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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Additional Information Supporting Request for License Amendment Regarding Ultimate Heat Sink

References:

1. Letter from P. R. Simpson (Exelon Generation Company, LLC) to U.S. NRC, "License Amendment Regarding Ultimate Heat Sink," dated June 30, 2009
2. Letter from M. J. David (U.S. NRC) to C. G. Pardee (Exelon Nuclear), "Byron Station, Unit Nos. 1 and 2 – Request for Additional Information Related to License Amendment Regarding Ultimate Heat Sink (TAC Nos. ME1669 and ME1670)," dated December 11, 2009

In Reference 1, Exelon Generation Company, LLC (EGC) requested a license amendment for Byron Station, Units 1 and 2, to revise Technical Specifications (TS) to add additional essential service water (SX) cooling tower requirements as a function of SX pump discharge temperature to reflect results of a revised analysis for the ultimate heat sink (UHS). In Reference 2, the NRC requested additional information to complete review of the proposed license amendment. In response to this request, EGC is providing the attached information.

Attachment 1 provides the response to the request for additional information. Attachment 2 includes revised markups of the affected TS pages. Appropriate changes to the TS Bases will also be made upon implementation of the proposed changes.

EGC has reviewed the information supporting a finding of no significant hazards consideration, and the environmental consideration, that were previously provided to the NRC in Attachment 1 of Reference 1. The additional information provided in this submittal does not affect the bases for concluding that the proposed license amendment does not involve a significant hazards consideration. In addition, the additional information provided in this submittal does not affect the bases for concluding that neither an environmental impact statement nor an environmental assessment needs to be prepared in connection with the proposed amendment.

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There are no regulatory commitments contained in this letter. If you should have any questions concerning this letter, please contact Ms. Jean M. Smith at (630) 657-2813.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 25th day of January 2010.

Respectfully,

Patrick R. Simpson
Manager – Licensing

Attachments:

1. Response to Request of Additional Information
2. Revised Markup of Proposed Technical Specifications Pages
3. Additional References

ATTACHMENT 1
Response to Request for Additional Information

NRC Request 1 – Operator Actions

NRC Request 1.a

Based on the revised design basis analysis for the UHS, it appears that there are two manual actions being credited: 1) manual initiation of cooling tower fans at the 10 minute mark of a loss-of-coolant accident (LOCA - scenarios 8D and 8D1); and 2) shedding of half the heat load at or prior to the 30 minute mark of a LOCA. Are these the only two manual actions being credited in the new UHS analysis? If not, please identify all manual actions being credited in the UHS analysis.

Response

Three operator actions are credited in the UHS temperature analyses:

1. Operator action will be taken within ten minutes to align the service water cooling tower (SXCT) to maximize the heat removal capacity. This action includes: 1) Opening riser valves, 2) Closing hot water basin bypass valves, 3) Verifying/Starting cooling tower fans in high speed, and 4) Closing the associated riser valve of any fan that does not start in high speed.
2. If a bypass valve fails to close, operator action will be taken within 30 minutes to manually close the bypass valve at the cooling tower.
3. If required, operator action will be taken at or prior to 21 minutes to turn off two of the four reactor containment fan coolers (RCFCs) to shed load.

NRC Request 1.b

Have any available times for significant operator actions been reduced for other accident scenarios and events, such as anticipated transients without scram, due to the revised UHS analysis? If so, list the operator actions required and the completion times assumed in the analysis.

Response

The proposed operator actions for this proposed change do not reduce any available times for significant operator actions for other accident scenarios and events.

NRC Request 2 – Operating Procedures

NRC Request 2.a

Describe any changes to operator actions in the emergency operating procedures, abnormal operating procedures, or other procedures required by the proposed LAR and how these changes will be integrated into the operator training program.

Response

No change to the emergency operating procedures or abnormal operating procedures are required for Actions 1 and 2 listed in the response to NRC Request 1.a. above. Steps to take these actions were added to the emergency operating procedures as part of the 1992 design basis reconstitution and associated Technical Specifications (TS) changes. Action 3 listed in the response to NRC Request 1.a. above will be added to the appropriate emergency operating procedures. The procedure changes associated with this TS amendment will be included in the Licensed Operator Continuing Training. The associated task involving the implementation of the primary emergency operating procedures requiring operator actions for this accident scenario is already in the Licensed Operator Continuing Training program at a required two year frequency. A review of the Licensed Operator Continuing Training program identified that over the six year period from 2004 through 2009, Large Break LOCA response was included in 19 simulator training scenarios, because that event is one of the three major emergency procedure accident scenarios.

NRC Request 2.b

What alarms, annunciators, or other alerting mechanism will be used to cue the operators that actions are required?

Response

The operators would be alerted to failures of required alignments via feedback/cues from current main control board (MCB) panel design indications (e.g., trip alarm when fan start is attempted, valve position indication does not change when MCB manipulation is attempted, etc.). These cues would inform the operator that "Response Not Obtained" actions are required. All the valves involved in the desired lineup requirements have open and close indications and controls on the MCB. An alarm and MCB amber disagreement light are the current indicators of when a fan control switch is positioned for fan start and the fan breaker is not closed.

NRC Request 2.c

Given that the assumed actions for UHS occur during the first 10 minutes and the first 30 minutes of a LOCA, what alternative actions are possible if an operator error of omission or timing occurs? What feedback or cue will alert operators to the fact that a required action has not been completed?

Response

If an operator error of omission occurs the increasing essential service water (SX) supply temperature will cause various high temperature alarms. The immediate operator action specified in the alarm response procedure for the SX pump discharge header temperature alarms directs the operators to procedures 1/2BOA PRI-7, "Essential Service Water Malfunction Unit 1/2," and BOP SX-T2, "SX Tower Operation Guidelines." Both of these procedures provide guidance on opening riser valves, starting all SXCT fans, and closing the bypass valves.

NRC Request 3 – Control Room Controls, Displays (Including the Safety Parameter Display System), and Alarms

NRC Request 3.a

Describe any changes, additions, or deletions to the main control room interface including setpoint changes and alarms.

Response

No control room changes are required.

NRC Request 3.b

What, if any, plant specific simulator modifications will be required?

Response

No modifications of control room controls, displays, or alarms of the reference unit, Byron Station Unit 1, are planned. The simulator is modeled after the reference unit; therefore, no modifications to the simulator will be needed.

NRC Request 4 – Control Room Plant Reference Simulator

NRC Request 4.a

How will the licensee verify the plant simulator's fidelity after the proposed LAR-related modifications are made?

Response

There are no modifications planned. The simulator will continue to be tested according to, and verified to be in compliance with, the applicable ANSI Standard (i.e., ANSI/ANS-3.5-1985, ANSI/ANS-3.5-2009 "Nuclear Power Plant Simulators for Use in Operator Training and Examination").

NRC Request 4.b

How have credited operator actions been validated as feasible and reliable? Include a discussion of both in-control room and ex-control room actions.

Response

The credited operator actions are considered feasible and reliable based on the following:

1. Operator action to align the SXCT to maximize the heat removal capacity is directed by Step 14.g. of emergency operating procedures 1/2BEP-0, "Reactor Trip or Safety Injection." The associated task involving the implementation of the primary emergency

operating procedures requiring operator actions for this accident scenario is already in the Licensed Operator Continuing Training program at a required two year frequency. A review of the Licensed Operator Continuing Training program identified that over the six year period from 2004 through 2009 Large Break LOCA response was included in 19 simulator training scenarios, because that event is one of the three major emergency procedure accident scenarios. Time testing on the simulator indicates that Step 14.g. is reached in approximately six minutes. The actions to open riser valves, close bypass valves, and start fans in high speed can be performed from the control room and can be completed within ten minutes.

2. Action to dispatch an operator to manually close the bypass valve at the cooling tower was validated by a combination of simulator time, actual measured time to dispatch the operator to the valve, and estimated time to manually close the valve using the handwheel. The total time was conservatively determined to be 20 minutes.

3. Operator action to turn off two out of four RCFCs has not yet been specifically added to the procedures or time validated. The procedure changes and implementation are planned for 2010. As discussed above, the step to start all fans in high speed is reached in approximately six minutes. The action to turn off RCFCs can be taken from the control room. It is reasonable to assume that with the appropriate steps added to the procedures, the control room operators can recognize that fans did not start and take action to secure two RCFCs well before the assumed 21 minutes used in the analysis.

NRC Request 5

Attachment 4, "Analytical Basis for Proposed Changes to TS," and Attachment 7, "Evaluation of Additional Scenarios for Postulated Single Failures," of the June 30, 2009, LAR provide the scenarios for postulated single failures of electrical circuit breakers serving SX system components occurring concurrent with a LOCA and a loss of offsite power on one unit with the opposite unit in normal shutdown. Provide a detailed discussion and supporting calculations why the scenarios analyzed in the LAR are bounding, considering both active and passive failures.

Response

Previous analyses for the 1992 ultimate heat sink (UHS) design basis reconstitution and March 31, 1992, license amendment request (Amendment 54 approved on May 17, 1993) evaluated a variety of initial conditions and single active failures. Postulated single active failures analyzed included: 1) Containment Spray (CS) pump failure, 2) SXCT fan failure, 3) Emergency Diesel Generator (EDG) failure, 4) SX pump failure, and 5) SX bypass valve failure. For comparison, the following results were obtained in the 1992 revisions of the UHS calculations for the different single active failure scenarios:

Single Active Failure	Initial Basin Temperature (°F)	Calculated Peak Basin Temperature (°F)
CS Pump	96	96.5
SXCT Fan	96	99.1
EDG Failure	96	96.0
SX Pump	96	96.0
0A SX Bypass Valve Fails Open	70	91.4
0B SX Bypass Valve Fails Open	70	90.9
EDG Failure which prevents Closure of an SX Bypass Valve	70	89.8

Subsequent revisions of the analysis for Steam Generator Replacement and Power Uprate focused on the most limiting scenarios of cooling tower fan and bypass valve failures.

For this license amendment request, analyses were revised to address postulated passive electrical failures that could result in the loss of two SXCT fans. Calculations UHS-01 Revision 4, "Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios," and UHS-04 Revision 3, "Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios for Cool Weather Operation," in Attachment 3 of this document were prepared to identify the bounding electrical failure scenarios. Additionally, a number of variations of scenario 8C (i.e., two fans initially out of service) were run to determine the bounding scenario.

The scenarios for this analysis are considered bounding, because two SXCT fans are assumed to fail with the full heat input until operator action can be taken to reduce the load. This scenario is more limiting than an EDG failure, because an EDG failure results in loss of power to two SXCT fans and two RCFCs. Thus, the heat load is lower for the EDG failure scenario.

NRC Request 6

Attachment 5, "Validation of Assumption 3.1 of Analytical Basis for Proposed Changes to Technical Specifications (TS)," of the LAR discusses the validation of Assumption 3.1 from the calculation in Attachment 4. Assumption 3.1 states that the fraction of water cooled for SX cooling tower cells with fans not running is assumed to be 0.10 (i.e., 10 percent) of the water delivered to that cell is effectively cooled. Assumption 3.1 also states that the cooling tower manufacturer provided 10 percent as a reasonable estimate for minimum cooling tower performance without fan air flow. Attachment 5 assumes an initial service water temperature of 98°F (Section 2.3), and the resulting maximum basin temperature is 113.7°F, when 10 percent cooling was used. Attachment 5, Section 8.0 concludes that, in comparison, greater than 10 percent cooling was used to calculate the maximum basin temperature of 109.3°F in Ceramic Cooling Tower Company Engineering Report NCT-683-55, "Response to Sargent and Lundy letter of 11-17-81; Complete Loss of Fans," and hence, 10 percent cooling is conservative. However, Report NCT-683-55 (page I15 of Attachment 5) states that the initial SX temperature entering the plant is 91 °F and, after the first cycle of cooling, the water leaving the fill area is 92.8°F. Provide a detailed explanation of the assumptions used in Report NCT-683-55 with regard to the SX temperature used. In addition, explain how the calculations are correlated (and can be compared) when different initial conditions are used, and how the comparison of the calculations validate the 10 percent cooling. Furthermore, is the value of 10 percent cooling affected by weather conditions such as outside temperature, wet bulb temperature, or humidity? If so, provide a detailed explanation of how the 10 percent value is conservative under different weather conditions.

Response

Report NCT-683-55 was prepared to predict performance of the SXCT with the postulated loss of all eight fans. The analysis performed by Ceramic Cooling Tower Company assumed an initial basin temperature of 91 °F. Original construction design criteria indicates that under normal operating conditions concurrent with 78 °F wet bulb, the maximum Byron SX temperature was expected to be approximately 91 °F with fans running in low speed. The expected maximum normal operating temperature was specified as the initial basin temperature for the NCT-683-55 analysis.

The NCT-683-55 calculation determined a predicted operating equilibrium temperature of:

Hot Water Temperature (HWT) Entering the Towers	112.2 °F
Cold Water Temperature (CWT) Leaving the Tower Fill Area	109.3 °F
Heat Dissipation	150×10^6 Btu/hr

For the same heat load, wet bulb temperature, flow of 13,000 gpm per cell, and an assumed ten percent cooling tower performance when no fans are in operation, the MathCAD model calculated an operating equilibrium temperature of 113.7 °F for the cold water temperature leaving the tower fill area.

The calculated equilibrium temperature is independent of the initial basin temperature. The MathCAD file was changed to use an initial basin temperature of 91 °F; Attachment 3 of this document contains the MathCAD file. After the first cycle of cooling ($\tau1$ = 1.068E6 gallons/104,000 gpm = 10.27 minutes) the MathCAD model predicted temperature is 93.6 °F, which is slightly higher than 92.8 °F predicted in NCT-683-55. The calculated equilibrium temperature remains 113.7 °F.

The comparison of the equilibrium temperatures indicates that assuming ten percent of water is cooled in a passive tower using the MathCAD model provides conservative results.

Performance testing of the Byron SXCT was performed in 1987. A copy of the test report was submitted to the NRC on February 1, 1988. The NRC retained Idaho National Engineering Laboratory (INEL) to review the test procedures, test data, and results. The NRC issued a Safety Evaluation on April 24, 1989, endorsing the INEL Technical Evaluation Report that concluded the tests done were conservatively designed and resulted in a reasonable estimate of the cooling tower's capability over the expected range of conditions. Cooling tower performance test data from the 1987 cooling tower test program included three tests of a fan cell with the fan off. Comparing the tests with no fan running to tests with similar outside air conditions and water flow rates when the fan was running indicates the heat removal rate with the fan off was between 16 to 21 percent of the heat removal rate with the fan on. This provides additional basis that the ten percent assumption used is conservative.

Cooling tower performance with the fans in service is calculated using the MRL Corporation/Environmental Service Corporation (ESC) model for the Byron cooling tower. The performance curves used as an input to the analysis are generated for the different assumed weather conditions. When a fan is not running, the same performance curve is used, but only ten percent of the water is assumed to be cooled.

From "Cooling Tower Fundamentals" published by SPX Cooling Technologies, the percentage of cooling tower performance with fans off versus fans on does get smaller as the wet bulb temperature drops. The ten percent value used in the analysis is considered conservative under different weather conditions, because the analyses were performed with assumed wet bulb temperatures of 70, 76, 78, and 82 °F. The cooling tower test data from the 1987 cooling tower test program that showed heat removal rate with the fan off was between 16 to 21 percent of the heat removal rate with the fan on was performed when wet bulb temperatures were between 67 and 68 °F. Thus, at the higher wet bulb temperatures used in the analysis for this proposed change, the heat removal rate with the fan off would be expected to be slightly higher than the 16 to 21 percent of the heat removal rate with the fan running.

NRC Request 7

The fan requirements of the UHS are dependent on the SX pumps' discharge temperature. New TS Table 3.7.9-1 states these fan requirements and defines the associated Limiting Condition for Operation (LCO). Note (a) of this table could be construed to reduce the fan requirement when in Condition B. Since this note is associated with the column of the table that specifies LCO requirements, an interpretation of Note (a) could imply that the fan requirements for the LCO are satisfied if in Condition B and there is one less fan running in high speed. Then one might conclude the plant is no longer in Condition B. This could present confusion as to the actual condition of the UHS.

Furthermore, Condition A explicitly states that if one or more required cooling tower fans are not running in high speed, then actions must be taken immediately to correct the condition and, if not corrected immediately, then Condition J should be entered and the plant must be shutdown. This would mean that when the plant was running high speed fans to meet the LCO requirements of Table 3.7.9-1 with the other fans out of service, failure of one or more of the running fans would cause entry into Condition J and Mode 3 in 6 hours. The same situation would exist if SX temperature increased such that an additional fan in high speed was required in accordance with Table 3.7.9-1 and an additional fan was not available.

Per discussion with the licensee via telecom on November 18, 2009, the licensee stated that the intent was, if in Condition B, to keep the remaining fans running in high speed during the 72 hours that the UHS was in Condition B. The intent was also to exit Condition A, if also in Condition B, and only one required fan (not more than one fan) was not running in high speed.

The licensee needs to explain how Note (a) of Table 3.7.9-1 and Condition A are not subject to possible misinterpretation or reword/relocate Note (a) of Table 3.7.9-1 and Condition A, as applicable, such that the intent of the LCO, Condition, Required Actions, and Completion Time of Conditions A and Condition B are not subject to possible misinterpretation.

Response

In response to the concern for possible misinterpretation with Note (a) of Table 3.7.9-1 and its relationship to Conditions A and B, Note (a) has been eliminated from Table 3.7.9-1, and Condition A has been reworded to read "One or more OPERABLE cooling tower fan(s) not running in high speed as required by Table 3.7.9-1." The proposed note for Condition A has also been eliminated. As defined in the TS Bases, an operable cooling tower fan must be capable of running in high speed. If Table 3.7.9-1 requires operable cooling tower fans to be running in high speed and one or more are not, then required Action A.1 would direct actions to be initiated immediately to place those required operable fan(s) that are currently operable in high speed mode. If Table 3.7.9-1 requires operable cooling tower fans to be running in high speed and one required fan is not capable of running in high speed, then the fan is considered inoperable. In this case, Condition B would apply. Condition A would not apply to this situation, since the fan is not operable. If Table 3.7.9-1 requires operable cooling tower fans to be running in high speed and more than one required fan is not capable of running in high speed, then these fans are considered inoperable. In this case, Condition J would apply.

Table 3.7.9-1 has been revised to encompass all SX pump discharge temperature ranges. Subsequently, the word "ADDITIONAL" has been removed from the heading of the second column of Table 3.7.9-1, and SR 3.7.9.2 has been revised to read "Verify cooling tower fan requirements in Table 3.7.9-1 are met."

The LCO statement has been revised to state "The UHS shall be OPERABLE and the SX cooling tower fans shall be OPERABLE and operating as specified in Table 3.7.9-1." This revision ensures consistency with other LCOs that contain tables that further define the LCO requirements. In addition, a typographical error was corrected in Required Action B.2; the word "fans" has been changed to "fan."

Condition C has been modified to read "Two inoperable cooling tower fans not required to be OPERABLE by Table 3.7.9-1 that are powered by the same electrical division." Attachment 2 provides the revised markups of the affected TS pages.

NRC Request 8

Each accident scenario described in Attachment 4 to the June 30, 2009, LAR specifies that half of the reactor containment fan cooler (RCFC) heat load is subtracted at 30 minutes. The "UHS Accident Heat Load Profile L42" for each accident scenario shows the slope of the decreasing heat rate (MBTU/hr) input into the UHS becoming less negative at the time (approximately 1800 sec) when the RCFC heat load is removed from the UHS. Intuitively, it should be more negative because a set of RCFCs is no longer providing heat to the UHS.

a. Explain why the heat load profile shows a decrease in the slope of the decreasing heat rate profile at 1800 seconds. How does this relate to removing one-half the RCFC heat load to the UHS?

b. What is the cause of the rapid decrease in the heat input at t = 1400 seconds?

Response

The calculated total heat load to the UHS with load shedding is as follows:

Time (seconds)	Total Heat Load to the UHS (Btu/hr)
1,299	8.04E+08
1,799	5.27E+08
2,399	4.52E+08

The large decrease in load between time 1,299 and 1,799 seconds is caused by the reduction in RCFC heat load assumed to be complete at time = 30 minutes. The smaller decrease in load between 1,799 and 2,399 seconds is a reduction in decay heat input to containment that results in lower accident unit heat load.

MathCAD uses a linear interpolation of the heat load and time data points to generate the curves in Attachment 4. With a linear interpolation, the MathCAD curve shows a rapid decrease in the heat load starting at time 1,299 seconds ending at time 1,799 seconds (i.e., the RCFC heat input starts to reduce at time = 1,300 seconds and is complete at time = 1,799 seconds). The slope of the curve becomes less negative after the RCFC load reduction is complete at time = 1,800 seconds.

The technical evaluation for the previously submitted proposed changes indicated that action to shed heat load by securing up to two of the four RCFCs would be taken within 30 minutes. Based on the method for inputing and using load in the calculations, the time to complete the action to shed heat load is actually 21.6 minutes. As discussed in the response to NRC Request 4.b. above, the operator actions to secure RCFCs are expected to start and complete well before 1,300 seconds (21.6 minutes).

NRC Request 9

Assumption 3.3 in Attachment 4 of the LAR states that, for scenarios 8D and 8D1, no cooling is credited prior to fan initiation at 10 minutes after the LOCA.

Cold weather scenarios 10 through 13 require fans to be started and riser valves to be opened within 10 minutes of the LOCA and bypass valves to be manually shut within 30 minutes.

NRC Request 9.a

Explain the existing or planned processes and procedures that cause the required number of fans, the required fan speed and applicable valves to be open or shut within 10 and 30 minutes after the LOCA such that UHS basin temperature will not exceed 100°F.

Response

Emergency Operating Procedures 1/2BEP-0 Step 14.g. directs the operators to open the riser valves, close the hot water basin bypass valves, and verify/start the cooling tower fans in high speed. The Response Not Obtained column directs the operators to dispatch operator(s) to close any open hot water basin bypass valve and if any fan does not start in high speed, then close its associated riser valve. As discussed in the response to NRC Request 4.b., these actions support the assumed action times used in the temperature analyses.

NRC Request 9.b

Specify what operator actions from the control room and outside the control room, and their time completion requirements, are necessary for each scenario.

Response

Three operator actions are credited in the UHS temperature analyses:

1. Operator action will be taken within ten minutes to align the service water cooling tower (SXCT) to maximize the heat removal capacity. This action includes: 1) Opening riser valves, 2) Closing hot water basin bypass valves, 3) Verifying/Starting cooling tower fans in high speed, and 4) Closing associated riser valve of any fan that does not start in high speed. These operator actions are taken from the control room.
2. If a bypass valve fails to close, operator action will be taken within 30 minutes to manually close the bypass valve at the cooling tower. This action is taken outside the control room.
3. If required, operator action will be taken at or prior to 21 minutes to turn off two of the four RCFCs to shed load. Actions to turn off the RCFCs will be taken from the control room

NRC Request 9.c

Explain the basis for assuming initial basin temperature is 74°F in scenarios 10 through 13.

Response

The cold weather scenarios evaluate the cases when the SXCT bypass valves may be open to prevent overcooling. The bypass valves are typically controlled manually but will auto-open when SX pump discharge temperature drops below 52 °F and will auto-close when SX pump discharge temperature increases above 70 °F. An initial basin temperature of 74 °F was selected to provide margin to the bypass valve auto-close setpoint.

NRC Request 10

The LAR specifies a new Surveillance Requirement 3.7.9.10, which will check outside wet bulb temperature every 12 hours. Discuss what instrumentation will be used to obtain these temperature measurements.

Response

Three options for checking outside wet bulb temperature for the surveillance requirement (SR) are planned.

Option 1: Obtain the outside air dry bulb temperature reading from the plant computer (input is from the met tower). If the outside air dry bulb temperature is below the SR temperature then the SR requirement is satisfied (wet bulb temperature cannot be below the dry bulb temperature).

Option 2: If the outside air dry bulb temperature reading is above the SR temperature, obtain the dew point temperature reading from the plant computer (input is from the met tower). A website-based calculator will then be used to obtain the wet bulb temperature using the outside air temperature and dew point readings.

Option 3: If the met tower data or the website is not available, a hand-held instrument will be used to directly measure the wet bulb temperature.

NRC Request 11

Attachment 4, Section 6.0, Method of Analysis, refers to the "ESW [essential service water] cooling tower transient model" from Appendix G of calculation NED-M-MSD-009.

NRC Request 11.a

Discuss the origin of this model and how it relates to the current licensing basis of the UHS.

Response

The time-dependent, two-cooling-tower model was developed as part of the 1991 Byron UHS Design Basis Reconstitution effort and is described in a January 9, 1992, report to the NRC. The model has been used in support of Byron's March 31, 1992, and May 6, 1997, license amendment requests. The model was used to develop the current Technical Specifications limits on basin UHS temperature.

NRC Request 11.b

For the cooling tower transient model:

- Define and explain the cooling tower transient model; include discussing the governing equations and process variables; include identifying the input to the model from various calculations. Discuss the accuracy of the model by comparing predicted model performance with actual test or operational data.

- Discuss how the model accounts for varying SX flow rates, as some accident scenarios have closed riser valves and/or open bypass valves.

- Discuss how the model accounts for time varying LOCA heat loads from the SX system to the UHS.
- Include how the model accounts for varying number of fans running in either fast speed or slow speed.
- Explain how the model accounts for varying dry bulb temperatures at the maximum wet bulb temperature.
- Discuss how the model predicts bulk UHS basin temperature, which is limited to 100°F.

Response

Please refer to Calculations NED-Q-MSD-1, "ESW Cooling Tower Transient Model: Part I," and NED-Q-MSD- 6, "ESW Cooling Tower Transient Model: Part III," in Attachment 3 of this document for the governing equations and variables. In the MathCAD model, the solution to the time-dependent basin temperature is approximated by a first-order Taylor expansion. The MathCAD model results were compared to hand calculations based on the exact analytical solution of the differential equation describing the transient response of the basin temperature. The comparison showed only small differences, and the MathCAD program was judged to provide acceptable results. Subsequently, the MathCAD model equation was enhanced to account for bypass flow in both towers.

The following inputs are used in the transient temperature model:

- The cooling tower performance curves (T_{hot} vs T_{cold}) are generated using the MRL/ESC model for the Byron cooling tower. The following description of the MRL/ESC model was provided in the January 9, 1992, Byron UHS Design Basis Reconstitution Final Report submittal to the NRC (Note – refer to the January 9, 1992 report for quoted reference documents):

> Cooling tower performance is dependent upon the three parameters; ambient wet bulb temperature, heat load, and water/air flow rates. In turn, values for each of these are dictated by features of the specific accident scenario under evaluation. This section describes the program undertaken by CECo to determine the performance of the Byron UHS cooling towers under the postulated accidents discussed above.
>
> The heat transfer model used to evaluate and predict the performance of these cooling towers was derived from the Merkel theory developed in 1925, as modified by M.R. Lefevre in 1984 (Reference 22). As water passes through the fill region of the tower it is dispersed into a large number of small droplets so as to maximize the heat transfer surface area. Merkel assumed that at a given elevation in the tower each water droplet has a uniform temperature and is surrounded by a film of fully saturated air at the same temperature. Heat is transferred from the water primarily by evaporation from the film into the air. Additionally, because the air is cooler than the water, some degree of sensible heat transfer takes place as well. Using several approximations Merkel showed

that the total rate of heat transfer was proportional to the droplet-film to air enthalpy difference. This relationship was then incorporated into an integral, referred to as the demand integral, which could be used directly to evaluate tower performance.

M. R. Lefevre's contributions improved upon the earlier approximations with the end result that more accurate and conservative predictions of tower performance were achieved. Using these principles, the MRL Corporation developed a general computer program, which as used extensively in the UHS reconstitution effort.

The Byron UHS cooling tower test program was completed in 1987 and had as the main objective the determination of the tower characteristic, (Ref. 3). A total of 33 separate tests were completed, with varying wet bulb temperatures, water flow rates and heat loads. Simultaneous measurements of the air flow allowed for the relationship of air-to-water flow to be determined as well. The tower characteristic and air-water curve are required when predicting performance at conditions other than those directly measured. These Byron specific cooling tower functions were then incorporated into the MRL computer program by Environmental Systems Corporation.

Before using a computer program for safety-related applications it must first undergo a validation-verification process per CECo procedures. The validation plan utilized a hand calculation to independently verify the accuracy and reliability of the code (Ref. 23). The results of this comparison are documented in the validation report (Ref. 15).

The hand calculation used the MRL heat transfer model, together with the Byron UHS tower characteristic and air/water flow relationship. The only differences between the hand calculation and the computer program methodology were as follows:

1. The MRL program used a multi-point Simpson's Rule integration scheme to evaluate the demand integral; the hand calculation used the alternate method of Gaussian Quadrature to complete this task, and
2. The program used an iteration scheme to determine the sensible and latent heat transfers separately, instead of assuming fully saturated air upon entry into the tower, as was the case in the hand calculation.

A total of nineteen comparisons between the MRL program outputs and the hand calculations were made, (Ref. 9). The main parameters were varied over the following ranges:

-ambient wet bulb temperature: 50, 70 and 82 °F Twb
-water flow per cell: 6,000; 8,000; 10,000; and 16,500 gpm
-cooling tower range (ΔT): 4, 20, 23, 30, 38 and 40 °F

These broad parameter variations enveloped the conditions required for evaluation of the accident scenarios.

The level of agreement between the MRL program predictions and the hand calculations was shown to be very high. Values of the predicted cold water basin temperature agreed to within - 0.40 to + 0.02 °F with an average difference of - 0.09 °F. Additionally, for all but three cases, the hand calculations yielded cold temperatures below those given by the program. The MRL program, then, as judged by the hand calculation, was seen to give conservatively high values of cold water temperatures over a wide spectrum of flows, cooling tower ranges and wet bulb temperatures.

In summary, this reanalysis of the performance testing of the Byron cooling towers confirms the results obtained in 1987. Therefore, the tower characteristic and resultant predicted performance remain unchanged from that given in the ESC test report (Ref. 3). Further, the successful validation of the Byron specific MRL computer program allows for its use at conditions specified by each accident scenario.

- New total heat load versus time input was calculated for scenarios where RCFC heat load was shed at 30 minutes. Please refer to the response to NRC Request 12.a below for additional information on the heat load input to the model. The MathCAD time dependent two cooling tower model uses a linear interpolation function to determine the heat input to the UHS for each time step when integrating to solve for basin temperature.

- Total flow to the towers, flow to the individual risers in the towers, and RCFC flows are generated for each scenario using the Byron SX PIPE-FLO model. The flow model accounts for the varying flow rates for each scenario due to closed riser valves and/or open bypass valves. When operator action is assumed to close riser valves or bypass valves, separate inputs are calculated and used in the MathCAD time dependent two cooling tower model and the integration is split into separate time intervals (i.e. t_i = 0 to 10 minutes, t_i = 10 to 30 minutes, and t_i > 30 minutes).

- SX water inventory is determined based on the TS minimum level.

Tower cells are either considered to be active with the fans running in high speed or passive with fans not running in high speed. When fans are running in low speed the cell is conservatively assumed to be passive.

The cooling tower performance curves are conservatively based on the limiting wet bulb temperature and a relative humidity of 75 percent. This results in a constant air inlet dry bulb temperature for the event. For the design wet bulb temperature of 82 °F, the dry bulb temperature at 75 percent relative humidity is 88.9 °F. For a mechanical draft cooling tower, the wet bulb temperature is the primary driver of thermal performance.

NRC Request 11.c

Page H6 refers to "Eq (3)" which is not defined in the LAR. Describe and define Eq (3), and discuss how it relates to the essential service water cooling tower transient model which predicts UHS performance.

Response

Page 12 of Calculation NED-M-MSD-009 defines Equation 3 as:

$$Tb_{i+1} = Tb_i + (ATb_i + Lt_iB + C)H$$

Where:

Tb_i = Basin Temperature at time t_i

A, B, and C = Intermediate constants

Lt_i = Total heat load at time t_i

H = time step size used

The MathCAD transient model uses this formula to calculate incremental changes in temperature for the time increment.

NRC Request 12

Attachment 4, Section 6.0, Methods of Analysis, Item 1 refers to the revised total heat load to the UHS curve and Item 3 refers to the new flow rates and tower performance curves.

NRC Request 12.a

Discuss the reasons why the total heat load to the UHS had to be revised for this LAR. Discuss the conservatism and design margin of the revised total heat load to the UHS.

Response

For the postulated passive electrical failures, preliminary runs were made to determine the required initial basin temperature for 0, 1, and 2 fans out of service. The preliminary results with the existing total heat load indicated that for some of the postulated scenarios the required initial basin temperatures to keep the peak basin temperatures below the design temperature of 100 °F would be too low to support plant operation in the summer months (the required initial basin temperature was below typical summer basin temperature ranges). Thus, it was decided to pursue load shedding for the passive electrical failure scenarios.

The primary conservatism in the calculated heat load is in how the accident heat load was calculated. For the first hour of an event, the heat input for the time dependent accident unit is the bulk of the heat load (78 to 91 percent of the total heat load). The calculated heat input from the accident unit is maximized by:

- RCFC performance is maximized by assuming: higher SX flow rates, higher airflow rates, and an SX supply temperature of 32 °F. In actuality, the initial SX water supply temperature is typically near 70 °F and will quickly approach the design temperature of 100 °F during an event with failures that minimize UHS heat removal.
- Assuming earlier switchover to containment recirculation phase and corresponding earlier Residual Heat Removal (RH) heat loads.
- Component Cooling (CC) Water and RH heat exchanger performance is maximized by assuming the clean heat exchanger transfer rate and maximum water flows.

Additionally, the design heat load for the heat exchangers and coolers served by the SX system was used to maximize the constant miscellaneous heat input to the UHS. For this LAR the heat load from equipment that has been abandoned reduced the constant miscellaneous heat load.

NRC Request 12.b

Discuss why new tower flow rates and tower performance curves had to be generated for this LAR. Discuss the conservatism and design margin of the new flow rates and tower performance curves.

Response

Cooling tower performance is dependent on the water flow rate through the tower fill. Previous analyses assumed that for an active fan failure, operator action would be taken to isolate the associated riser valve to optimize heat removal in the cooling tower. Postulated breaker failures would also result in the loss of power to the motor operated riser valves for the impacted SXCT cell. If the riser valve for the affected cell was open prior to the postulated breaker failure, operator actions to isolate the riser valves and redistribute SX return water to active cooling tower cells is not practical (the riser valves are in tornado protected enclosures). Thus, new tower flow rates had to be generated for the postulated breaker failure scenarios. Additionally the amount of assumed riser and bypass valve leak-by was reduced based on new acceptance criteria for valve leak-by monitoring.

New tower performance curves were needed for the revised water flows through the cooling tower fill. New tower performance curves were also needed for the scenarios where two fans are initially out of service on the bus and a lower outside air wet bulb temperature was assumed.

A PIPE-FLO computer model was used to determine total tower, RCFC, and individual tower cell flows. The Byron SX PIPE-FLO model was previously calibrated based on system test data to more accurately predict actual Essential Service Water system flows and pressure conditions.

SX pump performance and flow through the CC heat exchangers were biased high to maximize flow to the cooling towers. A higher flow through the cooling tower cells conservatively reduces cooling tower performance.

NRC Request 13

The calculations for each scenario in Attachment 4 use the terms M11, B11, M12, and B12. Discuss the meaning of these terms and how they are used to determine model performance.

Response

The cooling tower heat exchange process is modeled as a linear function. Hot water enters the fill region of the tower at a temperature, T_h, releases heat to the counter-flowing air by both latent and sensible heat transfer, and enters the basin at the cold water temperature, T_c. The resultant rate of heat transfer for a given mass flow rate, m, is given by the product of m and the temperature decrease, or range, $R = T_h - T_c$. The dependence of T_c, upon T_h, is the relationship approximated as a linear function.

M11 is the slope, and B11 is the intercept for a line that determines Tower 1 performance for first time interval. M12 is the slope, and B12 is the intercept for a line that determines Tower 1 performance for second time interval. See the response to NRC Request 15 below for additional information on the method for calculating M11, B11, M12, and B12.

NRC Request 14

The calculations for each scenario in Attachment 4 use the terms β1 and β2 and define them as the fraction of load to Tower 1. Explain why the fraction is defined in terms of flow to the RCFC only.

Response

The peak temperatures occur early in the events (e.g., the maximum basin temperature in Scenario 8C occurs at 40 minutes). During the initial time of the postulated scenarios, the heat input to the UHS is dominated by the accident heat input, which until the accident unit goes on RH recirculation, is from the RCFCs. The miscellaneous heat loads are generally split evenly between trains. Thus, the RCFC flow fraction provides a reasonable input for the fraction of heat load going to Tower 1.

NRC Request 15

For cooling tower performance, each scenario in Attachment 4 uses temperatures Th1 through Th4 and Tc1 through Tc4. Explain how these values are obtained and how they are used for predicting cooling tower performance.

Response

For each scenario, two points were selected from the applicable tower performance data to provide a linear approximation of tower performance over the range of T_{Hot} and T_{Cold}

temperatures. These points are listed as Th1, Th2, Th3, Th4, Tc1, Tc2, Tc3, and Tc4 in the MathCAD models.

For example in Accident Scenario 8A, the following points taken from the tower performance data are used (a curve of the data is shown in Figure H-1, the actual data points come from Calculation BYR97-127):

Tower 1 (T_{Hot}, T_{Cold}): (119.02, 91.02) and (111.8, 89.8)

Tower 2 (T_{Hot}, T_{Cold}): (118.79, 90.79) and (111.6, 89.6)

In MathCAD, the data is input as a matrix format:

$$\mathrm{Th1} := \begin{pmatrix} 119.02 \\ 111.8 \end{pmatrix} \cdot \mathrm{F} \qquad \mathrm{Tc1} := \begin{pmatrix} 91.02 \\ 89.8 \end{pmatrix} \cdot \mathrm{F}$$

$$\mathrm{Th2} := \begin{pmatrix} 118.79 \\ 111.6 \end{pmatrix} \cdot \mathrm{F} \qquad \mathrm{Tc2} := \begin{pmatrix} 90.79 \\ 89.6 \end{pmatrix} \cdot \mathrm{F}$$

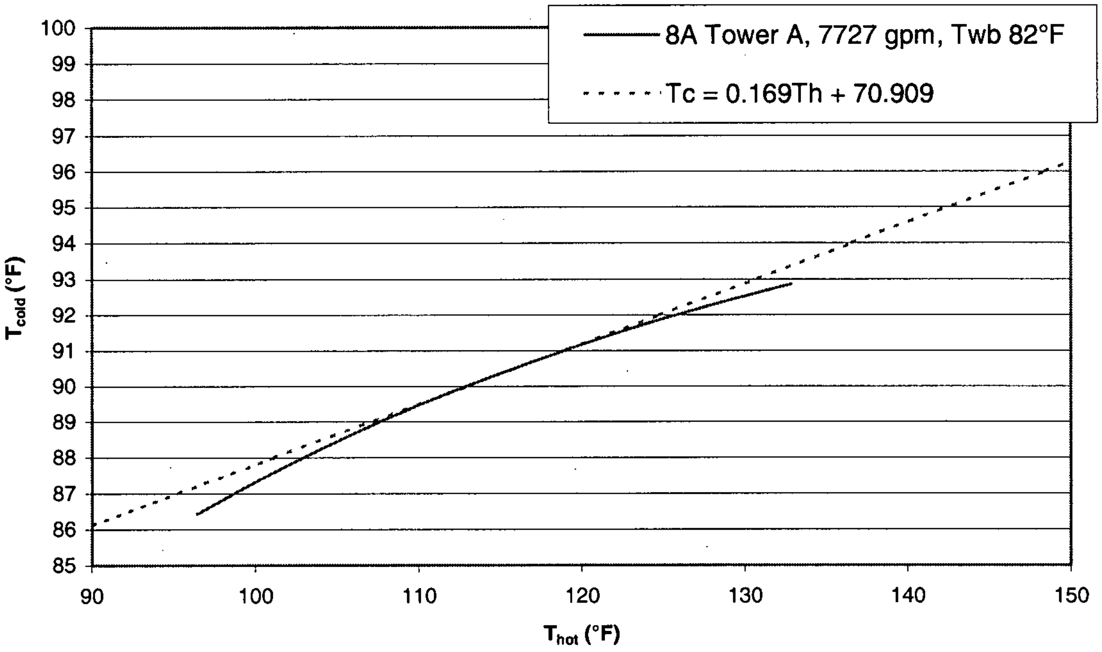
To generate the linear approximation, MathCAD calculates the slope and intercept of the line generated by the two points for each tower. M11 is the slope and B11 is the intercept calculated by MathCAD for Tower 1 in the first time period, and M21 and B21 are the slope and the intercept, respectively, calculated by MathCAD for Tower 2 for the first time period.

To accommodate actions that change the water flow distribution in the towers, the MathCAD model is setup for two time periods. In Scenario 8A, the first time period is time = 0 to 30 minutes and the second period is time ≥ 30 minutes. Th3 and Tc3 provide the tower performance data for Tower 1, and Th4 and Tc4 provide the tower performance data for Tower 2 during the second time period. MathCAD uses the input to calculate the slope and intercept for each tower for the second time period (M12, M22, B12 and B22).

For Scenario 8A there is no change in water flow distribution in the tower, thus Th1 = Th3, Tc1 = Tc3, Th2 = Th4, and Tc2 = Thc4.

