.7	92.99	5.30	89.23	15	89.23	86.93	33.29	84	149	185
488	491.8	92.99	5.30	89.01	14	89.01	86.93	33.51	84	149	185
493	497.0	92.99	5.30	88.85	13	88.85	86.93	33.73	84	149	185
498	502.1	92.99	5.30	88.72	12	88.72	86.93	33.96	84	149	185
503	507.2	92.48	4.77	88.62	11	88.62	86.93	34.19	85	170	185

Figure 7

CATAWBA -WORST HEAT TRANSFER- PA

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
508	512.3	92.48	4.77	88.53	10	88.53	86.93	34.42	85	170	185
513	517.5	92.48	4.77	88.47	9	88.47	86.93	34.64	85	170	185
518	522.6	92.48	4.77	88.41	8	88.41	86.93	34.87	85	170	185
524	527.7	92.48	4.77	88.36	7	88.36	86.93	35.10	85	170	185
529	532.8	92.48	6.77	88.18	6	88.18	86.93	35.31	81	149	185
534	537.9	92.48	6.77	88.03	5	88.03	86.93	35.52	81	149	185
539	543.1	92.48	6.77	87.89	4	87.89	86.93	35.73	81	149	185
544	548.2	92.48	6.77	87.77	3	87.77	86.93	35.94	81	149	185
549	553.3	92.48	5.74	87.71	2	87.71	86.93	36.11	82	133	185
554	558.4	92.48	5.74	87.67	1	87.67	87.67	36.28	82	133	185
559	563.6	93.22	6.15	87.64	1	87.64	87.64	36.45	82	133	185
565	568.7	93.19	6.13	87.61	1	87.61	87.61	36.63	82	133	185
570	573.8	93.16	6.12	87.58	1	87.58	87.58	36.81	82	133	185
575	578.9	93.13	5.60	87.58	1	87.58	87.58	37.02	84	159	185
580	584.1	93.13	5.60	87.57	1	87.57	87.57	37.23	84	159	185
585	589.2	93.12	5.60	87.57	1	87.57	87.57	37.44	84	159	185
590	594.3	93.12	5.59	87.57	1	87.57	87.57	37.65	84	159	185
595	599.4	93.12	5.59	87.57	1	87.57	87.57	37.87	84	159	185
600	604.6	92.74	4.84	87.91	19	87.57	87.57	38.07	85	164	185
606	609.7	92.74	4.84	87.91	19	87.91	87.57	38.27	85	164	185
611	614.8	92.74	4.84	87.91	18	87.91	87.57	38.48	85	164	185
616	619.9	92.74	4.84	87.91	19	87.91	87.57	38.68	85	164	185
621	625.0	92.74	5.36	87.80	16	87.80	87.57	38.86	84	159	185
626	630.2	92.74	5.36	87.73	15	87.73	87.57	39.05	84	159	185
631	635.3	92.74	5.36	87.68	14	87.68	87.57	39.23	84	159	185
636	640.4	92.74	5.36	87.64	13	87.64	87.57	39.41	84	159	185
641	645.5	92.74	5.36	87.61	12	87.61	87.57	39.59	84	159	185
647	650.7	92.74	3.76	88.98	19	87.61	87.57	39.81	87	178	185
652	655.8	92.74	3.76	88.98	19	88.98	87.57	40.02	87	178	185
657	660.9	92.74	3.76	88.98	18	88.98	87.57	40.23	87	178	185
662	666.0	92.74	3.76	88.98	19	88.98	87.57	40.44	87	178	185
667	671.2	92.74	3.76	88.98	19	88.98	87.57	40.65	87	178	185
672	676.3	92.74	-0.17	92.92	19	88.98	87.57	40.65	93	190	185
677	681.4	92.74	-0.17	92.92	19	92.92	87.57	40.65	93	190	185
682	686.5	92.74	-0.17	92.92	18	92.92	87.57	40.65	93	190	185
688	691.6	92.74	-0.17	92.92	19	92.92	87.57	40.65	93	190	185
693	696.8	92.74	1.88	92.51	16	92.51	87.57	40.86	90	194	185
698	701.9	92.74	1.88	92.23	15	92.23	87.61	41.08	90	194	185
703	707.0	92.79	1.92	92.04	14	92.04	87.61	41.30	90	194	185
708	712.1	92.79	1.92	91.89	13	91.89	87.61	41.51	90	194	185
713	717.3	92.79	1.92	91.78	12	91.78	87.61	41.73	90	194	185
718	722.4	92.79	1.92	91.69	11	91.69	87.61	41.95	90	194	185

Figure 7

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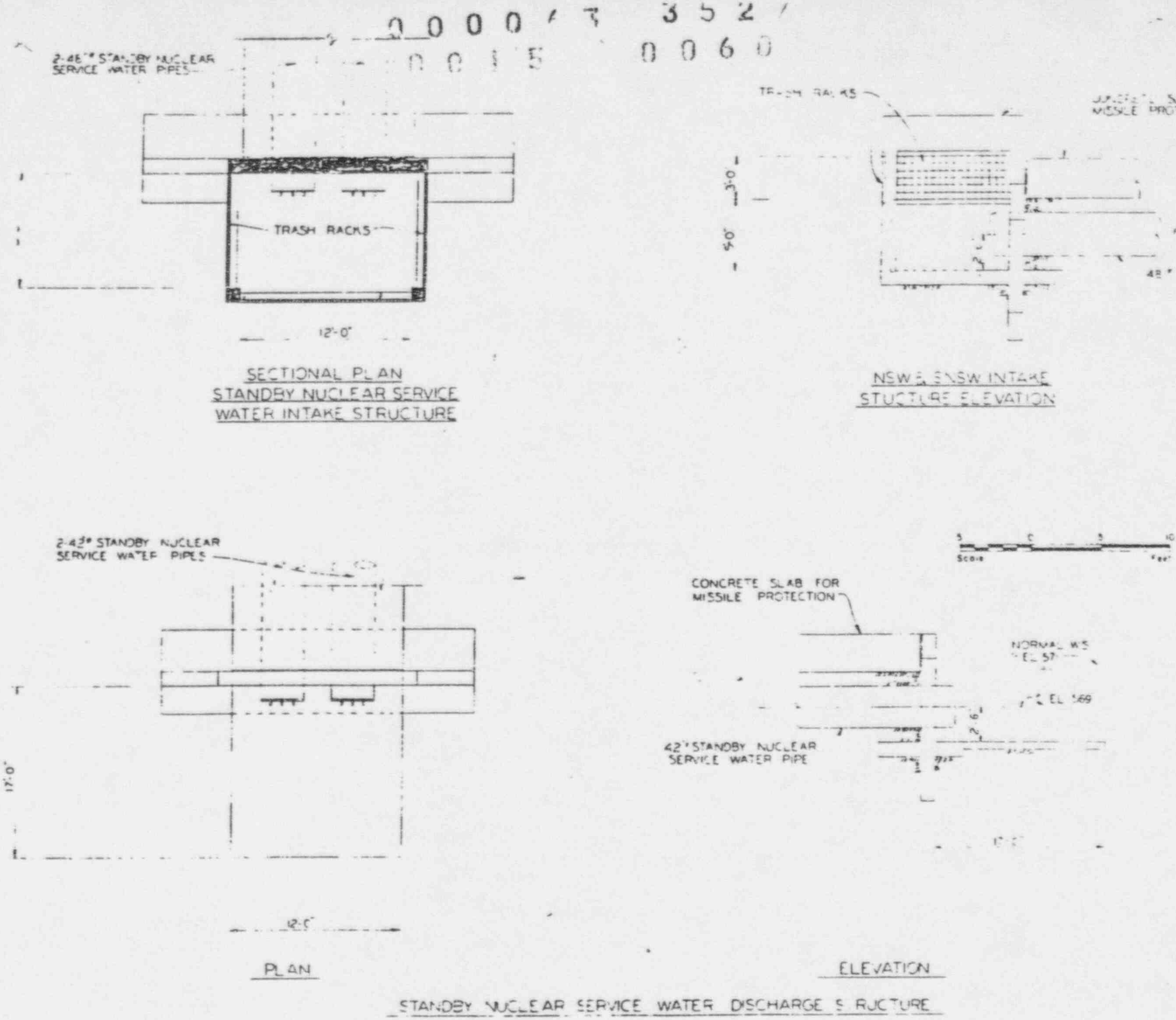

Figure 8. Catawba SNSWP Intake and Discharge Structures

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LIST OF ATTACHMENTS

Attachment A - Area-Volume Information

This attachment includes information regarding the area-volume values for the Catawba SNSWP simulation. The area-volume values are from CNC 1150.04-00-0009 and the seepage values are from CNC-1150.01-00-0004

Item	*Page Number*
Area-Volume values for elevation 542 - 571.3 ft msl	A3-A4
Area-Volume values for elevation 570 - 590 ft msl	A5
SNSWP Area Curve	A6
SNSWP Volume Curve	A7
Model Run with Initial Elevation of 571 ft msl	A8-A12
Seepage information	A13-A14

The initial volume shown in this run (447.5 ac-ft) at elevation 571 ft msl is used with the total 6-day losses (use 13.5 ac-ft) determined from:

- Evaporation losses of 11.7 acre-ft (see page A10)
- Seepage losses of 0.36 acre-ft (see page A14)
- System losses of 1.31 acre-ft (see Attachment B)

to determine the area-volume values used for the top two layers as shown below:

Elevation (ft msl)	*Area (ac)*	*Volume (ac-ft)*
571	39.0	447.5
570	35.95	410.0

447.5 - 13.5 = 434 ac-ft

$$\frac{447.5 - 434}{447.5 - 410} = 0.36$$

$$571 - 0.36*(571 - 570) = 570.64 \text{ ft msl}$$

$$39.0 - 0.36*(39.0 - 35.95) = 37.90$$

The initial values at the start of the simulation are assumed to be:

Elevation (ft msl)	*Area (ac)*	*Volume (ac-ft)*
570.64	37.90	434.0

The volume of the second layer is determined as follows:

$$434.0 - 37.9 = 396.1$$

The volumes of the top two layers and the volumes for elevations 569-540 (from A3-A4) are used in the input sets for the two model simulations presented in Figures 7 and 8.

SHEET 10

CATAWBA NUCL. STATION, UNITS 1 & 2 FILE NO.
REV. 1 CNC 1150.04-00-0009

STANDBY NUCL. SERV. WATER POND, AREA/VOLUME

BY: WBB 12/27/94 CK. SR Christopher 12/27/94 For Info Only

ELEV	AREA (FT²)	AREA (ACRES)	AVG AREA (AC)	(FT)	(AC-FT)	VOL. (AC-FT)
571.3	1,683,719	38.65				
			37.30	1.3	48.49	458.46
570	1,565,889	35.95				
			35.11	1	35.11	409.97
569	1,492,954	34.27				
			33.46	1	33.46	374.86
568	1,422,407	32.65				
			30.975	2	61.95	341.40
566	1,276,287	29.30				
			28.405	1	28.405	279.45
565	1,198,531	27.51				
			26.695	1	26.695	251.04
564	1,127,243	25.88				
			24.355	2	48.71	224.35
562	994,363	22.83				
			21.335	2	42.67	175.64
560	864,281	19.84				
			18.355	2	36.71	132.97
558	734,793	16.87				
			15.32	2	30.64	92.26
556	599,635	13.77				
			13.02	1	13.02	65.62
555	534,692	12.27				
			11.47	1	11.47	52.60
554	464,736	10.67				
			9.14	2	18.28	41.13
552	331,458	7.61				
			6.545	2	13.09	22.35
550	238,621	5.48				
			4.18	2	8.36	9.76
548	125,510	2.88				2.19

SEE NEXT PAGE FOR CONTINUATION.

