W3F1-97-0111

SUPPLEMENT TO

NPF-38-179

ATTACHMENT B

CSP PORTION OF
CALCULATION EC-M95-012, Rev. 1 CN#1

ENTERGY

CALCULATION CHANGE COVER SHEET

B13.18 (Original R-Type or R-Type from Attachment VII)

Calculation: EC-M95-012 (Number) 1 (Revision) 1 (Change Number)

☐ Markup Calculation Change ☒ Finalized Format Calculation Change

Initiating Document: No.: N/A Rev.: ______

Calculation Performed Under:

☒ Waterford-3 Procedures ☐ Supplier Approved Procedures

Computer Software Used: ______ Code ______ Version ______ Disk

Description of Change:

Revise page 1 to correct a typographical error. Stated minumum CSP level is revised from 1.48% to 1.53%.

(Use additional pages as needed)

This Calculation Change is considered NOT to be installed until the engineer initials and dates below. If no installation/implementation is required then initial and date to indicate an as-built condition. This Calculation Change may be canceled by initialing and dating below:

	Initial	Date
Completely Installed/Implemented:	RBG	5/6/97
Partially Installed/Implemented:		
Change Canceled:		

(list loads partially installed below)

(use additional pages as needed) 4/19

I have reviewed this Calculation Change in conjunction with any changes previously installed/implemented. The impact of these changes on the subject calculation do not result in exceeding its design basis/design margin.

R. GILMORE
R. B. Gilmore 5/6/97 — Prepared By/Date

[signature] 5/6/97 — Verified/~~Reviewed~~ By/Date

Paul A. Gropp 5/7/97 — Approved By/Date

NOECP-011, REV. 3
Form No. 5, Rev. 1

ENTERGY

ENGINEERING CALCULATION COVER SHEET

B13.18 (Original R-Type or R-Type from Attachment VII)

CALCULATION NO. EC-M95-012 REV. NO. 1

TITLE Minimum Pipe Submergence to Prevent Vortexing Calculation

SUBJECT Vortexing in storage pools and vessels due to pump operation

AFFECTED SYSTEMS CSP, EDG, CVC, SI

THIS CALCULATION SUPERSEDES N/A

COMPUTER SOFTWARE USED N/A

CODE VERSION DISK

CALCULATION CLASSIFICATION:

- ☐ Non-Quality Related
- ☒ Safety Related
- ☐ Quality Related: Important to Safety

CALCULATION PERFORMED UNDER:

- ☒ Waterford 3 Procedures
- ☐ Supplier Approved Quality Procedures

CALCULATION STATUS: 999

- ~~☒~~ Final - List Pending Calculation(s) and/or Calculation Changes Incorporated (KMF 12-9-96)

X FINAL KMF 12-26-96

- ☐ Void
- ☐ Superseded - New Calc. No. ______
- ☒ Pending (Not Currently Installed)
- ☐ Partially Installed ______ Initial ______ Date
- ☐ Completely Installed ______ Initial ______ Date
- ☐ Canceled ______ Initial ______ Date

Prepared By: [signature] ENGINEER Date: 10/29/96

Verified/Reviewed By: [signature] Date: 11/5/96

Approved By: Paul A. Griggs SUPERVISOR Date: 12/4/96

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RECORD OF REVISION

REVISION CHANGE NUMBER	DESCRIPTION OF REVISION/CHANGE	EFFECTIVE DATE	PAGES AFFECTED
0	Initial Release	12-1-95	1-6
1	Revised calculation using a method provided in EC-M-96-014 Rev. 0 and included the BAM Tanks, EDG Oil Storage and Feed Tanks, RWSP and VCT. Since the calculation was revised in its entirety, no revision bars are used.	12-15-96	1-20

1.0 PURPOSE

The purpose of this calculation is to determine the minimum liquid level in the Condensate Storage Pool, Boric Acid Makeup Tanks, Emergency Diesel Generator Storage and Feed Tanks, Refueling Water Storage Pool and Volume Control Tank to prevent air entrainment, due to vortexing during pump operation, into the suction piping of the associated pumps.

This calculation can be used as input for determining the correct low level alarms for each of these storage pools or tanks.

2.0 CONCLUSION

The minimum liquid level and corresponding liquid level percentage in the evaluated storage pools and tanks to prevent vortexing into the pump suction is provided in the following table. All liquid levels are referenced from the 0% indicator level [5].