Adding the MathCAD generated linear interpolation (M11=0.169 and B11 = 70.909) to the applicable Scenario 8A curve, it can be seen that the straight-line interpolation conservatively envelops the tower performance curve; i.e., T_{cold} is conservatively high for a T_{hot} input value.

Figure H-1: Scenario 8A



ATTACHMENT 2
Revised Markup of Proposed Technical Specifications Pages

Byron Station Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66

REVISED TECHNICAL SPECIFICATIONS PAGES

3.7.9-1
3.7.9-5
3.7.9-6

3.7 PLANT SYSTEMS

3.7.9 Ultimate Heat Sink (UHS)

LCO 3.7.9 The UHS shall be OPERABLE and the SX cooling tower fans shall be OPERABLE and operating as specified in Table 3.7.9-1.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
~~A. One required cooling tower fan inoperable.~~	~~A.1 Verify remaining required OPERABLE cooling tower fans are capable of being powered by an OPERABLE emergency power source.~~ ~~AND~~ ~~A.2 Restore required cooling tower fan to OPERABLE status.~~	~~1 hour~~ ~~72 hours~~
~~B~~. One or more basin level(s) < 60%.	~~B.1~~ Restore both basin levels to ≥ 60%.	6 hours

(continued)

E

E.1

Replace with INSERT 3.7.9-1

INSERT 3.7.9-1

A. One or more OPERABLE cooling tower fan(s) not running in high speed as required by Table 3.7.9-1.	A.1 Initiate actions to operate OPERABLE cooling tower fan(s) in high speed.	Immediately
B. One required cooling tower fan inoperable.	B.1 Verify remaining required OPERABLE cooling tower fans are capable of being powered by an OPERABLE emergency power source.	1 hour
	<u>AND</u>	
	B.2 Restore required cooling tower fan to OPERABLE status.	72 hours
C. Two inoperable cooling tower fans not required to be OPERABLE by Table 3.7.9-1 that are powered by the same electrical division. <u>AND</u> Outside air wet bulb temperature > 76°F.	C.1 Restore cooling tower fan configuration such that two inoperable cooling tower fans are not powered by the same electrical division.	72 hours
D. Essential Service Water (SX) pump discharge temperature > 96°F.	D.1 Be in MODE 3.	6 hours
	<u>AND</u>	
	D.2 Be in MODE 5.	36 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.7.9.1	Verify water level in each cooling tower basin is ≥ 60%.	24 hours
SR 3.7.9.2	~~Verify essential service water pump discharge water temperature is:~~ ~~a. ≤ 80°F;~~ ~~b. ≤ 90°F, with all required cooling tower fans running on high speed; or~~ ~~c. ≤ 96°F, with ≥ 7 cooling tower fans running on high speed.~~	24 hours
SR 3.7.9.3	Verify river water level is > 670.6 ft MSL and ≤ 702.0 ft MSL.	24 hours
SR 3.7.9.4	Operate each required cooling tower fan on high speed for ≥ 15 minutes.	31 days
SR 3.7.9.5	Verify each SX makeup manual, power operated, and automatic valve in the flow path that is not locked, sealed, or otherwise secured in the open position, is in the correct position.	31 days
SR 3.7.9.6	Verify that each SX makeup pump starts on a simulated or actual low basin level signal and operates for ≥ 30 minutes.	31 days

(continued)

Verify cooling tower fan requirements in Table 3.7.9-1 are met.

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.7.9.7	Verify each diesel driven SX makeup pump fuel oil day tank level ≥ 47%.	31 days
SR 3.7.9.8	Cycle each testable valve in the SX makeup pump flow path through at least one complete cycle of full travel.	18 months
SR 3.7.9.9	Verify fuel oil properties are tested in accordance with and maintained within the limits of the Diesel Fuel Oil Testing Program.	In accordance with the Diesel Fuel Oil Testing Program

SR 3.7.9.10	----------------NOTE---------------- Only required when two inoperable cooling tower fans are powered by the same electrical division. -------------------------------------- Verify outside air wet bulb temperature is ≤ 76°F.	12 hours

Add INSERT 3.7.9-2 as a new page

INSERT 3.7.9-2

Table 3.7.9-1 (page 1 of 1)
Cooling Tower Fan Requirements

SX PUMP DISCHARGE TEMPERATURE REGION	REQUIREMENTS
≤ 77°F	6 cooling tower fans are required to be OPERABLE
> 77°F and ≤ 82°F	Either 6 required OPERABLE cooling tower fans running in high speed, or 7 cooling tower fans are required to be OPERABLE
> 82°F and ≤ 84°F	6 required OPERABLE cooling tower fans running in high speed
> 84°F and ≤ 91°F	7 required OPERABLE cooling tower fans running in high speed
> 91°F and ≤ 96°F	8 required OPERABLE cooling tower fans running in high speed

ATTACHMENT 3
Additional References

1. UHS-01 Revision 4, "Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios"
2. UHS-04 Revision 3, "Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios for Cool Weather Operation"
3. MathCAD file for NRC Request 6
4. Calculation NED-Q-MSD-001, "ESW Cooling Tower Transient Model: Part I"
5. Calculation NED-Q-MSD-6, "ESW Cooling Tower Transient Model: Part III"

ATTACHMENT 3
Additional References

1. UHS-01 Revision 4, "Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios"

ATTACHMENT 1
Design Analysis Major Revision Cover Sheet
Page 1 of 5

Design Analysis (Major Revision)
Last Page No. B23
Analysis No.: UHS-01 **Revision:** 4
Title: Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios

EC/ECR No.: EC 371386 **Revision:** 0

Station(s): Byron
Unit No.: 1 & 2
Discipline: NUDC
Descrip. Code/Keyword: N01
Safety/QA Class: Safety Related
System Code: SX
Structure: NA

Component(s):	

CONTROLLED DOCUMENT REFERENCES

Document No.:	From/To	Document No.:	From/To
NED-M-MSD-009	To		
BYR96-259	To		

Is this Design Analysis Safeguards Information? Yes ☐ No ☒ If yes, see SY-AA-101-106
Does this Design Analysis contain Unverified Assumptions? Yes ☐ No ☒ If yes, ATI/AR#: NA
This Design Analysis SUPERCEDES: NA **in its entirety.**

Description of Revision (list affected pages for partials): Replaced pages 1A and 1 with New Cover Page, and Owner's Acceptance Review Checklist (page 1a). Added Attachment B. Revised pages 1b, and 2.

This is the initial issue of Attachment B to Calculation UHS-01. Attachment B is added to address additional scenarios for postulated single failures associated with electrical breakers serving the Essential Service Water (SX) system components.

Preparer: A. Milicevic - S&L (Print Name) (Sign Name) 12-03-08 (Date)

Method of Review: Detailed Review ☒ Alternate Calculations (attached) ☐ Testing ☐
Reviewer: B.J. Andrews - S&L (Print Name) B.J. Andrews (Sign Name) 12-3-2008 (Date)
Review Notes: Independent review ☒ Peer review ☐

(For External Analyses Only)
External Approver: MICHAEL A. NENA (Print Name) (Sign Name) 12/23/2008 (Date)
Exelon Reviewer: D. SARGENT (Print Name) D. Sargent (Sign Name) 4/17/2009 (Date)

Independent 3rd Party Review Reqd? Yes ☐ No ☒
Exelon Approver: Ed Blondin (Print Name) Ed Blondin (Sign Name) 4/21/09 (Date)

ATTACHMENT 2
Owners Acceptance Review Checklist for External Design Analysis
Page 1 of 1

DESIGN ANALYSIS NO. UHS-01 **REV:** 4

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☒	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
3.	Do the design inputs have sufficient rationale?	☒	☐	☐
4.	Are design inputs correct and reasonable?	☒	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☐	☐	☒
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☐	☐	☒
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	☒	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
10.	Does the Design Analysis include the applicable design basis documentation?	☒	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	☐	☐	☒
12.	Are there any unverified assumptions?	☐	☒	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☒
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	☒	☐	☐
15.	Do the sources of inputs and analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources or analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code)	☒	☐	☐
16.	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	☒	☐	☐

EXELON REVIEWER: D. SARGENT / D Sargent **DATE:** 4/17/09
Print / Sign

Exhibit D
NEP-12-02
Revision 4

COMMONWEALTH EDISON COMPANY
CALCULATION TABLE OF CONTENTS

	PROJECT NO. NA	
CALCULATION NO. UHS-01	REV. NO. 4	PAGE NO. 1b

I. Purpose/Introduction

The purpose of this calculation is to document the post LOCA single failure modes that will be analyzed by Commonwealth Edison Company Nuclear Engineering Department for Byron Ultimate Heat Sink (UHS) design basis reconstitution. The following provides a discussion of the accident scenarios that will be analyzed for the UHS. These scenarios were chosen as discussed at the series of 1991 meetings in CECo's Downer's Grove office between Byron Station Operating, Tech Staff, Regulatory Assurance, Projects, CECo NFS, NED Systems, NED - M & S, Licensing, Westinghouse, Sargent & Lundy and an Independent Consultant for CECo. In addition, comments from the June 17, 1991 draft scenarios comment meeting held at Byron Station between Byron Station Operating, Tech Staff, Regulatory Assurance, Projects, NED Systems, NED-M & S and Licensing have been incorporated herein. Table 1 provides a listing of the scenarios for ease of comparison. Base scenarios chosen for analysis are designated by sequential numerical prefixes. These scenarios each postulate a LOCA as the initiating event and Loss of Offsite Power (LOOP) on the accident unit (reference 4). Unit 1 was consistently chosen as the accident unit for matter of convention. The base scenarios were postulated by assuming various single failures. Variations of each base scenario are considered since current Technical Specifications and Administrative controls predicate unique sets of initial UHS conditions based on UHS cold water basin temperature (i.e. above or below 80°F). Variations of each single failure scenario are designated by alpha suffixes.

Additional scenarios (i.e., scenarios 5, 6, and 7) are described on pages 24-33. Attachment A provides an estimation of the essential service water cooling tower (SXCT) riser valve leakage used in scenarios 5, 6, and 7.

Attachment B to this calculation addresses additional scenarios for postulated single failures associated with electrical breakers serving the Essential Service Water (SX) components.

II. Assumptions

1. The single failure scenarios assume the following initial conditions:

   A. Two units operating at full power with:
      a. One ESW pump running on each unit
      b. The ESW pump discharge train crosstie valves (1/2SX033 and 1/2SX034) open
      c. The ESW pump discharge unit crosstie valves (1/2SX005) closed
      d. The ESW return header crosstie valves (1/2SX136, 1/2SX010, 1/2SX011) open
      e. ESW flow being provided to the following heat exchangers

- 0CC01A	CC Hx (Aligned to Unit 1)
- 1/2CC01A	CC Hx's
- 1/2VA01SA/SB	SX Pump Cubicle Coolers
- 1/2SX01AA/AB	SX Pump Oil Coolers
* - 1/2WO01CA/CB	Containment Chillers *
- 1/2SI01SA/SB	SI Pump Bearing Oil Coolers

- 1/2VA04SA/SB	SI Pump Cubicle Coolers
- 0WO01CA/CB	Control Room Chillers
- 1/2VA02SA/SB	RH Pump Cubicle Coolers
- 1/2CV02SA/SB	CV Pump Gear Coolers
- 1/2CV03SA/SB	CV Pump Lube Oil Coolers
- 1/2VA06SA/SB	CV Pump Cubicle Coolers
- 1/2VA05S	PD Pump Cubicle Coolers
- 1/2VA03SA/SB	CS Pump Cubicle Coolers
- 1/2VA07S	FC Pump Cubicle Coolers
- 1/2VP01AA/AB/AC/AD	RCFC's

* Automatically bypassed on accident unit based on post accident ESF signal.

f. ESW flow isolated to the following heat exchangers:

- 1/2AF01AA	MDAF Pump Oil Coolers
- 1/2AF01AB	DDAF Pump Oil Coolers
- 1/2SX02K	DDAF Pump Angle Gear Oil Coolers
- 1/2SX01K	DDAF Pump Engine Closed Coolers
- 1/2VA08S	DDAF Pump Cubicle Coolers
- 1/2AF02A	DDAF Pump Gear Oil Coolers
- 1/2DG01KA/KB	DG Jacket Water Coolers

- AFW Pump Suction Supplies

B. ESW Cooling Tower cold water basin level is assumed to be at the Technical Specification minimum.

C. Administrative controls for the UHS require Unit Shutdown if the tower cold water basin temperature is over 88°F. Therefore no analyses will be performed assuming initial cold water basin temperatures above 88°F.

D. Administrative controls require at least six fans operating on high speed when the basin temperature is equal to or greater than 80°F. It will be assumed that the riser valves associated with the running fans are open and all bypass valves are closed. Based on administrative controls, the two fans that are out of service (OOS) in this configuration must be powered from different unit's power supplies. It will be assumed that the riser valves associated with the OOS fans are closed. The various single failure scenarios will be analyzed assuming an initial basin temperature of 88°F and either one fan OOS on each tower or two fans OOS on one tower depending on whichever is more limiting for the specific scenario.

E. Administrative controls do not require any fans running on high speed when the basin temperature is less than 80°F. Therefore, the single failure scenarios will also be analyzed assuming an initial basin temperature of 80°F and assuming no fans are initially running. It will be assumed that the bypass valves are closed and at least four riser valves on operable cells are open. It is assumed that the riser valves associated with the two OOS fans are closed. These scenarios will not take credit for UHS ambient heat dissipation until post LOCA operator actions are initiated for system re-alignment.

2. When operator actions are required in the Main Control Room, it is assumed these actions can be initiated 10 minutes following safeguards signals.

3. It is assumed that only one non-accident unit SX pump is running in the post accident modes since the non-running pump would not receive an auto-start signal.

4. An 82°F ambient wet bulb temperature will be assumed for all scenarios.

5. It is assumed that the non-accident unit is initially at power operation and proceeds to an orderly shutdown following the postulated LOCA on the accident unit. It is assumed that the non-accident unit would not achieve hot shutdown conditions (T_{AVG} = 350°F) until 10 hours after the LOCA.

III. Scenario Descriptions

1. Scenario 1A (Figure 1)

   A. Single Failure - The single failure considered for this scenario is the higher capacity containment spray pump on the accident unit.

   B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 80°F. All other initial conditions are as described in Section II for a cold water basin water temperature of less than 80°F. It is assumed that one SX pump is running on each unit and each tower has two passive cells operating. It is assumed that two tower cells are out of service which is permitted by administrative controls. It is assumed that the two OOS cells are on the same tower since this may result in a higher rate of temperature rise in the affected tower basin.

   C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 loss of off site power (LOOP). The single failure considered for this case is the higher capacity containment spray pump on the accident unit. This maximizes the injection phase heat load on the UHS since four RCFC's would be removing heat from the accident unit and both Unit 1 emergency diesels would be running. In addition, it is assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no immediate credit is taken for UHS ambient heat dissipation until operator action is initiated to open additional riser valves and start tower fans. The post accident system lineup consists of three SX pumps supplying automatically aligned post accident ESW loads. The two accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have two active cells (fan running on high and riser valve open) and no passive cells (fan not running and riser valve open). Tower B will have four active cells and no passive cells.

2. <u>Scenario 1B</u> (Figure 1)

   A. Single Failure - The single failure considered in this scenario is the higher capacity containment spray pump on the accident unit.

   B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 88°F. All other initial conditions are as described in Section II for a cold water basin water temperature equal to or greater than 80°F. It is assumed that one SX pump is running on each unit and tower A has two active cells and tower B has four active cells operating. It should be noted that normally eight fans would be operating in this condition, however it is assumed that two tower cells are OOS. It is assumed that the two OOS cells are on the same tower since this may result in a higher rate of temperature rise in the affected tower basin.

   C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 loss of off-site power (LOOP). The single failure considered in this case is again the higher capacity containment spray pump as in Scenario 1A. Following the postulated LOCA, credit is taken for UHS heat removal immediately since the tower fans that were running initially will be automatically re-energized following a LOOP and subsequent diesel starts before the ESW pumps are automatically sequenced on. No operator action is assumed for this case. The post accident lineup consists of three SX pumps supplying automatically aligned post accident ESW loads. The two accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have two active cells and no passive cells. Tower B will have four active cells and no passive cells.

3. Scenario 2A (Figures 2 and 3)

   A. Single Failure - The single failure considered for this scenario is an essential service water cooling tower fan.

   B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 80°F. All other initial conditions are as described in Section II for a cold water basin water temperature of less than 80°F. It is assumed that one SX pump is running on each unit and six passive cooling tower cells are operating. It is assumed that two tower cells are OOS which is permitted by administrative controls. It is assumed that the two cells are on the same tower since this may result in a higher rate of temperature rise in the affected tower basin.

   C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is an ESW tower fan. Initially, the corresponding riser valve is assumed to be open. The injection phase heat load imposed on the UHS would be less in this scenario than in scenarios 1A and 1B since both CS pumps would be running on the accident unit. Both trains of the accident unit SX system heat loads are assumed to be aligned. In addition, it is assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until operator action is initiated to open riser valves, start tower fans and close the riser valve corresponding to the failed fan. The post accident system lineup consists of three SX pumps running and supplying the additional automatically aligned ESW loads. The two accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have one active cell and no passive cells. Tower B will have four active tower cells.

4. Scenario 2B (Figures 2 and 3)

   A. Single Failure - The single failure considered for this scenario is an essential service water cooling tower fan.

   B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 88°F. All other initial conditions are as described in Section II for a cold water basin water temperature equal to or greater than 80°F. It should be noted that normally eight fans and risers would be operating in this condition, however it will be assumed that two tower cells are OOS. It is assumed that the two OOS cells are on the same tower since this may result in a higher rate of temperature rise in the affected tower basin.

   C. Accident Conditions - The initiating event is a LOCA on Unit 1 and a coincident Unit 1 LOOP. The single failure considered in this case is again an ESW tower fan. The corresponding riser valve is assumed to remain open until operator action is initiated to close the valve. Following the postulated LOCA, credit is taken for UHS heat removal immediately since the tower fans that were running initially will be automatically re-energized, following a LOOP and subsequent diesel starts, before the ESW pumps are automatically sequenced on. The post LOCA accident lineup consists of three SX pumps running and supplying the additional automatically aligned ESW loads. Both accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have one active cell and no passive cells. Tower B will have four active cells.

5. Scenario 3A (Figure 4)

A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail to start and the corresponding riser valves are assumed to fail in the open position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 80°F. All other initial conditions are as described in Section II for a cold water basin water temperature of less than 80°F. It is assumed that one SX pump is running on each unit and each tower has three passive cells operating. It is assumed that two tower cells are out of service which is permitted by administrative controls. It is assumed that one cell is out of service on each of the two towers. This will result in the maximum number of cells out of service after the postulated failure of the diesel.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is a 1B emergency diesel failure. This failure will result in a less than maximum injection phase heat load on the UHS because only two RCFC fans will be functional on the accident unit. In addition, the 1B train SX heat exchangers and cubicle coolers would not significantly contribute to UHS heat load. The 1B diesel failure envelopes the 1A diesel failure because the UHS will receive heat load from both accident unit auxiliary feedwater pumps. In the case of a 1A diesel failure, the UHS would only receive heat load from the 1B AFW pump since the 1A AFW pump is motor driven. In addition, it will be assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until operator action is initiated to start tower fans. The post accident system lineup consists of two SX pumps running and the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have three active cells and no passive cells. Tower B will have one active cell and two passive cells.

6. Scenario 3B (Figure 4)

A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail to start and the corresponding riser valves are assumed to fail in the open position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 88°F. All other initial conditions are as described in Section II for a cold water basin water temperature equal to or greater than 80°F. It is assumed that one SX pump is running on each unit and that each tower has three active cells operating. It should be noted that normally eight fans would be operating in this condition, however it will be assumed that two tower cells are OOS. It is assumed that one cell on each tower is OOS. This will result in the most cells OOS in conjunction with the 1B diesel failure.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered is again the 1B emergency diesel failure as in Scenario 3A. Following the postulated LOCA credit is taken for UHS ambient heat dissipation immediately since the tower fans that were running initially will be automatically re-energized following a LOOP and subsequent diesel starts before the ESW pumps are sequenced on. No operator action is assumed for this case. The post accident lineup consists of two SX pumps running and supplying the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have three active cells and no passive cells. Tower B will have one active cell and two passive cells.

7. Scenario 3C (Figure 5)

   A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail to start and the corresponding riser valves are assumed to fail in the closed position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

   B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 80°F. All other initial conditions are as described in Section II for a cold water basin water temperature less than 80°F. It is assumed that one SX pump is running on each unit and tower A has three passive cells and tower B has one passive cell operating. It is assumed that two tower cells are out of service which is permitted by administrative controls. It is assumed that one cell is out of service on each of the two towers. This will result in the maximum number of cells out of service after the postulated failure of the diesel.

   C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is again a 1B emergency diesel failure. This scenario is the same as Scenario 3A with the exception of the failure position of two riser valves. In this Scenario it is assumed that the two affected riser valves fail in the closed position as opposed to the open position. Following the postulated LOCA, no credit is taken for UHS heat dissipation until operator actions are initiated. The post accident system lineup consists of two SX pumps running and supplying the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have three active cells and no passive cells. Tower B will have one active cell and no passive cells.

8. Scenario 4A (Figure 6)

A. Single Failure - The single failure considered for this scenario is an ESW pump failure on the accident unit.

B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 80°F. All other initial conditions are as described in Section II for a cold water basin water temperature of less than 80°F. It is assumed that one SX pump is running on each unit and each tower has two passive cells operating. It is assumed that two tower cells are OOS which is permitted by administrative controls. It is assumed that two cells are out of service on the same tower since this may result in a higher rate of temperature rise in the affected tower basin.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is an SX pump failure on the accident unit. This failure will result is a less than maximum injection phase heat load on the UHS because two CS pumps would be functional on the accident unit. Both trains of the accident unit SX system heat exchangers are assumed to be aligned. In addition, it will be assumed that Unit 2 proceeds to an orderly shutdown. Following the postulated LOCA, no immediate credit is taken for UHS ambient heat dissipation until operator action is initiated to start tower fans and open riser valves. The post accident system lineup consists of two SX pumps running and the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have two active cells and no passive cells. Tower B will have four active cells.

9. Scenario 4B (Figure 6)

A. Single Failure - The single failure considered for this scenario is an ESW pump failure on the accident unit.

B. Initial Conditions - This scenario assumes an initial cold water basin water temperature of 88°F. All other initial conditions are as described in Section II for a cold water basin water temperature equal to or greater than 80°F. It is assumed that one SX pump is running on each unit and tower A has two active cells and tower B has four active cells operating. It should be noted that normally eight fans would be operating in this condition, however it will be assumed that two tower cells are OOS. It is assumed that two cells on one tower are OOS. This may result in a higher rate of temperature rise in the affected tower basin.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered is again one SX pump on the accident unit. Following the postulated LOCA, credit is taken for UHS ambient heat dissipation immediately since the tower fans that were running initially will be automatically re-energized following a LOOP and subsequent diesel starts before the SX pumps are sequenced on. No operator action is required for this case. The post accident lineup consists of two SX pumps running and the additional automatically aligned SX loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have two active cells and no passive cells. Tower B will have four active cells.

4. OBOS 0.1 - Rev. 3
5. 1/2BOA PRI-7 Rev. 3 "Essential Service Water Malfunction"
6. BAR 1/2-2-B2 Rev. 52 "Annunciator Response Procedure"
7. OBOS 7.5-1a Rev. 2 "UHS Technical Specification LCO 3.7.5"
8. Correspondence from K. D. Brennan (CECo) to R. Pleniewicz (CECo) dated April 22, 1991 regarding "Design Criteria for Ultimate Heat Sink (UHS)"
9. Code of Federal Regulations 10CFR50 Appendix A, January 1, 1990 Edition
10. Regulatory Guide 1.27 Rev. 2 January 1976
11. Byron Electrical Schematic Drawings
    6E-1-4030SX15 Rev. F
    6E-1-4030SX16 Rev. F
    6E-1-4030SX01 Rev. T
    6E-1-4030SX02 Rev. U
    6E-2-4030SX15 Rev. E
    6E-2-4030SX16 Rev. E
    6E-2-4030SX01 Rev. N
    6E-2-4030SX02 Rev. M
    6E-0-4030SX01 Rev. R
    6E-0-4030SX02 Rev. R
    6E-0-4030SX03 Rev. R
    6E-0-4030SX04 Rev. S
    6E-0-4030SX05 Rev. S
    6E-0-4030SX06 Rev. R
    6E-0-4030SX07 Rev. T
    6E-0-4030SX08 Rev. T
12. Correspondence from T. K. Schuster/D. Chrzanowski (CECo) to G. Contrady (CECo) dated August 2, 1991 regarding "Byron Station Ultimate Heat Sink Design".
13. Byron/Braidwood Updated Final Safety Analysis Report (UFSAR) Revision 2 submitted December 17, 1991.
14. ANSI/ANS-58.8-1984 American Nuclear Society time response design criteria for nuclear safety related operator actions.
15. BOP SX-T2 Rev. 1 "SX Tower Operation Guidelines".
16. 1BEP-0 Rev. 3 "Reactor Trip or Safety Injection - Unit 1".

IV. Other Failures Considered That Are Enveloped

1. Riser Valve Failure to Open

   Single failure of one tower riser valve to open is enveloped by Scenarios 2A and 2B. In lieu of one riser valve failure, Scenarios 2A and 2B postulate failure of one fan and assume that the associated riser valves close. This results in the same configuration (five active cells and no passive cells) as a riser valve failure. The heat load imposed on the tower is the same for both scenarios and corresponds to two CS pumps and four RCFC's operating on the accident unit.

2. Station Blackout

   The 11-02-90 CECo resubmittal to the NRC of the Station Blackout Analysis addresses design adequacy for Blackout conditions. CECo NED will be responsible for reviewing the impact of SBO on the UHS by March 1, 1992 as discussed at the April 29, 1991 meeting in Downer's Grove.

3. Containment Chiller Bypass/Isolation Failure

   Failure of the containment chiller bypass and isolation valves is not significant. No additional heat load would be imposed on the UHS due to these failures since the containment isolation valves would isolate chilled water flow to the containment coils. In addition, if the chiller bypass valve failed in the closed position, the UHS would only receive heat load from one train (2 RCFC's vs. 4 RCFC's) of RCFC's.

4. Failure of ECCS or AFW Pumps or Coolers

   Failure of ECCS or AFW pumps would result in lower UHS heat loading.

V. Input Data/References

1. Piping and Instrumentation Drawings
   M-42-1A and 1B Rev. Z
   M-42-2A and 2B Rev. AC
   M-42-3 Rev. AL
   M-42-4 Rev. AH
   M-42-5 Rev. Y
   M-42-6 Rev. AH
   M-42-7 Rev. M
   M-42-8 Rev. K

2. Byron Technical Specifications Amendment 39

3. 1/2BEP-0/WOF-1A Rev. 3 "Reactor Trip or Safety Injection"

VI. Conservatisms

1. The following are conservatively assumed to occur coincidentally for analysis purposes:

   a. postulated LOCA.

   b. loss of offsite power (LOOP) on accident unit.

   c. worst case single failure in addition to having two tower cells OOS.

   d. 82°F ambient wet bulb temperature.

2. When the cold water basin water temperature is below 80°F, it is conservatively assumed that no fans are running. As a result, no UHS ambient heat dissipation is credited until after operator actions have been initiated.

3. It is assumed that two cells are OOS when the cold water basin temperature is between 80°F and 88°F. Normally, all 8 cells would actually be in service with riser valves open and fans running.

4. The minimum Technical Specification basin level (50%) is used for analysis purposes to conservatively minimize the passive UHS heat capacity. The basin is normally maintained at or above 70% which would provide additional tower heat capacity.

5. No credit is taken for passive cooling tower cell ambient heat dissipation.

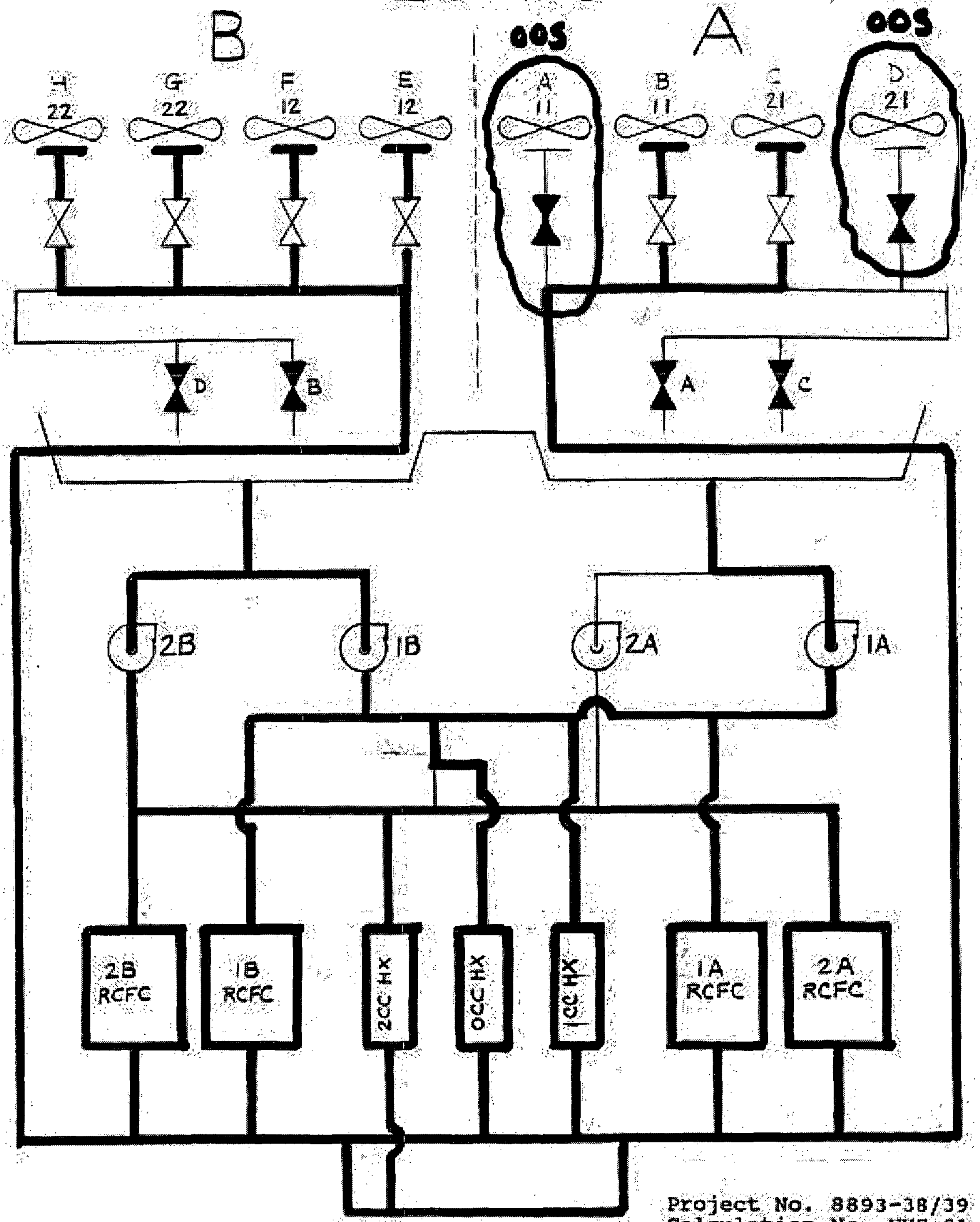
6. No credit is taken for the cooling contribution from the ESW makeup to the tower basins.

VII. Conclusion

Single failure scenarios were developed and described in Section II. Figures 1 through 6 provide simplified diagrams to illustrate the scenarios. This calculation will be used as input to CECo for detailed evaluation of UHS performance.

This review was accomplished by a detailed review of the original calculation.
9-17-91

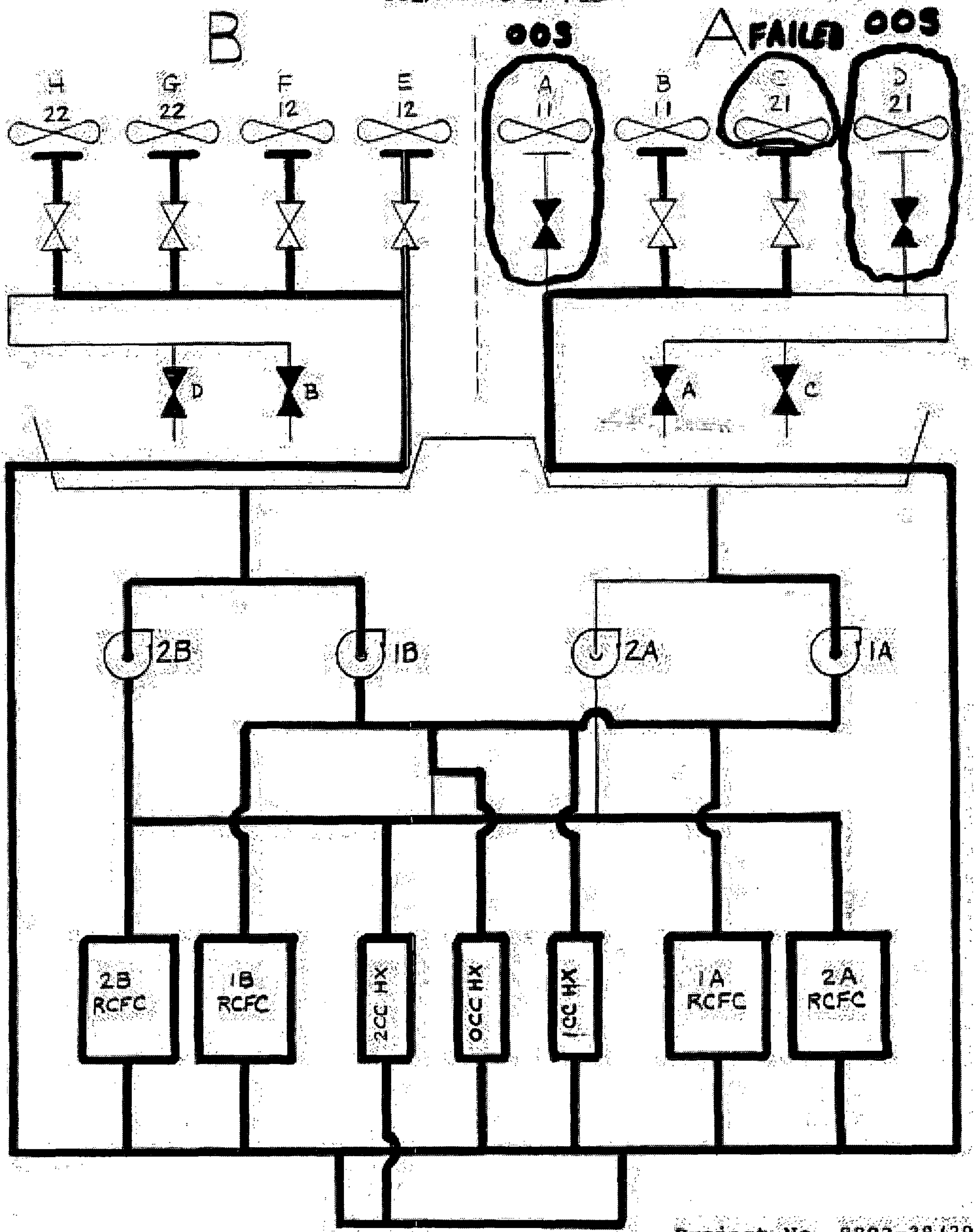
FIGURE 1
POST LOCA CONFIGURATION
SCENARIOS 1A & 1B



Project No. 8893-38/39
Calculation No. UHS-01
Revision 2

FIGURE 2

POST LOCA CONFIGURATION (PRIOR TO OPERATOR ACTION)
SCENARIOS 2A & 2B



Project No. 8893-38/39
Calculation No. UHS-01
Revision 2

FIGURE 3

POST LOCA CONFIGURATION (AFTER OPERATOR ACTION)
SCENARIOS 2A & 2B

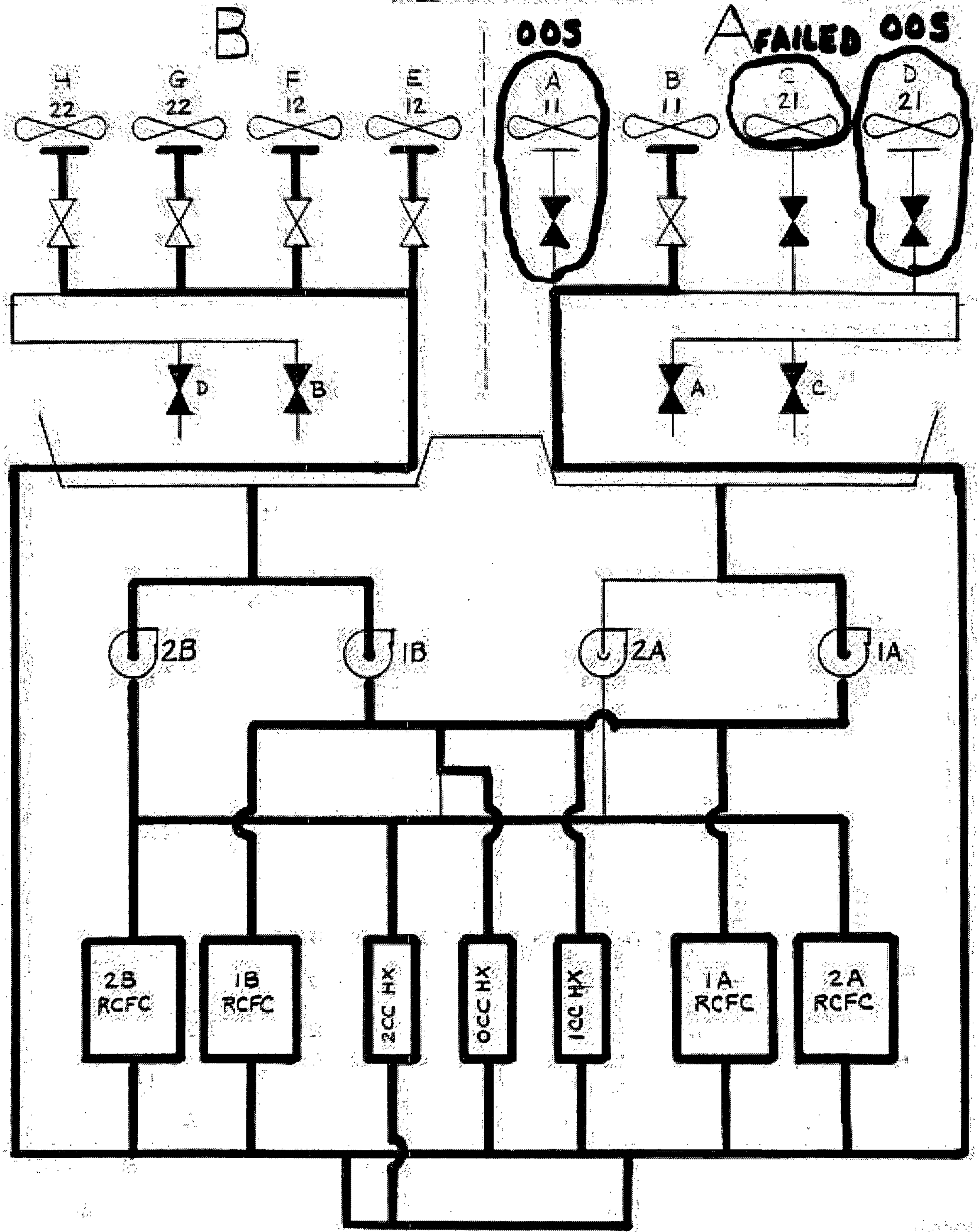
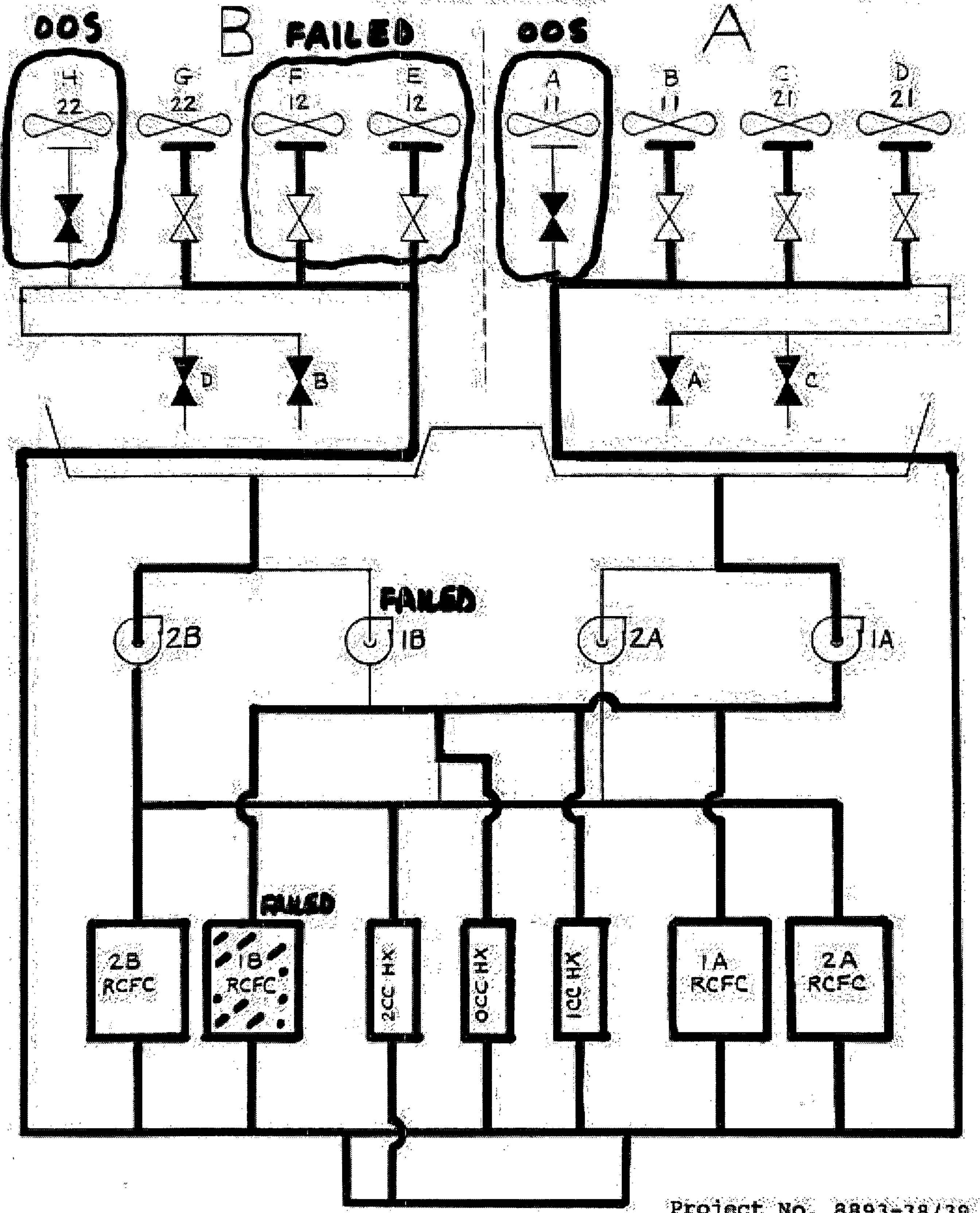