~~NOTE THAT THIS PAGE IS FOR COMPARISON PURPOSES ONLY~~ WBB

~~SEE ATTACHMENT 3 FOR VOLUMES.~~ BY: WBB 1/3/95

REV 2 DELETE SENTENCES MARKED OUT. CK:

CATAWBA NUCL. STATION, UNITS 1 & 2 FILE NO.
REV. 1 CNC 1150.04-00-0009

STANDBY NUCL. SERV. WATER POND, AREA/VOLUME

BY: WBB 12/27/94 CK SRC 12/27/94

For Info Only

ELEV.	AREA (FT^2)	AREA (ACRES)	AVG AREA (AC)	DEPTH (FT)	VOL. (AC·FT)	CUM VOL. (AC·FT)
546 B	19,703	0.45				
			0.255	1	0.255	0.255
545 B	2,765	0.06				
546 A	34,007	0.78				
			0.595	1	0.595	1.145
545 A	17,985	0.41				
			0.31	1	0.31	0.55
544	9,343	0.21				
			0.12	2	0.24	0.24
542	1,368	0.03				

~~NOTE THAT THIS PAGE IS FOR COMPARISON~~

~~PURPOSES ONLY. SEE ATTACHMENT 3 FOR VOLUMES~~

REV 2 DELETE SENTENCES MARKED OUT

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9.4
Standby Nuclear Service Water Pond, El 570 through 590 Areas and Volumes

EL	Area (Acres)	Avg. Area (Acres)	Depth (FT)	Vol. (Ac-Ft)	Cum Vol. (Ac-Ft)
570	35.95				409.97
		37.48	1	37.48	
571	39				447.45
		39.8	1	39.8	
572	40.6				487.25
		45.8	2	91.6	
574	51				578.85
		54	2	108	
576	57				686.85
		60	2	120	
578	63				806.85
		66	2	132	
580	69				938.85
		72	2	144	
582	75				1,082.85
		78	2	156	
584	81				1,238.85
		84	2	168	
586	87				1,406.85
		90	2	180	
588	93				1,586.85
		96	2	192	
590	99				1,778.85

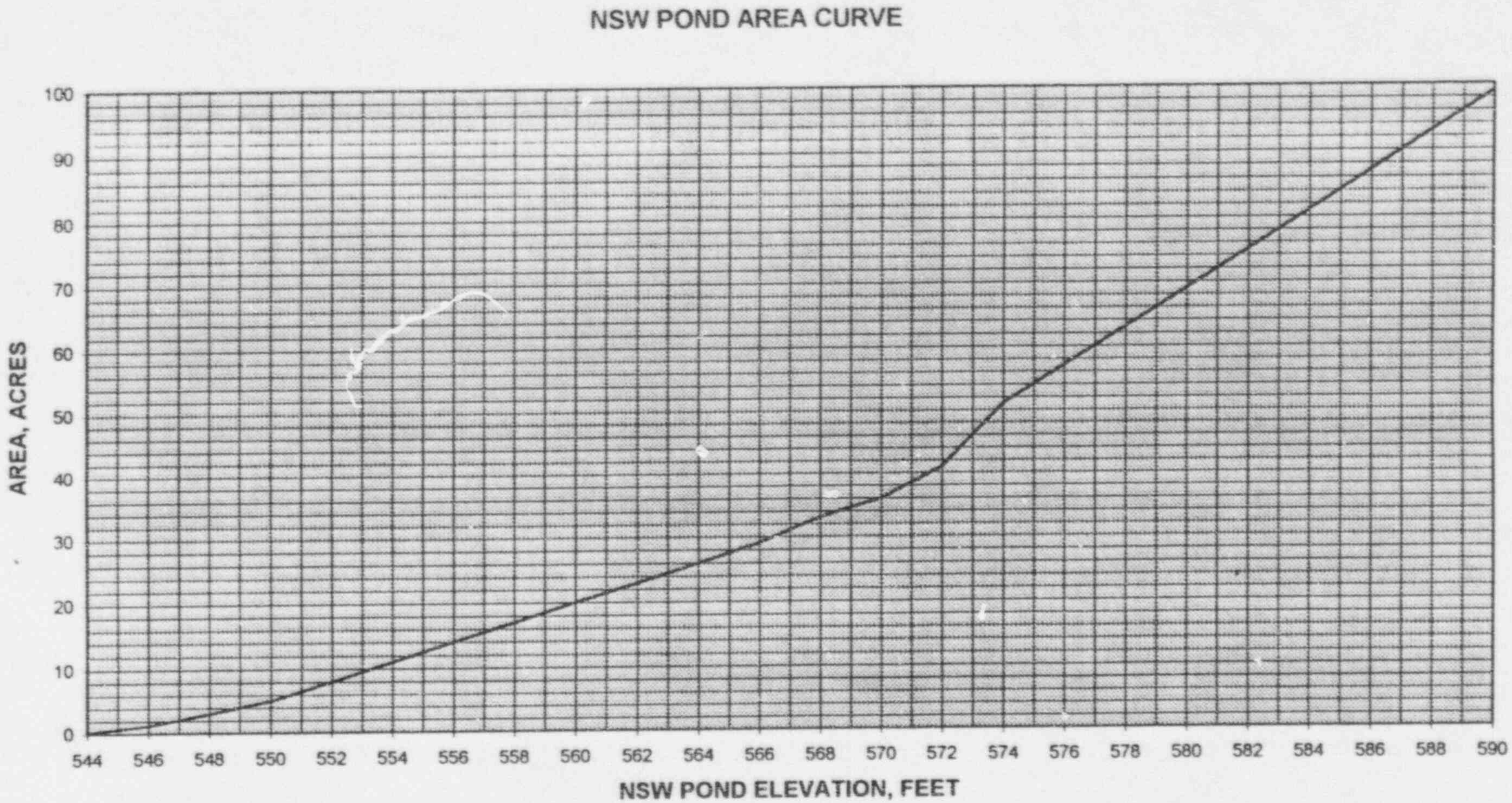
9.5
Revised SNSW POND Area and Volume curves have been generated based on the December 1994 survey (Revision 1) and the information contained in Section 9.4. These revised curves are provided on Sheets 17 and 18.

10.0 Conclusions

The current SNSW POND areas (at the various elevations) and cumulative volumes (below specified Pond surface elevations) are as provided on Sheets 10, 11 and 16.

The current SNSW POND area and volume curves are provided on Sheets 17 and 18.

A6



Catawba Nuclear Station
CNC-1150.04-00-0009
Area and volume of Standby Nuclear Service Water Pond
Sheet 17 Rev. 3
By SR Christopher 4/10/95 Checked: WMMiller

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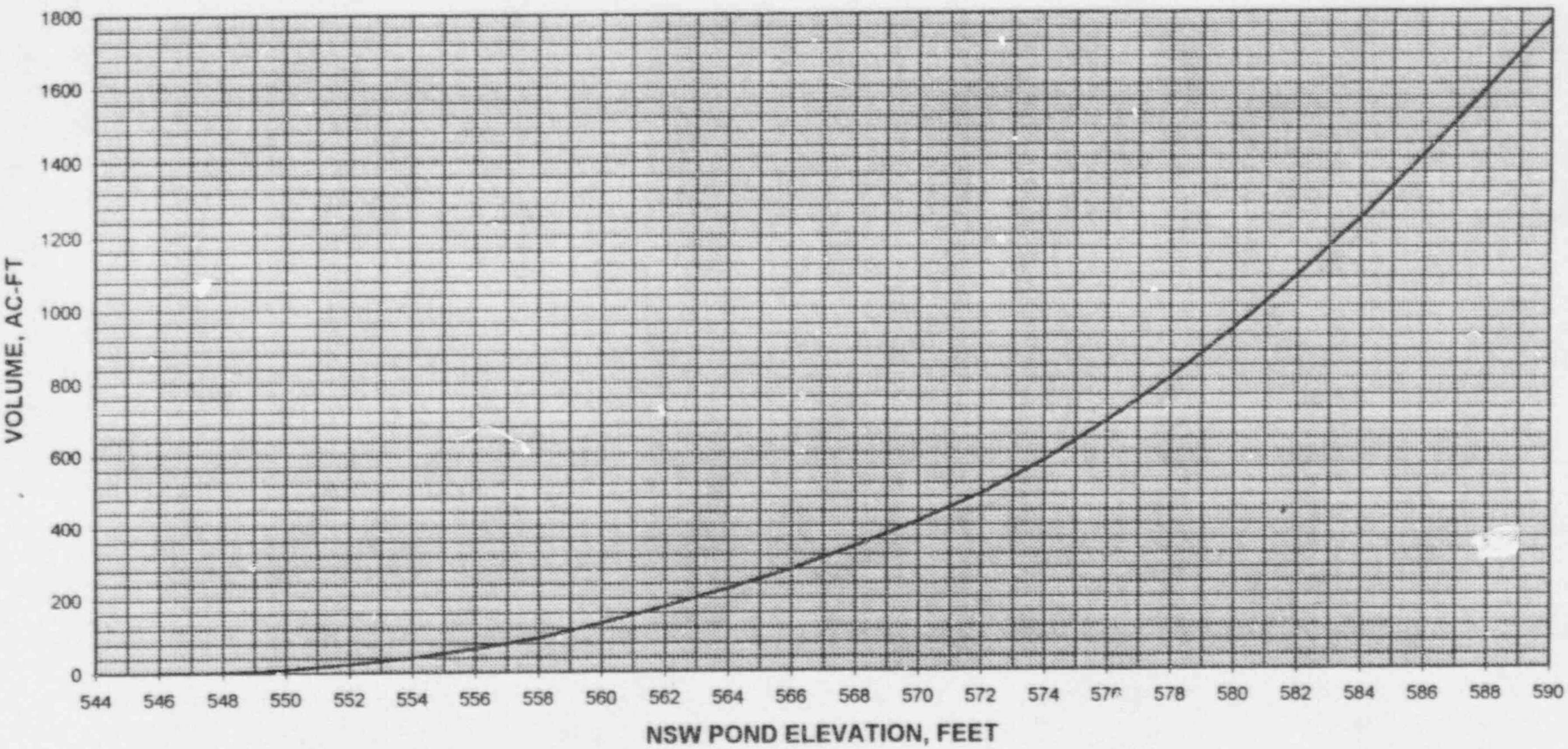
NSW POND VOLUME CURVE



A7

Catawba Nuclear Station
CNC-1150.04-00-0009
Area and Volume of Standby Nuclear Service Water Pond
Sheet 18 Rev 3
By SR Christopher 4/10/95 Checked WM Miller

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DATASET: CNOPMETE.DATA

```
  CATAWBA    PLANT
       -WORST HEAT TRANSFER-      TITLE
  720         T1:   # OF HOURS INPUT
   20         L1:   # OF UNIT VOLUME LAYERS
   20         K2:   OUTPUT CHECK SPACING
C
   31         S1:   # OF VERTICAL STAGES (FT)
C
C        S(I,1):    VOLUME IN POND AT EACH STAGE (ACFT)
C
0 0 0 0 0 1 1 2 6 10 16 23 32 41
53 66 79 92 113 133 154 176 200 224 251 279 310 341
374 408.5 447.5
C
C        S(I,2):    INITIAL TEMPERATURE AT EACH STAGE (F)
C
   91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
   91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
   91.5 91.5 91.5 91.5 91.5 91.5 91.5 91.5
   91.5 91.5 91.5 91.5 91.5 91.5 91.5
C
C        LOOPING VALUES AND PLANT FLOWS FOR T(I,3) (1000*CU.FT/HR)
C
    4  369.0
  720  184.5
C
C        T(I,1):    INPUT HEAT (MBTU/HR)
C
117.4 171.7 182.9 188.2 147.9 262.9 258.5 253.9
249.9 245.9 242.1 238.2 234.2 231.4 227.8 224.2
222.0 219.1 216.0 214.1 211.8 211.8 211.8 211.8
195.0 195.0 195.0 195.0 195.0 186.8 177.9 167.2
159.3 159.3 151.0 151.0 142.0 142.0 142.0 142.0
142.0 142.0 142.0 128.5 128.5 128.5  85.5  77.1
 69.8  63.9  59.6  59.6
C
C A(J) P(J) W(J) Y(J) E(J)
C
81 72 2 170 90
85 71 2 186 93
89 70 2 184 92
89 72 2 189 94
91 71 2 198 95
83 72 5 197 85
79 71 3 142 81
83 71 3 166 86
72 61 5 154 73
73 58 3 166 82
75 60 2 163 86
77 62 4 187 84
78 63 4 167 80
72 66 3 135 77
73 69 3 133 78
77 70 2 157 86
77 68 4 159 80
```

Attachment A - Model Run with Initial Elevation of 571 ft msl

DATASET: CNOPMETE.DATA

72	55	2	131	77
74	60	3	155	80
77	63	1	153	88
77	65	2	149	84
78	68	3	170	85
76	69	3	149	81
78	71	2	133	82
80	70	3	159	84
80	71	3	164	85
83	72	3	159	84
86	69	3	178	87
88	69	2	190	93
87	70	3	194	90