Storage Tank	Minimum Liquid Level	Minimum Liquid Level %
Condensate Storage Pool	0.32 ft	1.53%
Boric Acid Make-up Tanks	-1.49 ft	<0%
EDG Storage Tank	0.11 ft	0.24%
EDG Feed Tank	-0.91 ft	<0%
Refueling Water Storage Pool	1.14 ft	5.70%
Volume Control Tank	-1.20 ft	<0%

The minimum required level in the Condensate Storage Pool to prevent vortexing into the Emergency Feedwater Pumps is 1.53%. The remaining water volume, below the 1.53% level, should not be considered for uninterrupted flow into the steam generators. CH.1

The Emergency Diesel Oil Storage Tank is susceptible to vortexing. However, the centerline of the pump is located 1.25 ft below the 0% tank level which will allow the Diesel Oil Transfer Pump to maintain its prime. Since the pump discharges to the Diesel Oil Feed Tanks and not directly to the diesel engine, the air that may be entrained in the fuel will be vented from the fuel in the feed tank and not affect the operation of the Emergency Diesel Generator.

The Refueling Water Storage Pool was evaluated for both symmetric flow (both trains operating) and asymmetric flow (only one train operating) at pump runout conditions for the Containment Spray, HPSI and LPSI pumps. The analysis revealed that even at the highest flowrates (pump runout) vortexing under asymmetric flow conditions will not occur above the top of the suction strainers. Therefore, any flow rotation induced by asymmetric flow in the RWSP will not cause vortexing to occur at a level higher than the level for symmetric flow.

Operation of the BAM Tanks, the EDG Feed Tank and Volume Control Tank is unaffected by vortexing because the minimum liquid level is below the 0% level of each of the tanks.

3.0 REFERENCES

1. Waterford 3 SES Condition Report 95-0657
2. Goulds Pump Manual Third Edition
3. Crane Technical Paper 410, Flow of Fluids Through Valves, Fittings & Pipe
4. Waterford 3 Manual 459000184, CEN-152 Rev. 3, Combustion Engineering Emergency Procedure Guidelines Figure 8-3
5. Waterford 3 Engineering Calc. EC-M84-001 Rev. 6, Tank Volume vs. Level
6. Waterford 3 Engineering Calc. EC-M96-014 Rev. 0, Minimum Height for Fluid Level in RWSP Without Vortexing
7. Waterford 3 DBD-003 Rev. 0, Emergency Feedwater System
8. Waterford 3 SES Drawing 1564-G-905 Rev. 5
9. Waterford 3 SES Drawing 1564-G-906 Rev. 3
10. Waterford 3 SES Drawing 1564-G-907 Rev. 9
11. Waterford 3 SES Flow Diagram 1564-G-160 Sh. 6 of 6 Rev. 6
12. Waterford 3 SES Isometric Diagram 4305-6636 Rev. 9
13. Waterford 3 Technical Manual 457000313 Rev. 11
14. Waterford 3 Technical Manual 457000149 Rev. 16

15. Waterford 3 SES Station Information Management System

16. Waterford 3 SES Drawing 1564-427 Rev. 5, Boric Acid Makeup Tank

17. Waterford 3 SES Drawing 1564-280 Rev. 4, Volume Control Tank

18. Ebasco Spec. 1564.725A Rev. 6, Misc. Field Erected Water Storage Tanks

19. Waterford 3 SES Isometric Drawing 4305-9525 Rev. 2

20. Waterford 3 SES 1564-2525 Rev. 2, Diesel Oil Storage Tank

21. Waterford 3 SES 1564-4559 Rev. 3, Diesel Oil Feed Tank

22. Waterford 3 SES Letter W3J83-0324 dated August 9, 1983

23. Waterford 3 Letter PSA-89-255, Decay Heat Power Curves 1979 and 1973 ANS Standard

24. Waterford 3 Engineering Calc. EC-S96-005 Rev. 0, Cycle 10 Power Uprate Safety Analysis Groundrules

25. ASME Steam Tables Fifth Edition

4.0 INPUT CRITERIA

The results of calculation EC-S89-003 [4] are interpreted to determine the required flowrate into the steam generators at the time the Condensate Storage Pool is nearing a low level. The interpreted required flowrate is the rate at which water is pumped into the steam generator which results in an increasing steam generator level. The pump capabilities are provided in the Design Basis Document [7].

Vessel dimensions are located on the referenced tank drawings and engineering calculations. The source for these inputs is referenced within the calculation.

Waterford 3 engineering calculation, EC-M96-014 Minimum Height for Fluid Level in RWSP Without Vortexing [6], provides the methodology, initially developed by Combustion Engineering, for determining the height at which vortex formation begins for flow with no rotation. Since there are no disturbances (i.e. structural columns) in the flow stream of any of these vessels, except to the RWSP, rotation does not have to be considered when determining vortex formation.