FIGURE 4
POST LOCA CONFIGURATION
SCENARIOS 3A & 3B



Project No. 8893-38/39
Calculation No. UHS-01
Revision 2

FIGURE 5
POST LOCA CONFIGURATION
SCENARIO 3C

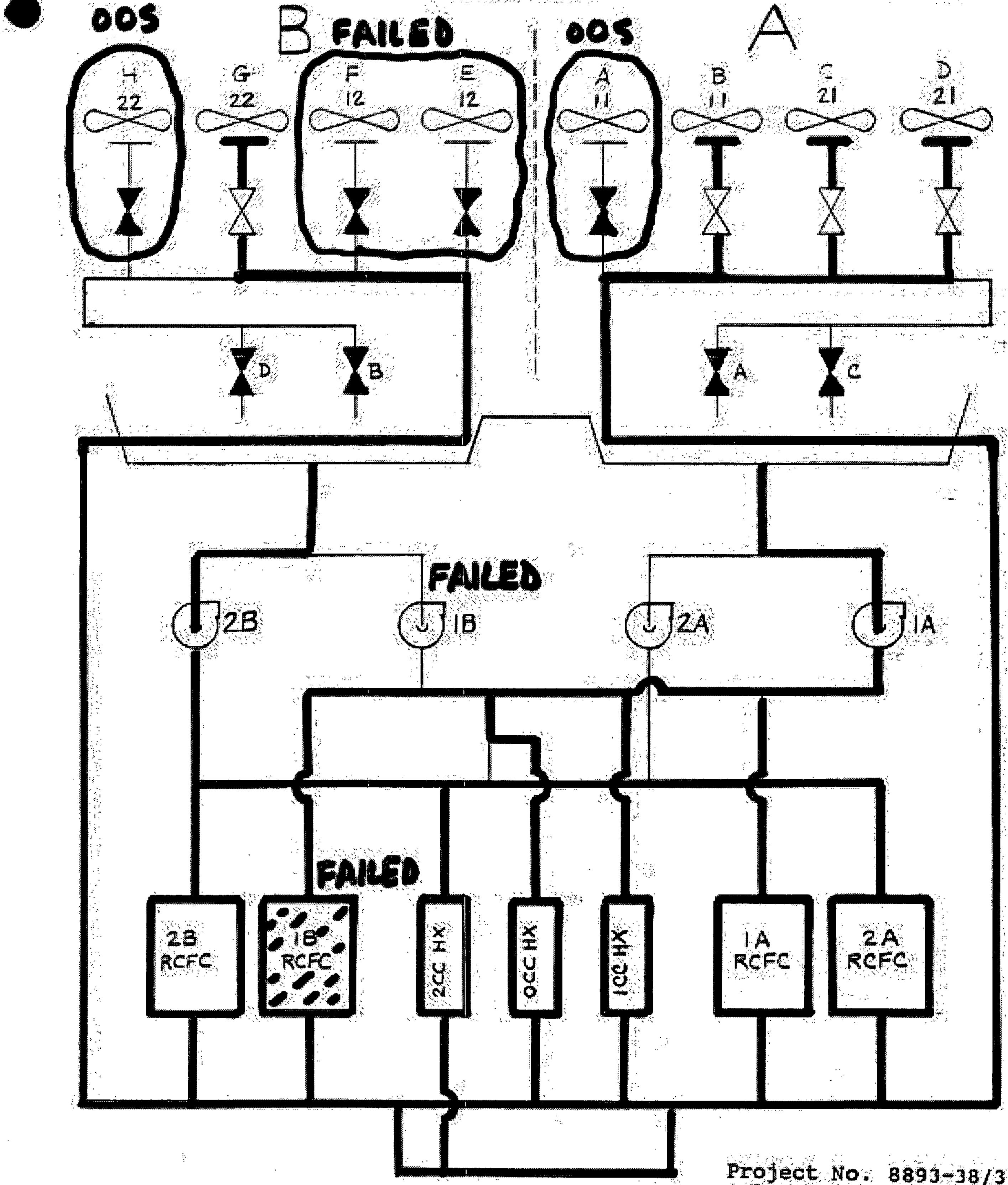


FIGURE 6
POST LOCA CONFIGURATION
SCENARIOS 4A & 4B

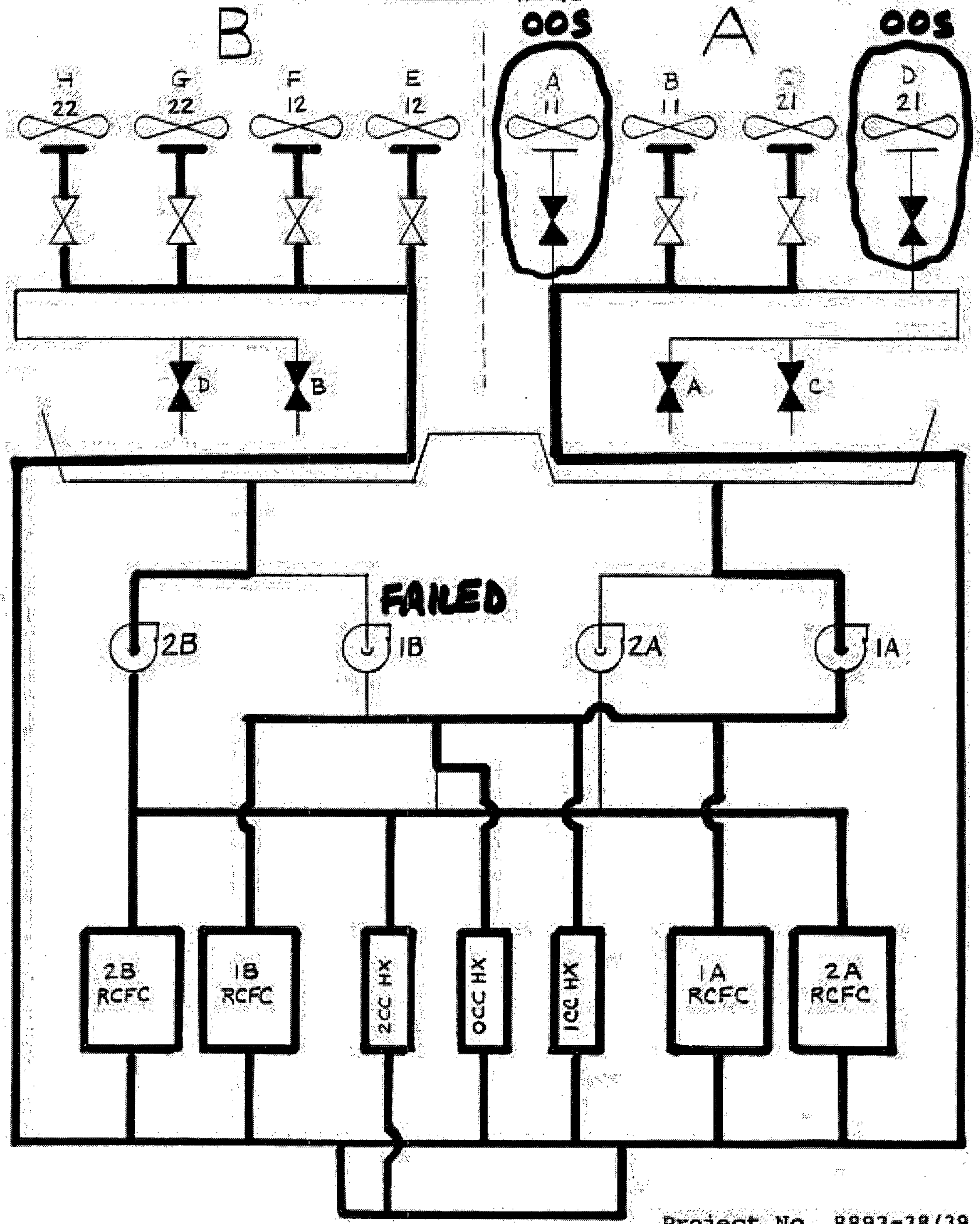


TABLE 1

SCENARIO	INIT. EVENT	SINGLE FAILURE	HEAT LOAD BASIS	INITIAL TOWER BASIN TEMP	CELLS OOS	SX PUMPS RUNNING POST LOCA	INITIAL TOWER CONFIGURATION								POST LOCA TOWER CONFIGURATION FOLLOWING OPERATOR ACTION							
							TOWER A				TOWER B				TOWER A				TOWER B			
							FANS RUNNING	RISER VALVES OPEN	ACTIVE CELLS	PASSIVE CELLS	FANS RUNNING	RISER VALVES OPEN	ACTIVE CELLS	PASSIVE CELLS	FANS RUNNING	RISER VALVES OPEN	ACTIVE CELLS	PASSIVE CELLS	FANS RUNNING	RISER VALVES OPEN	ACTIVE CELLS	PASSIVE CELLS
1A	U-1 LOCA	CS PUMP ON ACCIDENT UNIT	1CS PUMP 4 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	80°F	A/D	3	0	2	0	2	0	2	0	2	2	2	2	0	4	4	4	0
1B	U-1 LOCA	CS PUMP ON ACCIDENT UNIT	1CS PUMP 4 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	88°F	A/D	3	2	2	2	0	4	4	4	0	2	2	2	0	4	4	4	0
2A	U-1 LOCA	COOLING TOWER FAN	2CS PUMPS 4 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	80°F	A/D	3	0	2	0	2	0	4	0	4	1	1	1	0	4	4	4	0
2B	U-1 LOCA	COOLING TOWER FAN	2CS PUMPS 4 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	88°F	A/D	3	2	2	2	0	4	4	4	0	1	1	1	0	4	4	4	0
3A	U-1 LOCA	DG FAILURE (1B) ON ACCIDENT UNIT	1CS PUMP 2 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	80°F	A/H	2	0	3	0	3	0	3	0	3	3	3	3	0	1	3	1	2
3B	U-1 LOCA	DG FAILURE (1B) ON ACCIDENT UNIT	1CS PUMP 2 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	88°F	A/H	2	3	3	3	0	3	3	3	0	3	3	3	0	1	3	1	2
3C	U-1 LOCA	DG FAILURE (1B) ON ACCIDENT UNIT	1CS PUMP 2 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	80°F	A/H	2	0	3	0	3	0	1	0	1	3	3	3	0	1	1	1	0
4A	U-1 LOCA	SX PUMP ON ACCIDENT UNIT	2CS PUMPS 4 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	80°F	A/D	2	0	2	0	2	0	2	0	2	2	2	2	0	4	4	4	0
4B	U-1 LOCA	SX PUMP ON ACCIDENT UNIT	2CS PUMPS 4 RCFC'S PLUS ORDERLY U-2 SHUTDOWN	88°F	A/D	2	2	2	2	0	4	4	4	0	2	2	2	0	4	4	4	0

Purpose/Objective:

The purpose of Revision 3 is to document additional post-LOCA single failure modes that will be analyzed for the UHS. The additional scenarios are selected to bound potential valve leak-by of the tower riser and bypass valves and administrative controls to maintain 7 SX cooling tower fans operable. These new scenarios supplement the scenarios documented in Revision 2 of this calculation.

Methodology and Acceptance Criteria:

The worst case scenario will be identified from the basin temperature calculation (Reference 1). The worse case scenario description will be revised for the new conditions (i.e., valve leakage, number of fans initially out of service). Scenarios will be done for the "as installed" condition with 3/4" riser drain lines and the proposed 2" riser drain lines. Simplified diagrams will be generated to illustrate the new scenarios. The results of this calculation will be used as input for additional analysis of UHS performance.

Assumptions:

All assumptions from Revision 2 of the calculation are used in this Revision except as follows:

1. Revision 2 assumed a maximum initial cold water basin temperature of 88°F. Amendment 54 for Tech Spec 3/4.7.5 changed the SX pump discharge temperature limit to 96°F with all OPERABLE fans running in high speed. UHS temperature analysis will be performed assuming an initial maximum cold water basin temperature of 96°F.

2. Revision 2 assumed two SX cooling tower fans OOS with the riser valves associated with the OOS fans closed. Additional scenarios will be analyzed assuming administrative controls which require 7 SX cooling tower fans to be operable (only one fan OOS).

3. Based on the as-found leak-by for the closed bypass and riser valves (References 2 and 3), the following leak-by flow rate will be conservatively assumed for the closed riser and bypass valves:

Riser Valves:	635 gpm/valve
Bypass Valves:	900 gpm/valve

4. From Reference 1 (pgs 198-202), the tower bypass flow through the proposed 2 inch riser drain line is assumed to be 250 gpm per open riser.

5. To account for the bypass flow for the 3/4" drain lines, the riser valve leakby will be conservatively increased from 635 gpm to 1000 gpm per valve and no flow will be assumed through the 3/4" riser drain line. The flow in the 3/4" drain line can be estimated from the 2" line flow. Using Eq 3.19 & 3.24 from Ref. 5 :

   $Q \propto \sqrt{\frac{1}{K}}$ and for a different pipe I.D. $K_a = K_b \left(\frac{d_a}{d_b}\right)^4$

   For 2" pipe d_a = 1.939 in (assume schedule 80 pipe)
   For 3/4" pipe d_b = 0.742 in (assume schedule 80 pipe)

   $$\frac{K_a}{K_b} = \left(\frac{d_a}{d_b}\right)^4 = \left(\frac{1.939}{0.742}\right)^4 = 46.63$$

   Q_a = 250 Reference 1 pages 198-202

   $$Q_b = 250\text{x} \sqrt{\frac{1}{K_a/K_b}} = 36.6 \text{ gpm}$$

   With 7 open risers, the total bypass flow would be approximately 256 gpm which is bounded by the 365 gpm increase in assumed riser valve leakby.

Design Input:

1. From calculation NED-M-MSD-9 the most limiting SX basin temperature occurs for Scenario 2B which corresponds to Figures 2 and 3 of Revision 2 of this calculation.

2. Riser valves leakage is obtained from Reference 2.

3. Bypass valve leakage is obtained from Reference 3.

4. The flow rate for the 2-inch riser drain line is obtained from Reference 1.

References:

1. Calculation NED-M-MSD-9, Revision 3, dated 4-16-96.
2. Letter from Mike Robinson to Kevin Passmore, dated 11-18-96, Subject: Estimation of Essential Service Water Cooling (SXCT) Riser Valve Leakage (attached).
3. Calculation BYR96-281, Revision 0, dated 12/20/96, "Determination of SXCT Bypass Valve Leakage."
4. Byron Technical Specification 3/4.7.5, Ultimate Heat Sink, Amendment No. 54.
5. Crane Technical Paper No. 410, Flow of Fluids Through Valves, Fittings and Pipe, 1980 Edition.

Calculations:

From Reference 1 Scenario 2B is most limiting. Use the same initiating event, single failure, heat load and number of SX pumps running for the new scenarios.

Scenario 5: (3/4" drain lines, One fan OOS)

Initial Tower Basin Temp = 96°F (Assumption 1)
Cells OSS: D (Assumption 2)
Initial Tower Configuration:
Tower A: 2 Fans Running, 3 Riser Valves Open, 2 Active Cells, 1 Passive Cell
Tower B: 4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells
Post-LOCA Tower Configuration After Operator Action:
Tower A: 2 Fans Running, 2 Riser Valves Open, 2 Active Cells, 0 Passive Cells
Tower B: 4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells
Riser Valve Leakby = 1000 gpm/valve (Assumption 5)
Bypass Valve Leakby = 900/gpm valve (Assumption 3)
Drain Line Bypass Flow = 0 (Included in Riser Leakby, Assumption 5)

Scenario 6: (Case 2B, 2" drain lines, and Valve Leakby)

Initial Tower Basin Temp = 96° (Assumption 1)
Cells OSS: B & D
Initial Tower Configuration:
Tower A: 1 Fan Running, 2 Riser Valves Open, 1 Active Cell, 1 Passive Cell
Tower B: 4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells
Post-LOCA Tower Configuration After Operator Action:
Tower A: 1 Fan Running, 1 Riser Valve Open, 1 Active Cell, 0 Passive Cells
Tower B: 4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells
Riser Valve Leakby = 635 gpm/valve (Assumption 3)
Bypass Valve Leakby = 900 gpm/valve (Assumption 3)
Drain Line Bypass Flow = 250 gpm/ open riser (Assumption 4)

Scenario 7: (One Fan 00S, 2" drain lines, and Valve Leakby)

Initial Tower Basin Temp = 96°F (Assumption 1)
Cells OSS: D (Assumption 2)
Initial Tower Configuration:
Tower A: 2 Fans Running, 3 Riser Valves Open, 2 Active Cells, 1 Passive Cell
Tower B: 4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells
Post-LOCA Tower Configuration After Operator Action:
Tower A: 2 Fans Running, 2 Riser Valves Open, 2 Active Cells, 0 Passive Cells
Tower B: 4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells
Riser Valve Leakby = 635 gpm/valve (Assumption 3)
Bypass Valve Leakby = 900 gpm/valve (Assumption 3)
Drain Line Bypass Flow = 250 gpm/open riser (Assumption 4)

Summary and Conclusions:

New scenarios were developed as described above. Figures 7 through 12 provide simplified diagrams to illustrate the scenarios.

FIGURE 7
POST LOCA CONFIGURATION (PRIOR TO OPERATOR ACTION)
SCENARIO 5

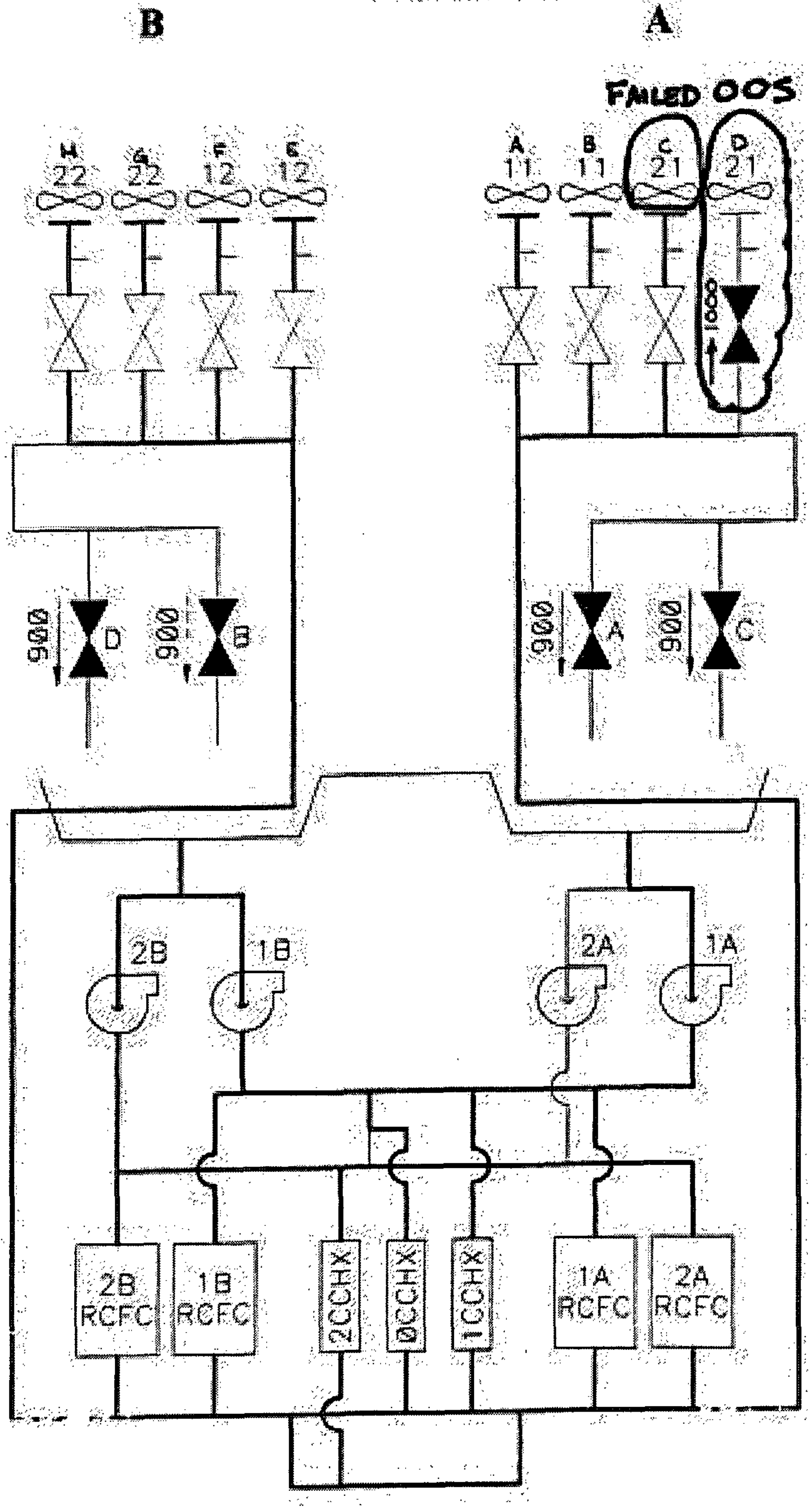


FIGURE 8
POST LOCA CONFIGURATION (AFTER OPERATOR ACTION)
SCENARIO 5

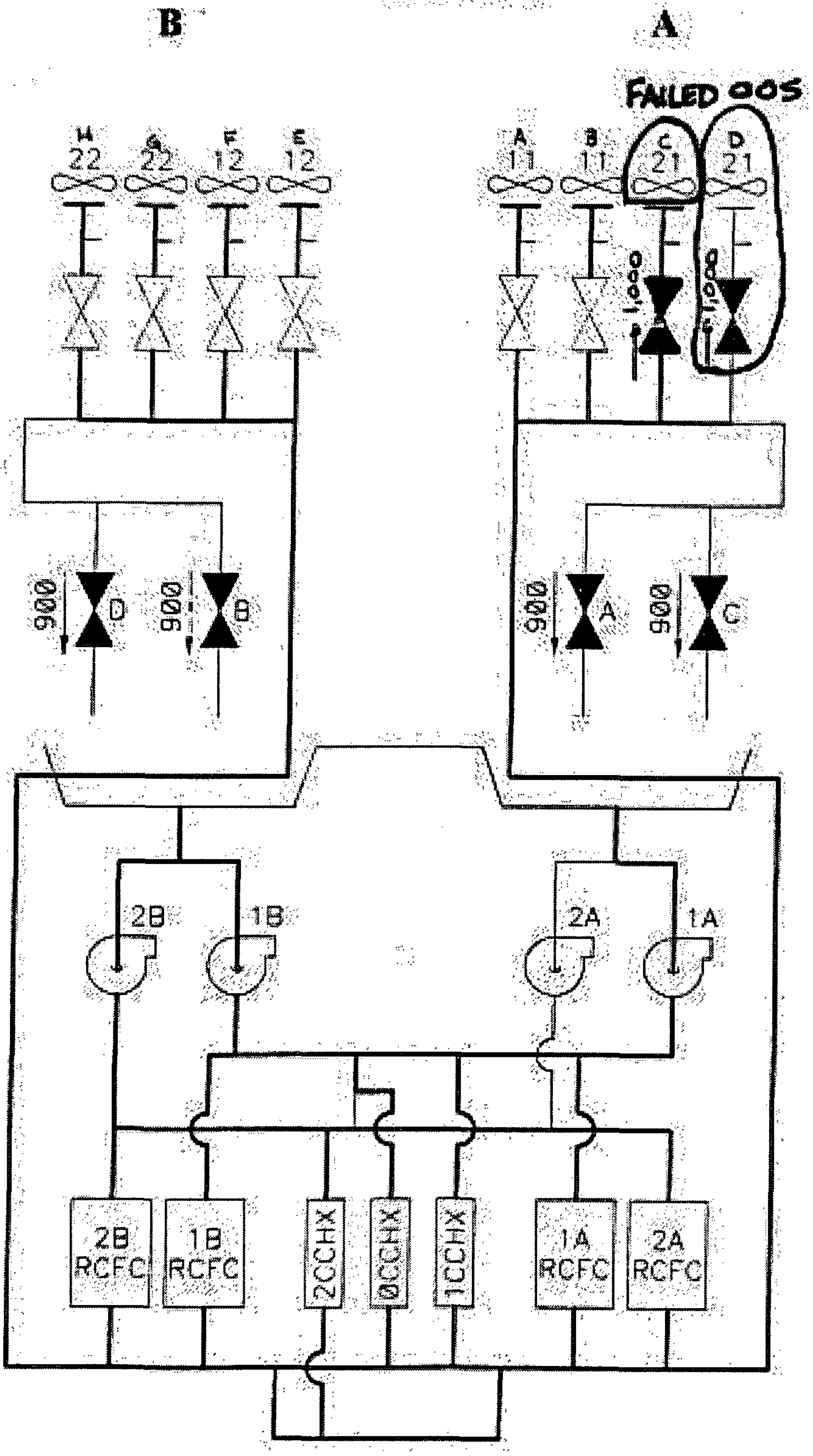


FIGURE 9
POST LOCA CONFIGURATION (PRIOR TO OPERATOR ACTION)
SCENARIO 6

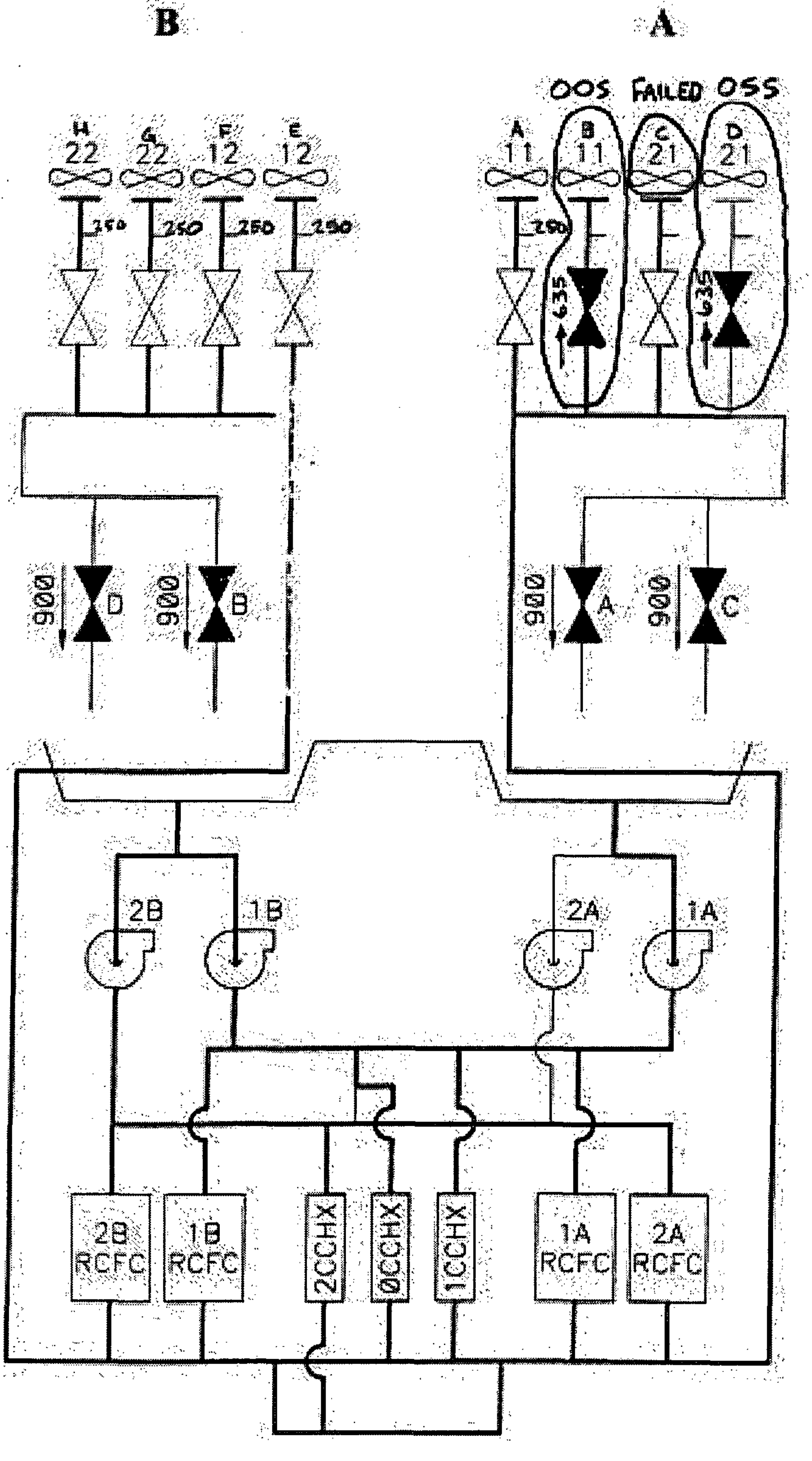


FIGURE 10
POST LOCA CONFIGURATION (AFTER OPERATOR ACTION)
SCENARIO 6

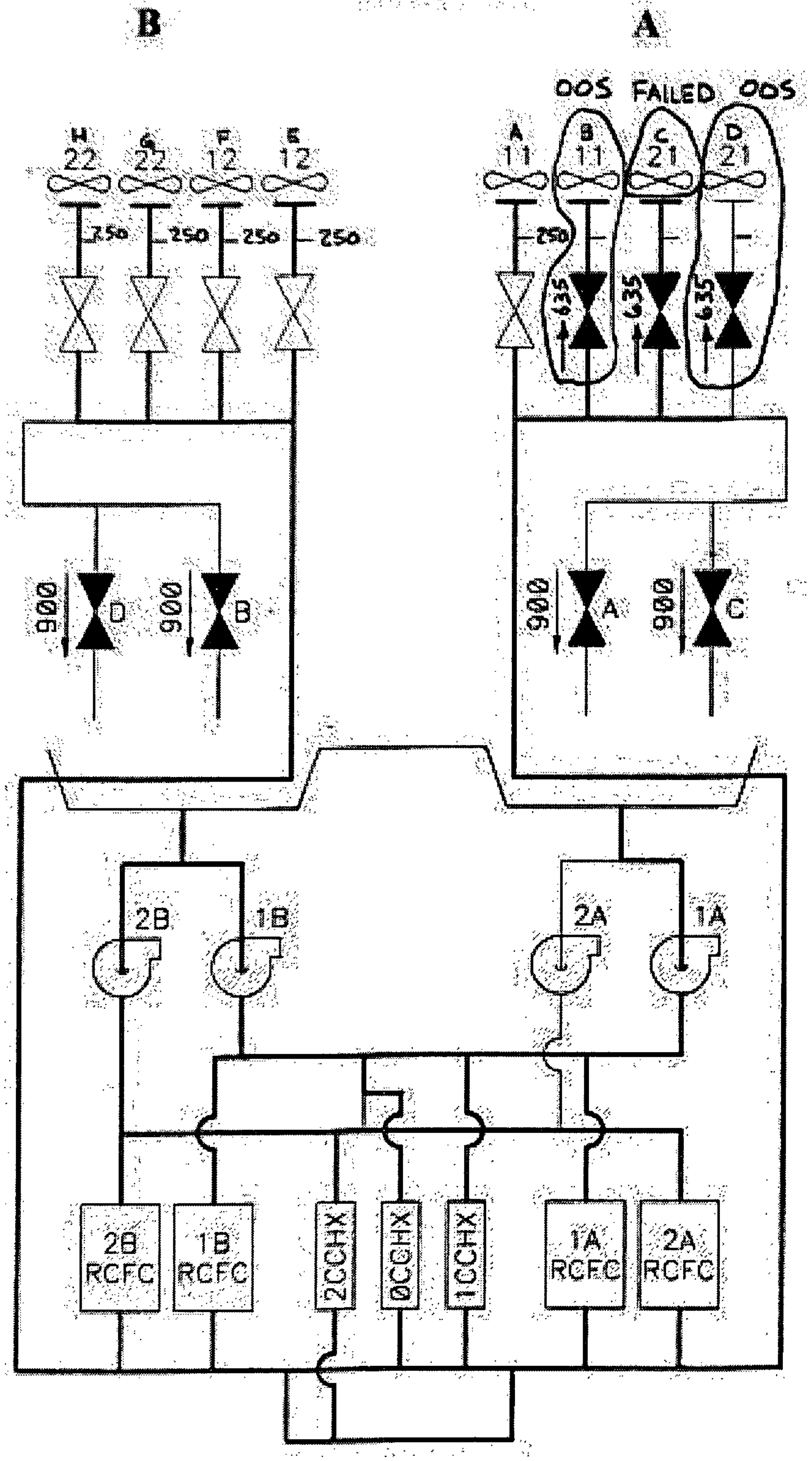
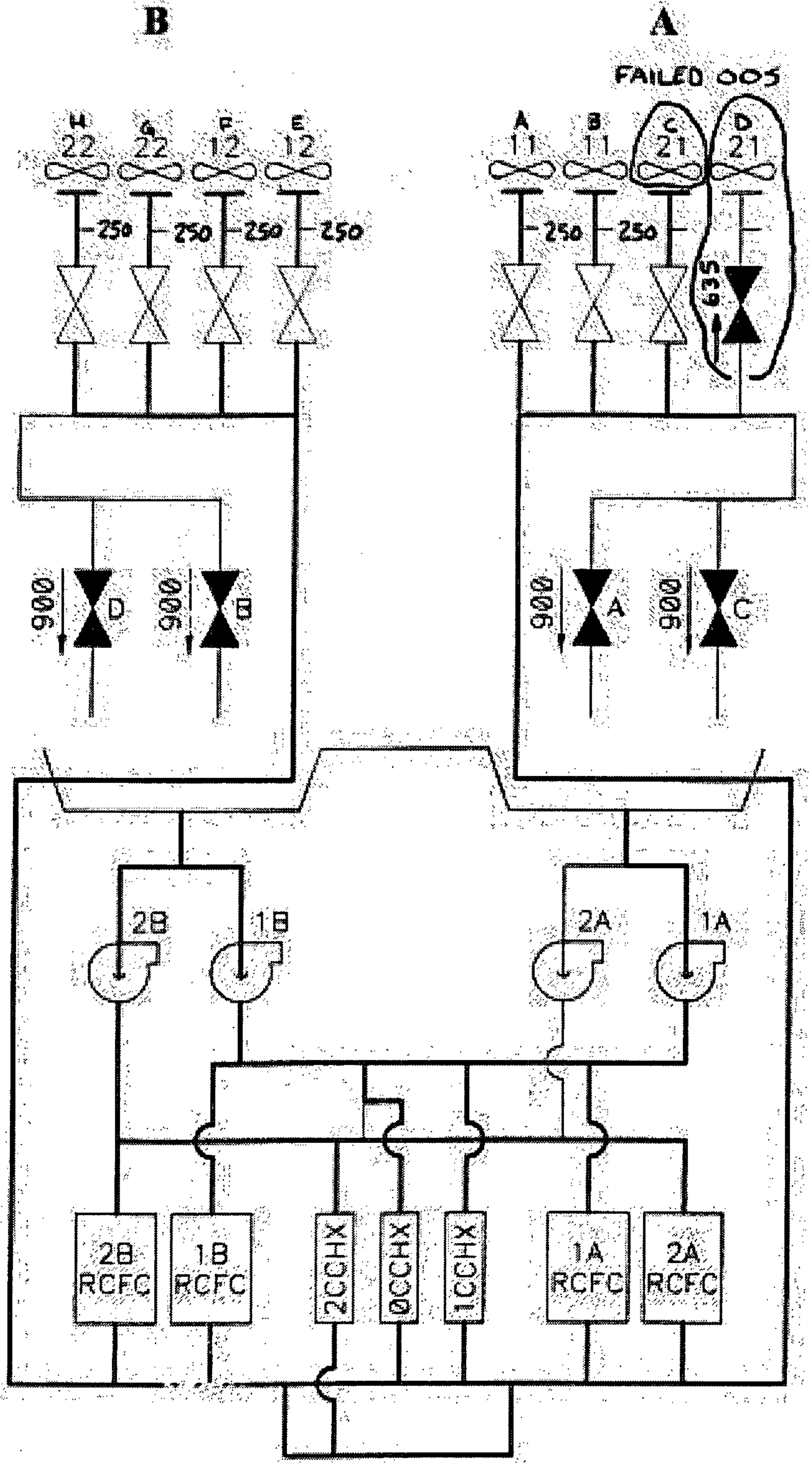
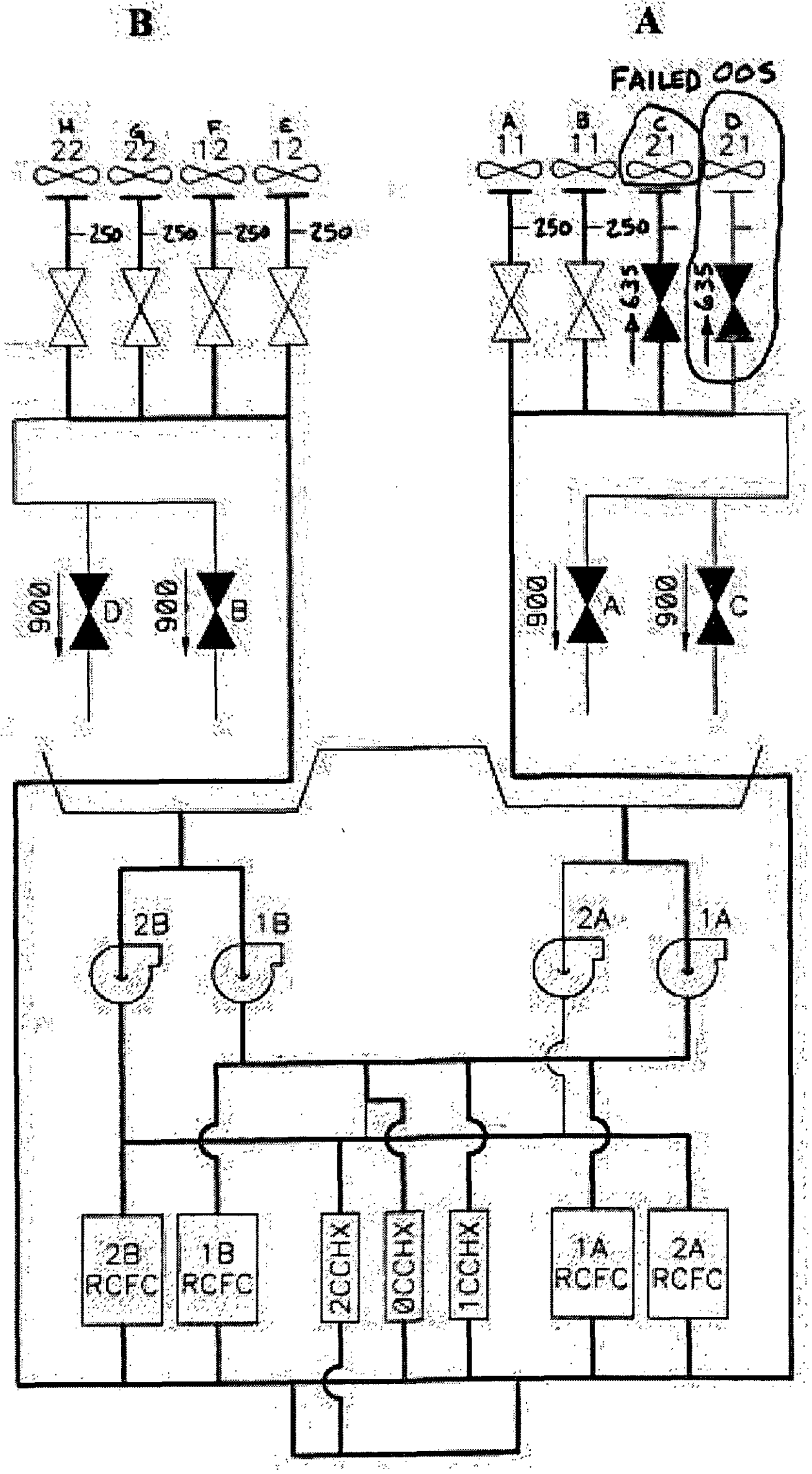


FIGURE 11
POST LOCA CONFIGURATION (PRIOR TO OPERATOR ACTION)
SCENARIO 7



Calculation No. UHS-01
Revision 3

FIGURE 12
POST LOCA CONFIGURATION (AFTER OPERATOR ACTION)
SCENARIO 7



November 18, 1996

TO: Kevin Passmore
Station Support Engineering Supervisor

SUBJECT: Estimation of Essential Service Water Cooling Tower (SXCT) Riser Valve Leakage.