CATAWBA -WORST HEAT TRANSFER- PA

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
1	2.6	96.60	2.69	93.91	19	91.50	91.50	0.13	90	170	369
4	5.3	99.67	3.94	95.74	19	93.91	91.50	0.29	90	170	369
6	10.6	114.34	15.78	98.56	19	95.74	91.50	0.82	90	170	185
12	15.8	112.19	14.39	98.18	19	98.18	91.50	1.30	90	170	185
17	21.1	110.78	13.48	97.89	18	97.89	91.50	1.77	90	170	185
22	26.4	109.90	11.51	98.38	19	97.89	91.50	2.23	93	186	185
27	31.7	108.44	10.52	98.15	19	98.15	91.50	2.66	93	186	185
33	37.0	107.73	10.03	98.00	18	98.00	91.50	3.08	93	186	185
38	42.3	107.73	10.03	97.92	17	97.92	91.50	3.51	93	186	185
43	47.5	106.95	9.51	97.85	13	97.85	91.50	3.92	93	186	185
49	52.8	106.95	10.13	97.74	12	97.74	91.50	4.31	92	184	185
54	58.1	106.02	9.50	97.61	11	97.61	91.50	4.69	92	184	185
59	63.4	106.02	9.50	97.52	10	97.52	91.50	5.07	92	184	185
64	68.7	105.34	9.03	97.41	9	97.41	91.50	5.44	92	184	185
70	74.0	105.34	7.79	97.55	19	97.41	91.50	5.81	94	189	185
75	79.2	105.34	7.79	97.55	19	97.55	91.50	6.18	94	189	185
80	84.5	104.62	7.29	97.47	18	97.47	91.50	6.53	94	189	185
86	89.8	104.62	7.29	[illegible]	17	97.43	91.50	6.89	94	189	185
91	95.1	104.62	7.29	[illegible]	4	97.41	91.50	7.25	94	189	185
96	100.4	104.62	6.77	[illegible]	19	97.41	93.91	7.61	95	198	185
101	105.7	106.25	7.92	98.33	19	97.85	95.74	8.00	95	198	185
107	110.9	108.07	9.20	98.87	19	98.33	97.41	8.42	95	198	185
112	116.2	109.75	10.38	99.37	19	98.87	97.41	8.86	95	198	185
117	121.5	109.75	17.38	97.40	1	97.40	97.40	9.41	85	197	185
123	126.8	109.73	17.37	97.15	1	97.15	97.15	9.96	85	197	185
128	132.1	109.48	17.19	96.90	1	96.90	96.90	10.50	85	197	185
133	137.3	109.24	17.02	96.67	1	96.67	96.67	11.04	85	197	185
138	142.6	109.00	16.86	96.44	1	96.44	96.44	11.57	85	197	185
144	147.9	108.78	16.18	96.25	1	96.25	96.25	12.02	81	142	185
149	153.2	108.59	16.06	96.07	1	96.07	96.07	12.47	81	142	185
154	158.5	108.40	15.96	95.88	1	95.88	95.88	12.91	81	142	185
159	163.8	108.22	15.85	95.71	1	95.71	95.71	13.35	81	142	185
165	169.0	108.04	14.10	95.62	1	95.62	95.62	13.79	86	166	185
170	174.3	106.78	13.29	95.51	1	95.51	95.51	14.21	86	166	185
175	179.6	106.68	13.22	95.41	1	95.41	95.41	14.63	86	166	185
181	184.9	106.57	13.16	95.31	1	95.31	95.31	15.05	86	166	185
186	190.2	106.47	13.09	95.21	1	95.21	95.21	15.47	86	166	185
191	195.5	106.38	20.43	94.75	1	94.75	94.75	16.02	73	154	185
196	200.7	105.91	20.14	94.30	1	94.30	94.30	16.56	73	154	185
202	206.0	101.73	17.58	93.79	1	93.79	93.79	17.03	73	154	185
207	211.3	101.22	17.27	93.30	1	93.30	93.30	17.48	73	154	185
212	216.6	100.73	11.98	93.07	1	93.07	93.07	17.91	82	166	185
218	221.9	100.50	11.83	92.85	1	92.85	92.85	18.34	82	166	185
223	227.2	100.28	11.69	92.64	1	92.64	92.64	18.76	82	166	185
228	232.4	100.07	11.56	92.43	1	92.43	92.43	19.18	82	166	185
233	237.7	99.86	11.42	92.23	1	92.23	92.23	19.59	82	166	185
239	243.0	99.66	8.65	92.17	1	92.17	92.17	19.96	86	163	185
244	248.3	99.60	8.61	92.11	1	92.11	92.11	20.33	86	163	185
249	253.6	99.54	8.57	92.06	1	92.06	92.06	20.70	86	163	185
255	258.9	99.48	8.53	92.00	1	92.00	92.00	21.06	86	163	185

6th day

End of 6th day = 144 hours

Interpolation to find evaporation value at end of 6th day

1) $\frac{144 - 142.6}{147.9 - 142.6} = 0.264$

2) $11.57 + 0.264(12.02 - 11.57)$

3) 11.69 ac-ft

A10

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFH
260	264.1	99.43	10.54	91.85	1	91.85	91.85	21.49	84	187	185
265	269.4	99.27	10.44	91.70	1	91.70	91.70	21.91	84	187	185
270	274.7	99.12	10.33	91.55	1	91.55	91.55	22.33	84	187	185
276	280.0	98.98	10.23	91.41	1	91.41	91.41	22.74	84	187	185
281	285.3	98.84	10.14	91.27	1	91.27	91.27	23.16	84	187	185
286	290.5	98.70	12.00	91.05	1	91.05	91.05	23.54	80	167	185
292	295.8	98.47	11.86	90.82	1	90.82	90.82	23.91	80	167	185
297	301.1	98.25	11.71	90.61	1	90.61	90.61	24.28	80	167	185
302	306.4	97.31	11.11	90.39	1	90.39	90.39	24.64	80	167	185
307	311.7	97.09	10.97	90.18	1	90.18	90.18	24.99	80	167	185
313	317.0	96.87	11.21	89.95	1	89.95	89.95	25.29	77	135	185
318	322.2	96.65	11.08	89.73	1	89.73	89.73	25.58	77	135	185
323	327.5	96.43	10.96	89.52	1	89.52	89.52	25.88	77	135	185
329	332.8	96.21	10.84	89.31	1	89.31	89.31	26.16	77	135	185
334	338.1	96.01	10.06	89.14	1	89.14	89.14	26.43	78	133	185
339	343.4	95.84	9.96	88.98	1	88.98	88.98	26.69	78	133	185
344	348.7	95.68	9.87	88.82	1	88.82	88.82	26.95	78	133	185
350	353.9	95.52	9.78	88.67	1	88.67	88.67	27.20	78	133	185
355	359.2	95.36	9.70	88.52	1	88.52	88.52	27.46	78	133	185
360	364.5	95.21	5.70	89.51	19	88.52	88.52	27.69	86	157	185
366	369.8	95.21	5.70	89.51	19	89.51	88.52	27.93	86	157	185
371	375.1	95.21	5.70	89.51	18	89.51	88.52	28.16	86	157	185
376	380.4	95.21	5.70	89.51	19	89.51	88.52	28.40	86	157	185
381	385.6	95.21	9.49	88.75	16	88.75	88.52	28.69	80	159	185
387	390.9	95.21	9.49	88.44	1	88.44	88.44	28.97	80	159	185
392	396.2	95.13	9.44	88.30	1	88.30	88.30	29.26	80	159	185
397	401.5	95.00	9.35	88.17	1	88.17	88.17	29.54	80	159	185
402	406.8	94.23	8.88	88.02	1	88.02	88.02	29.82	80	159	185
408	412.0	94.09	9.45	87.86	1	87.86	87.86	30.11	77	131	185
413	417.3	93.92	9.36	87.69	1	87.69	87.69	30.40	77	131	185
418	422.6	93.75	9.27	87.53	1	87.53	87.53	30.69	77	131	185
424	427.9	93.59	9.18	87.37	1	87.37	87.37	30.98	77	131	185
429	433.2	93.44	8.26	87.27	1	87.27	87.27	31.28	80	155	185
434	438.5	93.33	8.19	87.16	1	87.16	87.16	31.57	80	155	185
439	443.7	93.22	8.12	87.06	1	87.06	87.06	31.87	80	155	185
445	449.0	93.12	8.06	86.96	1	86.96	86.96	32.17	80	155	185
450	454.3	93.02	8.00	86.86	1	86.86	86.86	32.46	80	155	185
455	459.6	92.92	3.00	89.92	19	86.86	86.86	32.69	88	153	185
461	464.9	92.92	3.00	89.92	19	89.92	86.86	32.91	88	153	185
466	470.2	92.92	3.00	89.92	18	89.92	86.86	33.14	88	153	185
471	475.4	92.92	3.00	89.92	19	89.92	86.86	33.37	88	153	185
476	480.7	92.92	5.35	89.45	16	89.45	86.86	33.60	84	149	185
482	486.0	92.92	5.35	89.14	15	89.14	86.86	33.84	84	149	185
487	491.3	92.92	5.35	88.91	14	88.91	86.86	34.07	84	149	185
492	496.6	92.92	5.35	88.75	13	88.75	86.86	34.31	84	149	185
498	501.9	92.92	5.35	88.61	12	88.61	86.86	34.54	84	149	185
503	507.1	92.41	4.80	88.51	11	88.51	86.86	34.78	85	170	185
508	512.4	92.41	4.80	88.43	10	88.43	86.86	35.02	85	170	185
513	517.7	92.41	4.80	88.36	9	88.36	86.86	35.27	85	170	185
519	523.0	92.41	4.80	88.30	8	88.30	86.86	35.51	85	170	185

A11

CATAWBA -WORST HEAT TRANSFER- PAG

TIME	REAL TIME	DISC TEMP	HEAT LOSS	COOL DOWN	UN MIX	MIXED TEMP	INTAKE TEMP	EVAP AC-FT	E	K	TEMP TCFM
524	528.3	92.41	6.84	88.11	7	88.11	86.86	35.73	81	149	185
529	533.6	92.41	6.84	87.94	6	87.94	86.86	35.95	81	149	185
535	538.8	92.41	6.84	87.79	5	87.79	86.86	36.17	81	149	185
540	544.1	92.41	6.84	87.66	4	87.66	86.86	36.39	81	149	185
545	549.4	92.41	6.84	87.54	3	87.54	86.86	36.61	81	149	185
550	554.7	92.41	5.81	87.49	2	87.49	86.86	36.78	82	133	185
556	560.0	92.41	5.81	87.45	1	87.45	87.45	36.96	82	133	185
561	565.2	93.00	6.14	87.42	1	87.42	87.42	37.15	82	133	185
566	570.5	92.97	6.13	87.39	1	87.39	87.39	37.33	82	133	185
572	575.8	92.94	6.11	87.36	1	87.36	87.36	37.51	82	133	185
577	581.1	92.91	5.56	87.36	1	87.36	87.36	37.73	84	159	185
582	586.4	92.91	5.56	87.36	1	87.36	87.36	37.96	84	159	185
587	591.7	92.91	5.56	87.36	1	87.36	87.36	38.18	84	159	185
593	596.9	92.91	5.56	87.36	1	87.36	87.36	38.40	84	159	185
598	602.2	92.91	5.02	87.89	19	87.36	87.36	38.62	85	164	185
603	607.5	92.54	4.79	87.82	19	87.82	87.36	38.83	85	164	185
609	612.8	92.54	4.79	87.80	18	87.80	87.36	39.04	85	164	185
614	618.1	92.54	4.79	87.78	17	87.78	87.36	39.25	85	164	185
619	623.4	92.54	4.79	87.78	16	87.78	87.36	39.47	85	164	185
624	628.6	92.54	5.33	87.68	15	87.68	87.36	39.66	84	159	185
630	633.9	92.54	5.33	87.62	14	87.62	87.36	39.85	84	159	185
635	639.2	92.54	5.33	87.56	13	87.56	87.36	40.04	84	159	185
640	644.5	92.54	5.33	87.53	12	87.53	87.36	40.23	84	159	185
645	649.8	92.54	3.68	88.85	19	87.53	87.36	40.45	87	178	185
651	655.1	92.54	3.68	88.85	19	88.85	87.36	40.67	87	178	185
656	660.3	92.54	3.68	88.85	18	88.85	87.36	40.89	87	178	185
661	665.6	92.54	3.68	88.85	19	88.85	87.36	41.11	87	178	185
667	670.9	92.54	3.68	88.85	19	88.85	87.36	41.33	87	178	185
672	676.2	92.54	-0.32	92.86	19	88.85	87.36	41.33	93	190	185
677	681.5	92.54	-0.32	92.86	19	92.86	87.36	41.33	93	190	185
682	686.7	92.54	-0.32	92.86	18	92.86	87.36	41.33	93	190	185
688	692.0	92.54	-0.32	92.86	19	92.86	87.36	41.33	93	190	185
693	697.3	92.54	1.77	92.44	16	92.44	87.36	41.56	90	194	185
698	702.6	92.54	1.77	92.16	15	92.16	87.53	41.78	90	194	185
704	707.9	92.70	1.88	91.97	14	91.97	87.53	42.01	90	194	185
709	713.2	92.70	1.88	91.83	13	91.83	87.53	42.24	90	194	185
714	718.4	92.70	1.88	91.71	12	91.71	87.53	42.47	90	194	185
719	723.7	92.70	1.88	91.62	11	91.62	87.53	42.70	90	194	185

Determine Daily and Total 30 Day Loss to Groundwater Recharge - WORST CASE

WORST CASE: k = 150 ft/yr; In-situ silty sand (saprolite)