5.0 ASSUMPTIONS

A. The shape of the vessel does not affect the required minimum pipe submergence.

B. The flow is irrotational: viscous effects and other sources of relative rotation are absent.

C. Flow is quasi-steady - flow is established and the free surface is maintained at a constant depth.

6.0 METHOD OF ANALYSIS

This analysis uses standard engineering conversions to determine the fluid velocity into suction piping. The predictive model used in engineering calculation EC-M96-014 [6] uses a sink-flow model for cases of no rotation to determine the critical height at which the flow above the drain extends into the drain almost instantaneously.

6.1 Definition of Variables

v	=	Specific gravity (lb/ft^3)
d	=	Drain diameter (ft)
D	=	Sink diameter (2R) (ft)
D_c	=	Column width (ft)
Fr_s	=	Sink Froude number
Fr_d	=	Drain Froude number
g	=	Gravitational constant (32.2 ft/sec^2)
Δh	=	Enthalpy difference between CSP and SG steam (Btu/lb)
H	=	Free surface height (ft)
H_c	=	Critical height (ft)
k_o	=	Initial vortex strength
k	=	Final vortex strength
N_r	=	Rotation number
Q	=	Volumetric Flowrate (GPM)
q	=	Decay heat load (Btu/min)
R	=	Sink radius based on distance from side wall to drain center (ft)
U_{avg}	=	Average cross flow velocity (ft/sec)
U_{fs}	=	Free surface cross flow velocity (ft/sec)
V_s	=	Sink velocity (ft/sec)
V_d	=	Drain velocity (ft/sec)
W	=	Width of the tank (ft)

6.2 Listing of Equations for Cases Without Rotation

In order to calculate the sink velocity, V_s, Equation 1 is used.

$$V_s = \frac{Q}{\pi(448.83)R^2} \tag{1}$$

The sink Froude number is then calculated using Equation 2.

$$Fr_s = \frac{V_s^2}{gR} \tag{2}$$

The critical height is then calculated using Equation 3.

$$H_c = R\left[1.25\left(\frac{Fr_s}{2}\right)^{\frac{1}{5}} - 0.25\left(\frac{Fr_s}{2}\right)\right] \tag{3}$$

6.3 Methodology for Asymmetric Flow in the RWSP with Rotation

Asymmetric flow conditions exist when only one train of safety injection is operating. Columns located along the centerline of the RWSP will cause rotation in the water which will increase the height at which vortex formation begins. The suction strainers located above the suction piping reduce the rotation so that no affect will occur for vortexing which begins below the top of the screens. However, the suction screens will not prevent vortexing when formation starts above the top of the strainers.

In order to calculate the drain velocity, V_d, Equation 4 is used.

$$V_d = \frac{Q}{\frac{\pi}{4}(448.83)d^2} \tag{4}$$

Once the drain velocity has been calculated, the drain Froude number is calculated using Equation 5.

$$Fr_d = \frac{V_d}{\sqrt{gd}} \tag{5}$$

The average cross flow velocity is equal to the volumetric flowrate into the drain divided by the area across the tank at the location of the columns in the RWSP. Calculation EC-M96-014 [6] determined that vortex strength for free surface levels below 4.53 feet, should be based on the cross flow velocity at a free surface height 4.65 times the actual height. Therefore, the following equation is used to calculate the average cross flow velocity.

$$U_{avg} = \frac{Q}{(7.48052)(60)(2)(4.65)H(W-2D_c)} = \frac{Q}{(4174.13)H(W-2D_c)}$$

Since the RWSP width is 63 feet and the width across each column is 3 feet [6], the previous equation further reduces to Equation 6.

$$U_{avg} = \frac{Q}{(237,925.41)H} \qquad (6)$$

Calculation EC-M96-014 [6] also determined that the free surface cross flow velocity as a function of the average cross flow velocity can be expressed as Equation 7.

$$U_{fs} = 0.0001133 + 0.095075(U_{avg}) + 24.045(U_{avg})^2 - 227.955(U_{avg})^3 \qquad (7)$$

Combining Equations 6 and 7 yields Equation 8 for free surface velocity in terms of volumetric flowrate and free surface height.

$$U_{fs} = 0.0001133 + 3.996(10)^{-7}\left(\frac{Q}{H}\right) + 4.248(10)^{-10}\left(\frac{Q}{H}\right)^2 - 1.693(10)^{-14}\left(\frac{Q}{H}\right)^3 \qquad (8)$$