On 11-18-96 data was collected at the 0A SXCT in order to provide an estimate of riser valve leakage. Visual observation of the four 0A SXCT cells indicates that the C cell (riser valve 0SX163C) is leaking the worst, followed by A and B (roughly the same), then D with the least leakage. Data was collected in the C cell to provide the most conservative estimates.

The method used was to record the time to collect two gallons of water from each of the five spray nozzles tested. Three trials were run for each of the five nozzles. Although there is some variation in estimated flowrate between the five nozzles, they appeared visually to provide a representative sample of the nozzles in the C cell. The attached copy of drawing M-900, Sheet 25 indicates the locations of the nozzles tested (SE corner of C cell).

Tabulated below are the SX system conditions during the data collection:

<u>0A Tower</u>
Riser Valves (0SX163A/B/C/D) - all closed.
Bypass Valves (0SX162A/C) - both closed.

<u>0B Tower</u>
Riser Valves (0SX163E/F/G/H) - all open.
Bypass Valves (0SX162B/D) - both closed.

<u>Pumps</u>
1A - off.
1B - on (146 amps).
2A - off.
2B - on (148 amps).

SX Discharge Header Pressure
1PI-SX007 - 97 psig.
1PI-SX008 - 98 psig.
2PI-SX007 - 99 psig.
2PI-SX008 - 97 psig.

Attachment A
Calculation No. UHS-01
Revision No. 3 Page No. A1

November 18, 1996

Estimation of Essential Service Water Cooling Tower (SXCT) Riser Valve Leakage.

Note that during normal system operation, pressure upstream of the riser and bypass valves is higher than during the system post-LOCA alignment. In post-LOCA alignment with higher system flows, system pressures would be lower. Thus the riser leakrates calculated from this data collection should be conservative with regard to leakrates during post-LOCA alignment.

Using the average of the five nozzle flowrates, and applying that average to all 144 nozzles (reference attached drawing M-900, Sheet 25), the 0SX163C leakage is estimated at 470gpm (360 gpm using lowest nozzle leakrate, 635 gpm using highest nozzle leakrate).

Prepared By: Date: 11-18-96

Reviewed By: Date: 11/18/96

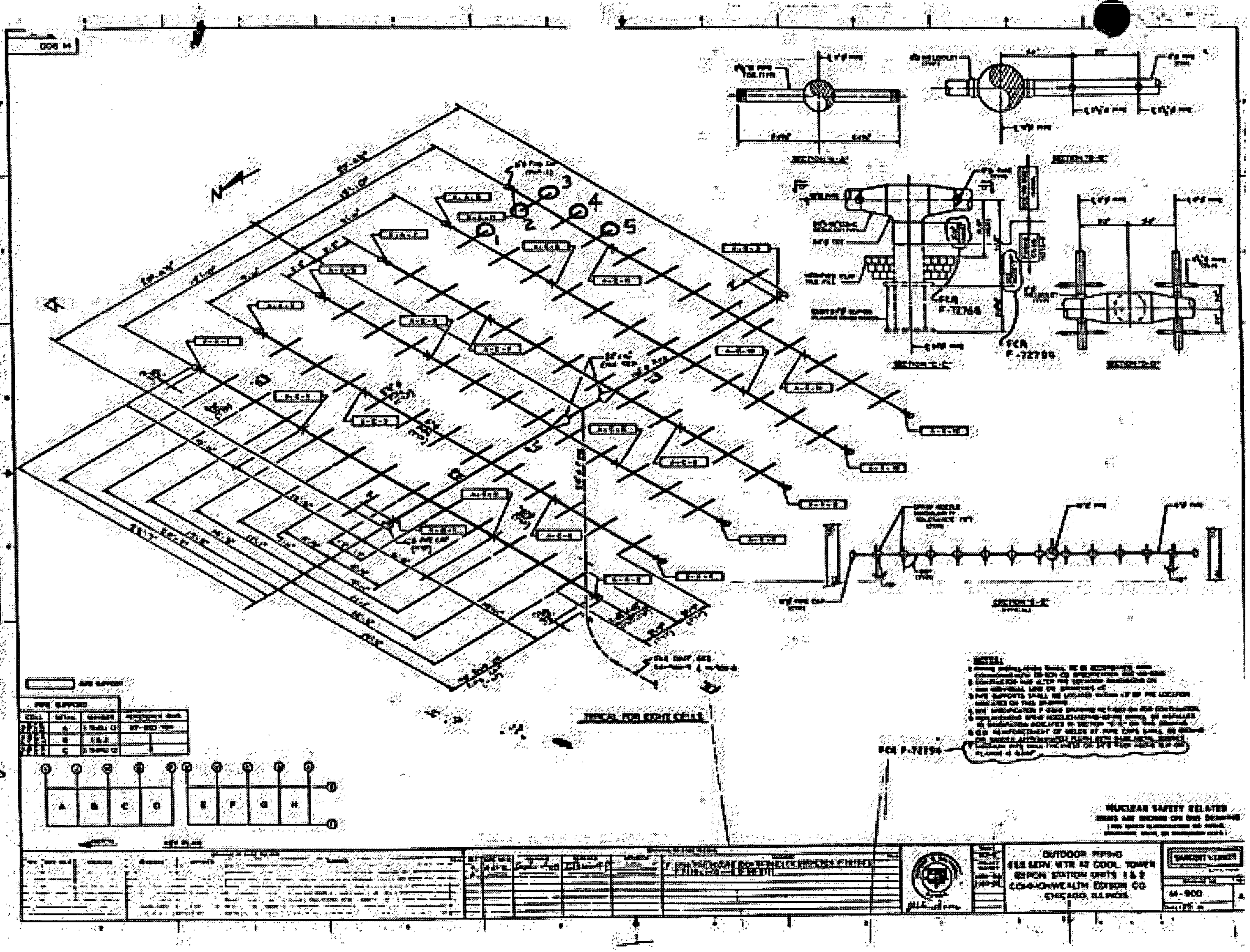
cc: S. Gackstetter
W. Walter
B. Adams
D. Sargent

TABLE 1

SXCT RISER VALVE LEAKAGE ESTIMATION

NOZZLE ID	TRIAL 1 (sec)	TRIAL 2 (sec)	TRIAL 3 (sec)	AVERAGE (sec)	AVERAGE (gpm)
1	32.14	31.22	31.15	31.50	3.81
2	27.13	27.09	27.62	27.28	4.40
3	40.62	41.21	41.29	41.04	2.92
4	48.47	48.29	47.57	48.11	2.49
5	44.74	44.79	45.99	45.17	2.66

NOTES: 1) Trial times represent the time to collect two gallons from the individual nozzle.
2) Refer to the attached copy of M-900, Sheet 25 for nozzle locations.



Attachment A
Calculation No. UHS-01
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Attachment B

Analysis of Additional UHS Post-LOCA Single Failure Scenarios

Table of Contents

1.0 PURPOSE

Attachment B to Calculation UHS-01 documents additional post-loss of coolant accident (LOCA) single failure scenarios that will be analyzed for the Ultimate Heat Sink (UHS). The additional scenarios are selected to bound the potential impact of supplementing the existing licensing basis single failure assumptions with additional failure assumptions, that of a failure of any one of the several electrical breakers (for 480 Vac Buses) which are 'fixed in place' for the accident. These new scenarios supplement the scenarios documented in Revision 2 and 3 to Calculation UHS-01.

2.0 BACKGROUND

The UHS for the Byron station consists of two (2) redundant essential service water (SX) mechanical-draft Cooling Towers (CTs) and the makeup system to these CTs. Each of the two (2) safety-related CTs consists of a water storage basin, four (4) fans, four (4) riser valves, and two (2) bypass valves (Reference 5.1). The basins of the two (2) CTs are connected by an overflow. Normal makeup is provided from the circulating water system. Safety-related makeup pumps automatically start on a low water level signal to pump water from the river. In the event of the probable maximum flood, there are deep well pumps available to provide makeup to the basin.

The mechanical-draft CTs are used as the heat sink for the SX system during normal operation, and they are required for safe shutdown. The UHS is capable of providing adequate cooling during a LOCA coincident with a loss of offsite power (LOOP) in one (1) unit, and a simultaneous shutdown and cooldown of the other unit from maximum power to Mode 5 using normal shutdown operation procedures.

During the 2005 NRC safety systems design and performance capability inspection, the inspectors noted that in Technical Specification (TS) Amendment No. 95 for the Byron Station (changes to the ultimate heat sink to support steam generator replacement), the most limiting single failure evaluated was the failure of active breakers or switches in the 480 Vac SX CT bus which resulted in the failure of one service water CT fan. The inspectors noted that the licensee did not address the 480 Vac feed breakers between the 4160/480 Vac transformer and bus 131Z (for example). The inspectors also noted that a single failure of either of these breakers would de-energize the bus and result in a power loss of two SX CT fans (Reference 5.3).

The licensee disagreed, stating the breakers were normally closed and therefore, a passive failure need not be considered. The configuration of the breakers and the licensee's assessment that passive failures need not be considered was previously reviewed and approved by the NRC. The issue was unresolved pending determination on whether the loss of the 4160 volt or 480 Vac feed breaker should have been considered as the single failure. Subsequent to the initiation of the unresolved item (URI), the inspectors concluded that although TS Amendment 95 did not adequately distinguish single failure of electrical components (active vs passive), consistent with the definition of a single failure presented in 10 CFR Part 50, Appendix A, and General Design Criterion 44, the failure of the 4160 volt or 480 Vac feed breaker should have been considered a valid single failure and assessed (Reference 5.3).

3.0 DESIGN INPUTS

3.1 Loading on 4160-Volt ESF Buses - The loading on each of the four (4) 4160 volt ESF Buses (141/142/241/242) are found on Design Information Transmittal (DIT) No. S040-BYR-6074-00 (Reference 5.4) and can be seen in Appendix A.

3.2 The 480 Vac feed breakers and associated loadings can be seen in Drawings 6E-1-4001A (Reference 5.8) and 6E-2-4001A (Reference 5.9).

3.3 Drawing M-42 (Reference 5.1) provides a diagram of the SX CT. The drawing shows which SX CT fan is associated with which cell riser valve and the associated piping for the SX CT. Drawing M-42 was used to model the figures in this calculation, which show the post-LOCA scenario configurations.

4.0 ASSUMPTIONS

All assumptions from Revision 3 to Calculation UHS-01 are used in this attachment except as follows:

4.1 Revision 3 assumed two (2) initial cold water SX CT Basin temperatures of 80° F and 96° F. These served as the minimum and maximum values, respectively. The current Byron TS B 3.7.9 (Reference 5.5) for the UHS are based on various combinations of fans in service and initial basin temperatures of 80°, 90°, and 96° F. These temperatures will be used as a starting point for the new scenarios but may need to be lowered in a separate analysis to obtain an acceptable peak basin temperature. This analysis is performed in Calculation NED-M-MSD-009.

4.2 Leak-by flow rates for closed SX CT bypass and riser valves and total bypass flow rates will be accounted for in detailed UHS analyses performed in separate calculations (Calculations NED-M-MSD-009 and BYR96-259).

4.3 Based on the gearing in the MOVs (locking gears), the loss of power to an SX CT bypass or riser valve will cause the valve to remain in the position the valve is in when the loss of power occurs.

4.4 Revision 3 assumed that the two (2) out-of-service (OOS) SX CT fans are powered from opposite unit's power supplies. However, this assumption is not supported by the way the plant is operated. Maintenance is performed on electrical that results in two (2) fans OOS from the same unit power supply. Therefore, it will be assumed that the case scenario in which two (2) OOS fans are powered from the same unit's power supply is possible.

4.4 Operator Actions

For the bus breaker failure scenarios, the following operator actions are credited:

1) CT fans not running initially, which don't lose power from the single failure, are remotely started 10 minutes following the LOCA/LOOP (Reference 5.7). Riser valves for corresponding cells are also opened at 10 minutes.

2) Riser valves to which power is lost from the single failure are assumed to remain in their initial position following the LOCA/LOOP with no operator action. The riser valves are not easily accessible and therefore no operator action (remote or manual) is credited.

5.0 REFERENCES

5.1 Exelon Generation Company, LLC, Byron Station, Unit No. 1 and 2, Drawing M-42, "Diagram of Essential Service Water," Sheet No. 7, Revision AE

5.2 Byron Station Units 1 and 2, Updated Final Safety Analysis Report (UFSAR), Revision 11

5.3 United States Nuclear Regulatory Commission Letter to Mr. Charles G. Pardee (Exelon Nuclear), entitled "Byron Station, Units 1 and 2 Follow Up Inspection of an Unresolved Item (URI) 05000454/2008008; 05000455/2008008," May 5, 2008

5.4 Design Information Transmittal (DIT) S040-BYR-6074-00, "Safety related equipment that may be lost in the event of failure of the 4.16kV Switchgear breakers," Issue Date December 22, 2006 (Included as Appendix A)

5.5 Exelon Generation Company, LLC, Byron Station, Unit No. 1 & 2, Appendix A to the Facility Operating License, "Technical Specifications Bases," Amended through Amendment No. 154, B 3.7.9

5.6 Exelon Generation Company, LLC, Byron Station, Unit No. 1 & 2, Appendix A to the Facility Operating License, "Technical Specifications," Amended through Amendment No. 154, LCO 3.7.9.A

5.7 Byron Nuclear Licensing Administrator Letter to Mr. Gary Contrady (Byron Project Management), entitled "Byron Station Ultimate Heat Sink Design," August 2, 1991, Chron # 170796

5.8 Exelon Generation Company, LLC, Byron Station, Unit No. 1, Drawing 6E-1-4001A, "Station One Line Diagram," 08/01/95, Revision O

5.8 Exelon Generation Company, LLC, Byron Station, Unit No. 2, Drawing 6E-2-4001A, "Station One Line Diagram," 01/16/97, Revision N

6.0 METHODOLOGY AND ACCEPTANCE CRITERIA

METHODOLOGY

The SX system is designed to ensure that sufficient capacity is available to provide adequate cooling during normal and accident conditions. The SX system is a two (2) unit shared system with various cross tie headers on both pump suction and discharge sides for both divisions and units. Appropriate (redundant) cross tie isolation valves are provided to achieve various system alignments necessary within the licensing and design bases. Heat is rejected by the SX system via two (2) mechanical-draft CTs. Each CT consists of four (4) cells with each cell served by a single two (2)-speed fan. The cold water basin for each CT serves a pair of SX pumps, one (1) from each unit. The cold water basins for the two (2) towers are cross-connected by what is termed an "overflow" pathway in the UFSAR. Depending on ambient conditions (i.e. summer or cool weather conditions), the towers are permitted to have one (1) or two (2) fans OOS while still being considered to be operable.

The worst case scenarios will be identified from the existing licensing basis single failure assumptions associated with the SX CT operation. Each scenario will be revised for the new conditions (i.e., failure of any one of the 4 kV or 480 Vac electrical breakers). Scenarios will be done for the most limiting design conditions. The results of this calculation will be used as input for additional detailed analysis of UHS performance, performed in a separate calculation (Calculation NED-M-MSD-009).

Scenarios 2A to 3C and 5 to 7 from this calculation (Revisions 2 and 3) are used as reference in defining the limiting sets of serviceable equipment, alignments, and accident conditions for the new case scenarios. The same initiating event used in this calculation (Revisions 2 and 3) will apply for the new case scenarios (i.e. LOCA and LOOP on the accident unit). The new single failure condition is the failure of a breaker for the 480 Vac Buses associated with the SX CT. Each of the four (4) Buses (131Z, 132Z, 231Z, and 232Z) are assumed to fail due to a failure of a feed breaker [i.e., 1415Z, 131Z, 1425Z, 132Z, 2415Z, 231Z, 2425Z, or 232Z (Reference 5.4, 5.8, and 5.9)] for the 480 Vac Bus in question. Only a single breaker is assumed to fail at a time.

The failure scenarios assume that up to two (2) SX CT fans are OOS at a time. The TS, Reference 5.6, LCO 3.7.9.A, states that if one (1) of the required CT fans is inoperable, then within 72 hours restore the required CT fan to operable status. The TS Bases, Reference 5.5, Section B 3.7.9, states that the design basis analyses assume two (2) tower cells (i.e., two (2) fans or water distribution to two (2) cells) are OOS. Thus, at least six (6) of the eight (8) SX CT fans must be operable.

The scenarios assume either no SX CT fans are OOS, one (1) SX CT fan is OOS, or two (2) SX CT fans are OOS when the single failure occurs. The SX CT fan(s) that is/are OOS is/are not the same as the SX CT fans that fail for the breaker failure case.

As can be seen in the DIT S040-BYR-6074-00 (Reference 5.4) and drawings 6E-1-4001A (Reference 5.8) and 6E-2-4001A (Reference 5.9), failure of a feed breaker to one of the four (4) 480 Vac Buses will result in the power loss of two (2) SX fans, the two (2) SX riser valves for the cells associated with the lost SX fans, and the power loss of one (1) SX Basin bypass valve for the SX CT that has the lost SX fans and associated riser valves. Thus, regardless of which one of the eight (8) 4 kV or 480 Vac feed breakers that fail, the effect on the SX CT system is the same; that is, the power loss of two (2) SX fans, the two (2) SX riser valves associated with those fans, and one (1) SX Basin bypass valve associated with the failed SX fans. Therefore, the scenarios for only one (1) feed breaker needs to be presented, since the failure of one of the other seven (7) feed breakers would have the same impact on the SX CT system.

The failure of breaker 1425Z at the 4160 V Bus 142 will be discussed in this calculation. The remaining breakers (1415Z, 131Z, 132Z, 2415Z, 231Z, 2425Z, and 232Z) will not be discussed in this calculation since the overall effects to the SX CT system is the same regardless of which breaker fails.

Each scenario is described in the results section of this calculation and figures are provided to illustrate each of the scenarios.

ACCEPTANCE CRITERIA

No acceptance criteria are provided for this calculation. This calculation identifies new single failure scenarios associated with the SX CT operation.

7.0 RESULTS

The following is a description of the scenarios associated with the SX CT and failure of the 480 Vac Buses.

Scenario 8A:

Initial Condition

CT Basin temperature: To be determined (TBD) (96° F starting point)
cells OOS: none
fan speed: high
SX pumps: one (1) running on each Unit

CT configuration:
Tower A: 4 fans running, 4 riser valves open, 4 active cells, 0 passive cells, 0 bypass valves open
Tower B: 4 fans running, 4 riser valves open, 4 active cells, 0 passive cells, 0 bypass valves open

Failure Condition

single failure: **breaker 1425Z at 4160V Bus 142 fails open** – loss of power to CT cell E & F fans (0SX03CE and 0SX03CF)

Also loss of power to:
480V Bus 132Z
480V MCC 132Z1
Deep Well Pump 0WW01PB (non-ESF)
ESS Service Water Make-Up Valve 0SX157A
Cell E Riser Valve 0SX163E
480V MCC 132Z1A (non-ESF)
Cell F Riser Valve 0SX163F
Basin Bypass Valve 0SX162B
Switchgear Room Vent Fan 1VX06C
120/208Vac Distribution Panelboard
Motor 0SX03CE Space Heater
HVAC Local Control Panel 1VX06J
Damper Starter Panel 1VX99J
ESW CT 0B Basis Level Switch 0LS-SX097
Motor 0SX03CF Space Heater
MOV 0SX163E Limit Switch Space Heater
MOV 0SX163F Limit Switch Space Heater

Accident Condition

(The post accident system lineup consists of three (3) SX pumps running, two (2) on accident unit, one (1) on non-accident unit.)

post-LOCA CT configuration:
CT A: 4 fans running, 4 riser valves open, 4 active cells, 0 passive cells, 0 bypass valves open
CT B: 2 fans running, 4 riser valves open, 2 active cells, 2 passive cells, 0 bypass valves open

(Following the postulated LOCA, credit is taken for UHS ambient heat dissipation immediately.)

Scenario 8B:

Initial Condition

CT Basin temperature: TBD (96° F starting point)
cells OOS: cell G
fan speed: high
SX pumps: one (1) running on each Unit

CT configuration:
Tower A: 4 fans running, 4 riser valves open, 4 active cells, 0 passive cells, 0 bypass valves open
Tower B: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open

Failure Condition

single failure: **breaker 1425Z at 4160V Bus 142 fails open** – loss of power to CT cell E & F fans (0SX03CE and 0SX03CF)

Also loss of power to:
480V Bus 132Z
480V MCC 132Z1
Deep Well Pump 0WW01PB (non-ESF)
ESS Service Water Make-Up Valve 0SX157A
Cell E Riser Valve 0SX163E
480V MCC 132Z1A (non-ESF)
Cell F Riser Valve 0SX163F
Basin Bypass Valve 0SX162B
Switchgear Room Vent Fan 1VX06C
120/208Vac Distribution Panelboard
Motor 0SX03CE Space Heater
HVAC Local Control Panel 1VX06J
Damper Starter Panel 1VX99J
ESW CT 0B Basis Level Switch 0LS-SX097
Motor 0SX03CF Space Heater
MOV 0SX163E Limit Switch Space Heater
MOV 0SX163F Limit Switch Space Heater

Accident Condition

(The post accident system lineup consists of three (3) SX pumps running, two (2) on accident unit, one (1) on non-accident unit.)

post-LOCA CT configuration:
CT A: 4 fans running, 4 riser valves open, 4 active cells, 0 passive cells, 0 bypass valves open
CT B: 1 fan running, 3 riser valves open, 1 active cells, 2 passive cells, 0 bypass valves open

(Following the postulated LOCA, credit is taken for UHS ambient heat dissipation immediately.)

Scenario 8C:

Initial Condition

CT Basin temperature: TBD (90° F starting point)
cells OOS: cell A, cell G
fan speed: high
SX pumps: one (1) running on each Unit

CT configuration:
Tower A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
Tower B: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open

Failure Condition

single failure: **breaker 1425Z at 4160V Bus 142 fails open** – loss of power to CT cell E & F fans (0SX03CE and 0SX03CF)

Also loss of power to:
480V Bus 132Z
480V MCC 132Z1
Deep Well Pump 0WW01PB (non-ESF)
ESS Service Water Make-Up Valve 0SX157A
Cell E Riser Valve 0SX163E
480V MCC 132Z1A (non-ESF)
Cell F Riser Valve 0SX163F
Basin Bypass Valve 0SX162B
Switchgear Room Vent Fan 1VX06C
120/208Vac Distribution Panelboard
Motor 0SX03CE Space Heater
HVAC Local Control Panel 1VX06J
Damper Starter Panel 1VX99J
ESW CT 0B Basis Level Switch 0LS-SX097
Motor 0SX03CF Space Heater
MOV 0SX163E Limit Switch Space Heater
MOV 0SX163F Limit Switch Space Heater

Accident Condition

(The post accident system lineup consists of three (3) SX pumps running, two (2) on accident unit, one (1) on non-accident unit.)

post-LOCA CT configuration:
CT A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
CT B: 1 fan running, 3 riser valves open, 1 active cells, 2 passive cells, 0 bypass valves open

(Following the postulated LOCA, credit is taken for UHS ambient heat dissipation immediately.)

Scenario 8D:

Initial Condition

CT Basin temperature: TBD (80° F starting point)
cells OOS: cell A, cell G
fan speed: no fans running
SX pumps: one (1) running on each Unit

CT configuration:
Tower A: 0 fans running, 2 riser valves open, 0 active cells, 2 passive cells, 0 bypass valves open
Tower B: 0 fans running, 2 riser valves open, 0 active cells, 2 passive cells, 0 bypass valves open

Failure Condition

single failure: **breaker 1425Z at 4160V Bus 142 fails open** – loss of power to CT cell E & F fans (0SX03CE and 0SX03CF)

Also loss of power to:
480V Bus 132Z
480V MCC 132Z1
Deep Well Pump 0WW01PB (non-ESF)
ESS Service Water Make-Up Valve 0SX157A
Cell E Riser Valve 0SX163E
480V MCC 132Z1A (non-ESF)
Cell F Riser Valve 0SX163F
Basin Bypass Valve 0SX162B
Switchgear Room Vent Fan 1VX06C
120/208Vac Distribution Panelboard
Motor 0SX03CE Space Heater
HVAC Local Control Panel 1VX06J
Damper Starter Panel 1VX99J
ESW CT 0B Basis Level Switch 0LS-SX097
Motor 0SX03CF Space Heater
MOV 0SX163E Limit Switch Space Heater
MOV 0SX163F Limit Switch Space Heater

Accident Condition

(The post accident system lineup consists of three (3) SX pumps running, two (2) on accident unit, one (1) on non-accident unit.)

post-LOCA CT configuration (prior to 10-minute operator action):
CT A: 0 fans running, 2 riser valves open, 0 active cells, 2 passive cells, 0 bypass valves open
CT B: 0 fans running, 2 riser valves open, 0 active cells, 2 passive cells, 0 bypass valves open

post-LOCA CT configuration (following 10-minute operator action - at 10 minutes, start the operable fans in high speed and open riser valves):
CT A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
CT B: 1 fans running, 3 riser valves open, 1 active cells, 2 passive cells, 0 bypass valves open

(Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until operator action is initiated to start tower fans and open riser valves.)

All possibilities for the scenario 8C and 8D configurations are shown in Table 1.

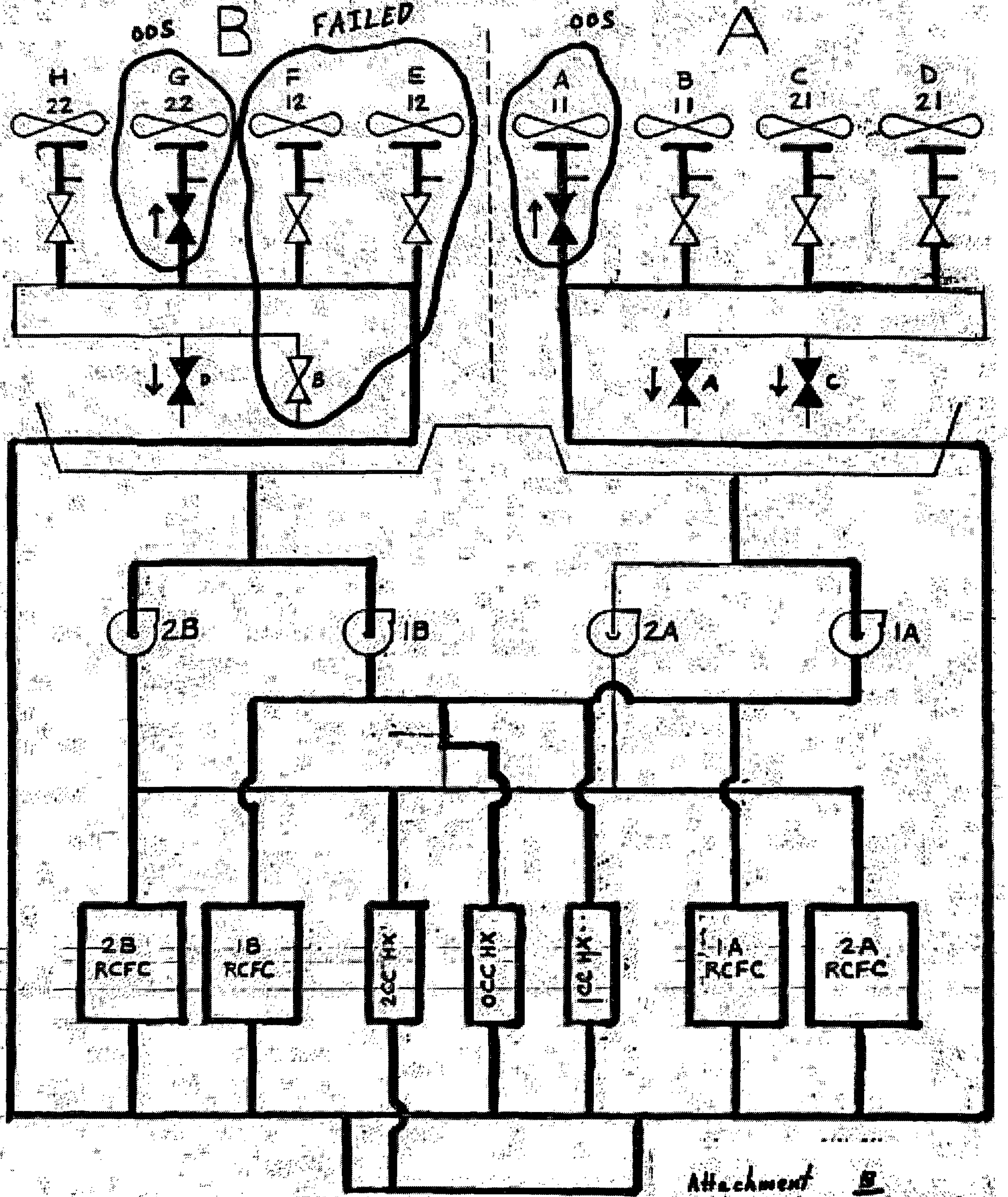
Table 1 - Scenario 8C and 8D Configurations

Cells OOS	Cells Failed
AB	CD or EF or GH
AC	EF or GH
AD	EF or GH
AE	CD or HG
AF	CD or HG
AG	CD or EF
AH	CD or EF
BC	EF or GH
BD	EF or GH
BE	CD or GH
BF	CD or GH
BG	CD or EF
BH	CD or EF
CD	AB or EF or GH
CE	AB or GH
CF	AB or GH
CG	AB or EF
CH	AB or EF
DE	AB or GH
DF	AB or GH
DG	AB or EF
DH	AB or EF
EF	AB or CD or GH
EG	AB or CD
EH	AB or CD
FG	AB or CD
FH	AB or CD
GH	AB or CD or EF

8.0 CONCLUSIONS

New scenarios were developed as described above for the failure of the electrical feed breakers for the 480 Vac Buses associated with the SX CTs. Figures 13 through 16 provide simplified diagrams to illustrate the scenarios. Note that variations can be made to each case scenario, as shown in Table 1 and as discussed in the results section in the body of this calculation. This calculation will be used as input for detailed evaluation of UHS performance.

FIGURE 13
POST LOCA CONFIGURATION (Initial Condition)
SCENARIO II



Attachment B
Calculation No. UHS-04
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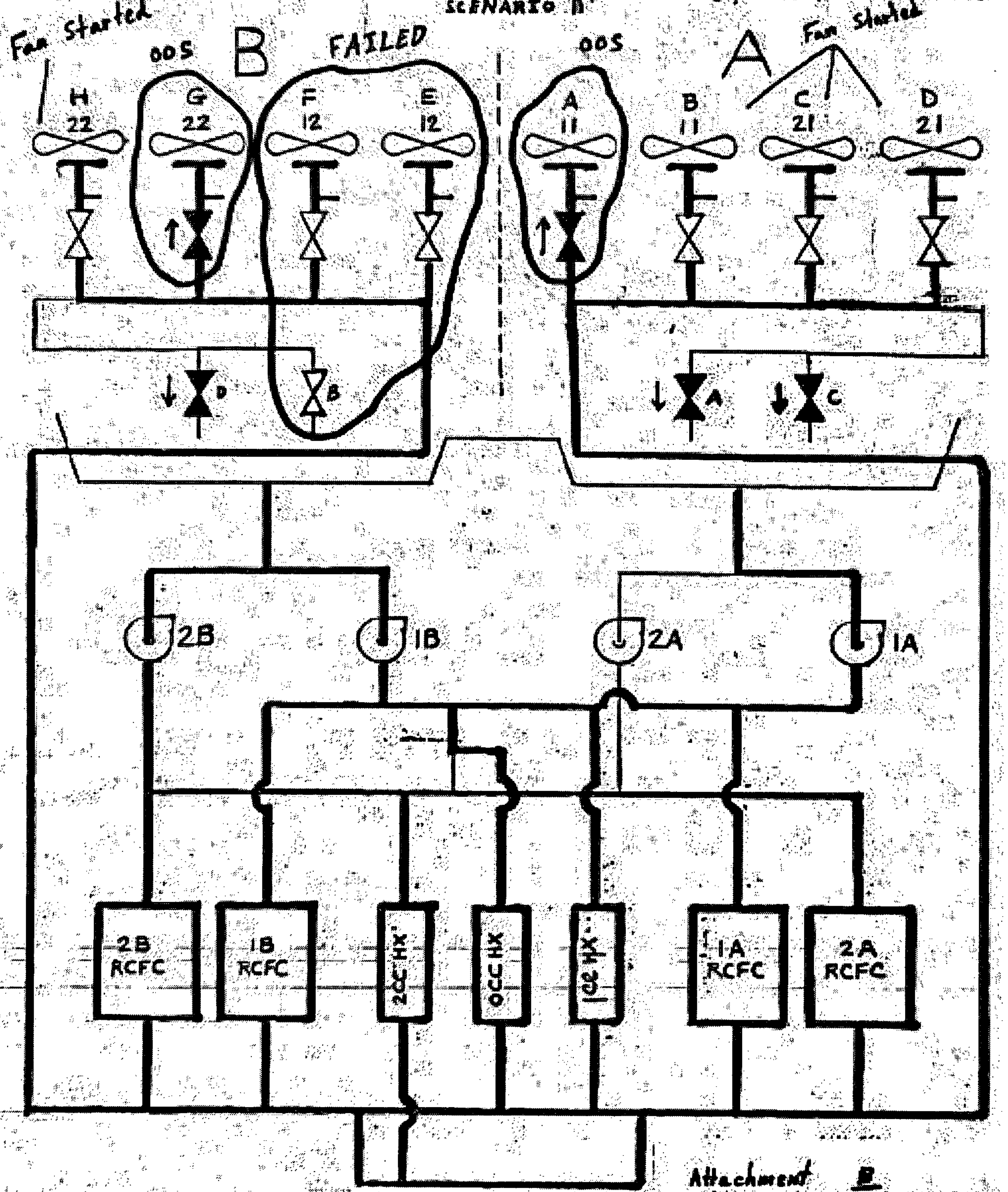
* → Valve Bypass Flow Leakage

FIGURE 14

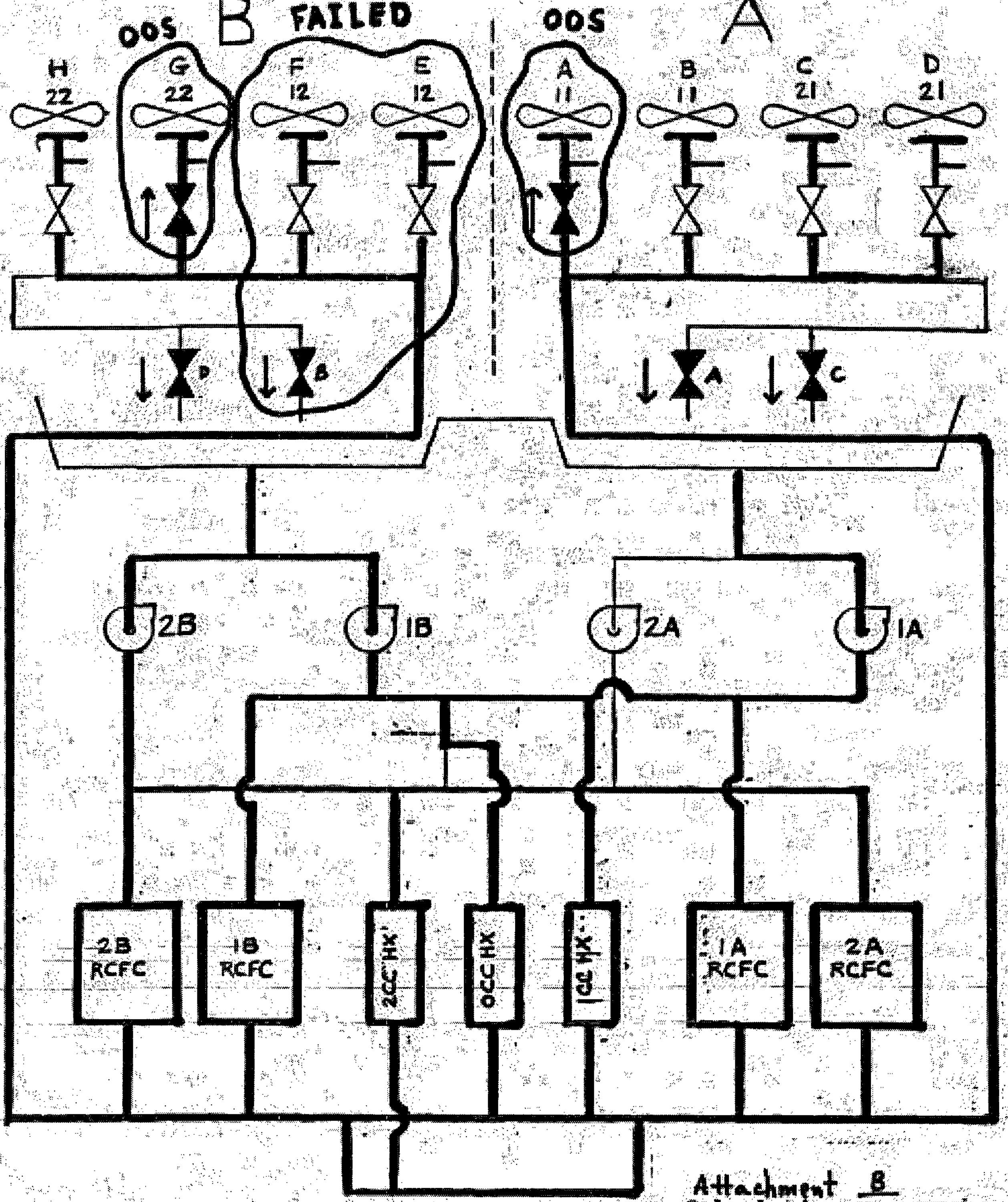
POST LOCA CONFIGURATION (10-min. Operator Action)

SCENARIO 11



* → Valve Bypass Flow Leakage

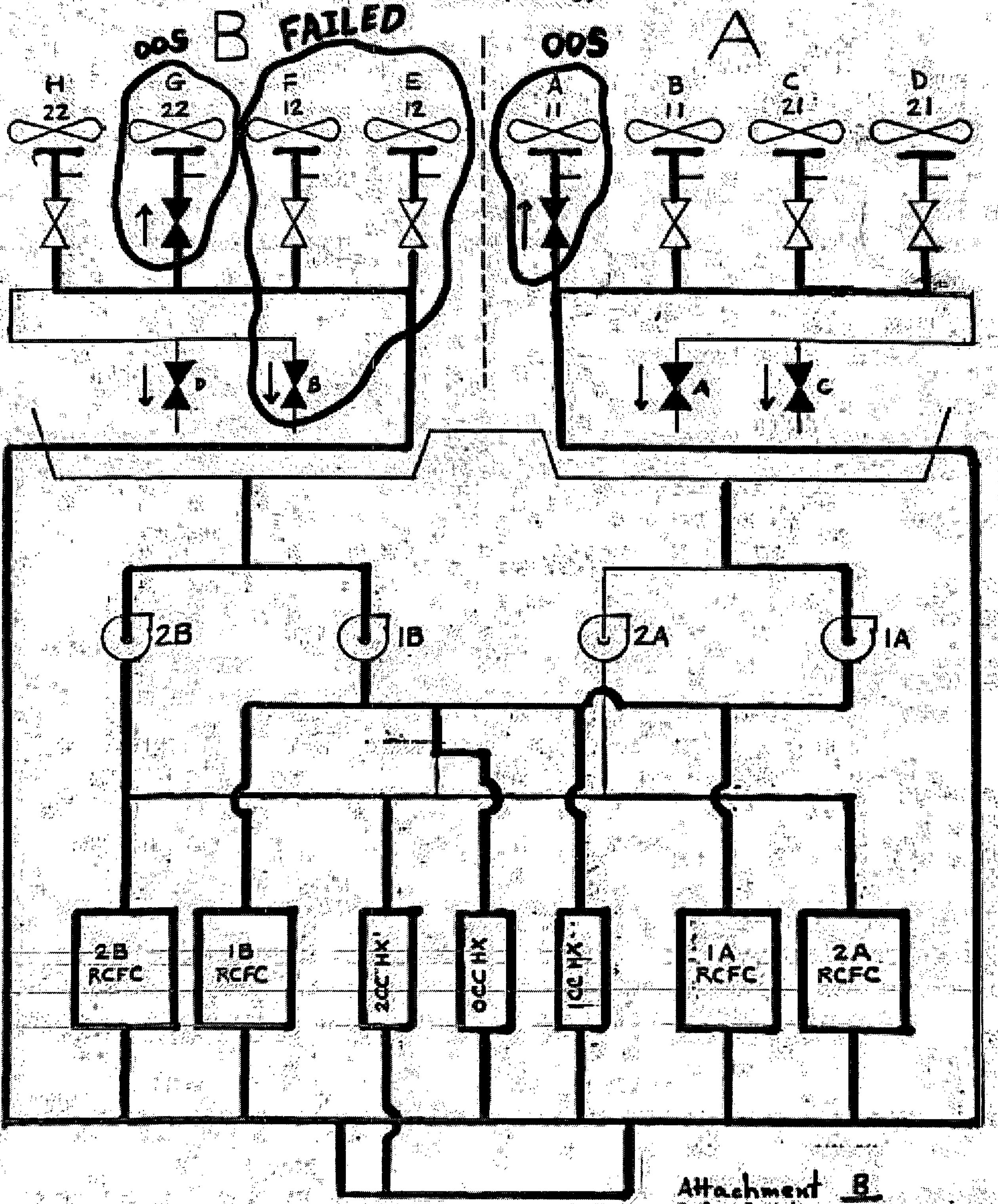
FIGURE 15
POST LOCA CONFIGURATION
SCENARIO 8C



* → Valve Bypass Flow Leakage

FIGURE 16

POST LOCA CONFIGURATION AFTER 10 MIN.
SCENARIO 8D



Attachment B
Calculation No. UHS-01
Revision No. 4
Page No. B19

✱ → Valve Bypass Flow Leakage

APPENDIX A
TO ATTACHMENT B to Calculation UHS-01

DIT S040-BYR-6074-00

Sargent & Lundy

DESIGN INFORMATION TRANSMITTAL

☒ Safety-Related ☐ Non-Safety-Related

DIT No. S040-BYR-6074-00

Page 1 of 3

To: M. A. Nena -23

Client: Exelon

Project No.: 11330-042

Station: Byron

Unit(s) 1 & 2

Subject: Safety related equipment that may be lost in the event of failure of the 4.16kV Switchgear breakers

MODIFICATION OR DESIGN CHANGE NUMBERS: N/A

J. A. Judikis/J. J. Bojan	NPT/EE & CD	Judikis / J. J. Bojan (Reviewer)	12/22/06
Preparer (Print Name)	Process Group	Preparer's Signature	Issue Date

STATUS OF INFORMATION:

This information being transmitted is approved for use and requires no further verification.