End of Day	SNSW Pond El [ft]	Storage Cap [ac ft]	GWT Elev [ft]	H [ft]	q [cuft/d/ft]	Perimeter [ft]	Day's Loss [cuft]	New Pond Elev [ft]
0	571.000	497.27	571.00					571.000
1	571.000	497.25	570.95	0.05	0.061	12,356	751	571.000
2	570.999	497.22	570.90	0.10	0.121	12,356	1,496	570.999
3	570.997	497.17	570.85	0.15	0.181	12,356	2,234	570.997
4	570.996	497.10	570.80	0.19	0.240	12,355	2,966	570.996
5	570.994	497.01	570.75	0.24	0.299	12,354	3,691	570.994
6	570.991	496.91	570.70	0.29	0.357	12,354	4,409	570.991
7	570.988	496.79	570.65	0.34	0.415	12,353	5,121	570.988
8	570.985	496.66	570.61	0.38	0.472	12,351	5,827	570.985
9	570.981	496.51	570.56	0.43	0.528	12,350	6,527	570.981
10	570.977	496.34	570.51	0.47	0.585	12,348	7,220	570.977
11	570.972	496.16	570.46	0.52	0.640	12,347	7,906	570.972
12	570.967	495.97	570.41	0.56	0.696	12,345	8,587	570.967
13	570.962	495.75	570.36	0.61	0.750	12,343	9,261	570.962
14	570.956	495.53	570.31	0.65	0.805	12,341	9,929	570.956
15	570.950	495.28	570.26	0.70	0.858	12,338	10,590	570.950
16	570.944	495.02	570.21	0.74	0.912	12,336	11,246	570.944
17	570.937	494.75	570.16	0.78	0.964	12,333	11,895	570.937
18	570.930	494.46	570.11	0.82	1.017	12,331	12,539	570.930
19	570.922	494.16	570.06	0.87	1.069	12,328	13,176	570.922
20	570.914	493.84	570.01	0.91	1.120	12,325	13,807	570.914
21	570.906	493.51	569.96	0.95	1.171	12,321	14,433	570.906
22	570.898	493.17	569.92	0.99	1.222	12,318	15,052	570.898
23	570.889	492.81	569.87	1.03	1.272	12,315	15,665	570.889
24	570.879	492.43	569.82	1.07	1.322	12,311	16,273	570.879
25	570.870	492.05	569.77	1.11	1.371	12,307	16,874	570.870
26	570.860	491.65	569.72	1.15	1.420	12,303	17,470	570.860
27	570.849	491.23	569.67	1.19	1.468	12,299	18,060	570.849
28	570.839	490.80	569.62	1.23	1.516	12,295	18,645	570.839
29	570.827	490.36	569.57	1.27	1.564	12,291	19,224	570.827
30	570.816	489.91	569.52	1.31	1.611	12,286	19,797	570.816

Total 6-day loss = 15,547 ft³

For Info Only

WORST CASE Total Drop in SNSW Pond Surface Elev = 0.184 ft

Cumulative Loss from the SNSW Pond = 320,670 cu ft
7.36 ac ft

Seepage Losses Through the SNSWP Dam Embankment Over the 30 Day Period:

Since these losses are expected to be negligible, fluctuations in the SNSW Pond surface elevations will be ignored.

For Info Only

Seepage through the embankment is given as:

q = ks [cu ft/day/ft of embankment length]

where: k = permeability
s = directrix = sqrt(H^2 + L^2) - L (see Page 8)
H = Elev Head Difference
L = Graphical horizontal distance from end of blanket drain to intersection of phreatic surface straight line segment with pond surface elevation

Using:	k =	2	ft/yr for the Compacted Silty Sand (Saprolite)
	H =	21	ft (571 - 550)
	L =	168	ft (see Page 8)
Then:	s =	1.31	ft
	q =	0.0072	cu ft/day/ft of embankment length

Assuming an effective embankment lenght = 1500 ft

Total Daily Seepage = 10.75 cu ft

Total 30 Day Seepage through the dam embankment = 322.4 cu ft
0.007 acft

Total Seepage loss at end of 6 days

15,547 ft^3 + 6(10.75) = 15,611.5 ft^3 = 0.36 ac-ft

Attachment B - Heat Loads, System Losses, and Heat Loads

This attachment includes information with regard to calculation inputs for:

This information is taken from CNC-1223.24-00-0041, "Design Basis Heat Load and Flow Demands on SNSWP."

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CONCLUSIONS

The conclusions of this calculation form the inputs to the SNSWP Thermal Analysis Model, CNC-1150.01-00-0001.

The rate at which heat is rejected to the SNSWP is determined on a component by component basis in the body of the calculation. The results are tabulated in Appendix A in a format convenient to be used as inputs to the thermal analysis referenced above.

Two cases should be considered in the SNSWP thermal analysis. The "High Flow" case should consider the flow to be 46,000 gpm for the first four hours of the event and 23,000 gpm thereafter. The "Low Flow" case should consider the flow to be 38,000 gpm for the first four hours of the event and 19,000 gpm thereafter. By evaluating the highest and lowest expected Design Basis Event flowrates, it is assumed that the analysis is valid for the full range of flowrates.

System, and therefore SNSWP, inventory losses total 1.24 E6 gallons. CA makeup accounts for 0.225 E6 gallons over the first 5 hours of the event. The remaining 1.01 E6 gallons is due to fuel pool boil off at a constant rate of 23.4 gpm over the 30 day event.

For Info Only

Rate of Heat Rejection to SNSWP for Design Basis LOCA/Shutdown

For Info Only

Hrs after LOCA	LOCA ND/NS (Btu/hr)	LOCA Auxiliaries (Btu/hr)	Shutdown ND (Btu/hr)	Shutdown Auxiliaries (Btu/hr)	TOTAL heat rejected (Btu/hr)
1	23.615 E6	40.983 E6	2.966E6 (NV)	49.876 E6	117.440 E6
2	77.831	40.983	2.966E6 (NV)	49.876	171.656
3	89.065	40.983	2.966E6 (NV)	49.876	182.890
4	94.360	40.983	2.966E6 (NV)	49.876	188.185
5	96.892	20.680	2.966E6 (NV)	27.380	147.918
6	97.928	20.680	116.899	27.380	262.887
7	97.853	20.680	112.582	27.380	258.495
8	97.243	20.680	108.858	27.380	253.888
9	96.121	20.680	105.702	27.380	249.883
10	94.747	20.680	103.127	27.380	245.934
11	93.305	20.680	100.725	27.380	242.090
12	91.604	20.680	98.543	27.380	238.207
13	89.422	20.680	96.681	27.380	234.163
14	88.364	20.680	94.996	27.380	231.420
15	86.362	20.680	93.364	27.380	227.786
16	84.244	20.680	91.864	27.380	224.168
17	83.397	20.680	90.541	27.380	221.998
18	81.782	20.680	89.225	27.380	219.067
19	79.966	20.680	88.002	27.380	216.028
20	79.100	20.680	86.916	27.380	214.076
21	77.849	20.680	85.899	27.380	211.808
25	75.127	20.680	71.780	27.380	194.967
30	71.061	20.680	67.646	27.380	186.767
40	66.158	20.680	63.645	27.380	177.863
50	60.990	20.680	58.128	27.380	167.178
60	56.987	20.680	54.294	27.380	159.341
80	52.981	20.680	49.985	27.380	151.026
100	48.536	20.680	45.423	27.380	142.019
168 (7 days)	41.247	20.680	39.226	27.380	128.533
200	35.725	4.680	33.705	11.380	85.490
300	31.292	4.680	29.757	11.380	77.109
400	28.231	4.680	25.465	11.380	69.756
500	25.129	4.680	22.687	11.380	63.876
600	22.897	4.680	20.664	11.380	59.621
720	21.537	4.680	18.940	11.380	56.537

The "TOTAL heat rejected (Btu/hr)" is the hourly rate of heat rejection for every hour in the interval. For example, at 1 hour after LOCA, the rate of heat rejection is 116.168 E6 Btu/hr for the interval (t = 0 to 1 hr) for a total of 116.168 E6 Btu for the interval. At 400 hours after LOCA, the rate of heat rejection is 69.756 E6 Btu/hr for the interval (t = 301 to 400 hrs) for a total of 6975.6 Btu.

Attachment C. - Worst Case Meteorology

The meteorological inputs to the Catawba SNSWP computer model consist of dry bulb temperature, dew point temperature, wind speed, heat transfer coefficient (computed) and the equilibrium temperature (computed). As suggested in Regulatory Guide 1.27, Revision 2, meteorology for the worst cooling period is used. The regulatory guide states in part, "The meteorological conditions considered in the design of the sink should be selected with respect to the controlling parameters and critical time periods unique to the specific design of the sink".

Forty-four years (January 1949 - December 1993) of daily average meteorological data from Charlotte, North Carolina Airport were scanned by computer (using Microsoft Excel) to identify the design basis periods. Meteorological data from Charlotte is considered representative of the Catawba site because it is located only 13 miles east of the site. The weather programs (which will be) described in COM-0203.C6-17-0147, "NWSMET: Surface Meteorological Observations and Hydrothermal Program" were used to generate the computed meteorological data (heat transfer coefficient and equilibrium temperature).

The "worst heat transfer" condition is defined as the period in which the equilibrium temperature is the highest. Equilibrium temperature is defined as the water surface temperature at which heat flux into the surface would equal heat flux out. Therefore, the historical period with the highest equilibrium temperature will define the period in which the least amount of heat will be lost from a thermal discharge and in which critical return temperature from the SNSWP would occur. The Ryan Heated equilibrium temperature (T_e) weather data generated for the years 1949-1993 was loaded into an Excel spreadsheet. The rolling 30,6,5,4,3, and 2-day averages (as well as the 1 day values) of the Ryan Heated T_e values were reviewed and the data with the highest equilibrium temperatures were extracted. The resulting data is shown in Table C1. The table shows the extracted data meeting the conditions of greatest values for each of the average lengths.

Table C1 - Equilibrium Temperature Scan

Date	*Length of Rolling Average Periods (days)*						
	one	*two*	*three*	*four*	*five*	*six*	*thirty*
520622	86.0	87.9	89.5	90.2	90.8	91.5	84.5
520623	89.7	91.2	91.5	92.1	92.6	91.4	84.7
520624	92.7	92.5	92.8	93.4	91.7	89.9	84.6
520625	92.2	92.9	93.6	91.4	89.3	88.7	84.5
520626	93.6	94.3	91.2	88.6	88.0	85.5	84.1
520627	95.0	90.0	86.9	86.6	83.8	83.5	83.8
930630	84.7	86.1	85.5	86.5	86.8	87.0	86.2
930701	87.5	85.9	87.0	87.4	87.4	87.7	86.1

The data shown in Table C1 was used to determine the first day of the 30-day period as described in Reg. Guide 1.27. The "critical time period unique to the specific design of the sink" is 5 days because the SNSWP intake temperature reaches its peak on the 5th day of the simulation. The maximum 5-day average period begins on 6/23/52. This 30-day period is used because of the 5-day peak timing. Although the 30-day period beginning 6/23/52 is not the worst 30-day time period (which begins 6/30/93), this 30-day period (6/23/52) does represent the most conservative meterological data during the critical time period for the specific design (including the heat rejection and flow rate characteristics) of the Catawba SNSWP. The data for the 30-day simulation period is shown in Table C2 "30-Day Worst Case Meteorolo[illegible]

Table C2 - Worst Case Meterology

Day	Date	Dry Bulb (°F)	Dew Point (°F)	2m Height Windspeed (mph)	Heat Transfer Coefficient BTU/ ft2 day(°F)	Equilibrium Temperature (°F)
1	520623	81	72	2	170	90
2	520624	85	71	2	186	93
3	520625	89	70	2	184	92
4	520626	89	72	2	189	94
5	520627	91	71	2	198	95
6	520628	83	72	5	197	85
7	520629	79	71	3	142	81
8	520630	83	71	3	166	86
9	520701	72	61	5	154	73
10	520702	73	58	3	166	82
11	520703	75	60	2	163	86
12	520704	77	62	4	187	84
13	520705	78	63	4	167	80
14	520706	72	66	3	135	77
15	520707	73	69	3	133	78
16	520708	77	70	2	157	86
17	520709	77	68	4	159	80
18	520710	72	55	2	131	77
19	520711	74	60	3	155	80
20	520712	77	63	1	153	88
21	520713	77	65	2	149	84
22	520714	78	68	3	170	85
23	520715	76	69	3	149	81
24	520716	78	71	2	133	82
25	520717	80	70	3	159	84
26	520718	80	71	3	164	85
27	520719	83	72	3	159	84
28	520720	86	69	3	178	87
29	520721	88	69	2	190	93
30	520722	87	70	3	194	90