The initial vortex strength can then be calculated as shown in Equation 9.

$$k_o = (3.87)(D_o)(U_{fs}) = (3.87)(3)U_{fs} = (11.61)U_{fs} \qquad (9)$$

Using the vortex strength factor constant, k/k_o, given in EC-M96-014 of 0.669, the final strength constant can be calculated by Equation 10.

$$k = (k/k_o)(11.61)U_{fs} = (0.669)(11.61)U_{fs} = (7.767)U_{fs} \qquad (10)$$

The rotation number, N_r, can then be calculated using Equation 11.

$$N_r = \frac{(448.83)kd}{Q} = \frac{(3486.1)(d)(U_{fs})}{Q} \qquad (11)$$

Calculation EC-M96-014 [6] derived the equation for critical height by summing the equation for critical height without rotation with the equation that dominates for large rotations. The resulting equation is given in Equation 12.

$$H_c = d\left[\left(\frac{1.25}{2}\right)(Fr_d)^{0.4} - \left(\frac{25}{2}\right)\left(\frac{d}{D}\right)^4 (Fr_d)^2\right] + d(5.6)\left[\left(N_r \frac{H_c}{d}\right)^{0.84} Fr_d\right]^{\frac{1}{2}} \qquad (12)$$

7.0 CALCULATION COMPUTATION

7.1 Condensate Storage Pool (CSP)

The required flowrate from the Condensate Storage Pool, CMUMPOL0001, into the Emergency Feedwater (EFW) Pump suction piping is calculated based on the decay heat load at the time the CSP is near empty and the heat load from operating four Reactor Coolant Pumps (RCPs).

The time at which the decay heat load is taken is based upon the Typical Feedwater Capacity versus Time Remaining Until Shutdown Cooling Required curve [4]. The initial water available in the CSP is 170,000 gallons, and the estimated upper bound CSP level for vortexing is 10% or 21,063 gallons [5]. Therefore, the Feedwater Capacity to use on the curve is approximately 149,000 gallons. The corresponding Time Remaining Until Shutdown Cooling Required is 9.2 hours. This calculation will conservatively use 4.5 hours.

At 4.5 hours post-accident, the upper bound decay heat load is 0.010454% of full thermal power [23]. Full thermal power per the Cycle 10 Power Uprate Safety Analysis Groundrules is 3661 MW, and the heat input by operation of four RCPs is 22.8 MW [24]. The total heat load at 4.5 hours post accident, in Btu/min, is calculated as follows.

$$q = \frac{[22.8 + (3661)(0.010454)](3,413,000)}{60} = 3,473,985 \ \text{Btu}/\text{min}$$

The volumetric Emergency Feedwater flowrate to maintain steam generator level is calculated by dividing the heat load by the change in enthalpy between the CSP water and saturated steam in the steam generator. Using the EFW pump suction piping design temperature of 115°F [15], gives an initial enthalpy of 83 Btu/lb [25]. At the lowest set main steam safety valve set pressure, including As-found tolerance, of 1102 psig [15], the saturated liquid enthalpy is 560 Btu/lb, and the latent heat of vaporization is 628 Btu/lb [25]. Therefore the EFW flowrate can be calculated as follows.

$$Q = \frac{q}{\Delta h} v(7.48052) = \frac{3,473,985}{[(560-83)+628]}(0.01618)(7.48052) = 381 \ \text{gpm}$$

The penetration for the Emergency Feedwater Pump suction piping is located 2.5 ft from the wall of the CSP [9]. Therefore, the sink radius is 2.5 ft. In order to calculate the sink velocity, V_s, Equation 1 is used.

$$V_s = \frac{381}{\pi(448.83)(2.5)^2} = 0.043 \ {}^{ft}\!/_{sec}$$

The sink Froude number is calculated using Equation 2.

$$Fr_s = \frac{(0.043)^2}{(32.2)(2.5)} = 2.30x10^{-5}$$

The critical height is calculated using Equation 3.

$$H_c = (2.5)\left[1.25\left(\frac{2.30x10^{-5}}{2}\right)^{\frac{1}{5}} - 0.25\left(\frac{2.30x10^{-5}}{2}\right)\right] = 0.32 \text{ ft}$$

Therefore, the minimum water level in the CSP to prevent vortexing into the EFW suction piping is 3.84 inches (0.32 ft) which corresponds to a liquid level of 1.53% [5].

W3F1-97-0111

SUPPLEMENT TO

NPF-38-179

ATTACHMENT C

VISUAL REPRESENTATION of CHANGES

Attachment C
CSP Level Comparison