IDENTIFICATION OF THE SPECIFIC DESIGN INFORMATION TRANSMITTED AND PURPOSE OF ISSUE
(List any supporting documents attached to DIT by its title, revision and/or issue date, and total number of pages for each supporting document.)

This design information transmittal identifies the equipment (by name and equipment number) that would be lost upon failure (i.e., spurious opening) of the upstream 4.16kV feed breakers. This information is being provided for use in the ultimate heat sink equipment failure analysis.

See pages 2 and 3 of the design information transmittal for the equipment identification numbers.

SOURCE OF INFORMATION

Calc No. N/A Rev. Date

Report No. N/A Rev. Date

Drawings:	6E-1-4006A, Revision H	6E-1-4006B, Revision J	6E-1-4007C, Revision J	6E-1-4007F, Revision J
	6E-1-4008AG, Revision P	6E-1-4008AN, Revision R	6E-2-4006A, Revision E	6E-2-4006B, Revision E
	6E-2-4007C, Revision H	6E-2-4007F, Revision K	6E-2-4008AG, Revision K	6E-2-4008AN, Revision N

DISTRIBUTION:
C. Morris – 16 (original)
J. J. Bojan – 16
D. C. Patel – 16

DESIGN INFORMATION TRANSMITTAL

DIT No.: S040-BYR-6074-00	Project No.: 11330-042	Page 2 of 3

<u>The loss of breaker 1415Z at 4160V Bus 141 would result in the loss of:</u>

480V ESF Substation Bus 131Z (1AP99E)
ESW Cooling Tower Fan 0SX03CA (High & Low Speed)
ESW Cooling Tower Fan 0SX03CB (High & Low Speed)
Non-ESF Deep Well Pump 0WW01PA
480V ESW Cooling Tower MCC 131Z1 (1AP93E)
ESW Make-Up Valve 0SX158A
ESW Service Water Cooling Tower 0A Basin Bypass Valve 0SX162A
ESW Cooling Tower 0A Cell A Riser Valve 0SX163A
ESW Cooling Tower 0A Cell B Riser Valve 0SX163B
ESW Cooling Tower Division 11 Switchgear Room Ventilation Fan 1VX05C
MCC 131Z1 120/208Vac Distribution Panelboard and Auxiliaries:

- Motor 0SX03CA Space Heater
- HVAC Local Control Panel 1VX05J
- Damper Starter Panel 1VX98J
- ESW Cooling Tower 0A Basin Level Switch 0LS-SX098
- Motor 0SX03CB Space Heater
- MOV 0SX163A Limit Switch Heater
- MOV 0SX163B Limit Switch Heater

Non-ESF 480V MCC 131Z1A (1AP89E)

<u>The loss of breaker 1425Z at 4160V Bus 142 would result in the loss of:</u>

480V ESF Substation Bus 132Z (1AP98E)
ESW Cooling Tower Fan 0SX03CE (High & Low Speed)
ESW Cooling Tower Fan 0SX03CF (High & Low Speed)
Non-ESF Deep Well Pump 0WW01PB
480V ESW Cooling Tower MCC 132Z1 (1AP92E)
ESW Make-Up Valve 0SX157A
ESW Service Water Cooling Tower 0B Basin Bypass Valve 0SX162B
ESW Cooling Tower 0B Cell E Riser Valve 0SX163E
ESW Cooling Tower 0B Cell F Riser Valve 0SX163F
ESW Cooling Tower Division 12 Switchgear Room Ventilation Fan 1VX06C
MCC 132Z1 120/208Vac Distribution Panelboard and Auxiliaries

- Motor 0SX03CE Space Heater
- HVAC Local Control Panel 1VX06J
- Damper Starter Panel 1VX99J
- ESW Cooling Tower 0B Basin Level Switch 0LS-SX097
- Motor 0SX03CF Space Heater
- MOV 0SX163E Limit Switch Heater
- MOV 0SX163F Limit Switch Heater

Non-ESF 480V MCC 132Z1A (1AP88E)

Sargent & Lundy	DESIGN INFORMATION TRANSMITTAL	
DIT No.: S040-BYR-6074-00	Project No.: 11330-042	Page 3 of 3

<u>The loss of breaker 2415Z at 4160V Bus 241 would result in the loss of:</u>

480V ESF Substation Bus 231Z (2AP99E)
ESW Cooling Tower Fan 0SX03CC (High & Low Speed)
ESW Cooling Tower Fan 0SX03CD (High & Low Speed)
480V ESW Cooling Tower MCC 231Z1 (2AP93E)
ESW Make-Up Valve 0SX158B
ESW Service Water Cooling Tower 0A Basin Bypass Valve 0SX162C
ESW Cooling Tower 0A Cell C Riser Valve 0SX163C
ESW Cooling Tower 0A Cell D Riser Valve 0SX163D
ESW Cooling Tower Division 21 Switchgear Room Ventilation Fan 2VX05C
MCC 231Z1 120/208Vac Distribution Panelboard and Auxiliaries:

- Motor 0SX03CC Space Heater
- HVAC Local Control Panel 2VX05J
- Damper Starter Panel 2VX98J
- Motor 0SX03CD Space Heater
- MOV 0SX163C Limit Switch Heater
- MOV 0SX163D Limit Switch Heater

Non-ESF 480V MCC 231Z1A (2AP89E)

<u>The loss of breaker 2425Z at 4160V Bus 242 would result in the loss of:</u>

480V ESF Substation Bus 232Z (2AP98E)
ESW Cooling Tower Fan 0SX03CG (High & Low Speed)
ESW Cooling Tower Fan 0SX03CH (High & Low Speed)
480V ESW Cooling Tower MCC 232Z1 (2AP92E)
ESW Make-Up Valve 0SX157B
ESW Service Water Cooling Tower 0B Basin Bypass Valve 0SX162D
ESW Cooling Tower 0B Cell G Riser Valve 0SX163G
ESW Cooling Tower 0B Cell H Riser Valve 0SX163H
ESW Cooling Tower Division 22 Switchgear Room Ventilation Fan 2VX06C
MCC 232Z1 120/208Vac Distribution Panelboard and Auxiliaries

- Motor 0SX03CG Space Heater
- HVAC Local Control Panel 2VX06J
- Damper Starter Panel 2VX99J
- Motor 0SX03CH Space Heater
- MOV 0SX163G Limit Switch Heater
- MOV 0SX163H Limit Switch Heater

Non-ESF 480V MCC 232Z1A (2AP88E)

ATTACHMENT 3
Additional References

2. UHS-04 Revision 3, "Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios for Cool Weather Operation"

ATTACHMENT 1
Design Analysis Major Revision Cover Sheet
Page 1 of 5

Design Analysis (Major Revision)

Last Page No.: B24

Analysis No.: UHS-04 **Revision:** 3

Title: Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios for Cool Weather Operation

EC/ECR No.: EC 371386 **Revision:** 0

		Component(s):	
Station(s):	Byron		
Unit No.:	1 & 2		
Discipline:	NUDC		
Descrip. Code/Keyword:	N01		
Safety/QA Class:	Safety Related		
System Code:	SX		
Structure:	NA		

CONTROLLED DOCUMENT REFERENCES

Document No.:	From/To	Document No.:	From/To
NED-M-MSD-011	To		
BYR96-259	To		

Is this Design Analysis Safeguards Information? Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? Yes ☐ No ☒ If yes, ATI/AR#: NA

This Design Analysis SUPERCEDES: NA **in its entirety.**

Description of Revision (list affected pages for partials): Replaced pages 1, 1A, 1B, and 1C with New Cover Page, Owner's Acceptance Review Checklist (page 1a), and Table of Contents (page 1b). Added Attachment B. Revised page 2. Incorporated item #1, #2, and #5 of DCR 970136 (EC 91616) on pages 1b, 4, and 25.

This is the initial issue of Attachment B to Calculation UHS-04. Attachment B is added to address additional scenarios for postulated single failures associated with electrical breakers serving the Essential Service Water (SX) system components.

Preparer: A. Milicevic - S&L (Print Name) (Sign Name) 12-03-08 (Date)

Method of Review: Detailed Review ☒ Alternate Calculations (attached) ☐ Testing ☐

Reviewer: B.J. Andrews - S&L (Print Name) BJ Andrews (Sign Name) 12-3-2008 (Date)

Review Notes: Independent review ☒ Peer review ☐

(For External Analyses Only)

External Approver: MICHAEL A. NENA (Print Name) (Sign Name) 12/23/2008 (Date)

Exelon Reviewer: D. SARGENT (Print Name) D Sargent (Sign Name) 4/17/2009 (Date)

Independent 3rd Party Review Reqd? Yes ☐ No ☒

Exelon Approver: Ed Blondin (Print Name) Ed Blondin (Sign Name) 4/21/09 (Date)

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Revision 8
Page 17 of 17

ATTACHMENT 2
Owners Acceptance Review Checklist for External Design Analysis
Page 1 of 1

DESIGN ANALYSIS NO. UHS-04 **REV:** 3

		Yes	No	N/A
1.	Do assumptions have sufficient rationale?	☒	☐	☐
2.	Are assumptions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
3.	Do the design inputs have sufficient rationale?	☒	☐	☐
4.	Are design inputs correct and reasonable?	☒	☐	☐
5.	Are design inputs compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
6.	Are Engineering Judgments clearly documented and justified?	☐	☐	☒
7.	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	☐	☐	☒
8.	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	☒	☐	☐
9.	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	☒	☐	☐
10.	Does the Design Analysis include the applicable design basis documentation?	☒	☐	☐
11.	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	☐	☐	☒
12.	Are there any unverified assumptions?	☐	☒	☐
13.	Do all unverified assumptions have a tracking and closure mechanism in place?	☐	☐	☒
14.	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	☒	☐	☐
15.	Do the sources of inputs and analysis methodology used meet current technical requirements and regulatory commitments? (If the input sources or analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code)	☒	☐	☐
16.	Have vendor supporting technical documents and references (including GE ORFs) been reviewed when necessary?	☒	☐	☐

EXELON REVIEWER: D. SARGENT / D Sargent **DATE:** 4/17/09
Print / Sign

COMMONWEALTH EDISON COMPANY
CALCULATION TABLE OF CONTENTS

	PROJECT NO. NA	
CALCULATION NO. UHS-04	REV. NO. 3	PAGE NO. 1b

REVISION 2

ATTACHMENTS

I. Purpose/Introduction

The purpose of this calculation is to document the post LOCA single failure modes that will be analyzed by Commonwealth Edison Company Nuclear Engineering Department for Byron Ultimate Heat Sink (UHS) design basis reconstitution for cool weather operation. This calculation supplements Calculation UHS-01 which documents single failure scenarios corresponding to an 82°F ambient wet bulb temperature. The following provides a discussion of the cool weather accident scenarios that will be analyzed for the UHS. These scenarios were chosen as discussed at the September 12, 1991 meeting between Byron Station Operating, Tech Staff, Regulatory Assurance, Projects, Licensing and Sargent & Lundy. Base scenarios chosen for analysis are numbered sequentially. These scenarios each postulate a LOCA as the initiating event and Loss of Offsite Power (LOOP) on the accident unit (reference 4). Unit 1 was consistently chosen as the accident unit for matter of convention. The base scenarios were postulated by assuming various single failures in combination with different sets of initial conditions. The scenarios focus on the effects of failed open bypass valves which divert flow from active cells.

Additional scenarios (i.e., scenarios 8 and 9) are described on pages 23-30. Attachment A provides an estimation of the essential service water cooling tower (SXCT) riser valve leakage used in scenarios 8 and 9.

Attachment B to this calculation addresses additional scenarios for postulated single failures associated with electrical breakers serving the Essential Service Water (SX) components.

II. Assumptions

1. The single failure scenarios assume the following initial conditions:

    A. Two units operating at full power with:

        a. One ESW pump running on each unit
        b. The ESW pump discharge train crosstie valves (1/2SX033 and 1/2SX034) open
        c. The ESW pump discharge unit crosstie valves (1/2SX005) closed
        d. The ESW return header crosstie valves (1/2SX136, 1/2SX010, 1/2SX011) open
        e. ESW flow being provided to the following heat exchangers

- 0CC01A	CC Hx (Aligned to Unit 1)
- 1/2CC01A	CC Hx's
- 1/2VA01SA/SB	SX Pump Cubicle Coolers
- 1/2SX01AA/AB	SX Pump Oil Coolers
* - 1/2WO01CA/CB	Containment Chillers *
- 1/2SI01SA/SB	SI Pump Bearing Oil Coolers
- 1/2VA04SA/SB	SI Pump Cubicle Coolers
- 0WO01CA/CB	Control Room Chillers
- 1/2VA02SA/SB	RH Pump Cubicle Coolers

- 1/2CV02SA/SB	CV Pump Gear Coolers
- 1/2CV03SA/SB	CV Pump Lube Oil Coolers
- 1/2VA06SA/SB	CV Pump Cubicle Coolers
- 1/2VA05S	PD Pump Cubicle Coolers
- 1/2VA03SA/SB	CS Pump Cubicle Coolers
- 1/2VA07S	FC Pump Cubicle Coolers
- 1/2VP01AA/AB/AC/AD	RCFC's

* Automatically bypassed on accident unit based on post accident ESF signal.

f. ESW flow isolated to the following heat exchangers:

- 1/2AF01AA	MDAF Pump Oil Coolers
- 1/2AF01AB	DDAF Pump Oil Coolers
- 1/2SX02K	DDAF Pump Angle Gear Oil Coolers
- 1/2SX01K	DDAF Pump Engine Closed Coolers
- 1/2VA08S	DDAF Pump Cubicle Coolers
- 1/2AF02A	DDAF Pump Gear Oil Coolers
- 1/2DG01KA/KB	DG Jacket Water Coolers
- AFW Pump Suction Supplies	

B. ESW Cooling Tower cold water basin level is assumed to be at the Technical Specification minimum.

C. It is assumed that two fans are initially out of service (OOS) for each of the scenarios. Based on administrative controls, the two fans that are out of service in this configuration must be powered from different unit's power supplies. It will be assumed that the riser valves associated with the OOS fans are closed.

D. The various single failure scenarios will be analyzed assuming an initial basin temperature of 70°F and either one fan OOS on each tower or two fans OOS on one tower.

E. Administrative controls do not require any fans running on high speed when the basin temperature is less than 80°F. Therefore, the single failure scenarios will be analyzed assuming no fans are initially running and various combinations of tower riser and bypass valve alignments are present. These scenarios will not take credit for UHS ambient heat dissipation until post LOCA control room operator actions are initiated for system re-alignment.

A.M.
09/24/08

2. When operator actions are required in the Main Control Room, it is assumed these actions can be initiated 10 minutes following safeguards signals.

3. When manual valve realignment is required, it is assumed these actions can be initiated 30 minutes following safeguards signals.

4. It is assumed that only one non-accident unit SX pump is running in the post accident modes since the non-running pump would not receive an auto-start signal.

5. A 70°F ambient wet bulb temperature and a 70°F cold water basin temperature will be assumed for all scenarios since administrative controls require bypass valves closed when the cold water basin temperature is above 70°F.

6. It is assumed that the non-accident unit is initially at power operation and proceeds to an orderly shutdown following the postulated LOCA on the accident unit. It is assumed that the non-accident unit would not achieve hot shutdown conditions (T_{AVG} = 350°F) until ~~10~~ 8 hours after the LOCA.

A.M.
09/24/08

III. Scenario Descriptions

1. Scenario 1 (Figure 1)

A. Single Failure - The single failure considered for this scenario is an essential service water cooling tower bypass valve.

B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that two cells are out of service on one tower. It is assumed that one SX pump is running on each unit and any combination of remaining riser valve and bypass valve alignment is present.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 loss of offsite power (LOOP). The single failure considered for this case is an open essential service water cooling tower bypass valve on the tower with two cells out of service. The injection phase heat load on the UHS corresponds to four RCFC's and two containment spray pumps operating. In addition, it is assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no immediate credit is taken for UHS ambient heat dissipation until control room operator action is initiated to open riser valves, start tower fans and close bypass valves. After 30 minutes, manual operator action is initiated to close the failed open tower bypass valve such that all tower flow is directed through risers. The post accident system lineup consists of three SX pumps supplying automatically aligned post accident ESW loads. The two accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have four active cells (fan running on high and riser valve open) and no passive cells (fan not running and riser valve open). Tower B will have two active cells and no passive cells.

2. Scenario 2 (Figure 2)

A. Single Failure - The single failure considered in this scenario is an essential service water cooling tower bypass valve.

B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that one cell is out of service on each tower. It is assumed that one SX pump is running on each unit and any combination of remaining riser valve and bypass valve alignment is present.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 loss of offsite power (LOOP). The single failure considered in this case is an open essential service water cooling tower bypass valve. The injection phase heat load on the UHS corresponds to four RCFCs and two containment spray pumps operating. In addition it is assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no immediate credit is taken for UHS heat dissipation until control room operator action is initiated to open riser valves, start tower fans and close bypass valves. After 30 minutes, manual operator action is initiated to close the failed open bypass valve such that all tower flow is directed through risers. The post accident lineup consists of three SX pumps supplying automatically aligned post accident ESW loads. The two accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have three active cells and no passive cells. Tower B will have three active cells and no passive cells.

3. Scenario 3 (Figure 3)

A. Single Failure - The single failure considered for this scenario is an essential service water cooling tower bypass valve.

B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that two tower cells are OOS on one tower. It is assumed that one SX pump is running on each unit and any combination of remaining riser valve and bypass valve alignment is present.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is an open essential service water cooling tower bypass valve on the tower with no cells out of service. The injection phase heat load on the UHS corresponds to four RCFCs and two containment spray pumps operating. Both trains of the accident unit SX system heat loads are assumed to be aligned. In addition, it is assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until control room operator action is initiated to open riser valves, start tower fans and close bypass valves. After 30 minutes, manual operator action is initiated to close the failed open tower bypass valve such that all tower flow is diverted through risers. The post accident system lineup consists of three SX pumps running and supplying the additional automatically aligned ESW loads. The two accident unit SX pumps would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump remains off since it would not receive an auto-start signal. Tower A will have two active cells and no passive cells. Tower B will have four active tower cells.

4. <u>Scenario 4</u> (Figure 4)

A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail and the corresponding riser valves and bypass valve are assumed to fail in the open position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that one cell is out of service on each tower. This will result in the maximum number of cells out of service after the postulated failure of the diesel. It is assumed that one SX pump is running on each unit, the division 12 riser valves and bypass valve are open and any combination of remaining riser and bypass valve alignment is present.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is a 1B emergency diesel failure. This failure will result in a less than maximum injection phase heat load on the UHS because only two RCFC fans will be functional on the accident unit. In addition, the 1B train SX heat exchangers and cubicle coolers would not significantly contribute to UHS heat load. The 1B diesel failure envelopes the 1A diesel failure because the UHS will receive heat load from both accident unit auxiliary feedwater pumps. In the case of a 1A diesel failure, the UHS would only receive heat load from the 1B AFW pump since the 1A AFW pump is motor driven. In addition, it will be assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until control room operator action is initiated to open riser valves, start tower fans and close bypass valves. It is assumed that the diesel failure affects two division 12 riser valves and one division 12 bypass valve that were initially open such that they remain in position after control room operator action is initiated. After 30 minutes, manual operator action is initiated to close the failed open tower bypass valve such that all tower flow is directed through risers. The post accident system lineup consists of two SX pumps running and the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have three active cells and no passive cells. Tower B will have one active cell and two passive cells.

5. Scenario 5 (Figure 5)

A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail, the corresponding riser valves are assumed to fail in the closed position and one bypass valve fails in the open position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that one cell is out of service on each tower. This will result in the maximum number of cells out of service after the postulated failure of the diesel. It is assumed that one SX pump is running on each unit, the division 12 riser valves are closed, the division 12 bypass valve is open and any combination of remaining riser and bypass valve alignment is present.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is again a 1B emergency diesel failure. This scenario is the same as Scenario 4 with the exception of the failure position of two riser valves. In this scenario it is assumed that the two affected riser valves fail in the closed position as opposed to the open position. Following the postulated LOCA, no credit is taken for UHS heat dissipation until control room operator actions are initiated to open riser valves, start tower fans and close bypass valves. It is assumed that the diesel failure affects the division 12 riser valves that were initially closed and division 12 bypass valve that was initially open such that they remain in position after control room operator action is initiated. After 30 minutes, manual operator action is initiated to close the failed open tower bypass valve such that all flow is directed through risers. The post accident system lineup consists of two SX pumps running and supplying the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have one active cell and no passive cells. Tower B will have three active cells and no passive cells.

6. Scenario 6 (Figure 6)

A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail and the corresponding riser valves and bypass valve are assumed to fail in the open position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that two cells are out of service on the tower opposite from division 12. It is assumed that one SX pump is running on each unit and the division 12 riser valves and bypass valve are open and any combination of remaining riser and bypass valve alignment is present.

C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is a 1B emergency diesel failure. This failure will result in a less than maximum injection phase heat load on the UHS because only two RCFC fans will be functional on the accident unit. In addition, the 1B train SX heat exchangers and cubicle coolers would not significantly contribute to UHS heat load. The 1B diesel failure envelopes the 1A diesel failure because the UHS will receive heat load from both accident unit auxiliary feedwater pumps. In the case of a 1A diesel failure, the UHS would only receive heat load from the 1B AFW pump since the 1A AFW pump is motor driven. In addition, it will be assumed that the non-accident unit proceeds to an orderly shutdown. Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until control room operator action is initiated to open riser valves, start tower fans and close bypass valves. It is assumed that the diesel failure affects two division 12 riser valves and one division 12 bypass valve that were initially open such that they remain in position after control room operator action is initiated. After 30 minutes, manual operator action is initiated to close the failed open tower bypass valve such that all tower flow is directed through risers. The post accident system lineup consists of two SX pumps running and the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have two active cells and no passive cells. Tower B will have two active cells and two passive cells.

7. Scenario 7 (Figure 7)

   A. Single Failure - The single failure considered for this scenario is a 1B emergency diesel failure. As a result, the two division 12 tower fans are assumed to fail, the corresponding riser valves are assumed to fail in the closed position and one bypass valve fails in the open position. It is assumed that essential division 12 components are aligned to receive ESW flow, however, no heat loading is assumed from these non-energized components.

   B. Initial Conditions - Initial conditions are as described in Section II. In addition, it is assumed that two cells are out of service on one tower. It is assumed that one SX pump is running on each unit, the division 12 riser valves are closed, the division 12 bypass valve is open and any combination of remaining riser and bypass valve alignment is present.

   C. Accident Conditions - The initiating event is a Unit 1 LOCA and a coincident Unit 1 LOOP. The single failure considered for this case is again a 1B emergency diesel failure. This scenario is the same as Scenario 6 with the exception of the failure position of two riser valves. In this scenario it is assumed that the two affected riser valves fail in the closed position as opposed to the open position. Following the postulated LOCA, no credit is taken for UHS heat dissipation until control room operator actions are initiated to open riser valves, start tower fans and close bypass valves. It is assumed that the diesel failure affects the division 12 riser valves that were initially closed and division 12 bypass valve that was initially open such that they remain in position after control room operator action is initiated. After 30 minutes, manual operator action is initiated to close the failed open tower bypass valve such that all flow is directed through risers. The post accident system lineup consists of two SX pumps running and supplying the additional automatically aligned ESW loads. The available accident unit pump would start automatically based on safeguards signals. The non-accident unit pump that was running initially would remain running. It is assumed that the other non-accident unit pump would remain off since it would not receive an auto-start signal. Tower A will have two active cells and no passive cells. Tower B will have two active cells and no passive cells.

IV. Other Failures Considered That Are Enveloped

Other failures that were considered are enveloped via Calculation UHS-01.

V. Input Data/References

1. Piping and Instrumentation Drawings
   M-42-1A and 1B Rev. Z
   M-42-2A and 2B Rev. AC
   M-42-3 Rev. AL
   M-42-4 Rev. AH
   M-42-5 Rev. Y
   M-42-6 Rev. AH
   M-42-7 Rev. M
   M-42-8 Rev. K

2. Byron Technical Specifications Amendment 39

3. 1/2BEP-0/WOF-1A Rev. 3 "Reactor Trip or Safety Injection"

4. OBOS 0.1 - Rev. 3

5. 1/2BOA PRI-7 Rev. 3 "Essential Service Water Malfunction"

6. BAR 1/2-2-B2 Rev. 52 "Annunciator Response Procedure"

7. OBOS 7.5-1a Rev. 2 "UHS Technical Specification LCO 3.7.5"

8. Correspondence from K. D. Brennan (CECo) to R. Pleniewicz (CECo) dated April 22, 1991 regarding "Design Criteria for Ultimate Heat Sink (UHS)"

9. Code of Federal Regulations 10CFR50 Appendix A, January 1, 1990 Edition

10. Regulatory Guide 1.27 Rev. 2 January 1976

11. Byron Electrical Schematic Drawings
    6E-1-4030SX15 Rev. F
    6E-1-4030SX16 Rev. F
    6E-1-4030SX01 Rev. T
    6E-1-4030SX02 Rev. U
    6E-2-4030SX15 Rev. E
    6E-2-4030SX16 Rev. E
    6E-2-4030SX01 Rev. N
    6E-2-4030SX02 Rev. M
    6E-0-4030SX01 Rev. R
    6E-0-4030SX02 Rev. R
    6E-0-4030SX03 Rev. R
    6E-0-4030SX04 Rev. S
    6E-0-4030SX05 Rev. S
    6E-0-4030SX06 Rev. R
    6E-0-4030SX07 Rev. T
    6E-0-4030SX08 Rev. T

12. Correspondence from T. K. Schuster/D. Chrzanowski (CECo) to G. Contrady (CECo) dated August 2, 1991 regarding "Byron Station Ultimate Heat Sink Design".

13. Byron/Braidwood Updated Final Safety Analysis Report (UFSAR) Revision 2 submitted December 17, 1991.

14. ANSI/ANS-58.8-1984 American Nuclear Society time response design criteria for nuclear safety related operator actions.

15. BOP SX-T2 Rev. 1 "SX Tower Operation Guidelines".

16. 1BEP-0 Rev. 3 "Reactor Trip or Safety Injection - Unit 1".

VI. Conservatisms

1. The following are conservatively assumed to occur coincidentally for analysis purposes:

    a. postulated LOCA.

    b. loss of offsite power (LOOP) on accident unit.

    c. worst case single failure in addition to having two tower cells OOS.

2. It is assumed that initially no fans are running. As a result, no UHS ambient heat dissipation is credited until after control room operator actions have been initiated.

3. It is assumed that two cells are OOS. Normally, all 8 cells would actually be in service.

4. The minimum Technical Specification basin level (50%) is used for analysis purposes to conservatively minimize the passive UHS heat capacity. The basin is normally maintained at or above 70% which would provide additional tower heat capacity.

5. No credit is taken for passive cooling tower cell ambient heat dissipation.

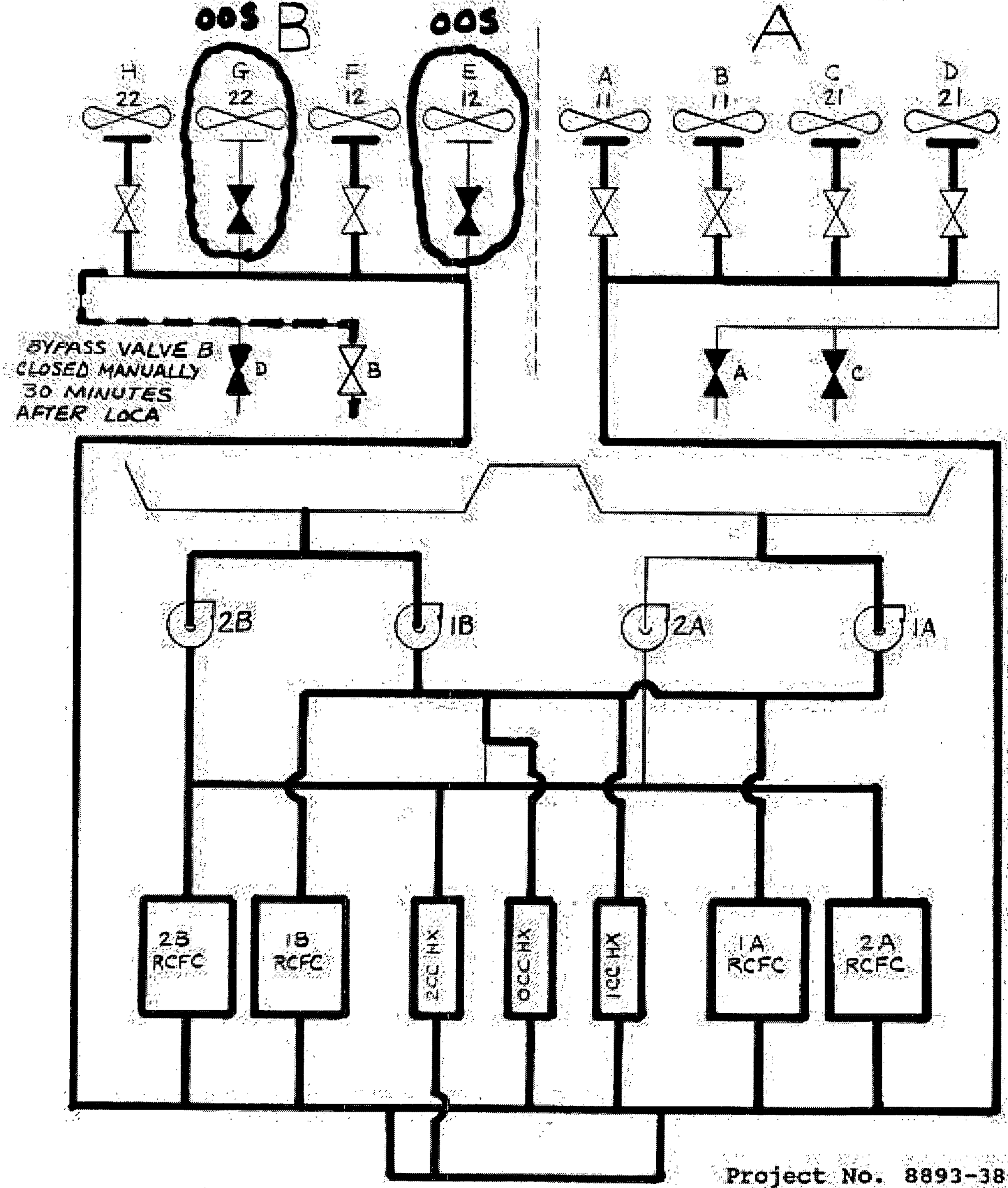
6. No credit is taken for the cooling contribution from the ESW makeup to the tower basins.

VII. Conclusion

Single failure scenarios were developed and described in Section II. Figures 1 through 7 provide simplified diagrams to illustrate the scenarios. This calculation will be used as input to CECo for detailed evaluation of UHS performance.

This review was accomplished by a detailed review of the original calculation.
Reviewer ________ Date 9-24-97