Attachment D. Withdrawl Depth

CNS SNSWP CALC. SUPPORT

TKZ

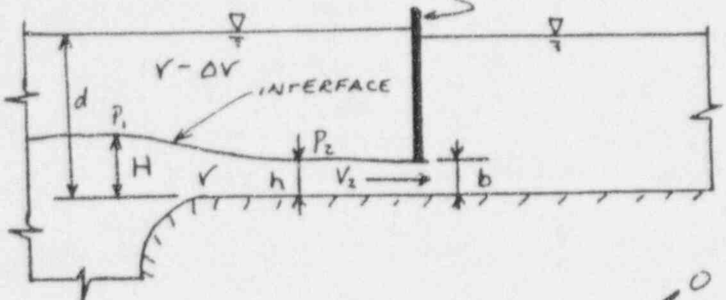

Fig. D1

BERNOULLI'S EQUATION: $\frac{P_1}{\gamma} + H + \cancel{\frac{V_1^2}{2g}}^{\,0} = \frac{P_2}{\gamma} + h + \frac{V_2^2}{2g} + \cancel{h_f}^{\,0}$

γ = SPECIFIC WEIGHT OF WATER (lb/ft³)

$P_1 = (\gamma - \Delta\gamma)(d - H)$ (lb/ft²)

$P_2 = (\gamma - \Delta\gamma)(d - h)$ (lb/ft²)

$$\Rightarrow \frac{(\gamma-\Delta\gamma)(d-H)}{\gamma} + H = \frac{(\gamma-\Delta\gamma)(d-h)}{\gamma} + h + \frac{V_2^2}{2g}$$

SOLVE FOR H:

$$H = -\left[\frac{(\gamma-\Delta\gamma)(d-H)}{\gamma}\right] + \left[\frac{(\gamma-\Delta\gamma)(d-h)}{\gamma}\right] + h + \frac{V_2^2}{2g}$$

MULTIPLY OUT:

$$H = -\left[\cancel{\frac{\gamma d}{\gamma}} - \frac{\cancel{\gamma} H}{\cancel{\gamma}} - \cancel{\frac{\Delta\gamma d}{\gamma}} + \frac{\Delta\gamma H}{\gamma}\right] + \left[\cancel{\frac{\gamma d}{\gamma}} - \frac{\cancel{\gamma} h}{\cancel{\gamma}} - \cancel{\frac{\Delta\gamma d}{\gamma}} + \frac{\Delta\gamma h}{\gamma}\right] + h + \frac{V_2^2}{2g}$$

$$\cancel{H} = \cancel{H} - \frac{\Delta\gamma H}{\gamma} \cancel{- h} + \frac{\Delta\gamma h}{\gamma} \cancel{+ h} + \frac{V_2^2}{2g}$$

$$0 = -\frac{\Delta\gamma H}{\gamma} + \frac{\Delta\gamma h}{\gamma} + \frac{V_2^2}{2g}$$

$$H\left(\frac{\Delta\gamma}{\gamma}\right) = h\left(\frac{\Delta\gamma}{\gamma}\right) + \frac{V_2^2}{2g}$$

$$\boxed{H = h + \frac{V_2^2}{2g\left(\frac{\Delta\gamma}{\gamma}\right)}}$$

CONTINUITY EQUATION: $Q = VA$ OR $V = \frac{Q}{A} = \frac{Q}{(Bh)}$

B = INTAKE WIDTH

SUBSTITUTE FOR V:

$$H = h + \frac{\left(\frac{Q}{Bh}\right)^2}{2g\left(\frac{\Delta\gamma}{\gamma}\right)}$$

SOLVE FOR Q:

$$(H-h) = \frac{\left(\frac{Q}{Bh}\right)^2}{2g\left(\frac{\Delta r}{r}\right)}$$

OR

$$\boxed{Q^2 = 2g\left(\frac{\Delta r}{r}\right) B^2 h^2 (H-h)}$$

FOR A GIVEN VALUE OF H, THE MAXIMUM FLOW RATE IS OBTAINED BY DIFFERENTIATING Q WITH RESPECT TO h AND EQUATING TO ZERO.

$$0 = \text{CONSTANT}\left(h^2(H-h)\right)$$

$$\frac{0}{\text{CONSTANT}} = \frac{d}{dh}\left[h^2(H-h)\right]$$

$$0 = \frac{d}{dh}\left(Hh^2 - h^3\right)$$

$$0 = \left(H2h - 3h^2\right)$$

(NOTE $h = h_c$ = CRITICAL DEPTH)

SOLVE FOR CRITICAL DEPTH (h_c):

$$H2h_c = 3h_c^2$$

$$H = \frac{3}{2}h_c \qquad \text{OR} \qquad \boxed{h_c = \frac{2}{3}H = \text{CRITICAL DEPTH}}$$

FIND CRITICAL DISCHARGE (Q_c) BY EVALUATING ABOVE EQN. AT h_c:

$$Q_c^2 = 2g\left(\frac{\Delta r}{r}\right) B^2 \left(\frac{2}{3}H\right)^2 \left(H - \frac{2}{3}H\right)$$

$$Q_c^2 = 2g\left(\frac{\Delta r}{r}\right) B^2 \left(\frac{2}{3}H\right)^2 \left(\frac{1}{3}H\right)$$

$$\boxed{Q_c^2 = g\left(\frac{\Delta r}{r}\right) B^2 \left(\frac{2}{3}H\right)^3}$$

SOLVE FOR CRITICAL INTERFACE HEIGHT H:

$$\left(\frac{2}{3}H\right)^3 = \frac{(Q/B)^2}{g\left(\frac{\Delta r}{r}\right)} \qquad \text{OR} \qquad \boxed{H = \frac{3}{2}\left[\frac{(Q/B)^2}{g\left(\frac{\Delta r}{r}\right)}\right]^{1/3}}$$

(Col. 2 of Tables 1 and 2);

a basin; and

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WITHDRAWAL FROM TWO-LAYER STRATIFIED FLOWS

By Donald R. F. Harleman,[1] M. ASCE, and Rex A. Elder,[2] F. ASCE

INTRODUCTION

During the past decade, the Tennessee Valley Authority (TVA) has built several intake structures designed to withdraw cold water from the lower levels of thermally stratified rivers and reservoirs. The cold water is used to supply condenser water for industrial cooling water systems. During the summer months, the primary flows in the Tennessee Valley system are controlled by releases from upstream storage dams through low level turbine intakes. Under certain conditions, the cold water discharged by the turbines may form a gravity underflow in the downstream rivers and reservoirs that may be from 10° to 15° F. colder than the overlying surface water.[3,4,5] Withdrawal of the colder bottom waters from such stratified conditions requires special intake structures that prevent the warmer top water from being pulled into the pumps.

In the absence of the stratification caused by reservoir releases, a thermal stratification will generally be developed in the vicinity of a steam power plant by the heat input caused by the return of the hot condenser water to the river. Part of the heated water flows upstream by virtue of its lesser density

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3 Fry, A. S. Churchill, M. A., and Elder, R. A., "Significant Effects of Density Currents in TVA's Integrated Reservoir and River System," Proceedings, Minnesota Internatl. Hydr. Convention, September, 1953, p. 335.

4 Elder, R. A., and Dougherty, G. B., "Thermal Density Underflow Diversion, Kingston Steam Plant," Journal of the Hydraulics Division, ASCE, Vol. 84, No. HY2, Paper No. 1583, April, 1958.

5 Elder, R. A., "Thermal Density Underflow Design and Experience," Proceedings, 7th Hydr. Conf., Iowa Inst. of Hydr. Research, Iowa City, Iowa, 1958.

D3

is recirculated through the power plant unless the intake structur[e is desig]ned to prevent such recirculation.[6]

[Th]e intake structures are in the form of submerged sluice gates with fix[ed] openings and are known as "skimmer walls." The skimmer walls have also been used on lock filling intakes in cases where navigation locks separate regions of fresh water and salt water. In this manner, salt water which intrudes into the fresh water basin during lock operations may be removed by using the denser salt water for lock filling. A summary of various types of selective withdrawal structures and their characteristics has been given by Harleman.[7]

The water in the intake channel downstream from a skimmer wall is homogeneous and, ideally, has a temperature equal to that of the lower layer of cold water in the river or reservoir. The colder water flows through the opening at the bottom of the skimmer wall by virtue of a head differential across the wall caused by the intake pumps. The problem is to determine, for a given intake geometry, the maximum colder water discharge that can be withdrawn without inducing appreciable withdrawal from the upper layer of warm water. A basic experimental and analytical investigation of this problem was conducted at the Hydrodynamics Laboratory of the Department of Civil Engineering at the Massachusetts Institute of Technology for the case of a one-dimensional, plane skimmer wall. An experimental study of two-dimensional (radial flow) skimmer walls was conducted at the TVA Engineering Laboratory, Norris, Tenn. This paper presents the results from both studies and supersedes an earlier paper[8] describing the preliminary studies on the one-dimensional work.

The experimental and theoretical results are for a two-layer system having a discrete interface across which the temperature and, hence, the specific weight of the water changes abruptly. For results that are reproductible in the laboratory, a sharp interface is desirable. It is recognized that in the field such a well-defined interface does not usually occur. However, an equivalent interface may be assumed to exist at the depth at which the vertical gradient of temperature or density is a maximum.

Notation.—The letter symbols adopted for use in this paper are defined where they first appear and listed alphabetically in the Appendix.

THEORETICAL CONSIDERATIONS

The two types of skimmer wall intake structures to be considered are shown in Figs. 1(a) and 1(b). In the plane skimmer wall, Fig. 1(a), the flow approaches the wall unidirectionally, whereas in the radial wall, Fig. 1(b), the direction of flow is radial. The one-dimensional energy equation is written between a point well upstream from the wall where the flow velocities are

6 Harleman, D. R. F., and Garrison, J. M., "The Effect of Intake Design on Condenser Water Recirculation," Technical Report No. 56, Hydrodynamics Lab., Massachusetts Inst. of Tech., Cambridge, Mass., August, 1962.

7 Harleman, D. R. F., "Stratified Flow," Section 26. Handbook of Fluid Dynamics, edited by Streeter, McGraw-Hill Book Co., Inc., New York, N. Y., 1961.

8 Harleman, D. R. F., Gooch, R. S., and Ippen, A. T., "Submerged Sluice Control of Stratified Flow," Journal of the Hydraulics Division, ASCE, Vol. 84, No. HY2, Proc. Paper 1584, April, 1958.

[n]egligible and a point just upstream from the skimmer wal[l ...]ng. It is [a]ssumed that only the lower layer fluid is in motion and frictio[n and] stream-[li]ne curvature effects are negligible. Using the notation of Fig. 1(c), the [e]nergy is

$$\frac{(\gamma - \Delta\gamma)(d - h_r)}{\gamma} + h_r = \frac{(\gamma - \Delta\gamma)(d - y)}{\gamma} + y + \frac{v^2}{2\,g} \quad \ldots\ldots\ldots (1)$$

[i]n which γ denotes the specific weight of the more dense lower layer fluid, [a]nd $\Delta\gamma$ represents the difference in specific weights of the two fluids.

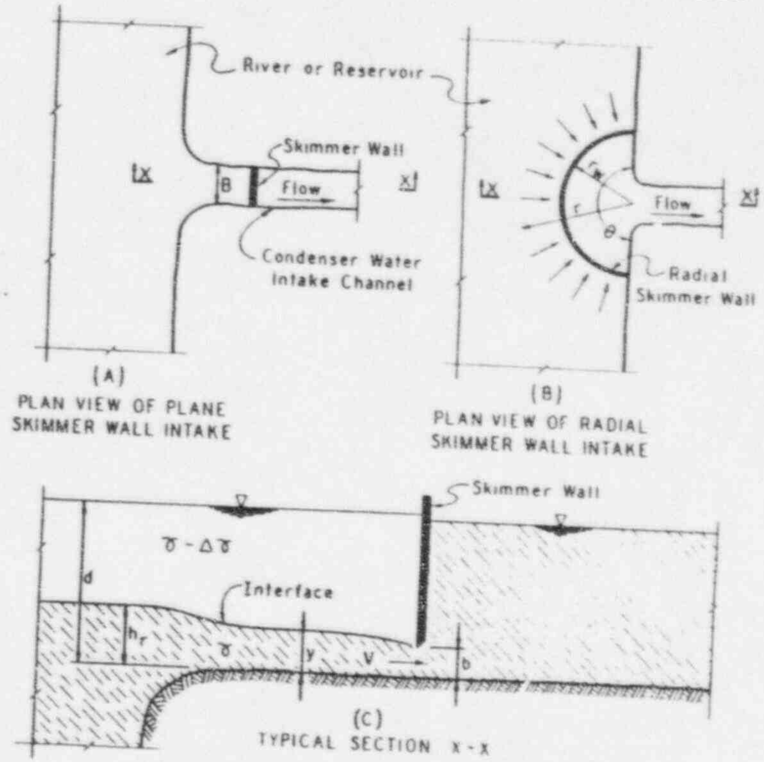

FIG. 1.—SKIMMER WALL

Expanding and simplifying,

$$h_r = y + \frac{v^2}{2\,g\,\frac{\Delta\gamma}{\gamma}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

For a given interface elevation, h_r, in the river or reservoir, the maximum flow rate that can occur in the lower layer is that which corresponds to critical flow in that layer. The total rate of flow through the skimmer wall depends

only on the wall opening and the water surface elevation differential across the skimmer wall. Hence, if the total discharge exceeds the critical flow rate of the lower layer, there must be a drawdown of the interface and a simultaneous inflow from the upper layer fluid. This condition is shown schematically in Fig. 2.

The conditions for critical flow in the lower layer are obtained for both the plane and radial skimmer walls in the subsequent sections.

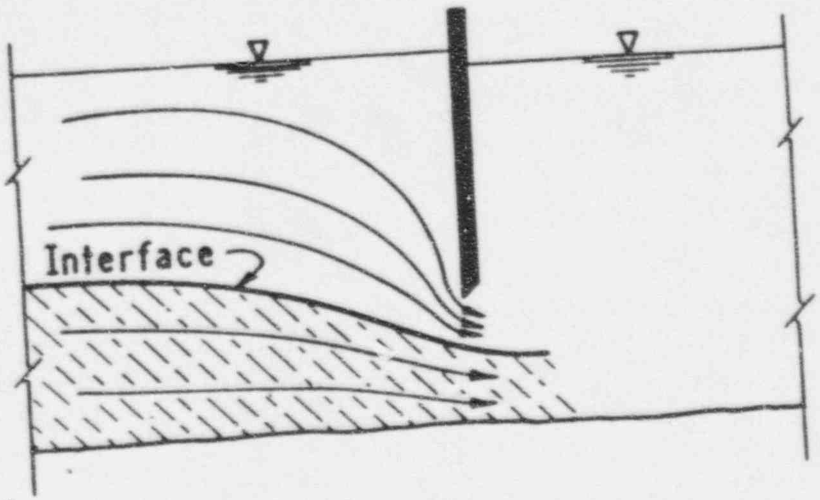

FIG. 2.—DISCHARGE OF BOTH UPPER AND LOWER FLUID THROUGH SKIMMER WALL

Plane Skimmer Wall.—Using the notation of Figs. 1(a) and 1(c), the mean velocity in the lower layer is

$$v = \frac{Q}{B\,y} \quad \text{.......... (3)}$$

Substituting for v in Eq. 2 and solving for the discharge,

$$Q^2 = 2\,g\,\frac{\Delta\gamma}{\gamma}\,B^2\,y^2\,(h_r - y) \quad \text{.......... (4)}$$

For a given value of h_r, the maximum flow rate is obtained by differentiating Q with respect to y and equating to zero. The critical depth obtained in this manner is

$$y_c = \frac{2}{3}\,h_r \quad \text{.......... (5)}$$

and from Eq. 4, the critical discharge is

$$Q_c = B\sqrt{g\,\frac{\Delta\gamma}{\gamma}\left(\frac{2}{3}\,h_r\right)^3} \quad \text{.......... (6)}$$

Eq. 6 reduces to the familiar critical discharge equation for free surface flow in a rectangular channel when the specific weight of the upper layer fluid is zero, hence $\Delta\gamma = \gamma$ and $\Delta\gamma/\gamma = 1$.

For a given channel width and value of $\Delta\gamma$, the critical discharge of the lower layer depends only on the height of the interface, h_r. Regardless of the skimmer wall geometry, the flow in the lower layer cannot exceed the critical discharge defined by Eq. 6.

However, the drawdown of the interface and simultaneous inflow from the upper layer may develop before critical flow is reached in the lower layer. This will occur if the skimmer wall opening, b, exceeds the approach depth, y. Again neglecting friction and curvature effects, the limiting condition which is termed incipient drawdown is given by Eq. 2 with b = y, thus

$$h_r = b + \frac{v_d^2}{2\,g\,\frac{\Delta\gamma}{\gamma}} \quad \text{.......... (7)}$$

The flow rate for incipient drawdown is

$$Q_d = v_d\,B\,b \quad \text{.......... (8)}$$

hence,

$$\frac{h_r}{b} = 1 + \frac{Q_d^2}{B^2\,2\,g\,\frac{\Delta\gamma}{\gamma}\,b^3} \quad \text{.......... (9)}$$

Solving Eq. 9 for Q_d and dividing the result by Eq. 6 gives the following ratio for the plane skimmer wall: or

$$\frac{Q_d}{Q_c} = 2.6\sqrt{\frac{\frac{h_r}{b} - 1}{\left(\frac{h_r}{b}\right)^3}} \quad \text{.......... (10)}$$

For values of h_r/b between 1 and 3/2, Eq. 10 gives the maximum discharge (Q_d) which can be obtained from the lower layer fluid without drawdown and simultaneous discharge from the upper layer. When $h_r/b = 3/2$, $Q_d/Q_c = 1$. Therefore, with $h_r/b \geq 3/2$, the critical flow in the lower layer is the limiting condition. The ratio of the drawdown discharge to the critical discharge is shown in Fig. 3 as a function of h_r/b.

Radial Skimmer Wall.—Using the notation of Figs. 1(b) and 1(c), the mean velocity in the lower layer at any radius, r, is

$$v = \frac{Q}{\frac{2\,\pi\,\theta}{360}\,r\,y} \quad \text{.......... (11)}$$

Substituting for v in Eq. 2 and solving for the discharge,

$$Q = \frac{2\,\pi\,\theta}{360}\,r\,y\sqrt{2\,g\,\frac{\Delta\gamma}{\gamma}\,(h_r - y)} \quad \text{.......... (12)}$$

Setting the derivative of Eq. 12 with respect to y equal to zero, gives the critical depth,

$$y_c = \frac{2}{3} h_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

The critical discharge at the skimmer wall is found from Eq. 12 with $r = r_w$ (radius of the wall) and $y = y_c = 2/3\ h_r$, or

$$\left(Q_c\right)_r = \left(\frac{2\pi\theta}{360}\right) r_w \sqrt{g \frac{\Delta\gamma}{\gamma} \left(\frac{2}{3} h_r\right)^3} \quad \ldots\ldots\ldots (14)$$

Thus, Eq. 14 for the radial skimmer wall is identical with the critical dis-

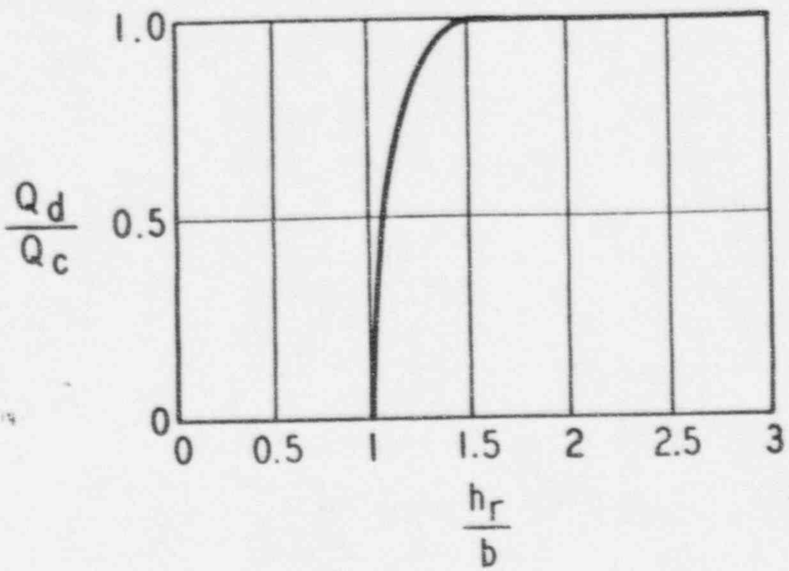

FIG. 3.—RATIO OF DRAWDOWN DISCHARGE TO CRITICAL DISCHARGE AS A FUNCTION OF h_r/b

charge equation for the plane wall if B is interpreted as the perimeter of the wall. Hence, for the radial wall,

$$B = \left(\frac{2\pi\theta}{360}\right) r_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

and the previous relations may be used for the radial wall as well as the plane wall.

Frictional effects, nonuniform velocity distributions, and flow curvatures may be expected to modify the results of the elementary analysis. Experimental results were, therefore, required to determine the magnitude of effects.

EXPERIMENTAL EQUIPMENT AND PROCEDURE

The experiments on the plane skimmer wall were carried out in the MIT Hydrodynamics Laboratory,[9] in the glass-walled flume shown in Fig. 4. The experiment was started by filling the reservoir and flume with salt water to

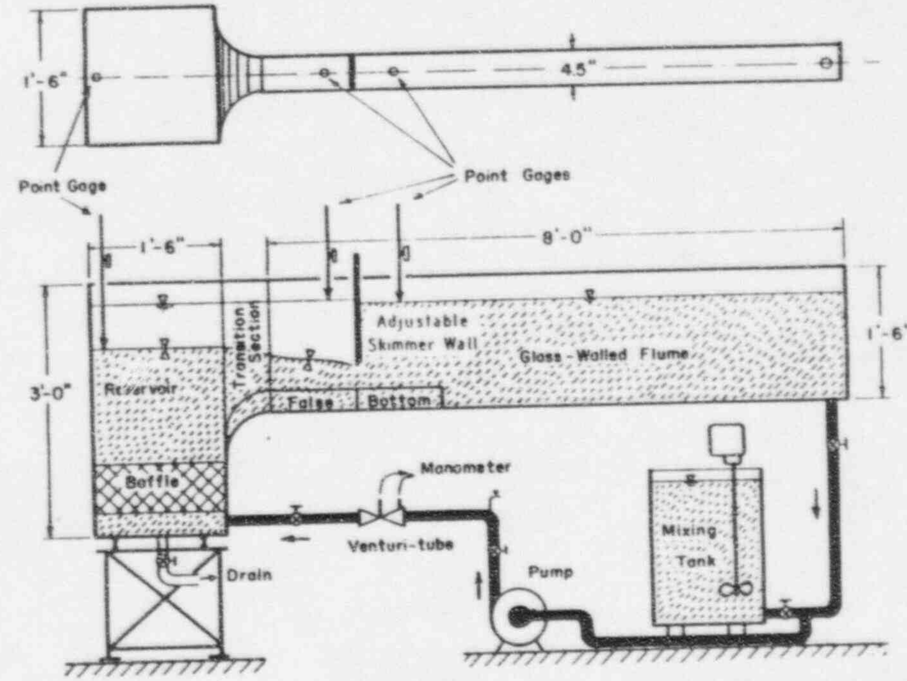

FIG. 4.—EXPERIMENTAL EQUIPMENT

a predetermined height. Fresh water of the same temperature as the salt water was then introduced slowly onto a baffle floating on the reservoir surface. To avoid mixing the two layers, a filling time of approximately 2 hr was required. Salt and fresh water, "rather than hot and cold water," were used to obtain the desired difference in specific weight, in order to avoid transient conditions resulting from heat transfer in the laboratory equipment.

The schematic diagram of the experimental equipment used in the tests at the TVA Engineering Laboratory on the radial wall is shown in Fig. 5.

9 Harleman, D. R. F., and Goda, Y., "Control Structures in Stratified Flows," Technical Report No. 54, Hydrodynamics Lab., Massachusetts Inst. of Tech., Cambridge, Mass., June, 1962.