FIGURE 1
POST LOCA CONFIGURATION
SCENARIO 1



Project No. 8893-38/39
Calculation No. UHS-04
Revision 0

FIGURE 2
POST LOCA CONFIGURATION
SCENARIO 2

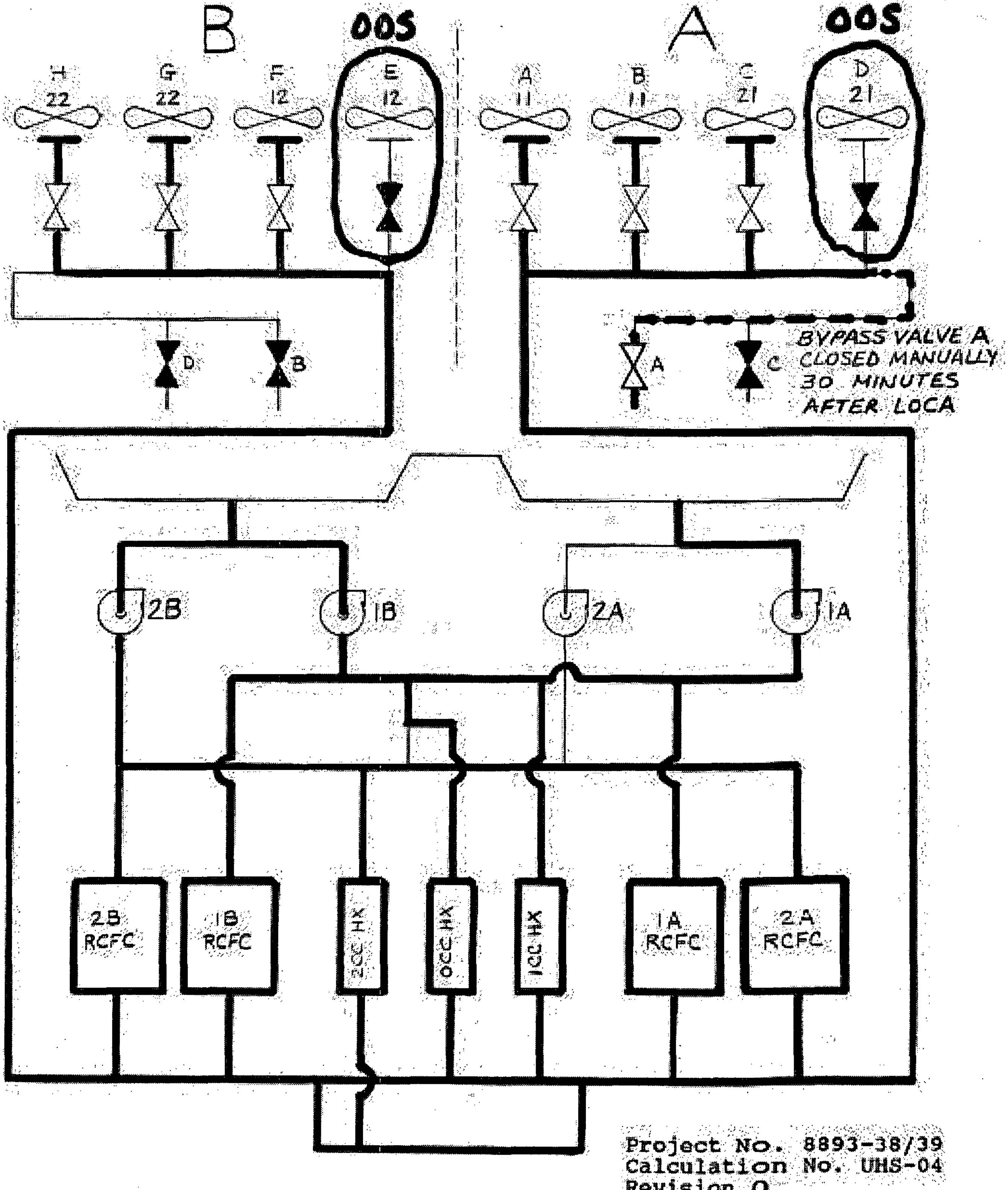


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FIGURE 3

POST LOCA CONFIGURATION
SCENARIO 3

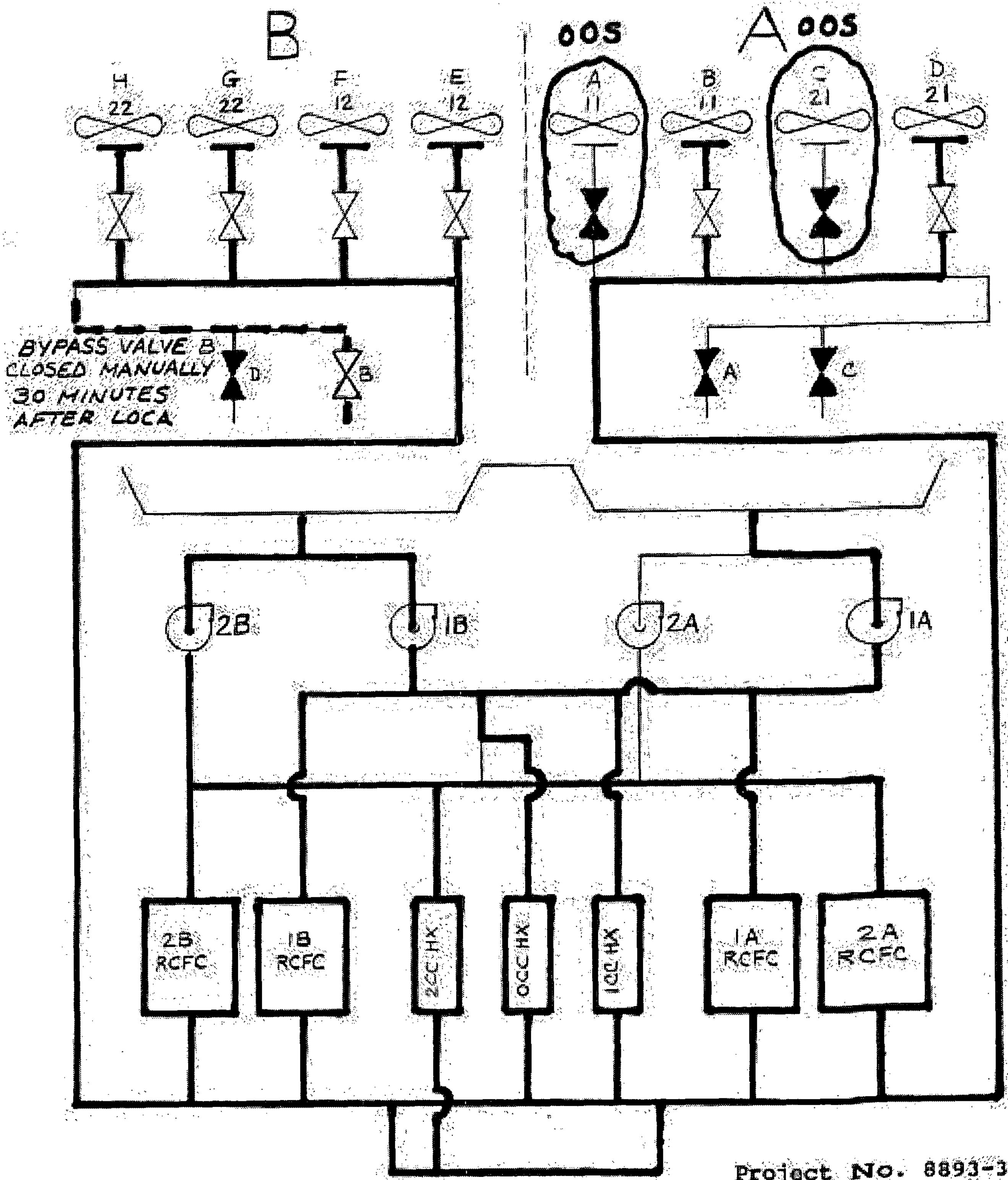

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FIGURE 4

POST LOCA CONFIGURATION

SCENARIO 4

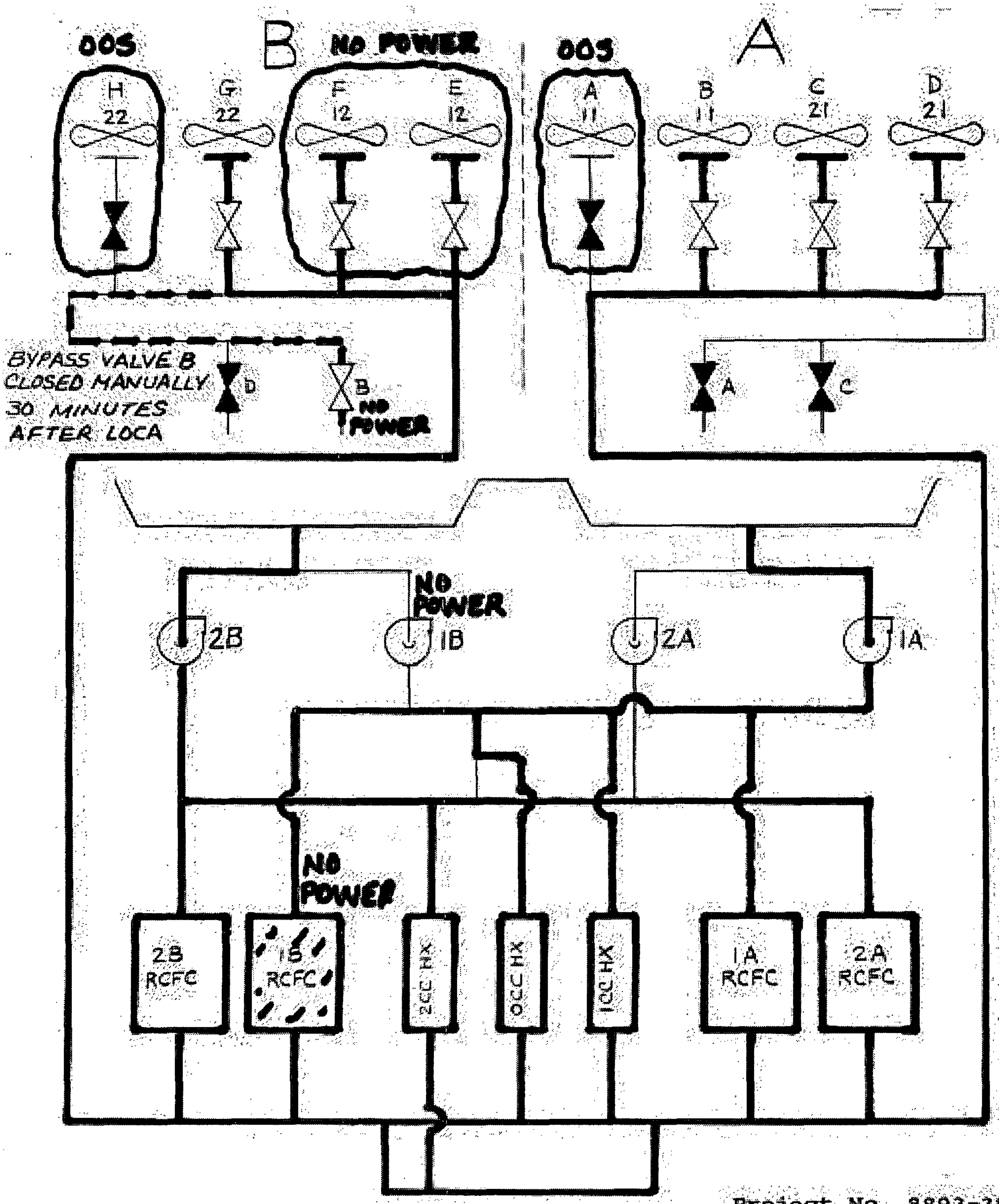

FIGURE 5
POST LOCA CONFIGURATION
SCENARIO 5

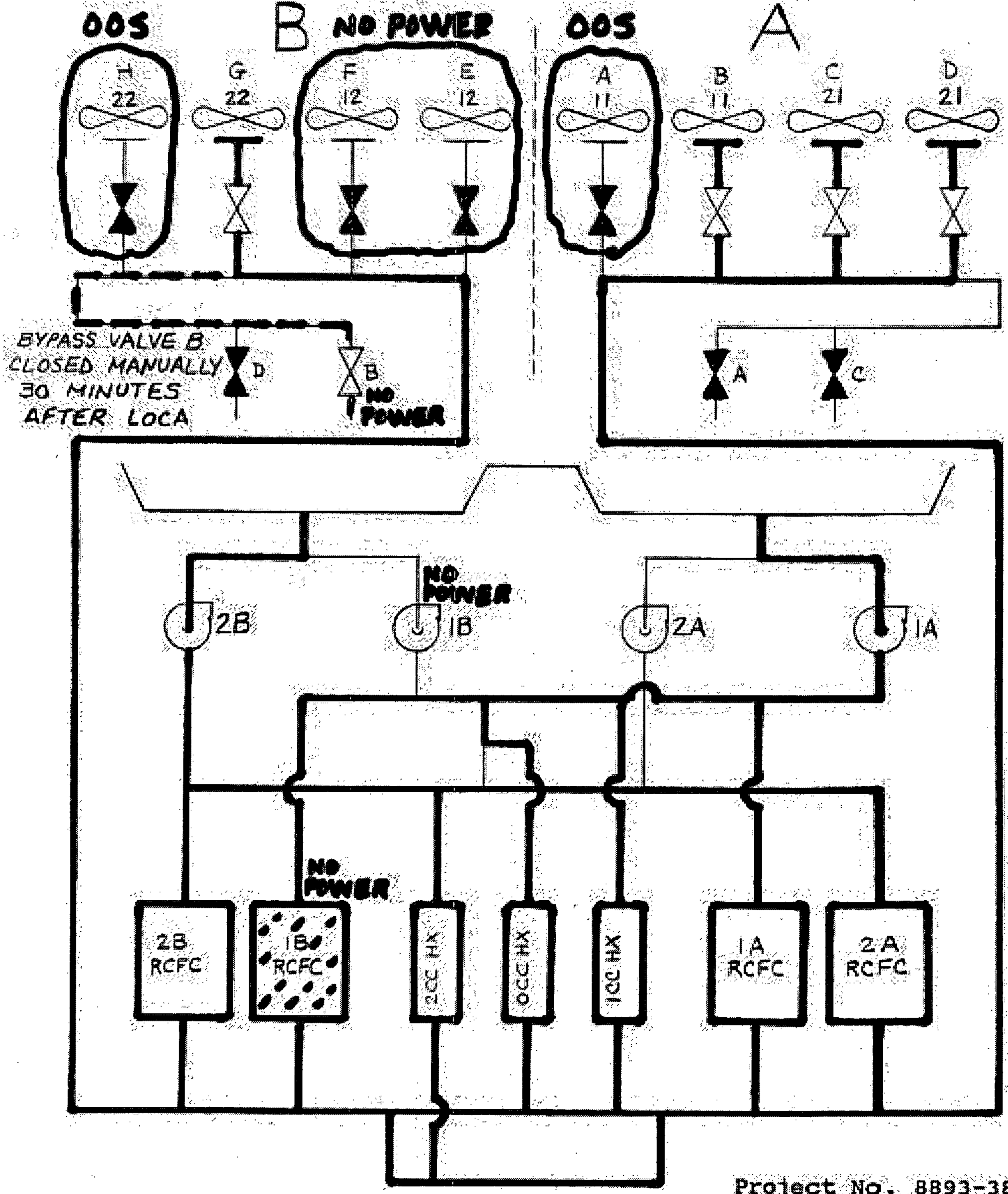

FIGURE 6

POST LOCA CONFIGURATION
SCENARIO 6

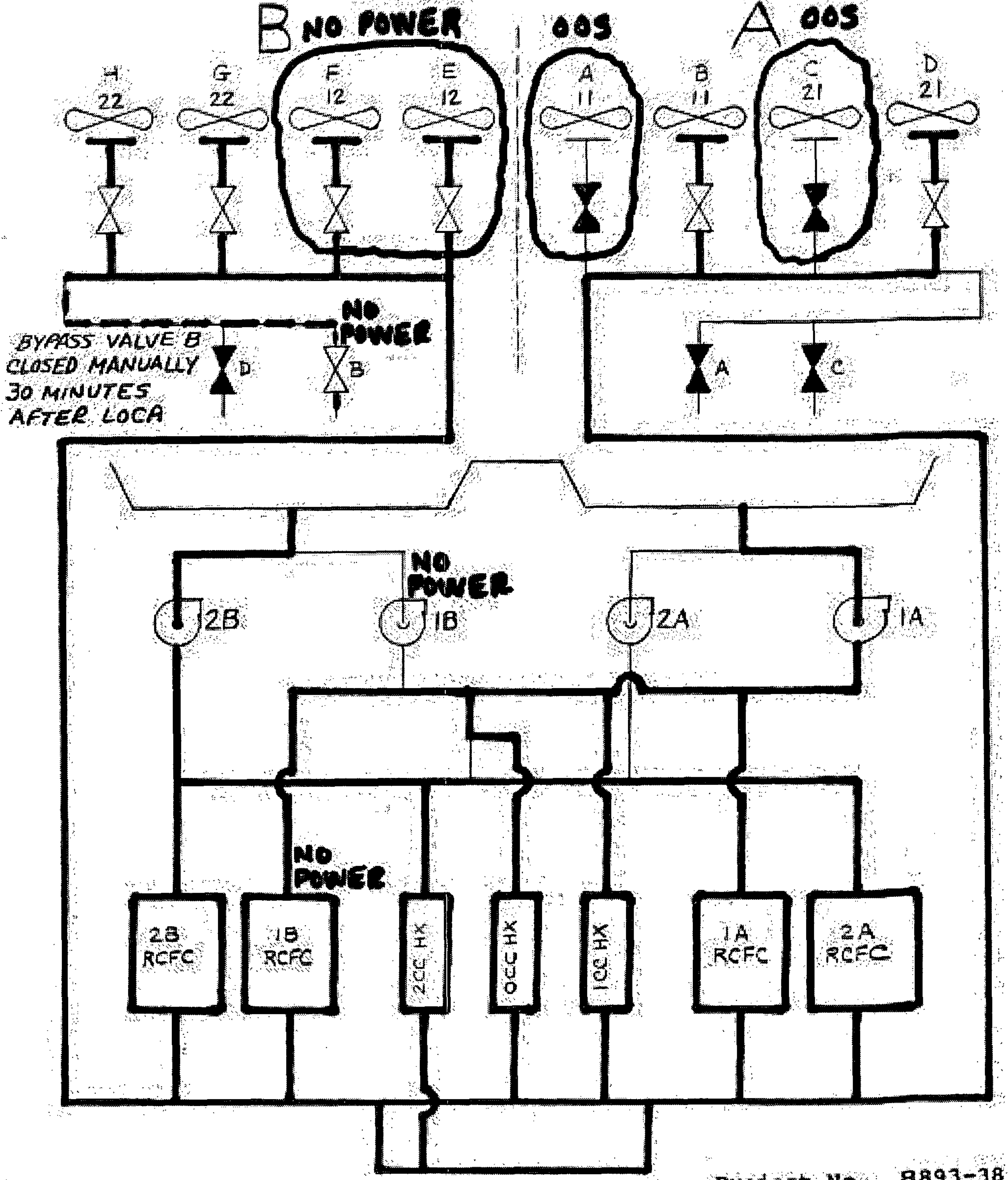

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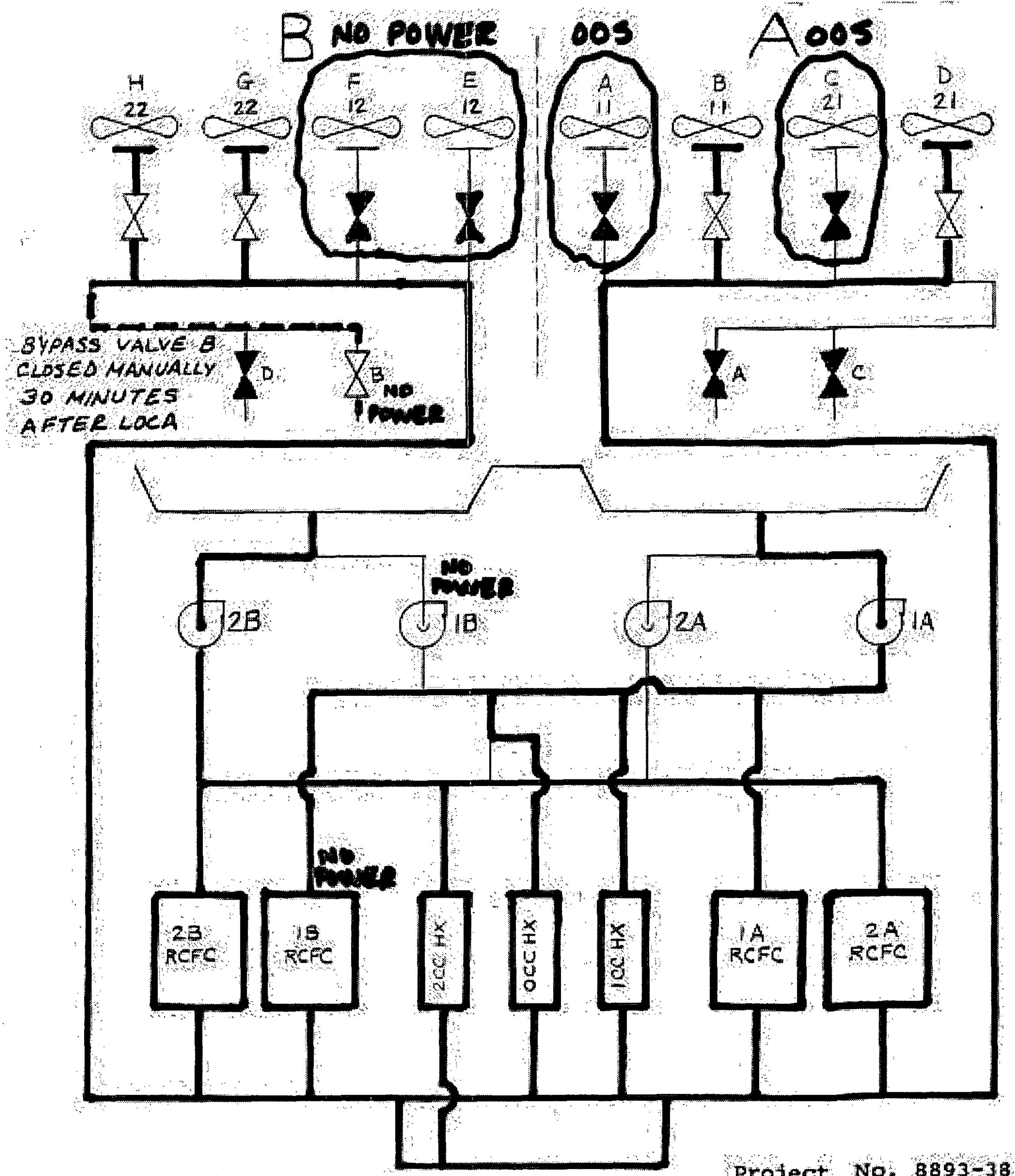
FIGURE 7

POST LOCA CONFIGURATION

SCENARIO 7



BYPASS VALVE B CLOSED MANUALLY 30 MINUTES AFTER LOCA

Purpose/Objective:

The purpose of Revision 2 is to document additional cool weather operation post-LOCA single failure modes that will be analyzed for the UHS. The additional scenarios are selected to bound potential valve leak-by of the tower riser and bypass valves. These new scenarios supplement the scenarios documented in Revision 0 of this calculation.

Methodology and Acceptance Criteria:

Reference 4 will be reviewed to determine the scenario(s) that resulted in the highest peak basin temperature for postulated accidents that occur during cool weather operation (SXCT Bypass valves initially open). The worse case scenario descriptions will be revised for the new conditions (i.e., valve leakage). The new scenarios will include tower bypass associated with the proposed 2" riser drain lines. Simplified diagrams will be generated to illustrate the new scenarios. The results of this calculation will be used as input for additional analysis of UHS performance.

Assumptions:

All assumptions from Revision 0 of the calculation are used in this Revision except as follows:

1. Revision 0 assumed a maximum initial cold water basin temperature of 70°F. The Bypass valve setpoint was changed from 70°F to 74°F via Reference 5. Therefore, the additional cool weather operation UHS temperature analysis will be performed assuming an initial maximum cold water basin temperature of 74°F.

2. Based on the as-found leak-by for the closed bypass and riser valves (References 2 and 3), the following leak-by flow rate will be conservatively assumed for the closed riser and bypass valves:

Riser Valves:	635 gpm/valve
Bypass Valves:	900 gpm/valve

3. From Reference 1 (pgs 198-202), the tower bypass flow through the proposed 2 inch riser drain line is assumed to be 250 gpm per open riser.

4. The time to reach hot shutdown conditions in the non-accident unit is assumed to be 8 hours not 10 hours as stated in Assumption 6 of Revision 0. This was a

typographical error and was not used in the analysis in Revision 0. Reference 12 of Revision 0 justifies the 8 hour time.

Design Input:

1. From calculation NED-M-MSD-11 the most limiting cool weather operation SX basin temperature occurs for Scenarios 2 (Max T_b bypass open) and 3 (Max T_b bypass closed > 30 min) which corresponds to Figures 2 and 3 of Revision 0 of this calculation.

2. Riser valve leakage is obtained from Reference 2.

3. Bypass valve leakage is obtained from Reference 3.

4. The flow rate for the 2-inch riser drain line is obtained from Reference 1.

References:

1. Calculation NED-M-MSD-9, Revision 3, "Byron UHS Cooling Tower Basin Temperature Calculations: Part IV" dated 4-16-96.

2. Letter from Mike Robinson to Kevin Passmore, dated 11-18-96, Subject: Estimation of Essential Service Water Cooling (SXCT) Riser Valve Leakage (Attachment A).

3. Calculation BYR96-281, Revision 0, dated 12/20/96, "Determination of SXCT Bypass Valve Leakage."

4. Calculation NED-M-MSD-11, Revision 0, dated 12/17/91, "Byron UHS Cooling Tower Basin Temperature Calculations: Part V (Bypass Operation)".

5. NDIT No. MSD-94-016, dated 4/18/94, "Byron UHS Bypass Valve Setpoint Change Evaluation".

Calculations:

From Reference 4, Scenarios 2 and 3 are most limiting. Use the same initiating event, single failure, heat load and number of SX pumps running for the new scenarios.

Scenario 8: (Scenario 3+ leakby)

OOS
A.M.
09/24/08

Initial Tower Basin Temp = 74°F (Assumption 1)
Cells ~~OSS:~~ A & C
Initial Tower Configuration:

Tower A:	0 Fans Running, 2 Riser Valves Open, 1 Bypass Valve Open, 0 Active Cells, 0 Passive Cells
Tower B:	0 Fans Running, 4 Riser Valves Open, 2 Bypass Valves Open, 0 Active Cells, 0 Passive Cells

Post-LOCA Tower Configuration After Operator Action (t = 10 minutes)

Tower A:	2 Fans Running, 2 Riser Valves Open, 2 Active Cells, 0 Passive Cells, 0 Bypass Valves Open
Tower B:	4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells, 1 Bypass Valve Open (Single Failure)

Post-LOCA Tower Configuration After Manual Action (t = 30 minutes):

Tower A:	2 Fans Running, 2 Riser Valves Open, 2 Active Cells, 0 Passive Cells, 0 Bypass Valves Open
Tower B:	4 Fans Running, 4 Riser Valves Open, 4 Active Cells, 0 Passive Cells, 0 Bypass Valves Open

Riser Valve Leakby = 635 gpm/valve (Assumption 2)
Bypass Valve Leakby = 900 gpm/valve (Assumption 2)
Drain Line Bypass Flow = 250 gpm/open riser

Scenario 9 (Scenario 2 + leakby)

OOS
A.M.
09/24/08

Initial Tower Basin Temp = 74°F (Assumption 1)
Cells ~~OSS:~~ D & E
Initial Tower configuration:

Tower A:	0 Fans Running, 3 Riser Valves Open, 2 Bypass Valves Open, 0 Active Cells, 0 Passive Cells
Tower B:	0 Fans Running, 3 Riser Valves Open, 2 Bypass Valves Open, 0 Active Cells, 0 Passive Cells

A.M.
09/24/08

Post - LOCA Tower Configuration After Operator Action (t = 10 minutes)

Tower A:	3 Fans Running, 3 Riser Valves Open, 3 Active Cells, 0 Passive Cells, 1 Bypass Valve Open (Single Failure)
Tower B:	3 Fans Running, 3 Riser Valves Open, 3 Active Cells, 0 Passive Cells, 0 Bypass Valves Open

Post - LOCA Tower Configuration After Manual Action (t = 30 minutes):

Tower A:	3 Fans Running, 3 Riser Valves Open, 3 Active Cells, 0 Passive Cells, 0 Bypass Valves Open
Tower B:	3 Fans Running, 3 Riser Valves Open, 3 Active Cells, 0 Passive Cells, 0 Bypass Valves Open

Riser Valve Leakby = 635 gpm/valve (Assumption 2)
Bypass Valve Leakby = 900 gpm/valve (Assumption 2)
Drain Line Bypass Flow = 250 gpm/open riser

Summary and Conclusions:

The new scenarios were developed as described above. Figures 8-1, 8-2, 9-1, and 9-2 provide simplified diagrams to illustrate the scenarios.

FIGURE 8-1
POST LOCA CONFIGURATION (t= 10 to 30 min.)
SCENARIO 8

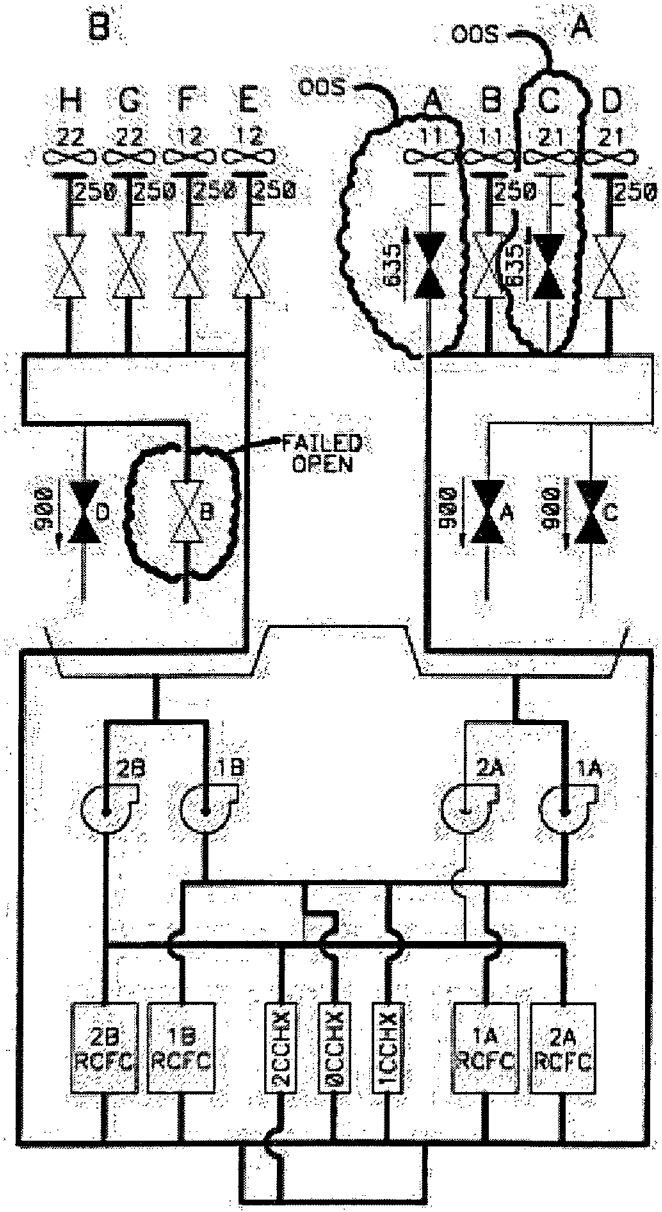


FIGURE 8-2
POST LOCA CONFIGURATION (t> 30 min.)
SCENARIO 8

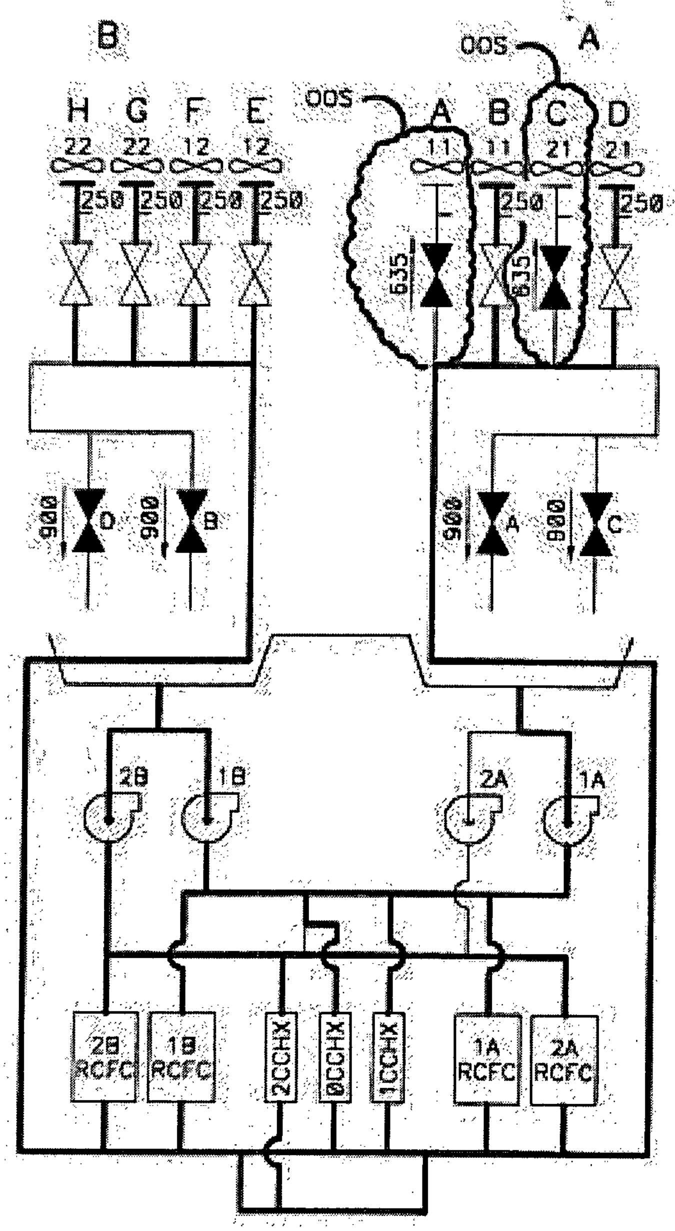


FIGURE 9-1
POST LOCA CONFIGURATION (t= 10 to 30 min.)
SCENARIO 9

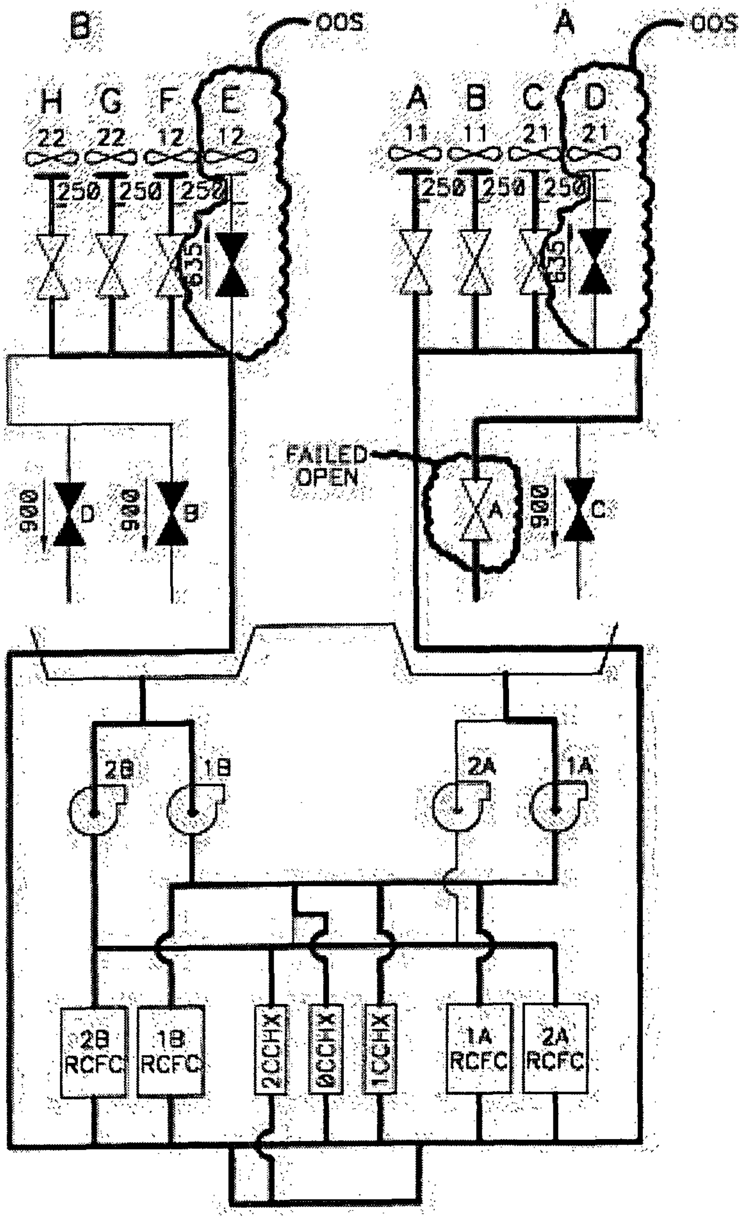
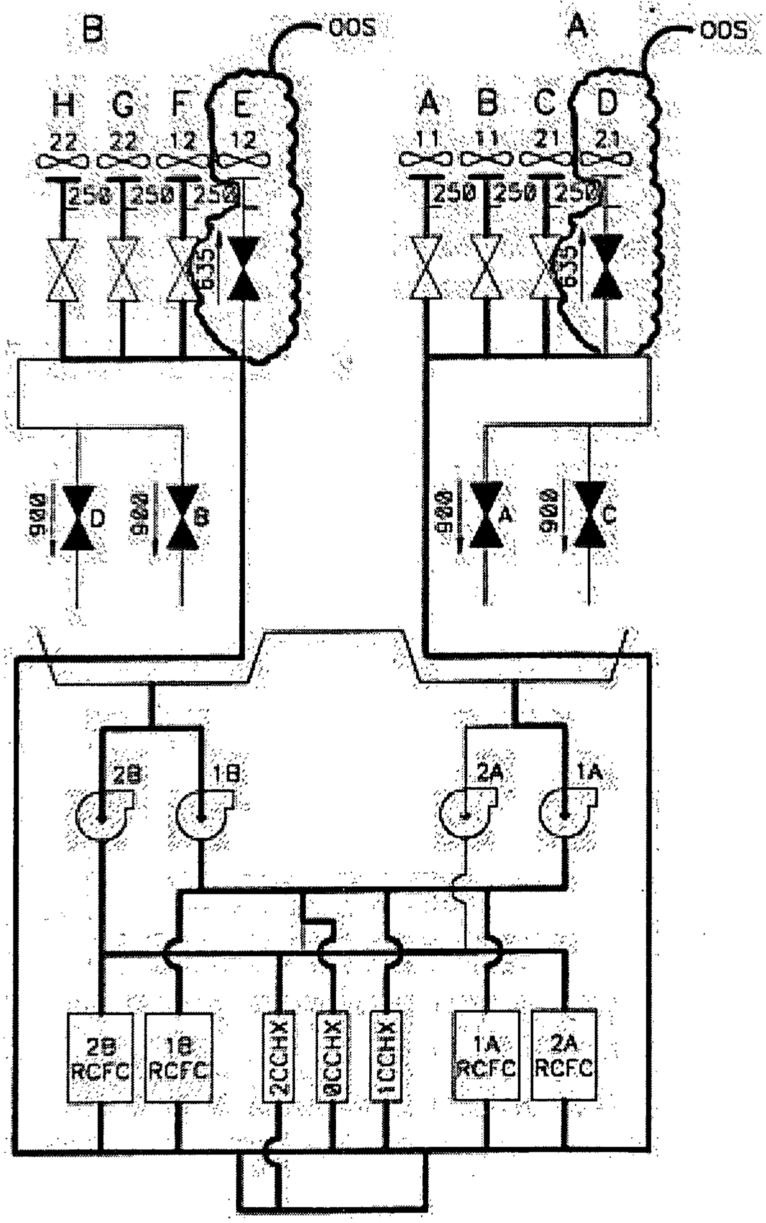


FIGURE 9-2
POST LOCA CONFIGURATION (t> 30 min.)
SCENARIO 9



Calculation No. UHS-04
Revision 2
Page 30 of 30 (FINAL)

November 18, 1996

TO: Kevin Passmore
Station Support Engineering Supervisor

SUBJECT: Estimation of Essential Service Water Cooling Tower (SXCT) Riser Valve Leakage.

On 11-18-96 data was collected at the 0A SXCT in order to provide an estimate of riser valve leakage. Visual observation of the four 0A SXCT cells indicates that the C cell (riser valve 0SX163C) is leaking the worst, followed by A and B (roughly the same), then D with the least leakage. Data was collected in the C cell to provide the most conservative estimates.

The method used was to record the time to collect two gallons of water from each of the five spray nozzles tested. Three trials were run for each of the five nozzles. Although there is some variation in estimated flowrate between the five nozzles, they appeared visually to provide a representative sample of the nozzles in the C cell. The attached copy of drawing M-900, Sheet 25 indicates the locations of the nozzles tested (SE corner of C cell).

Tabulated below are the SX system conditions during the data collection:

<u>0A Tower</u>
Riser Valves (0SX163A/B/C/D) - all closed.
Bypass Valves (0SX162A/C) - both closed.

<u>0B Tower</u>
Riser Valves (0SX163E/F/G/H) - all open.
Bypass Valves (0SX162B/D) - both closed.

<u>Pumps</u>
1A - off.
1B - on (146 amps).
2A - off.
2B - on (148 amps).

SX Discharge Header Pressure
1PI-SX007 - 97 psig.
1PI-SX008 - 98 psig.
2PI-SX007 - 99 psig.
2PI-SX008 - 97 psig.

Attachment A
Calculation No. UHS-04
Revision No. 2 Page No. A1

November 18, 1996

Estimation of Essential Service Water Cooling Tower (SXCT) Riser Valve Leakage.

Note that during normal system operation, pressure upstream of the riser and bypass valves is higher than during the system post-LOCA alignment. In post-LOCA alignment with higher system flows, system pressures would be lower. Thus the riser leakrates calculated from this data collection should be conservative with regard to leakrates during post-LOCA alignment.

Using the average of the five nozzle flowrates, and applying that average to all 144 nozzles (reference attached drawing M-900, Sheet 25), the 0SX163C leakage is estimated at 470gpm (360 gpm using lowest nozzle leakrate, 635 gpm using highest nozzle leakrate).

Prepared By: Date: 11-18-96

Reviewed By: Date: 11/18/96

cc: S. Gackstetter
W. Walter
B. Adams
D. Sargent

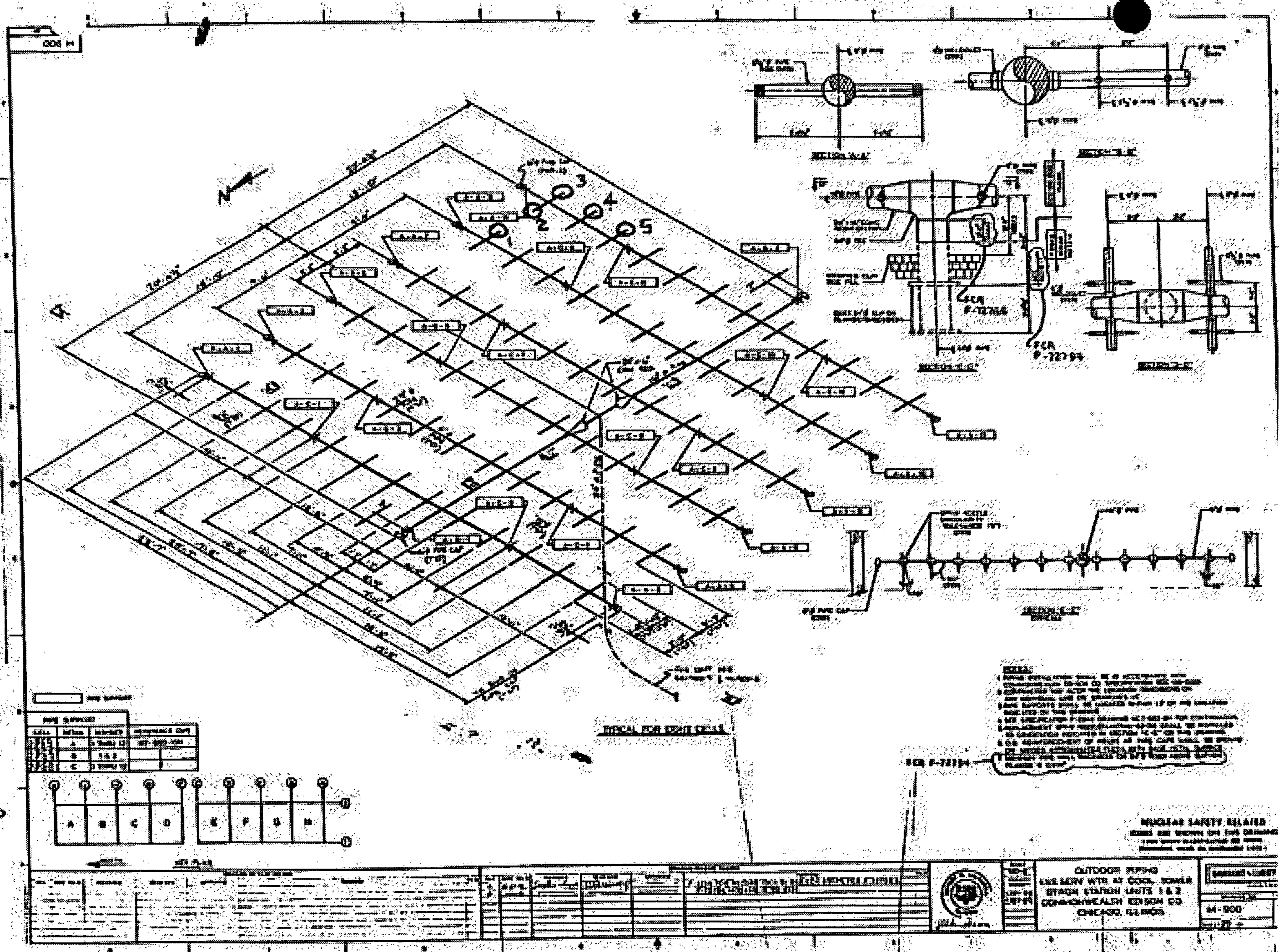
TABLE 1

SXCT RISER VALVE LEAKAGE ESTIMATION

NOZZLE ID	TRIAL 1 (sec)	TRIAL 2 (sec)	TRIAL 3 (sec)	AVERAGE (sec)	AVERAGE (gpm)
1	32.14	31.22	31.15	31.50	3.81
2	27.13	27.09	27.62	27.28	4.40
3	40.62	41.21	41.29	41.04	2.92
4	48.47	48.29	47.57	48.11	2.49
5	44.74	44.79	45.99	45.17	2.66

NOTES: 1) Trial times represent the time to collect two gallons from the individual nozzle.
2) Refer to the attached copy of M-900, Sheet 25 for nozzle locations.

Attachment A
Calculation No. UHS-04
Revision No. 2 Page No. A4 (Final)



Attachment B

Analysis of Additional Cool Weather Operation UHS Post-LOCA Single Failure Scenarios

Table of Contents

1.0 PURPOSE

Attachment B to Calculation UHS-04 documents additional cool weather operation post-loss of coolant accident (LOCA) single failure scenarios that will be analyzed for the Ultimate Heat Sink (UHS). The additional scenarios are selected to bound the potential impact of supplementing the existing licensing basis cool weather single failure assumptions with additional failure assumptions, that of the failure of any one (1) of the several electrical breakers (for 480 Vac Buses) which are 'fixed in place' for the accident. These new scenarios supplement the scenarios documented in Revision 1 and 2 to Calculation UHS-04.

2.0 BACKGROUND

The UHS for the Byron station consists of two (2) redundant SX mechanical-draft Cooling Towers and the makeup system to these Cooling Towers. Each of the two (2) safety-related Cooling Towers consists of a water storage basin, four (4) fans, four (4) riser valves, and two (2) bypass valves (Reference 5.1). The basins of the two (2) Cooling Towers are connected by an overflow. Normal makeup is provided from the circulating water system. Safety-related makeup pumps automatically start on a low water level signal to pump water from the river. In the event of the probable maximum flood, there are deep well pumps available to provide makeup to the basins.