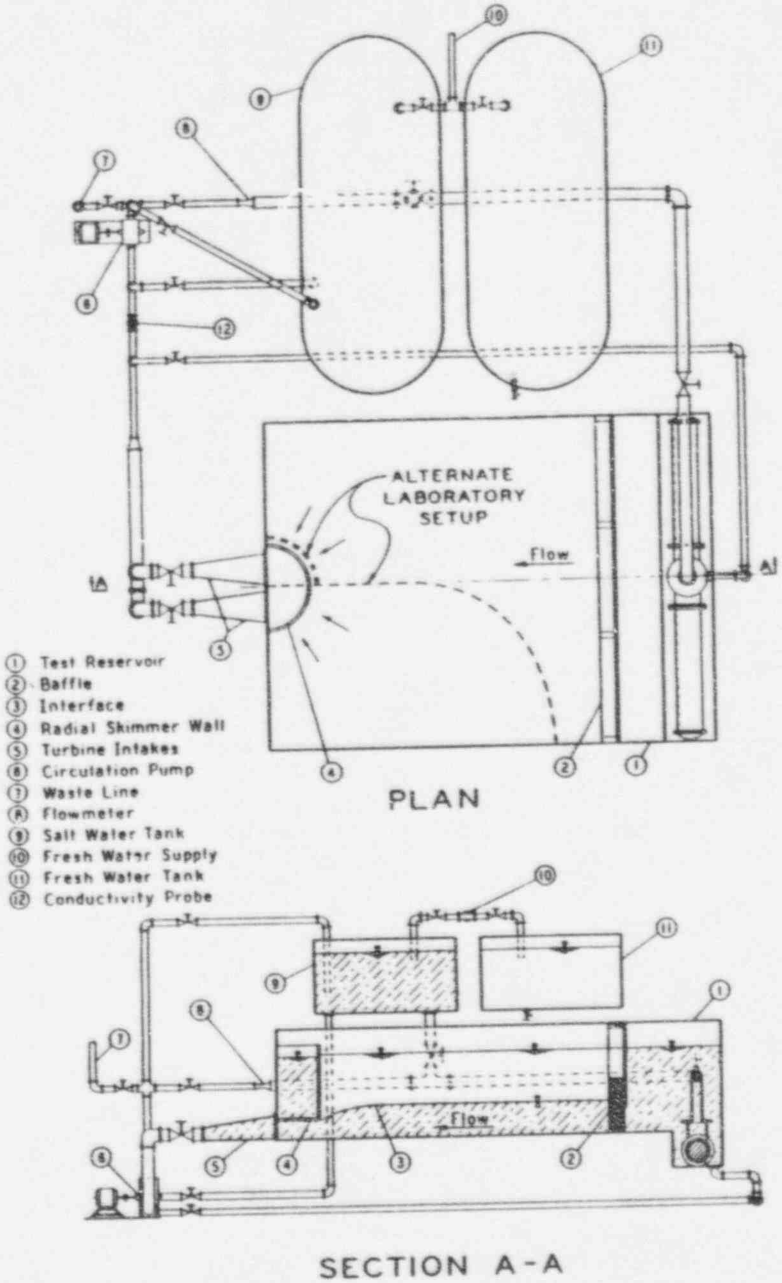

FIG. 5.—SCHEMATIC DIAGRAM OF EXPERIMENTAL TEST EQUIPMENT

The filling process was similar to that described previously; again salt and fresh water were used.

In either experiment, flow was begun beneath the wall by opening the discharge valve on the circulating pump. The interface upstream from the wall was thus depressed in accordance with Eq. 2. It was expected that the discharge could be increased in small increments until the point of incipient drawdown of the upper layer was observed. However, it was found to be extremely difficult to determine the discharge at the point of incipient drawdown. Criteria were developed, therefore, which allowed the accurate determination of the discharge at which a slight withdrawal from the upper layer commenced, i.e., what was determined was a discharge just in excess of the incipient drawdown discharge.

For the plane skimmer wall tests, it was found that: For any given flow rate, as long as there was no withdrawal from the upper layer, the interface elevation in the reservoir, h_r, remained constant with time. As the discharge increased, there was a tendency for the formation of a wedge of intermediate density fluid upstream from the wall. This wedge tended to obscure the visual indication of incipient drawdown of the upper layer. The wedge was removed by increasing the discharge beyond the point of incipient drawdown. This caused the interface to drop below the lip of the skimmer wall and a simultaneous withdrawal from both upper and lower layers occurred. The interfacial height, h_r, in the reservoir immediately started to rise, and the density difference decreased slightly as a result of the entrainment of the upper layer.

An example of the change in interface elevation as a function of time, after the increase of discharge necessary to cause drawdown, is shown in Fig. 6. Note that, while the new discharge was held constant, the rate of interfacial rise was a continuously decreasing function of time. Using the foregoing relationships, the following criterion was adopted: The discharge at incipient drawdown, Q_d, was defined as that discharge at which not more than 1% or 2% of the total flow under the skimmer wall comes from the upper layer water upstream of the wall. Hence,

$$Q_f = 0.02\, Q_d \text{ or } 0.01\, Q_d \quad \ldots\ldots\ldots\ldots (16)$$

in which Q_f is the discharge from the upper layer. If A_f is the horizontal area of the reservoir and skimmer wall approach channel, then

$$Q_f = A_f \frac{dh_r}{dt} \quad \ldots\ldots\ldots\ldots (17)$$

Eq. 17 relates the discharge from the upper layer to the time rate of change of h_r, which can be accurately measured. Therefore, from Eqs. 16 and 17 for the 2% case,

$$\left(\frac{dh_r}{dt}\right)_{2\%} = \frac{0.02\, Q_d}{A_f} \quad \ldots\ldots\ldots\ldots (18)$$

For example, in Fig. 6, if Q_d = 8.4 cu in. per sec and because A_f=400 sq in.

$$\left(\frac{dh_r}{dt}\right)_{2\%} = 0.00042 \text{ in. per sec or } 0.025 \text{ in. per min}$$

From the computed slope, the value of h_r can be determined graphically as shown in Fig. 6 (h_r = 2.63 in.). The interfacial height on the basis of a 1% withdrawal from the upper layer is also shown (h_r = 2.75 in.). In both cases, the method of defining incipient drawdown gave consistent and reproducible results.

The foregoing method was not feasible for the TVA experiments on the radial walls, because of the much larger volume of lower layer water and the consequent difficulty of accurately measuring interface changes as a function of time. It was, therefore, decided to measure the salinity concentration in the intake piping system as a means of determining the amount of

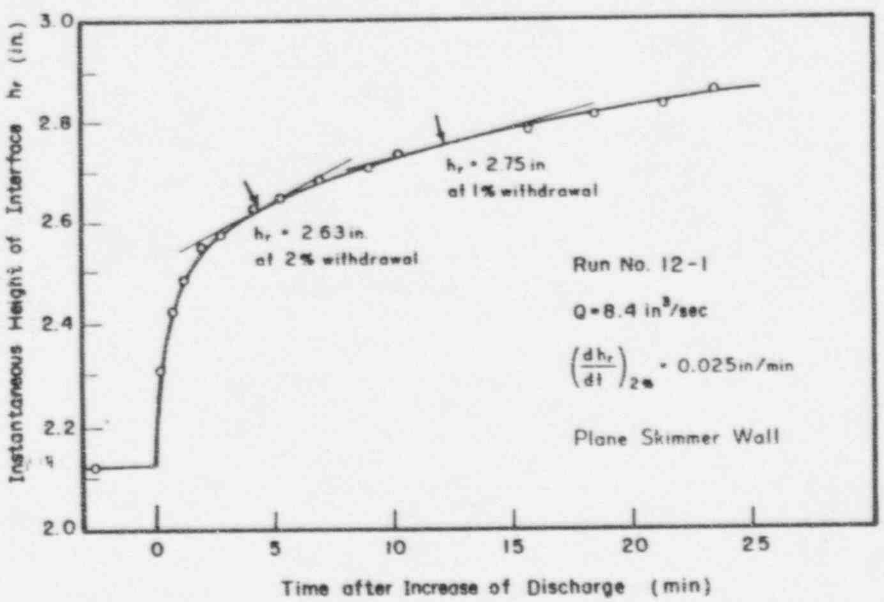

FIG. 6.—RISING INTERFACE AFTER INCREASE OF DISCHARGE

flow from the upper layer. A glass conductivity probe developed at the MIT Hydrodynamics Laboratory[10] was inserted in the piping system downstream from the radial wall. The discharge was increased slowly causing the interface height, h_r, to slowly decrease until the computed change in salinity concentration caused by a 2% drawdown of the upper layer was observed.

EXPERIMENTAL RESULTS

Table 1 gives a summary of the experimental data for the plane and radial walls for both 1% and 2% drawdown conditions. Fig. 7 shows a sequence of

10 Harleman, D. R. F., Hoopes, J. A., McDougall, D., and Goulis, D. A., "Salinity Effects on Velocity Distributions in an Idealized Estuary," Technical Report No. 50, Hydrodynamics Lab., Massachusetts Inst. of Tech., Cambridge, Mass., January, 1962.

three photographs for two types of plane skimmer walls indicating co[illegible] is (1) prior to drawdown, (2) at incipient drawdown, and (3) with flow from both upper and lower layers passing under the wall. The type II plane skimmer wall was tested to determine if there was any advantage in placing the lip of the wall at the same elevation as the bottom of the intake channel. Because

TABLE 1.—DRAWDOWN DISCHARGE

Run No.	Drawdown discharge, Q_d, in cu in. per sec	Density difference, $\frac{\Delta\gamma}{\gamma}$	1% Drawdown Condition: Interface height, h_r, in inches	Relative height, $\frac{h_r}{b}$	Relative discharge, $\frac{Q_d}{Q_c}$	2% Drawdown Condition: Interface height, h_r, in inches	Relative height, $\frac{h_r}{b}$	Relative discharge, $\frac{Q_d}{Q_c}$
(a) Plane Skimmer Wall (b = 1.5 in.)								
11-1	3.2	0.0031	2.04	1.36	0.41	2.03	1.36	0.42
11-2	5.2	0.0031	2.18	1.45	0.61	2.16	1.44	0.62
11-3	7.0	0.0031	2.55	1.70	0.66	2.41	1.61	0.71
11-4	10.2	0.0030	2.87	1.91	0.79	2.85	1.90	0.82
11-5	12.1	0.003[illegible]	3.22	2.15	0.82	3.14	2.10	0.84
11-6	16.6	0.0030	[illegible].93	2.62	0.82	3.72	2.48	0.89
11-7	23.0	0.[illegible]29	4.[illegible]6	3.24	0.85	4.65	3.10	0.90
11-8	31.7	0.00[illegible]	6.15	4.10	0.83	5.83	3.89	0.90
12-1	8.4	0.0029	2.75	1.84	0.73	2.63	1.75	0.78
12-2	13.5	0.0029	3.60	[illegible].40	0.78	3.40	2.26	0.85
12-3	19.7	0.0029	4.51	[illegible].01	0.81	4.36	2.91	0.85
12-4	27.3	0.0028	5.68	3.79	0.82	5.40	3.63	0.87
12-5	40.1	0.0027	7.70	5.14	0.77	7.20	4.80	0.85
12-6	2.6	0.0023	[illegible].08	1.26	0.44	1.83	1.23	0.46
12-7	5.8	0.0023	2.28	1.52	0.70	2.21	1.48	0.73
(b) Radial Skimmer Wall								
290	119.2	0.0078	0.597	1.09	0.35	-	-	-
291	283.4	0.0073	-	-	-	0.598	1.09	0.85
293	336.9	0.0076	0.679	1.36	0.83	-	-	-
294	438.9	0.0071	-	-	-	0.690	1.38	1.08
295	425.1	0.0074	0.705	1.57	0.995	-	-	-
296	480.3	0.0070	-	-	-	0.712	1.58	1.14
297	369.7	0.0069	0.[illegible]35	1.83	0.84	-	-	-
298	473.5	0.0070	0.742	2.12	1.06	-	-	-
299	480.3	0.0061	0.762	2.54	1.11	-	-	-
300	480.3	0.0060	0.759	3.04	1.12	-	-	-
301	480.3	0.0055	0.771	3.85	1.14	-	-	-
302	480.3	0.0039	0.787	5.27	1.32	-	-	-

the lower layer flow became critical at the step regardless of the downstream location of the wall, it was apparent that there was no advantage in the type II wall in comparison with the type I wall. Hence, an excavation of the intake channel bottom below that of the river bed cannot be justified. The type II wall may, in certain positions, interfere with the nappe of the underflow and

cause appreciable mixing with the upper layer. Fig. 8 shows the radial wall at incipient drawdown conditions.

The experimental data for the plane and radial skimmer walls are compared with Eq. 10 in Figs. 9 and 10, respectively. In general, the experimental results are in accord with the analytical relationship shown in Fig. 3, although the numerical results are modified by frictional and curvature

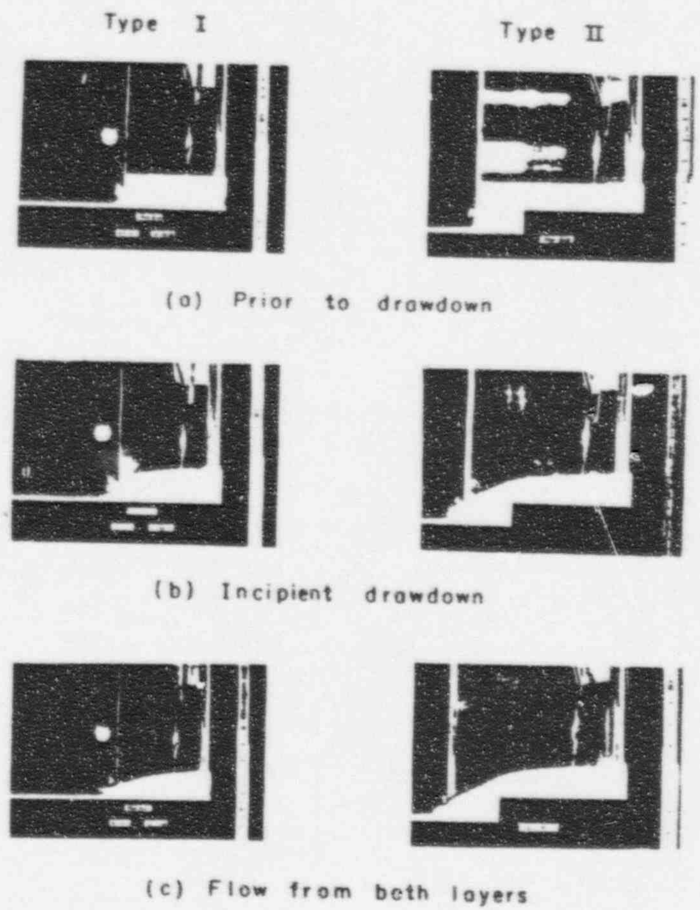

FIG. 7.—INCREASING DISCHARGE UNDER SKIMMER WALL

effects neglected in the theoretical investigation. Fig. 9 for the plane skimmer wall, shows the optimum value of h_r/b as approximately 2.5 rather than 1.5. If h_r/b is less than 2.5, drawdown tends to occur before critical flow is reached in the lower layer. The maximum flow of the lower layer never exceeded 90% aline of the critical flow computed from Eq. 6. There is no ap-

parent advantage in using openings where $h_r/b > 2.5$ because this would result in greater energy dissipation across the skimmer wall.

Fig. 10, for the radial skimmer wall, shows a better agreement with the theory. The optimum opening is close to the value of 1.5 predicted by Fq. 10. The 2% drawdown discharge is approximately 10% greater than the calculated critical flow rate. The agreement for the radial wall is attributed to the fact that, as a result of the radial nature of the flow, the velocities decrease more rapidly and curvature effects are reduced, and also to the fact that the Reynolds numbers for the flows in the radial wall tests were considerably larger

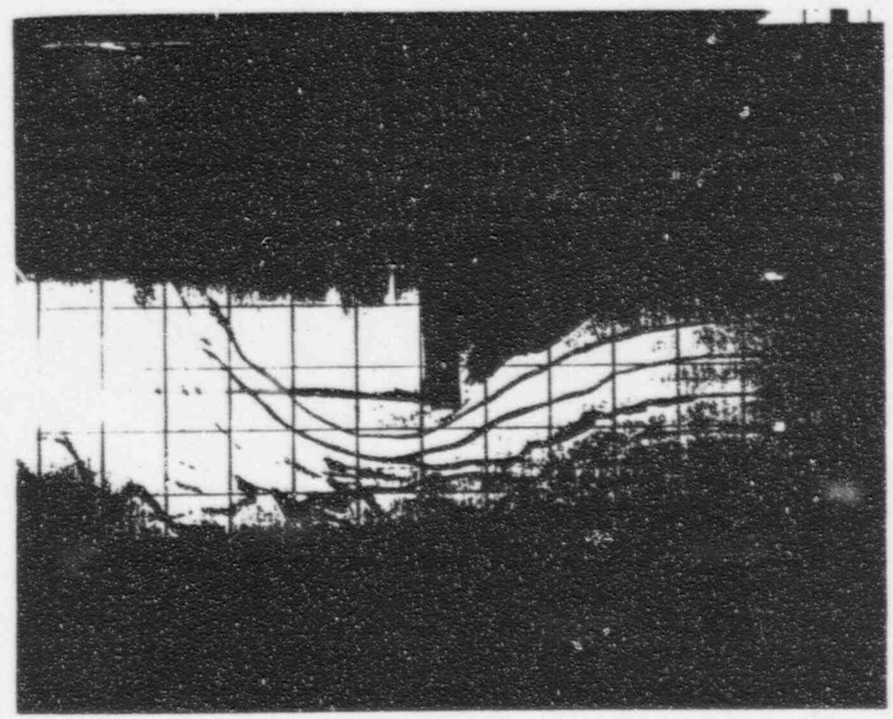

FIG. 8.—INCIPIENT DRAWDOWN CONDITIONS DEMONSTRATED IN LABORATORY MODEL TEST

than those for the plane wall tests. Hence, the viscous effects were less important for the radial wall tests.

CONCLUSIONS

The maximum discharge from the lower layer without simultaneous withdrawal from the upper layer corresponds to critical flow conditions in

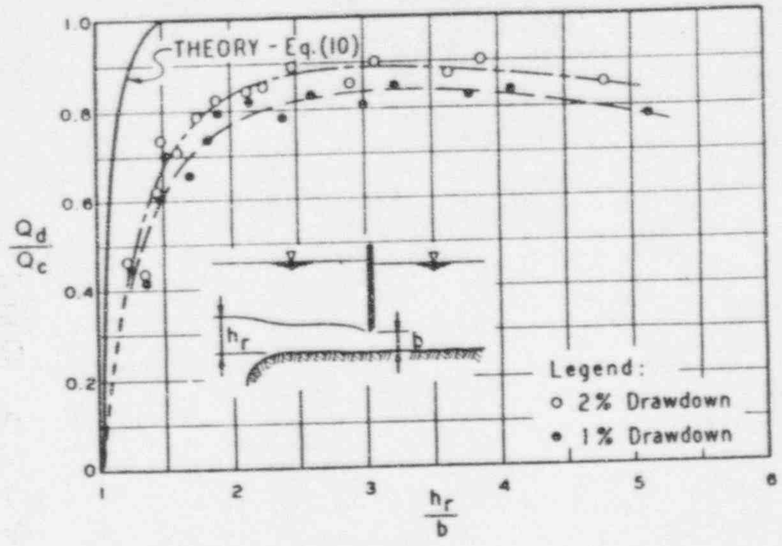

FIG. 9.—PLANE SKIMMER WALL—RATIO OF DRAWDOWN DISCHARGE Q_d TO CRITICAL DISCHARGE Q_c

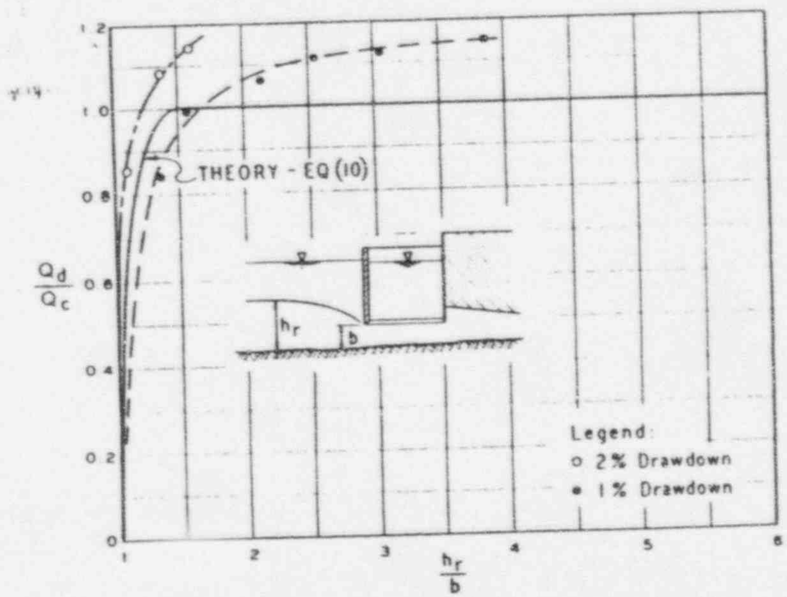

FIG. 10.—RADIAL SKIMMER WALL—RATIO OF DRAWDOWN DISCHARGE Q_d TO CRITICAL DISCHARGE Q_c

the lower layer at the wall. For a plane skimmer wall [Fig. 1(a)] this discharge,

$$Q_c = B\sqrt{g\frac{\Delta\gamma}{\gamma}\left(\frac{2}{3}\,h_r\right)^3} \quad \text{.........(6)}$$

depends only on the width of the wall B, the difference in specific weight between the upper and lower layers of water and the elevation of the interface, h_r, in the reservoir or river. In order to develop the maximum discharge from the lower layer the ratio of interface elevation to skimmer wall opening, h_r/b, should equal 2.5.

For a radial skimmer wall [Fig. 1(b)], the same discharge equation applies, provided B is interpreted as the perimeter of the wall. In this case, the ratio h_r/b may be reduced to 1.5.

If two-layer stratification exists at a proposed site, then physical measurement of the stratified river or reservoir is required to establish h_r. The specific weight difference, $\Delta\gamma$, is determined from measurements of the underflow temperature at the skimmer wall site and from the expected surface layer temperature after construction of the wall. The discharge, Q_c, is generally specified by the condenser water requirements of the thermal power plant. The skimmer wall opening, b, is determined from the h_r/b ratio given previously and the width (or perimeter), B, may then be calculated directly from Eq. 6.

If the stratification is self-induced, i.e., by upstream movement of warm water from the condenser water outlet, the construction of a skimmer wall is an effective method or preventing recirculation and reducing the condenser water temperature at the intake. In the case of existing plants with recirculation problems, site measurements may be used to determine h_r and $\Delta\gamma$ for design of a skimmer wall as outlined previously. The design of skimmer walls for the prevention of recirculation in new thermal plants must be based on predicted values of h_r and $\Delta\gamma$. This problem is currently being investigated in both MIT abd TVA laboratories.

ACKNOWLEDGMENTS

The writers wish to acknowledge the contributions of Y. Goda, Research Assistant in the MIT Hydrodynamics Laboratory, and J. Garrison, Research Engineer in the TVA Engineering Laboratory, who conducted the experimental work. The advice and guidance of Arthur T. Ippen, Professor of Civil Engineering at MIT, is also sincerely appreciated.

APPENDIX.—NOTATION

The following symbols have been adopted for use in this paper:

A_f = horizontal area of the reservoir and skimmer wall approach channel;

B = plane skimmer wall width;

b = skimmer wall opening height;
d = total depth of water at skimmer wall;
g = acceleration of gravity;
h_r = lower layer interface depth in river or reservoir;
Q = discharge of lower layer;
Q_c = critical discharge of lower layer;
Q_d = discharge of lower layer at incipient draw down;
Q_f = discharge from the upper layer;
r = radius;
r_w = skimmer wall radius;
v = velocity of lower layer;
v_d = velocity of lower layer at incipient drawdown;
y = approach depth of lower layer;
y_c = critical depth of lower layer;
γ = specific weight of the more dense lower layer fluid;
$\Delta\gamma$ = difference in specific weights of the two fluids; and
θ = angular opening of radial skimmer wall.

Journal of the
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Proceedings of the American Society of Civil Engineers

ENVIRONMENTAL EFFECTS OF FLOOD PLAIN REGULATIONS

Eugene W. Weber,[1] F. ASCE, and Walter G. Sutton[2]

INTRODUCTION

Flood plain regulation has been called a "New Approach to Local Flood Problems."[3] In recent years many engineers have begun to realize that structural flood control measures are not the only answer to improving man's environment through prevention and reduction of flood damages. Management of the flood plain through flood plain regulations is becoming recognized as an important environmental control measure but deserves even more attention by all concerned including engineers, planners, governmental agencies, and affected individuals.

Floods affect man's environment significantly: They threaten his life and health; they threaten his property—his home, his business, or his place of employment. Neither flood plain regulations nor other flood damage prevention measures are likely to eliminate these threats completely because man is powerfully attracted to use of the flood plain. However, they certainly can reduce them and they should be given increasing consideration.

In addition to regulations, there are other means of controlling the use of the flood plain. These include acquisition of flood plains by public agencies for uses that will serve the public need and which will not suffer or cause increased damages. Recreation areas are a prime example. "Open spaces" are becoming more appreciated as they become more scarce. Use of the flood plain for public parking is generally acceptable.

Tax policies, loan and finance practices, flood hazard information dissemination, warning signs, and other measures can also be used to help man use the flood plain wisely and safely.

Note.—Discussion open until December 1, 1965. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, Vol. 91, No. HY4, July, 1965.

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2 Chf., Flood Plains Sec., Planning Div., Civ. Works, Office, Chf. of Engrs., U. S. Dept. of the Army, Washington, D. C.

3 Vogel, H. D., "New Approach to Local Flood Problems," Journal of the Hydraulics Division, ASCE, Vol. 86, No. HY1, Proc. Paper 2336, January, 1960, pp. 53-61.

From: TEG6779 --PRDC Date and time 05/25/95 13:08:00
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cc: AHR4631 --PRDC WNP3375 --PRDC
SWB9911 --PRDC

Attachment E. Flow-Split Testing

From: Tom Gaye
CNS MSE/BOP
CN03SE / 831-5702

Subject: RN DISCHARGE FLOW SPLIT TESTS

Richard, here is a summary of the tests performed so far:

B Train (PT/0/A/4400/08J, RN B Train Discharge Flow Split Test)
-performed 4/13/95
-Long leg flow 6569 GPM (27.6%), Short Leg 17,269 GPM (72.4%), 23,838 GPM total
A Train (PT/0/A/4400/08I, RN A Train Discharge Flow Split Test)
-performed 4/20/95 & aborted
-performed 5/18/95 w/annubar
-Long leg flow 7740 GPM (31.9%), Short Leg 16,505 GPM (68.1%), 24,245 GPM total

Thanks, Tom

ATTACHMENT 2