The mechanical-draft Cooling Towers are used as the heat sink for the SX system during normal operation, and they are required for safe shutdown. The UHS is capable of providing adequate cooling during a LOCA coincident with a loss of offsite power (LOOP) in one (1) unit, and a simultaneous shutdown and cooldown of the other unit from maximum power to Mode 5 using normal shutdown operation procedures.

During the 2005 NRC safety systems design and performance capability inspection, the inspectors noted that in Technical Specification (TS) Amendment No. 95 for the Byron Station (changes to the ultimate heat sink to support steam generator replacement), the most limiting single failure evaluated was the failure of active breakers or switches in the 480 Vac SX CT bus which resulted in the failure of one (1) service water CT fan. The inspectors noted that the licensee did not address the 480 Vac feed breakers between the 4160/480 Vac transformer and bus 131Z (for example). The inspectors also noted that a single failure of either of these breakers would de-energize the bus and result in a power loss of two (2) SX CT fans (Reference 5.3).

The licensee disagreed, stating the breakers were normally closed and therefore, a passive failure need not be considered. The configuration of the breakers and the licensee's assessment that passive failures need not be considered was previously reviewed and approved by the NRC. The issue was unresolved pending determination on whether the loss of the 4160 volt or 480 Vac feed breaker should have been considered as the single failure. Subsequent to the initiation of the unresolved item (URI), the inspectors concluded that although TS Amendment 95 did not adequately distinguish single failure of electrical components (active vs passive), consistent with the definition of a single failure presented in 10 CFR Part 50, Appendix A, and General Design Criterion 44, the failure of the 4160 volt or 480 Vac feed breaker should have been considered a valid single failure and assessed (Reference 5.3).

3.0 DESIGN INPUTS

3.1 Loading on 4160-Volt ESF Buses - The loading on each of the four (4) 4160V ESF Buses (141/142/241/242) are found on Design Information Transmittal (DIT) No. S040-BYR-6074-00 (Reference 5.4) and can be seen in Appendix A.

3.2 The 480 Vac feed breakers and associated loadings can be seen in Drawings 6E-1-4001A (Reference 5.8) and 6E-2-4001A (Reference 5.9).

3.3 Drawing M-42 (Reference 5.1) provides a diagram of the SX Cooling Tower. The drawing shows which SX Cooling Tower fan is associated with which cell riser valve and the associated piping for the SX Cooling Tower. Drawing M-42 was used to model the figures in this calculation, which show the post-LOCA scenario configurations.

4.0 ASSUMPTIONS

All assumptions from Revision 2 to Calculation UHS-04 are used in this attachment except as follows:

4.1 Leak-by flow rates for closed SX Cooling Tower bypass and riser valves and total bypass flow rates will be accounted for in the detailed UHS analysis performed in separate calculations (Calculation NED-M-MSD-011 and BYR96-259).

4.2 Based on the gearing in the MOVs (locking gears), the loss of power to an SX CT bypass or riser valve will cause the valve to remain in the position the valve is in when the loss of power occurs.

4.3 Revision 2 assumed that the two (2) out-of-service (OOS) SX CT fans are powered from opposite unit's power supplies. However, this assumption is not supported by the way the plant is operated. Maintenance is performed on electrical that results in two (2) fans OOS from the same unit power supply. Therefore, it will be assumed that the case scenario in which two (2) OOS fans are powered from the same unit's power supply is possible.

4.4 Operator Actions

For the bus breaker failure scenarios, the following operator actions are credited:

1) CT fans not running initially, which don't lose power from the single failure, are remotely started 10 minutes following the LOCA/LOOP (Reference 5.7). Riser valves for corresponding cells are also opened at 10 minutes.

2) Riser valves to which power is lost from the single failure are assumed to remain in their initial position following the LOCA/LOOP with no operator action. The riser valves are not easily accessible and therefore no operator action (remote or manual) is credited.

3) In the event that power is lost to the bypass valve due to the breaker failure, operator action may be credited to close the bypass valve within 30 minutes.

A 30 minute operator response time to close a bypass value is 50% greater than the 20 minute value stated in NUREG 0800, Section 6.3 "Emergency Core Cooling System."

Section 6.3 III.19 of NUREG 0800 (Reference 5.10) states that:

> "The complete sequence of ECCS operation from accident occurrence through long-term core cooling is examined to see that a minimum of manual action is required and, where manual action is used, a sufficient time (greater than 20 minutes) is available for the operator to respond."

The Byron procedures to verify proper response of the automatic protection systems following manual or automatic actuation of a Reactor Trip or Safety Injection, to assess plant conditions, and to identify the appropriate recovery procedure contain steps to manual close open UHS basin bypass valves.

Step 14.g.2 of 1BEP-0 (Reference 5.11) and 2BEP-0 (Reference 5.12) states that:

> "ACTION/EXPECTED RESPONSE

All FOUR Hot Water Basin Bypass valves - <u>CLOSED</u>
- 0SX162A
- 0SX162B
- 0SX162C
- 0SX162D"

"RESPONSE NOT OBTAINED
2) Dispatch operator(s) to close any open Hot Water Basin Bypass valve:
- 0SX162A (872 F6 SXCT)
- 0SX162B (872 A6 SXCT)
- 0SX162C (872 F6 SXCT)
- 0SX162D (872 A6 SXCT)"

5.0 REFERENCES

5.1 Exelon Generation Company, LLC, Byron Station, Unit No. 1 and 2, Drawing M-42, "Diagram of Essential Service Water," Sheet No. 7, Revision AE

5.2 Byron Station Units 1 and 2, Updated Final Safety Analysis Report (UFSAR), Revision 11

5.3 United States Nuclear Regulatory Commission Letter to Mr. Charles G. Pardee (Exelon Nuclear), entitled "Byron Station, Units 1 and 2 Follow Up Inspection of an Unresolved Item (URI) 05000454/2008008; 05000455/2008008," May 5, 2008

5.4 Design Information Transmittal (DIT) S040-BYR-6074-00, "Safety related equipment that may be lost in the event of failure of the 4.16kV Switchgear breakers," Issue Date December 22, 2006 (Included as Appendix A)

5.5 Exelon Generation Company, LLC, Byron Station, Unit No. 1 & 2, Appendix A to the Facility Operating License, "Technical Specifications Bases," Amended through Amendment No. 154, B 3.7.9

5.6 Exelon Generation Company, LLC, Byron Station, Unit No. 1 & 2, Appendix A to the Facility Operating License, "Technical Specifications," Amended through Amendment No. 154, LCO 3.7.9.A

5.7 Byron Nuclear Licensing Administrator Letter to Mr. Gary Contrady (Byron Project Management), entitled "Byron Station Ultimate Heat Sink Design," August 2, 1991, Chron # 170796

5.8 Exelon Generation Company, LLC, Byron Station, Unit No. 1, Drawing 6E-1-4001A, "Station One Line Diagram," 08/01/95, Revision O

5.9 Exelon Generation Company, LLC, Byron Station, Unit No. 2, Drawing 6E-2-4001A, "Station One Line Diagram," 01/16/97, Revision N

5.10 NUREG-0800, Standard Review Plan (SRP) for the Review of Safety Analysis Reports for Nuclear Power Plants, March 2007

5.11 1BEP-0, Reactor Trip or Safety Injection Unit 1, Rev. 108, WOG-1C

5.12 2BEP-0, Reactor Trip or Safety Injection Unit 2, Rev. 108, WOG-1C

6.0 METHODOLOGY AND ACCEPTANCE CRITERIA

METHODOLOGY

The SX system is designed to ensure that sufficient capacity is available to provide adequate cooling during normal and accident conditions. The SX system is a two (2) unit shared system with various cross tie headers on both pump suction and discharge sides for both divisions and units. Appropriate (redundant) cross tie isolation valves are provided to achieve various system alignments necessary within the licensing and design bases. Heat is rejected by the SX system via two (2) mechanical-draft Cooling Towers. Each Cooling Tower consists of four (4) cells with each cell served by a single two (2)-speed fan. The cold water basin for each Cooling Tower serves a pair of SX pumps, one (1) from each unit. The cold water basins for the two (2) towers are cross-connected by what is termed an "overflow" pathway in the UFSAR. Depending on ambient conditions (i.e. summer or cool weather conditions), the towers are permitted to have one (1) or two (2) fans out-of-service (OOS) while still being considered to be operable.

The worst case scenarios will be identified from the existing licensing basis cool weather single failure assumptions associated with the SX Cooling Tower operation. Each scenario will be revised for the new conditions (i.e. failure of any one (1) of the 4 kV or 480 Vac electrical breakers). Scenarios will be done for the most limiting design conditions. The results of this calculation will be used as input for additional detailed analysis of UHS performance, performed in a separate calculation (Calculation NED-M-MSD-011).

Scenarios 1 to 9 from this calculation (Revisions 1 and 2) are used as reference in defining the limiting sets of serviceable equipment, alignments, and accident conditions for the new case scenarios. The same initiating event used in this calculation (Revisions 1 and 2) will apply for the new case scenarios (i.e. LOCA and LOOP on the accident unit). The single failure condition is the failure of a breaker for the 480 Vac Buses associated with the SX Cooling Tower. Each of the four (4) Buses (131Z, 132Z, 231Z, and 232Z) are assumed to fail due to a failure of the feed breaker [i.e., 1415Z, 131Z, 1425Z, 132Z, 2415Z, 231Z, 2425Z, or 232Z (Reference 5.4, 5.8, and 5.9)] for the 480 Vac Bus in question. Only a single breaker is assumed to fail at a time.

The failure scenarios assume that up to two (2) SX Cooling Tower fans are OOS at a time. The TS, Reference 5.6, LCO 3.7.9.A, states that if one (1) of the required Cooling Tower fans is inoperable, then within 72 hours restore the required Cooling Tower fan to operable status. The TS Bases, Reference 5.5, Section B 3.7.9, states that the design basis analyses assume two (2) tower cells (i.e., two (2) fans or water distribution to two (2) cells) are OOS. Thus, at least six (6) of the eight (8) SX Cooling Tower fans must be operable.

Since this calculation is being done for cool weather conditions all the scenarios assume two (2) SX Cooling Tower fans are OOS when the single failures occur. The SX Cooling Tower fans that are OOS are not the same as the SX Cooling Tower fans that fail for the breaker failure case.

As can be seen in the DIT S040-BYR-6074-00 (Reference 5.4), failure of a feed breaker to one (1) of the four (4) 480 Vac Buses will result in the power loss of two (2) SX fans, the two (2) SX riser valves for the cells associated with the lost SX fans, and the power loss of one (1) SX Basin bypass valve for the SX Cooling Tower that has the lost SX fans and associated riser valves. Thus, regardless of which one (1) of the eight (8) 4 kV or 480 Vac feed breakers that fail, the effect on the SX Cooling Tower system is the same; that is, the power loss of two (2) SX fans, the two (2) SX riser valves associated with those fans, and one (1) SX Basin bypass valve associated with the failed SX fans. Therefore, the scenarios for only one (1) feed breaker needs to be presented, since the failure of the other seven (7) feed breakers would have the same impact on the SX Cooling Tower system.

The failure of breaker 1425Z at the 4160 V Bus 142 will be discussed in this calculation. The remaining breakers (1415Z, 131Z, 132Z, 2415Z, 231Z, 2425Z, and 232Z) will not be discussed in this calculation since the overall effects to the SX Cooling Tower system is the same regardless of which breaker fails.

Each scenario is described in the results section of this calculation and figures are provided to illustrate each of the scenarios.

ACCEPTANCE CRITERIA

No acceptance criteria are provided for this calculation. This calculation identifies new single failure scenarios associated with the SX Cooling Tower operation.

7.0 RESULTS

The following is a description of the scenarios associated with the SX Cooling Tower and failure of the 480 Vac Buses.

Scenario 10:

Initial Condition

Cooling Tower Basin temperature: 74 °F
cells OOS: cell A, cell G
fan speed: no fans running
SX pumps: one (1) running on each Unit

Cooling Tower configuration:
Tower A: 0 fans running, 0 riser valves open, 0 active cells, 0 passive cells, 2 bypass valves open
Tower B: 0 fans running, 0 riser valves open, 0 active cells, 0 passive cells, 2 bypass valves open

Failure Condition

single failure: **breaker 1425Z at 4160V Bus 142 fails open** – loss of power to Cell E and F basin bypass valve 0SX162B and Cell E and F Cooling Tower Fans (0SX03CF and 0SX03CE).

Also loss of power to:
480V Bus 132Z
480V MCC 132Z1
Deep Well Pump 0WW01PB (non-ESF)
ESW Service Water Make-Up Valve 0SX157A
Cell E Riser Valve 0SX163E
480V MCC 132Z1A (non-ESF)
Cell F Riser Valve 0SX163F
Switchgear Room Vent Fan 1VX06C
120/208Vac Distribution Panelboard
Motor 0SX03CE Space Heater
HVAC Local Control Panel 1VX06J
Damper Starter Panel 1VX99J
ESW Cooling Tower 0B Basis Level Switch 0LS-SX097
Motor 0SX03CF Space Heater
MOV 0SX163E Limit Switch Space Heater
MOV 0SX163F Limit Switch Space Heater

Accident Condition

(The post accident system lineup consists of three (3) SX pumps running, two (2) on accident unit, one (1) on non-accident unit.)

post-LOCA Cooling Tower configuration (prior to 10-minute operator action):
Cooling Tower A: 0 fans running, 0 riser valves open, 0 active cells, 0 passive cells, 2 bypass valves open
Cooling Tower B: 0 fans running, 0 riser valves open, 0 active cells, 0 passive cells, 2 bypass valves open

post-LOCA Cooling Tower configuration (following 10-minute operator action - at 10 minutes, start the operable fans in high speed, open riser valves, and close bypass valves):
Cooling Tower A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
Cooling Tower B: 1 fan running, 1 riser valve open, 1 active cell, 0 passive cells, 1 bypass valve open

post-LOCA Cooling Tower configuration (following 30-minute operator action - at 30 minutes, manually close failed open Cell E and F basin bypass valve 0SX162B):
Cooling Tower A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
Cooling Tower B: 1 fan running, 1 riser valve open, 1 active cell, 0 passive cells, 0 bypass valves open

(Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until operator action is initiated to start tower fans, open riser valves, and close bypass valves.)

Scenario 11:

Initial Condition

Cooling Tower Basin temperature: 74 °F
cells OOS: cell A, cell G
fan speed: no fans running
SX pumps: one (1) running on each Unit

Cooling Tower configuration:
Tower A: 0 fans running, 3 riser valves open, 0 active cells, 3 passive cells, 0 bypass valves open
Tower B: 0 fans running, 3 riser valves open, 0 active cells, 3 passive cells, 1 bypass valve open

Failure Condition

single failure: **breaker 1425Z at 4160V Bus 142 fails open** – loss of power to Cell E and F basin bypass valve 0SX162B and Cell E and F Cooling Tower Fans (0SX03CF and 0SX03CE).

Also loss of power to:
480V Bus 132Z
480V MCC 132Z1
Deep Well Pump 0WW01PB (non-ESF)
ESW Service Water Make-Up Valve 0SX157A
Cell E Riser Valve 0SX163E
480V MCC 132Z1A (non-ESF)
Cell F Riser Valve 0SX163F
Switchgear Room Vent Fan 1VX06C
120/208Vac Distribution Panelboard
Motor 0SX03CE Space Heater
HVAC Local Control Panel 1VX06J
Damper Starter Panel 1VX99J
ESW Cooling Tower 0B Basis Level Switch 0LS-SX097
Motor 0SX03CF Space Heater
MOV 0SX163E Limit Switch Space Heater
MOV 0SX163F Limit Switch Space Heater

Accident Condition

(The post accident system lineup consists of three (3) SX pumps running, two (2) on accident unit, one (1) on non-accident unit.)

post-LOCA Cooling Tower configuration (prior to 10-minute operator action):
Cooling Tower A: 0 fans running, 3 riser valves open, 0 active cells, 3 passive cells, 0 bypass valves open
Cooling Tower B: 0 fans running, 3 riser valves open, 0 active cells, 3 passive cells, 1 bypass valve open

post-LOCA Cooling Tower configuration (following 10-minute operator action - at 10 minutes, start the operable fans in high speed):
Cooling Tower A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
Cooling Tower B: 1 fan running, 3 riser valves open, 1 active cell, 2 passive cells, 1 bypass valve open

post-LOCA Cooling Tower configuration (following 30-minute operator action - at 30 minutes, manually close failed open Cell E and F basin bypass valve 0SX162B):
Cooling Tower A: 3 fans running, 3 riser valves open, 3 active cells, 0 passive cells, 0 bypass valves open
Cooling Tower B: 1 fan running, 3 riser valves open, 1 active cell, 2 passive cells, 0 bypass valves open

(Following the postulated LOCA, no credit is taken for UHS ambient heat dissipation until operator action is initiated to start tower fans.)

(Note that several case scenario variations can be made to those scenarios listed above. Such variations include location of cells OOS, number and location of riser valves open, number and location of open bypass valves, number of SX pumps running, equipment failing in non 'fixed in place' positions, and location of electrical breakers failing open. However, these variations are limiting in the amount of further impact they will have on UHS design and can be analyzed further, as desired, in the detailed evaluation of UHS performance.)

All possibilities for the scenario 10 and 11 configurations are shown in Table 1.

Table 1 - Scenario 10 and 11 Configurations

Cells OOS	Cells Failed
AB	CD or EF or GH
AC	EF or GH
AD	EF or GH
AE	CD or GH
AF	CD or GH
AG	CD or EF
AH	CD or EF
BC	EF or GH
BD	EF or GH
BE	CD or GH
BF	CD or GH
BG	CD or EF
BH	CD or EF
CD	AB or EF or GH
CE	AB or GH
CF	AB or GH
CG	AB or EF
CH	AB or EF
DE	AB or GH
DF	AB or GH
DG	AB or EF
DH	AB or EF
EF	AB or CD or GH
EG	AB or CD
EH	AB or CD
FG	AB or CD
FH	AB or CD
GH	AB or CD or EF

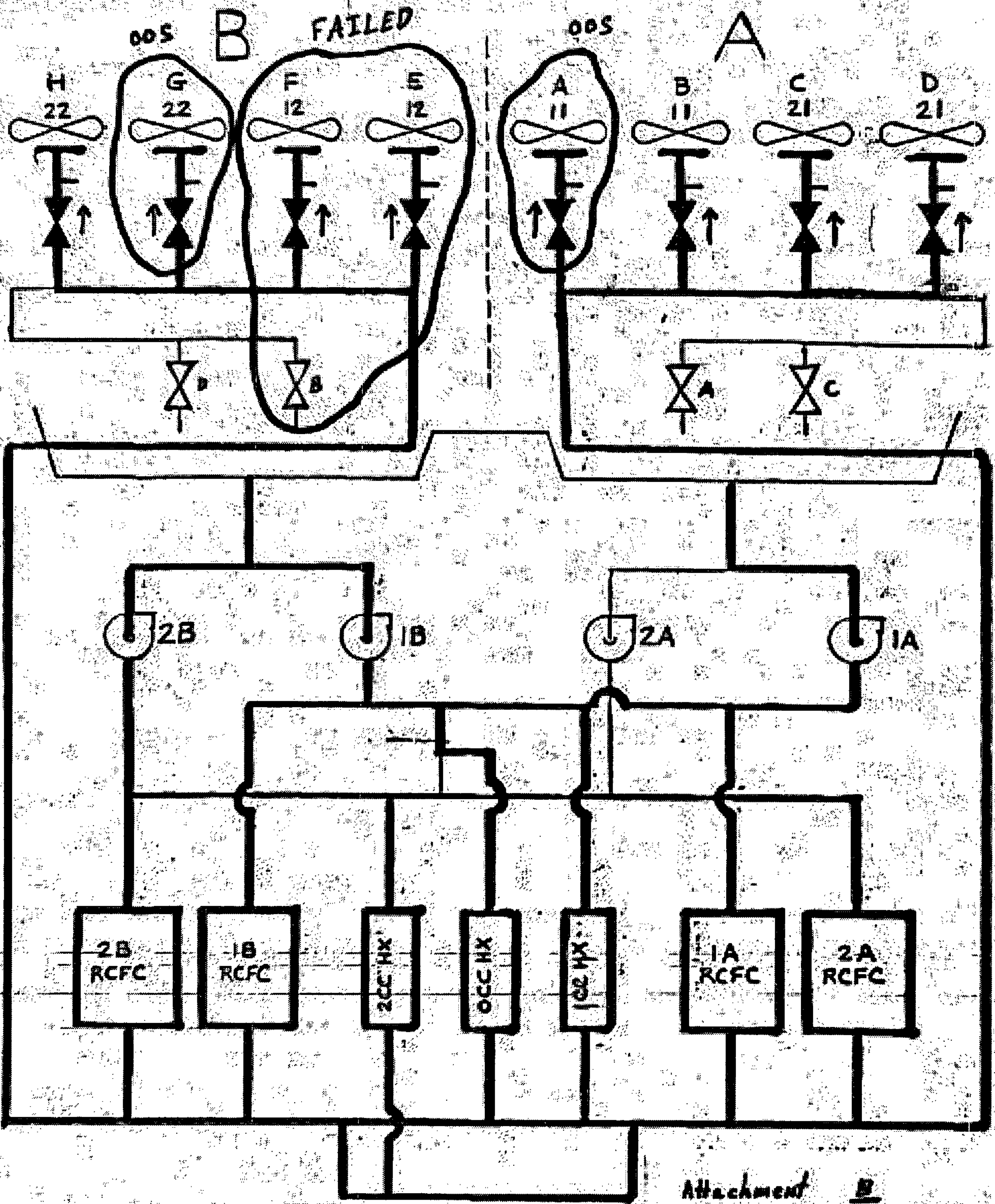
8.0 CONCLUSIONS

New scenarios were developed as described above for the failure of the electrical feed breakers for the 480 Vac Buses associated with the SX Cooling Towers. Figures 10 through 15 provide simplified diagrams to illustrate the scenarios. Note that variations can be made to each case scenario, as discussed in the results section. This calculation will be used as input for detailed evaluation of UHS performance.

FIGURE 10

POST LOCA CONFIGURATION (Initial Condition)

SCENARIO 15

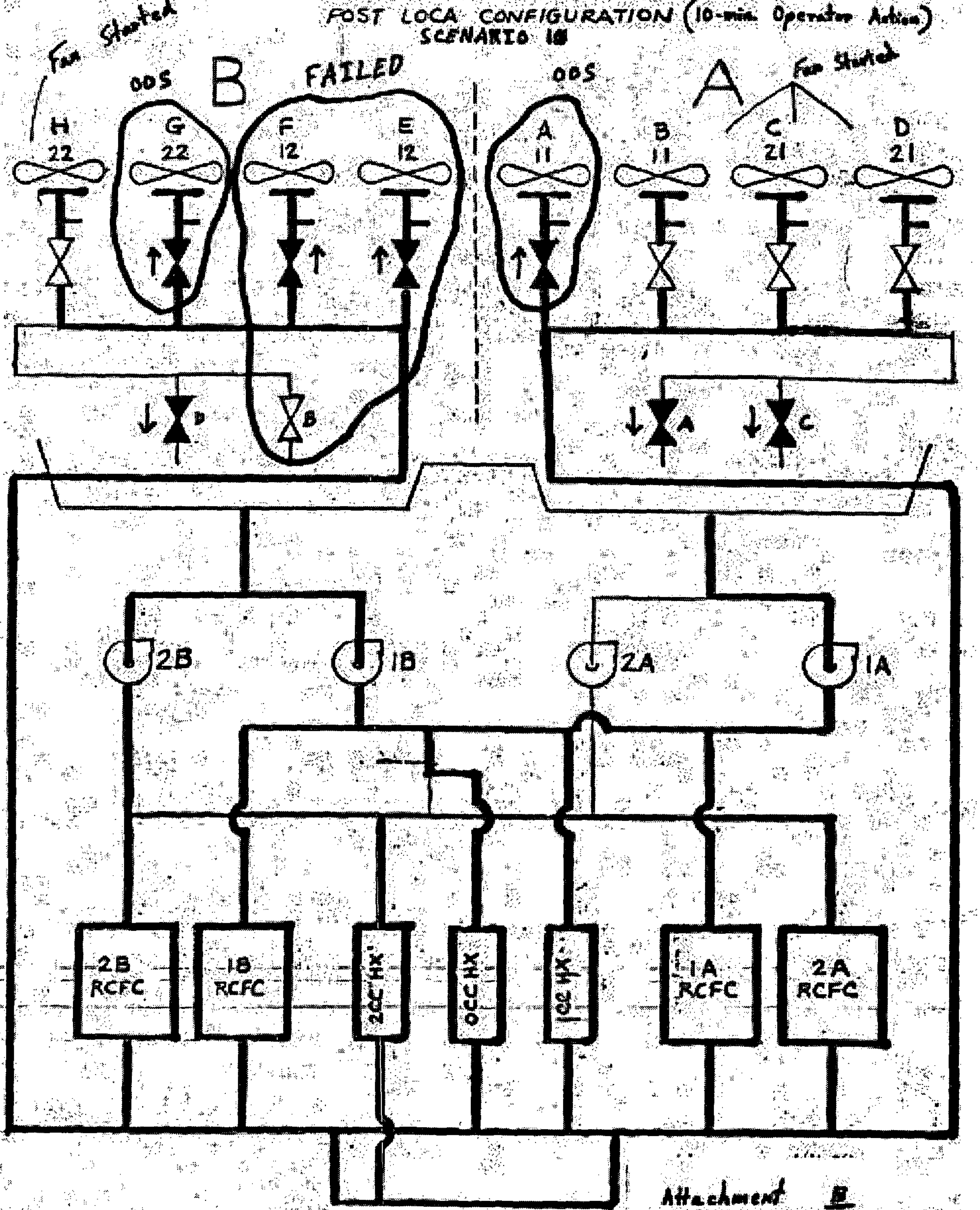


* → Valve Bypass Flow Leakage

FIGURE 11

POST LOCA CONFIGURATION (10-min. Operator Action)

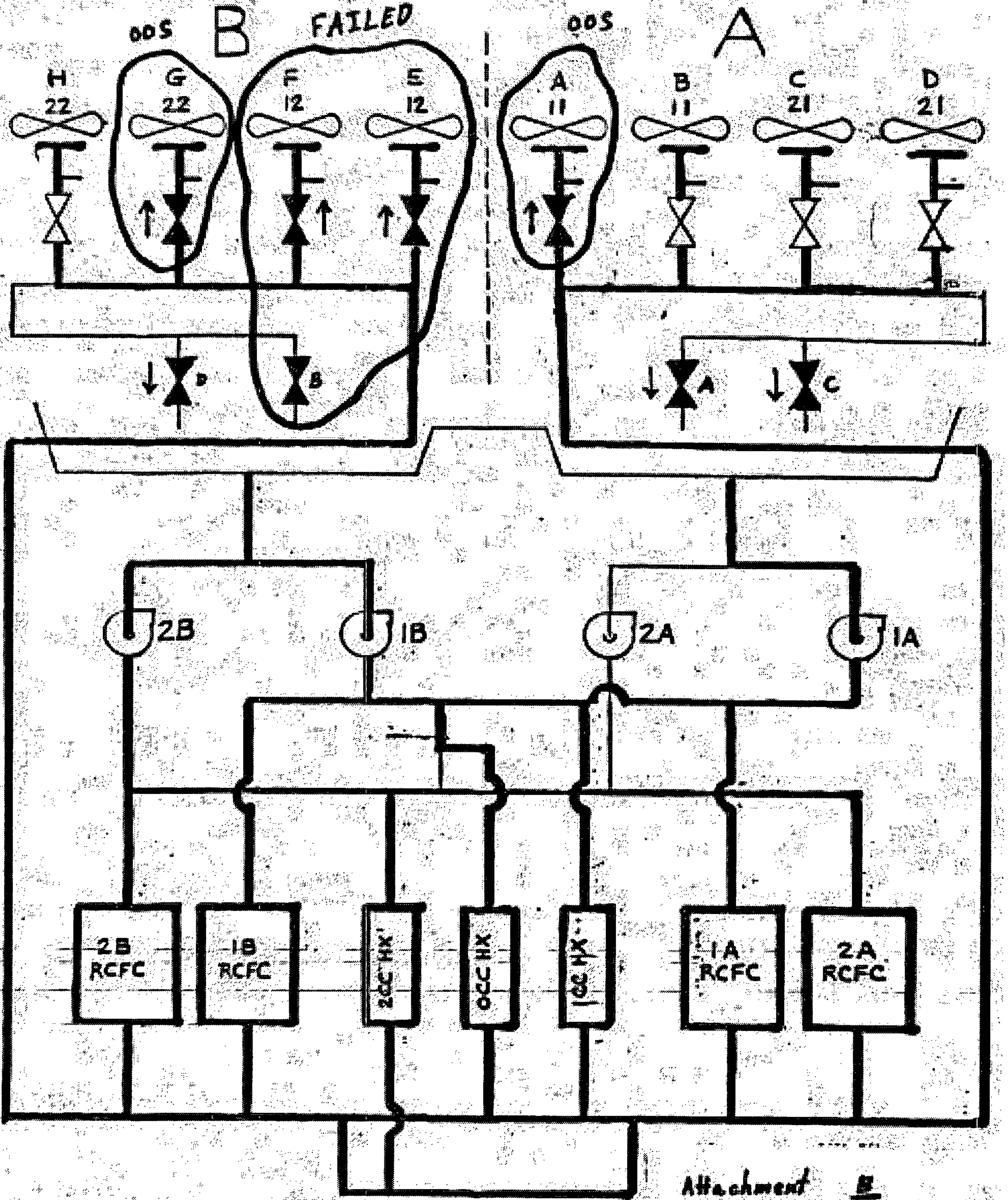
SCENARIO 18



Attachment B
Calculation No. UHS-04
Revision No. 1
Page No. B1C

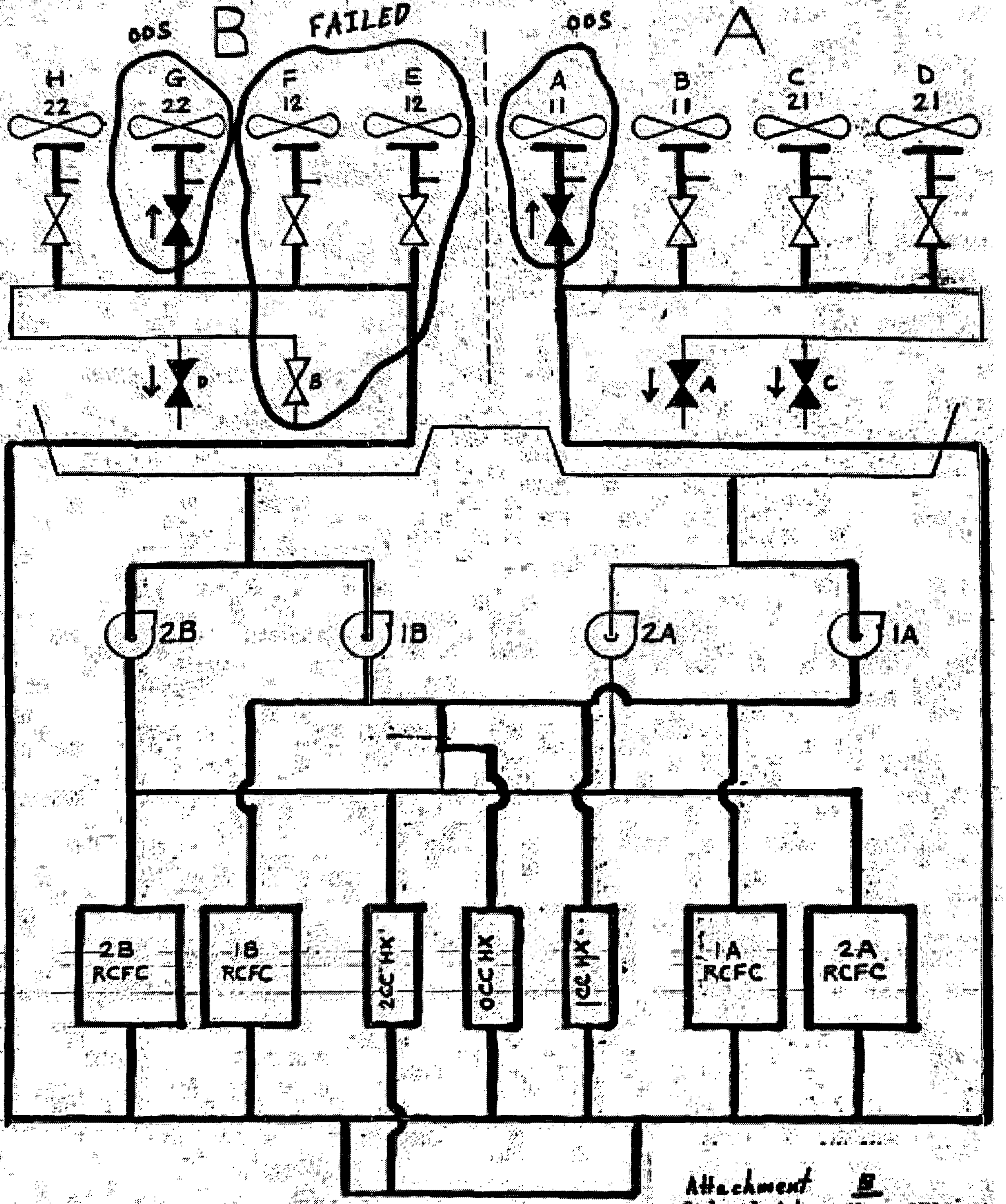
* —> Valve Bypass Flow Leakage

FIGURE 12
POST LOCA CONFIGURATION (30-min. Operator Action)
SCENARIO 1a



* → Valve Bypass Flow Leakage

FIGURE 13
POST LOCA CONFIGURATION (Initial Condition)
SCENARIO II



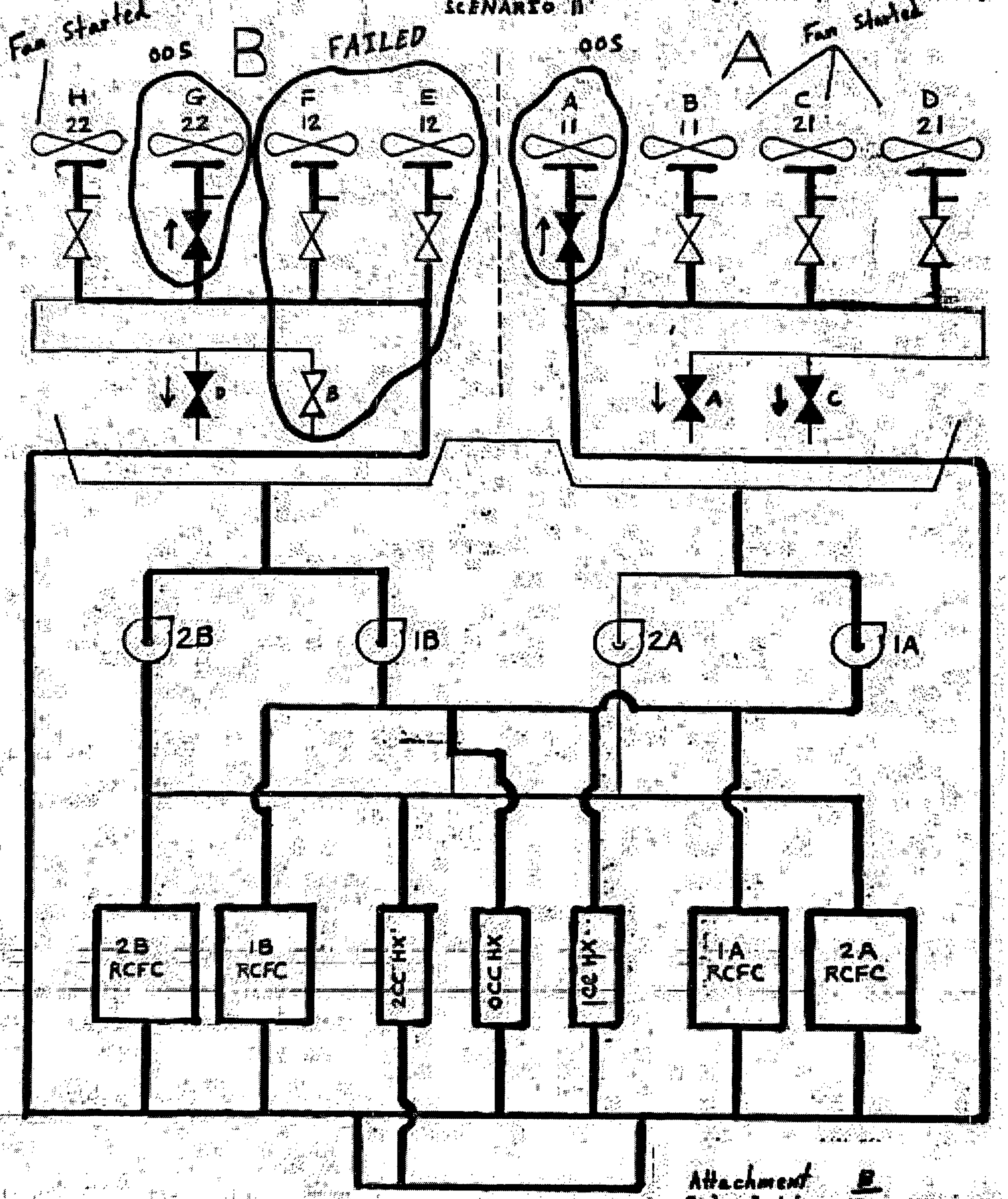
Attachment B
Calculation No. UHS-04
Revision No. 3
Page No. B19

* —> Valve Bypass Flow Leakage

FIGURE 14

POST LOCA CONFIGURATION (10-min. Operator Action)

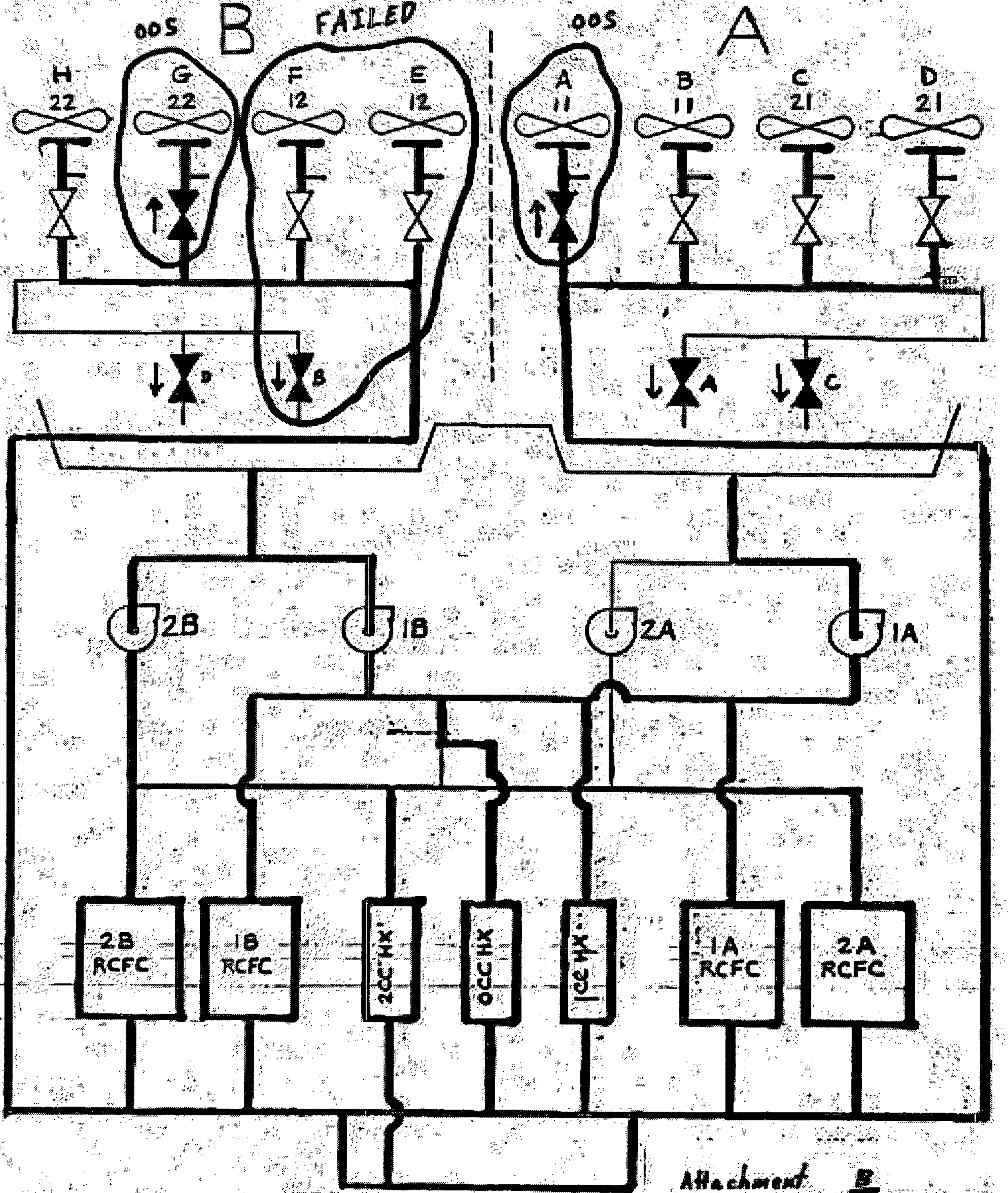
SCENARIO 11



* → Valve Bypass Flow Leakage

FIGURE 15

POST LOCA CONFIGURATION (30-min. Operator Actio
SCENARIO II



Attachment B
Calculation No. UHS-04
Revision No. 3
Page No. B20

* → Valve Bypass Flow Leakage

APPENDIX A
TO ATTACHMENT B to Calculation UHS-04

DIT S040-BYR-6074-00

DESIGN INFORMATION TRANSMITTAL

☒ Safety-Related ☐ Non-Safety-Related

DIT No. S040-BYR-6074-00

Client: Exelon
Project No.: 11330-042
Page 1 of 3
Station: Byron
Unit(s) 1 & 2
To: M. A. Nena -23
Subject: Safety related equipment that may be lost in the event of failure of the 4.16kV Switchgear breakers

MODIFICATION OR DESIGN CHANGE NUMBERS: N/A

J. A. Juodikis/J. J. Bojan
Preparer (Print Name)
NPT/EE & CD
Process Group
Judikis / JJBojan (Reviewer)
Preparer's Signature
12/22/06
Issue Date

STATUS OF INFORMATION:

This information being transmitted is approved for use and requires no further verification.

IDENTIFICATION OF THE SPECIFIC DESIGN INFORMATION TRANSMITTED AND PURPOSE OF ISSUE
(List any supporting documents attached to DIT by its title, revision and/or issue date, and total number of pages for each supporting document.)

This design information transmittal identifies the equipment (by name and equipment number) that would be lost upon failure (i.e., spurious opening) of the upstream 4.16kV feed breakers. This information is being provided for use in the ultimate heat sink equipment failure analysis.

See pages 2 and 3 of the design information transmittal for the equipment identification numbers.

SOURCE OF INFORMATION

Calc No. N/A Rev. Date
Report No. N/A Rev. Date

Drawings:			
6E-1-4006A, Revision H	6E-1-4006B, Revision J	6E-1-4007C, Revision J	6E-1-4007F, Revision J
6E-1-4008AG, Revision P	6E-1-4008AN, Revision R	6E-2-4006A, Revision E	6E-2-4006B, Revision E
6E-2-4007C, Revision H	6E-2-4007F, Revision K	6E-2-4008AG, Revision K	6E-2-4008AN, Revision N

DISTRIBUTION:
C. Morris – 16 (original)
J. J. Bojan – 16
D. C. Patel – 16

Sargent & Lundy	**DESIGN INFORMATION TRANSMITTAL**

DIT No.: S040-BYR-6074-00	Project No.: 11330-042	Page 2 of 3

<u>The loss of breaker 1415Z at 4160V Bus 141 would result in the loss of:</u>

480V ESF Substation Bus 131Z (1AP99E)
ESW Cooling Tower Fan 0SX03CA (High & Low Speed)
ESW Cooling Tower Fan 0SX03CB (High & Low Speed)
Non-ESF Deep Well Pump 0WW01PA
480V ESW Cooling Tower MCC 131Z1 (1AP93E)
ESW Make-Up Valve 0SX158A
ESW Service Water Cooling Tower 0A Basin Bypass Valve 0SX162A
ESW Cooling Tower 0A Cell A Riser Valve 0SX163A
ESW Cooling Tower 0A Cell B Riser Valve 0SX163B
ESW Cooling Tower Division 11 Switchgear Room Ventilation Fan 1VX05C
MCC 131Z1 120/208Vac Distribution Panelboard and Auxiliaries:

- Motor 0SX03CA Space Heater
- HVAC Local Control Panel 1VX05J
- Damper Starter Panel 1VX98J
- ESW Cooling Tower 0A Basin Level Switch 0LS-SX096
- Motor 0SX03CB Space Heater
- MOV 0SX163A Limit Switch Heater
- MOV 0SX163B Limit Switch Heater

Non-ESF 480V MCC 131Z1A (1AP89E)

<u>The loss of breaker 1425Z at 4160V Bus 142 would result in the loss of:</u>

480V ESF Substation Bus 132Z (1AP98E)
ESW Cooling Tower Fan 0SX03CE (High & Low Speed)
ESW Cooling Tower Fan 0SX03CF (High & Low Speed)
Non-ESF Deep Well Pump 0WW01PB
480V ESW Cooling Tower MCC 132Z1 (1AP92E)
ESW Make-Up Valve 0SX157A
ESW Service Water Cooling Tower 0B Basin Bypass Valve 0SX162B
ESW Cooling Tower 0B Cell E Riser Valve 0SX163E
ESW Cooling Tower 0B Cell F Riser Valve 0SX163F
ESW Cooling Tower Division 12 Switchgear Room Ventilation Fan 1VX06C
MCC 132Z1 120/208Vac Distribution Panelboard and Auxiliaries

- Motor 0SX03CE Space Heater
- HVAC Local Control Panel 1VX06J
- Damper Starter Panel 1VX99J
- ESW Cooling Tower 0B Basin Level Switch 0LS-SX097
- Motor 0SX03CF Space Heater
- MOV 0SX163E Limit Switch Heater
- MOV 0SX163F Limit Switch Heater

Non-ESF 480V MCC 132Z1A (1AP88E)

Sargent & Lundy	DESIGN INFORMATION TRANSMITTAL	
DIT No.: S040-BYR-6074-00	Project No.: 11330-042	Page 3 of 3

The loss of breaker 2415Z at 4160V Bus 241 would result in the loss of:

480V ESF Substation Bus 231Z (2AP99E)
ESW Cooling Tower Fan 0SX03CC (High & Low Speed)
ESW Cooling Tower Fan 0SX03CD (High & Low Speed)
480V ESW Cooling Tower MCC 231Z1 (2AP93E)
ESW Make-Up Valve 0SX158B
ESW Service Water Cooling Tower 0A Basin Bypass Valve 0SX162C
ESW Cooling Tower 0A Cell C Riser Valve 0SX163C
ESW Cooling Tower 0A Cell D Riser Valve 0SX163D
ESW Cooling Tower Division 21 Switchgear Room Ventilation Fan 2VX05C
MCC 231Z1 120/208Vac Distribution Panelboard and Auxiliaries:
- Motor 0SX03CC Space Heater
- HVAC Local Control Panel 2VX05J
- Damper Starter Panel 2VX98J
- Motor 0SX03CD Space Heater
- MOV 0SX163C Limit Switch Heater
- MOV 0SX163D Limit Switch Heater

Non-ESF 480V MCC 231Z1A (2AP89E)

The loss of breaker 2425Z at 4160V Bus 242 would result in the loss of:

480V ESF Substation Bus 232Z (2AP98E)
ESW Cooling Tower Fan 0SX03CG (High & Low Speed)
ESW Cooling Tower Fan 0SX03CH (High & Low Speed)
480V ESW Cooling Tower MCC 232Z1 (2AP92E)
ESW Make-Up Valve 0SX157B
ESW Service Water Cooling Tower 0B Basin Bypass Valve 0SX162D
ESW Cooling Tower 0B Cell G Riser Valve 0SX163G
ESW Cooling Tower 0B Cell H Riser Valve 0SX163H
ESW Cooling Tower Division 22 Switchgear Room Ventilation Fan 2VX06C
MCC 232Z1 120/208Vac Distribution Panelboard and Auxiliaries
- Motor 0SX03CG Space Heater
- HVAC Local Control Panel 2VX06J
- Damper Starter Panel 2VX99J
- Motor 0SX03CH Space Heater
- MOV 0SX163G Limit Switch Heater
- MOV 0SX163H Limit Switch Heater

Non-ESF 480V MCC 232Z1A (2AP88E)

ATTACHMENT 3
Additional References

3. MathCAD file for NRC Request 6

Design Verification

Two Tower Model - (Heat load for Power Uprate)

ORIGIN $\equiv$ 1 in $\equiv$ 1L lbm $\equiv$ 1M F $\equiv$ 1Q sec $\equiv$ 1T $\text{gpm} := \frac{\text{gal}}{\text{min}}$ BTU := lbm·F MBTU := $\text{BTU}\cdot 10^6$

Cooling Tower Performance

$\text{Th1} := \begin{pmatrix} 144.26 \\ 136.54 \end{pmatrix}\cdot F \qquad \text{Tc1} := \begin{pmatrix} 104.26 \\ 102.54 \end{pmatrix}\cdot F$

$\text{Th2} := \begin{pmatrix} 144.26 \\ 136.54 \end{pmatrix}\cdot F \qquad \text{Tc2} := \begin{pmatrix} 104.26 \\ 102.54 \end{pmatrix}\cdot F$

$\text{Th3} := \begin{pmatrix} 144.26 \\ 136.54 \end{pmatrix}\cdot F \qquad \text{Tc3} := \begin{pmatrix} 104.26 \\ 102.54 \end{pmatrix}\cdot F$

$\text{Th4} := \begin{pmatrix} 144.26 \\ 136.54 \end{pmatrix}\cdot F \qquad \text{Tc4} := \begin{pmatrix} 104.26 \\ 102.54 \end{pmatrix}\cdot F$

Uprate Heat load (L42)

$$L2 := \begin{pmatrix} 150 \\ 150 \end{pmatrix} \cdot \frac{MBTU}{hr} \qquad T2 := \begin{pmatrix} 0.00 \\ 0.17 \\ 0.35 \\ 0.50 \\ 0.75 \\ 2.00 \\ 2.17 \\ 2.33 \\ 2.50 \\ 3.32 \\ 4.98 \\ 6.65 \\ 8.32 \\ 9.98 \\ 11.50 \\ 11.65 \\ 13.32 \\ 14.98 \\ 16.65 \\ 18.32 \\ 19.98 \\ 21.65 \\ 23.32 \\ 29.98 \\ 39.98 \\ 49.98 \\ 59.98 \\ 83.32 \\ 116.65 \\ 166.65 \\ 333.32 \\ 480.00 \\ 480.17 \\ 540.00 \\ 600.00 \\ 627.50 \\ 660.00 \\ 660.17 \\ 732.00 \\ 732.17 \end{pmatrix} \cdot min$$

SX System Flow rate

$Q1 := 104000 \cdot gpm$ (Total flow to T1 and T2 gpm)

$Q2 := 104000 \cdot gpm$ (Total flow to T1 and T2 gpm)

Basin Mass

$V := 1.068 \cdot 10^{6} \cdot gal$ (Design input 2.1)

$\rho := 8.33 \cdot \frac{lbm}{gal}$ $M_b := \rho \cdot V$ $C_p := 1 \cdot \frac{BTU}{F \cdot lbm}$ $M_b = 8.9 \times 10^{6}\, lbm$

Fans (Active/Total)

$f11 := 0.156$ $f12 := 0.156$

$f21 := 0.156$ $f22 := 0.156$

Time Constant

$\tau 1 := \frac{V}{Q1}$ $\tau 2 := \frac{V}{Q2}$

$\tau 1 = 10.27\, min$ $\tau 2 = 10.27\, min$

Fraction of flow to Tower 1

$\alpha 1 := 0.5$ $\alpha 2 := 0.5$

Fraction of heat load to Tower 1

$\beta 1 := 0.53$ $\beta 2 := 0.53$

Find Slopes and Intercepts of cooling towers 1 and 2

$M11 := slope(Th1, Tc1)$ $B11 := intercept(Th1, Tc1)$ $M12 := slope(Th3, Tc3)$ $B12 := intercept(Th3, Tc3)$

$M21 := slope(Th2, Tc2)$ $B21 := intercept(Th2, Tc2)$ $M22 := slope(Th4, Tc4)$ $B22 := intercept(Th4, Tc4)$

$M11 = 0.223$ $B11 = 72.119\, F$ $M12 = 0.223$ $B12 = 72.119\, F$

$M21 = 0.223$ $B21 = 72.119\, F$ $M22 = 0.223$ $B22 = 72.119\, F$

Calculate Intermediate Constants

$$A1 := \left(-\frac{Q1}{V}\right)\cdot\left[1 - \alpha1\cdot[(1 - f11) + f11\cdot M11] - (1 - \alpha1)\cdot(1 - f21 + f21\cdot M21)\right]$$

$$A2 := \left(-\frac{Q2}{V}\right)\cdot\left[1 - \alpha2\cdot[(1 - f12) + f12\cdot M12] - (1 - \alpha2)\cdot(1 - f22 + f22\cdot M22)\right]$$

$$D1 := \frac{\beta1\cdot(1 - f11 + f11\cdot M11) + (1 - \beta1)\cdot(1 - f21 + f21\cdot M21)}{M_b\cdot C_p}$$

$$D2 := \frac{\beta2\cdot(1 - f12 + f12\cdot M12) + (1 - \beta2)\cdot(1 - f22 + f22\cdot M22)}{M_b\cdot C_p}$$

$$C1 := Q1\cdot\frac{\alpha1\cdot f11\cdot B11 + (1 - \alpha1)\cdot f21\cdot B21}{V}$$

$$C2 := Q2\cdot\frac{\alpha2\cdot f12\cdot B12 + (1 - \alpha2)\cdot f22\cdot B22}{V}$$

$A1 = -0.01\,\frac{1}{min}$ $D1 = 9.88 \times 10^{-8}\,\frac{F}{BTU}$ $C1 = 1.1\,\frac{F}{min}$

$A2 = -0.01\,\frac{1}{min}$ $D2 = 9.88 \times 10^{-8}\,\frac{F}{BTU}$ $C2 = 1.1\,\frac{F}{min}$

Integrating to Solve for Basin Temperature – Change initial temp to 91° F.

$Ub_1 := 91\cdot F$ $i := 1..299$ $H := .1\cdot min$ $st_i := i\cdot H$

$$Ub_{i+1} := Ub_i + \left[\left(A1\cdot Ub_i\right) + \left(\mathrm{linterp}\left(T2, L2, st_i\right)\cdot D1\right) + (C1)\right]\cdot H$$

use uprate heat load with operator action at t=30 minutes to reduce heat load

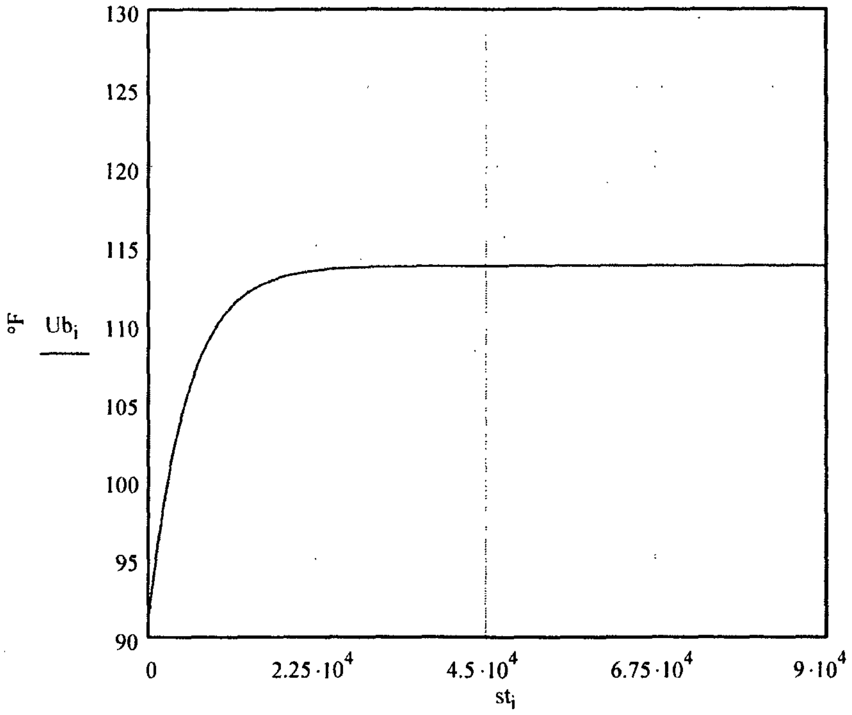
$i := 300..15000$ $H := .1\cdot min$ $st_i := i\cdot H$

$$Ub_{i+1} := Ub_i + \left[\left(A2\cdot Ub_i\right) + \left(\mathrm{linterp}\left(T2, L2, st_i\right)\cdot D2\right) + (C2)\right]\cdot H$$

use uprate heat load with operator action at t=30 minutes to reduce heat load

Results :

$i := 1, 20 .. 15000$



Basin Temperature Response vs. Time (sec)

use uprate heat load

$\max(Ub) = 113.71\ F$

$Ub_{300} = 97.8\ F$

$Ub_{100} = 93.5\ F$

$Ub_{103} = 93.6\ F$

```
maximum := | maximum ← 0
           | for  i ∈ 300 .. 15000
           |   maximum ← max(Ub_i)  if  max(Ub_i) ≥ maximum
```

$maximum = 113.71\ F$

```
index := | index ← 0
         | maximum ← 0
         | for  i ∈ 300 .. 15000
         |   | maximum ← max(Ub_i)  if  max(Ub_i) ≥ maximum
         |   | index ← i  if  max(Ub_i) ≥ maximum
```

$index = 1.5 \times 10^4$

$Ub_{index} = 113.71\ F$

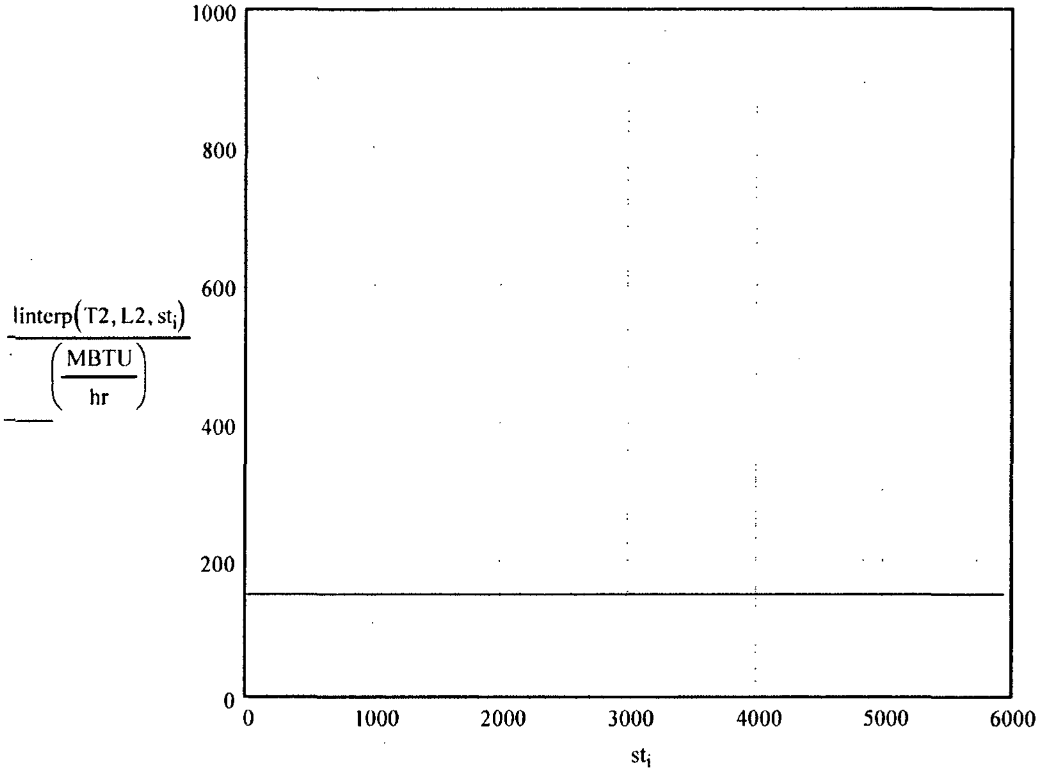
$st_{index} = 90000\ sec$

Basin Temperature and UHS Heat Load vs. Time

$i := 1, 26 .. 1000$

$\frac{Ub_i}{F} =$	$\frac{\operatorname{linterp}(T2, L2, st_i)}{\frac{MBTU}{hr}} =$	$\frac{st_i}{min} =$
91	150	0.1
91.66	150	2.6
92.3	150	5.1
92.93	150	7.6
93.53	150	10.1
94.12	150	12.6
94.69	150	15.1
95.24	150	17.6
95.78	150	20.1
96.3	150	22.6
96.81	150	25.1
97.3	150	27.6
97.78	150	30.1
98.24	150	32.6
98.69	150	35.1
99.13	150	37.6

$i := 1, 20 .. 6000$



Post LOCA Time (sec)

UHS Accident Heat Load Profile L42

ATTACHMENT 3
Additional References

4. Calculation NED-Q-MSD-001, "ESW Cooling Tower Transient Model: Part I"

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CALCULATION TITLE PAGE

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CALC # NED-Q-MSD-001

PROJECT/MOD NO ULTIMATE HEAT SINK OPERABILITY STUDY / NA	**PAGE: 1 OF 26**
CALCULATION TITLE: ESW COOLING TOWER TRANSIENT MODEL : PART I	☑ **SAFETY RELATED** ☐ **REG. RELATED** ☐ **NON-SAFETY RELATED**

CHRON NUMBER	**GROUP**	**CALC NUMBER**	**SYSTEM**
167695	MSD	NED-Q-MSD-1	ESSENTIAL SERVICE WATER

REV	**DATE**	**PREPARER**	**DATE**	**REVIEWER**	**DATE**	**APPROVER**	**DATE**
0	5/22/91	S. Powers	5/22/91		5/22/91	Paul R Donovan	5/22/91

Byron Nuclear Power Station
Entered in Computer
ROXANNE BELL

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PREPARED BY: S. Powers	DATE: 5/21/91	CALC. NO: NED-Q-MSD-1 PAGE NO: 3 OF 23
REVIEWED BY:	DATE: 5/22/91	REV 0 DATE: 5/22/91

SUBJECT: ULTIMATE HEAT SINK (UHS) OPERABILITY STUDY

DESCRIPTION OF REVISIONS/REASONS FOR CHANGE

ORIGINAL ISSUE /NA

AFFECTED PAGES

PAGES	DESCRIPTION

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NUCLEAR ENGINEERING DEPARTMENT
CALCULATION SUMMARY SHEET

CALCULATION NO: NED-Q-MSD-1 **REV.** 0 **PAGE** 4 **OF** 26

PURPOSE/OBJECTIVE OF CALCULATION

THE PURPOSE OF THIS CALCULATION IS TO DEVELOP A MODEL WHICH PREDICTS THE TIME DEPENDENT RESPONSE OF THE ESW COOLING TOWER BASIN TEMPERATURE (BYRON STATION) TO A TIME VARYING LOCA HEAT LOAD.

ASSUMPTIONS/DESIGN INPUTS

ASSUMPTIONS: ALL ASSUMPTIONS ARE INDICATED IN EACH APPROPRIATE SECTION OF THE CALCULATION.

DESIGN INPUTS: THE PARAMETERS USED FOR MODELING AND GENERATING THE SAMPLE FIGURES IN THE CALCULATION WERE BASED ON THE REFERENCES SHOWN.

REFERENCES

1. ENVIRONMENTAL SYSTEMS CORP. (ESC) TEST REPORT DATED 1/22/88; BYRON NUCLEAR GENERATING STATION ESSENTIAL SERVICE WATER COOLING TOWER THERMAL PERFORMANCE TEST REPORT.
2. UFSAR, SECTION 9.2
3. "BYRON STATION ESSENTIAL SERVICE WATER COOLING TOWER PERFORMANCE TEST PROGRAM, JANUARY, 1989", SARGENT & LUNDY LETTER TO MR. C.A. MOERKE DATED JANUARY 19, 1989, FILE NO. 917, (DFB-70), PROJECT NO. 7500-92.

CONCLUSIONS

THIS ANALYTICAL MODEL PROVIDES A METHOD TO DETERMINE THE ESW BASIN TEMPERATURE AS A FUNCTION OF TIME UNDER ACCIDENT CONDITIONS. REQUIRED INPUTS ARE BEST ESTIMATE TIME DEPENDENT LOCA HEAT LOADS AND ACTUAL TOWER PERFORMANCE CHARACTERISTICS.

COMMENTS	**PREPARER** Sam Powers	**DATE** 5/22/91
	REVIEWER	**DATE** 5/22/91
	APPROVER Paul R. Donavin	**DATE** 5/22/91

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NUCLEAR ENGINEERING DEPARTMENT
CALCULATION CHECKLIST

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REVIEWED BY: DATE: 5/22/91

	YES	NO	NA	REMARKS
1. IS THE OBJECTIVE OF THE ANALYSIS CLEARLY STATED?	✓			
2. ARE THE ASSUMPTIONS, ENGINEERING JUDGEMENTS VALID AND DOCUMENTED?	✓			
3. ARE THE ASSUMPTIONS THAT NEED REVERIFICATION IDENTIFIED?			✓	THIS CALC. IS FOR MODEL DEVELOPMENT
4. ARE THE REFERENCES (I.E. DRAWINGS, CODES, STANDARDS,) LISTED BY REV., EDITION, DATE, ETC.?	✓			
5. IS THE DESIGN METHOD CORRECT AND APPROPRIATE FOR THIS ANALYSIS?	✓			
6. IS THE CALCULATION IN COMPLIANCE WITH DESIGN CRITERIA, CODES, STANDARDS, AND REG. GUIDES?	✓			
7. ARE THE UNITS CLEARLY IDENTIFIED, AND EQUATIONS PROPERLY DERIVED AND APPLIED?	✓			
8. ARE THE DESIGN INPUTS AND THEIR SOURCES IDENTFIED AND ARE IN COMPLIANCE WITH UFSAR, TECH SPECS?	✓			
9. ARE THE RESULTS COMPATIBLE WITH THE INPUTS AND RECOMMENDATIONS MADE?	✓			SAMPLE CURVES ARE GENERATED TO SHOW HOW THE MODEL REACTS.
10. IS THIS A LINE BY LINE REVIEW? IF "NO" PROVIDE JUSTIFICATION FOR LIMITED REVIEW.	✓			

NUCLEAR ENGINEERING DEPARTMENT
CALCULATION SHEET

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PREPARED BY: San Powers	**DATE:** 5/22/91	**CALC. NO:** NED-Q-MSD-1 **PAGE NO:** 6 **OF** 26	
REVIEWED BY: w. p.	**DATE:** 5/22/91	**REV** 0	**DATE:** 5/22/91

SEE ATTACHED

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6.0 Body of Calculation

6.1 Overview of Model Development or Background

This section discusses the background and reasons for the development of a time-dependent model of the ESW cooling towers. The model is then presented and applied to two straightforward examples.

As discussed in Reference 3, the early preoperational testing of the towers indicated that their heat removal capabilities were significantly less than the original design values. At a wet bulb temperature of 78°F the basin temperature was not to exceed the design value of 98°F for loads of up to approximately 1040 MBtu/hr. Although the required heat removal rate for similar constraints was close to 600 MBtu/hr, the extrapolation of the test data resulted in a slightly lower value (≈ 570 MBtu/hr). If subsequent testing verified the above preliminary projection, hardware modifications and/or re-analysis of the design bases would have to be undertaken. This situation provided the motivation to develop the time-dependent cooling tower model.

The highly transient nature of the LOCA load suggests that the basin temperature would not exceed 98°F even for significantly degraded tower performance. For example, although the peak LOCA load is close to 600 MBtu/hr (Ref. 2, Fig. 9.2-7), the average load for the first hour is approximately 400 MBtu/hr (Ref. 2, Table 9.2-6). At two hours into the LOCA the heat load has decreased to ≈ 350 MBtu/hr, and at this load, the corresponding steady state basin temperature is approximately 92°F. Thus, it appeared reasonable to conjecture that if the ESW cooling tower response lagged behind the imposed load the corresponding steady state peak basin temperatures would not be reached.

The total water inventory of the ESW system, including the basin and associated piping, is approximately one million gallons (see Ref. 3, App. C, Part D). If the LOCA load was imposed on the cooling towers with an initial basin temperature of 80°F, the allowed 18°F temperature rise, together with the above water inventory, represents a thermal sink of approximately 150 MBtu. In turn, if the towers were completely inoperable, and all of the LOCA heat was dissipated in the ESW water, the allowed basin temperature of 98°F (Tech Spec) would not be reached for at least 16 minutes after LOCA onset. This thermal capacity was thought to be sufficient to introduce adequate lag in the tower response to the LOCA load.

The following section presents a time-dependent model of the ESW cooling towers. The major features of this treatment are the inclusion of the transient LOCA load and the thermal capacity of the ESW system.

6.2 Model Development

Development of the model proceeds from a discussion of steady state cooling tower performance. Conventional terminology is introduced and specifics relating to the Byron ESW cooling towers are presented. The transient LOCA load is then briefly discussed and approximated as a piecewise linear function. By performing a heat balance, including the transient heat load and ESW water inventory acting as a thermal reservoir, a general first order differential equation describing the time-dependent tower response is developed. This equation is then solved analytically for the case of an operational cooling tower. The final applications consider a partially non-functioning tower as this situation may be present at different times during certain accident scenarios.

6.2.1 Cooling Tower Heat Removal

The schematic shown in Figure 1 serves to illustrate the features and terminology required for the development of the cooling tower analytical model. For a total mass flow rate of $\dot{m}$, (in lb/hr), circulating through the system, the temperature rise, (in °F), in the coolant is given by

$$\Delta TL = L/\dot{m}C_p \qquad (1)$$

where L is the applied load, (in Btu/hr), and C_p is the specific heat of the water. For steady state loads, ΔTL is normally referred to as the range; that is, under equilibrium conditions the temperature rise across the load equals the temperature decrease across the tower. For a basin temperature of T_B, the hot water temperature exiting the load is

$$T_h = T_B + \Delta TL \qquad (2)$$

and in turn, T_h is the temperature of the water entering the cooling tower.

As the water passes through the tower, heat is transferred from the water to the air, and the water drops in temperature from T_h to T_c, the cold water exit temperature. The relationship between T_c and T_h is one that depends on the air and water flow rates, actual size and physical characteristics of the tower, and the ambient weather conditions. Reference 1 discusses the extensive test program undertaken to determine the specific thermal characteristics of the ESW cooling towers. Typical performance curves are given which show how T_c varies with wet bulb temperature under different heat loads. For development of the transient model this information is best displayed as shown in the attached Figure 2. At a given wet bulb temperature and water flow rate, T_c is observed to be a slowly varying function of T_h. To facilitate the analysis then, this function is approximated by a piecewise linear function:

$$T_c = M_i T_h + B_i \qquad (3)$$

where M_i and B_i are the slope and intercept constants for the i^{th} interval of T_h:

$$T_{i-1} \leqq T_h \leqq T_i$$

Typical valves are $M_i \approx 0.4$ and $B_i \approx 49°F$ in the range of T_h of interest, (See Ref. 1). Thus, with these constants and an example of $T_h = 100°F$, the exit temperature is $T_c = 89°F$, i.e., the water was cooled by 11°F as it passed through the tower. The size of the temperature interval chosen, $(T_i - T_{i-1})$, dictates both the accuracy of the approximation and the computational complexity of final calculations: smaller temperature intervals are clearly more accurate, but, as will be seen in the following, require significantly more calculations.

6.2.2 LOCA Heat Loads

Under accident conditions the load imposed on the towers is given by the sum of the LOCA load from one unit and a contribution from the other unit. The values of these loads are derived from both actual plant performance data and the application of models to various accident scenarios. UFSAR Table 9.2-6 gives a LOCA unit heat rejection summary listing results at specific time intervals (see Figure 3). For example, at 45 seconds after LOCA onset the heat rejected is 515 MBtu/hr, and at 100 seconds the load has increased to a peak 556 MBtu/hr. Using these results, and adding the NON-LOCA unit load, the total load is expressed as a piecewise linear function:

$$L = M_j t + B_j \qquad (4)$$

where L is the total load at time t, (in Btu/hr), and M_j, (in $\frac{\text{BTU/hr}}{\text{min.}}$) and B_j, (in BTU/hr) are the slope and intercept constants for the j^{th} time interval:

$$t_{j-1} \leqq t \leqq t_j$$

Using equations (1) and (4) then gives the temperature rise across the load:

$$\begin{aligned}\Delta TL &= (M_j t + B_j)/(\dot{m}C_p)\\ &= m_j t + b_j \qquad (5)\end{aligned}$$

where now, m_j and b_j are the slope and intercept constants characterizing the temperature rise in the j^{th} time interval.

$$m_j = \frac{M_j}{\dot{m}C_p}, \ °F/min.$$

$$b_j = \frac{B_j}{\dot{m}C_p}, \ °F$$

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6.2.3 Time Dependent Heat Balance

Figure 1 schematically displays the parameters and variables required for the following development. For the purposes of this analysis it is assumed that the ESW water inventory, M_B, is a constant. This is a reasonable assumption since the safety-related makeup capability exceeds the losses due to evaporation, drift and blowdown. The makeup water enters the basin at the ambient temperature of the Rock River.

In the interval of time Δt, the quantity of water $\dot{m}\Delta t$ both enters and exits the basin. Because the entering and exiting temperatures are T_c and T_B, respectively, the quantity of heat added to the basin in time Δt is

$$\Delta Q = (\dot{m}\Delta t)C_p(T_c - T_B)$$

Further, the differential change in basin temperature in time Δt is given by

$$\Delta T_B = \Delta Q/M_B C_p$$

Taking the limit as Δt goes to zero yields

$$\frac{dT_B}{dt} = (T_c - T_B)\dot{m}/M_B$$

Letting $\tau_T = M_B/\dot{m}$ yields

$$\frac{dT_B}{dt} = (T_c - T_B)/\tau_T \qquad (6)$$

where τ_T is recognized as the time required to replace the total inventory M_B when the total flowrate is $\dot{m}$.

6.2.4 Time Dependent Cooling Tower Operation

The effect of heat removal in the tower, together with the transient nature of the LOCA load, will now be incorporated. Combining equations 2, 3, and 5 yields

$$Tc = M_i(T_B + m_j t + b_j) + B_i \qquad (7)$$

and this applies to the i^{th} T_h interval and j^{th} time interval.

When this expression is inserted into (6) and terms are re-arranged the final differential equation describing the response of the basin temperature to the LOCA load is obtained (see Appendix A):

$$\frac{dT_B}{dt} + \frac{T_B}{\tau_i} = K_i(m_j t + b_j)/\tau_i + \frac{B_i}{(1-M_i)(\tau_i)} \qquad (8)$$

where $K_i = \frac{M_i}{1-M_i}$

and $\tau_i = \frac{\tau_T}{(1-M_i)}$

Recognizing that M_i, B_i, m_j, b_j and τ_T are constants, the solution to (8) is straight forward and given by

$$T_B(t) = C_{ij}e^{-t/\tau_i} + m_j K_i \tau_i(-1 + t/\tau_i) + K_i b_j + \frac{B_i}{(1-M_i)} \qquad (9)$$

where $$C_{ij} = \left[T_B(t_{ij}) - m_j K_i \tau_i(-1 + t_{ij}/\tau_i) - K_i b_j - \frac{B_i}{1-M_i}\right] e^{(t_{ij}/\tau_i)} \qquad (10)$$

and t_{ij} is that time when the solution has to be re-initialized due to transferring to either a different time interval or a different T_h interval. See Appendix B.

A brief explanation of the initialization constant C_{ij} is warranted at this time. As indicated earlier, m_j and b_j represent the constants for the piecewise linear approximation to the LOCA load for the j^{th} time interval. For example, the first set of constants only describe the LOCA load for the time interval of 0-45 sec. At the end of this interval the constant C_{ij} is re-evaluated and inserted into (9) for the next linear interval. Note that in the subsequent interval the next set of constants are also incorporated into (10). Similar re-initialization is required when transferring from one tower segment to another. In summary, the constant C_{ij} will be evaluated several times, and its application provides continuity in the final solution for $T_B(t)$.

6.2.5 Cooling Tower Heat Removal with Faulted Cells.

There are four separate cells in each of the Byron ESW cooling towers and water flow from either unit may be diverted to either tower and any of the eight available cells. Depending upon the operational alignment at LOCA onset, and further, depending upon the postulated accident scenario, it is possible that for some period of time the imposed heat load will be deposited directly into the ESW water inventory. Further, it is possible that for the duration of the LOCA, some water may be passing through cells with inoperable fans. Although there will be some cooling of water, via natural circulation of air, a conservative analysis assumes zero heat removal for such faulted cells. The following analysis considers the three cases of:

a) Zero heat removal for the initial portion of the LOCA

b) Normal heat removal with operational cells concurrent with zero heat removal in faulted cells,

c) Normal heat removal with operational cells concurrent with partial heat removal (natural convection) in faulted cells.

6.2.5.a Tower Response With No Cooling

With no heat removal at LOCA onset, the full LOCA load is deposited in the ESW water inventory. This condition could arise, for example, during cold weather operation when all ESW water is bypassing the cells and is being diverted directly to the basin. The water entering the basin is then at the temperature given by Equation (2):

$$T_c = T_h = T_B + \Delta TL$$

$$= T_B + m_j t + b_j$$

Equation (6), describing the time dependent heat balance of the basin, then becomes

$$\frac{dT_B}{dt} = (m_j t + b_j)/\tau_T \qquad (11)$$

for the j^{th} time interval. The solution to this differential equation is as follows (see Appendix C):

$$T_B(t) = C_j + [m_j t^2/2 + b_j t]/\tau_T \qquad (12)$$

$$\text{where} \quad C_j = T_B(t_{j-1}) - [m_j t^2{}_{j-1}/2 + b_j t_{j-1}]/\tau_T \qquad (13)$$

and t_{j-1} is that time which defines the end of the $(j-1)^{th}$ time interval, (or equivalently, the beginning of the jth interval). As with the initialization constant C_{ij} for Equation (9), C_j allows for transitions from one linear segment of the LOCA load to another. Evaluation of C_j at each cross-over point constrains $T_B(t)$ to be, as required, a continuous function.

6.2.5.b Operational and Fully-Faulted Tower Cells.

The conservative case of zero heat removal in faulted cells, together with some number of operational cells will now be discussed. Water enters the tower at T_h and exits operational cells at T_c as given

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by Equation (3). For zero heat removal cells the exit temperature is just T_h. Defining f as the fraction of operational cells, the average temperature of the water entering the basin, T_e, is given by the weighted average of cooled and uncooled water:

$$T_e = fT_c + (1-f)T_h \qquad (14)$$

Following the development of Equation (6), using T_e in place of T_c, then yields:

$$\frac{dT_B}{dt} = \frac{Te - T_B}{\tau_T} \qquad (15)$$

Using Equation (14) with (15) and following the previous development which led to Equations (8), (9) and (10) it is found that the present differential equation, (15), and its solution are identical to those given already, provided that two constants are redefined as follows:

$$\tau_i = \tau_T/(1 - M_i)f \qquad (16)$$

$$K_i = (-1 + 1/f + M_i)/(1-M_i) \qquad (17)$$

Although formally identical to fully operational tower response, when faulted cells are considered, the response is slower as shown by the inverse dependence of the system time constant, τ_i, upon f. This is expected of course, because the tower as a whole is now removing less heat per cycle through the system. In summary, the tower response to the LOCA, for situations with $f < 1$, (i.e. some water passing through zero heat removal cells), is given by Equations (9) and (10) together with the constants defined in Equations (16) and (17).

6.2.5.c <u>Operational and Partially-Faulted Tower Cells</u>.

The benefit of natural convection cooling in faulted cells will now be considered. When hot water passes through a cell with a non-operating fan, the local air heating that takes place will induce a certain air flow through the cell, i.e. natural convection. Although the resultant water cooling may be much less than that of a functional cell, any level of heat removal may be significant under certain accident situations.

Given that the range of an operable cell is $R = T_h - T_c$ for given conditions, assume that the corresponding temperature drop for a non-operational cell is $R_f = \beta R$, where $0 \leqq \beta \leqq 1$. Clearly $\beta = 0$ is the zero heat removal case, and $\beta = 1$ corresponds to a fully functioning cell. Incorporating this benefit into Equation (14) yields:

$$\begin{aligned} T_e &= fT_c + (1-f)(T_h - R_f) \\ &= [f + (1-f)\beta]T_c + (1-f)(1-\beta)T_h \qquad (18) \end{aligned}$$

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This relation could now be used with Equation (15) and new constants τ_i and K_i, could be derived as before. To avoid this additional analysis, a new factor F is introduced:

$$F = f + (1-f)\beta \qquad (19)$$

and the average temperature of water entering the basin is now

$$T_e = FT_c + (1-F)T_h \qquad (20)$$

Note that this relation is formally identical to Equation (14), when f is replaced by F. Whereas f was the fraction of operable cells when no cooling takes place in inoperable cells, F can be viewed as an effective fraction of operable cells, when natural convection cooling effects are considered. The earlier derived solutions, including the constants of Equations (16) and (17), apply directly to the natural convection case, provided that f is replaced with F.

Consider one example to demonstrate the potential benefit of this effect. One accident scenario that may have to be evaluated is that of passing water through 3 cells, 2 of which are inoperable. Assume that $\beta = 0.1$, i.e., natural convection cooling only removes 10% of the load that an operating cell removes. Equation (19) yields $F = 0.4$, an improvement of 23% over the $f = 0.33$ case. With $\beta = 0.2$, $F = 0.47$, an improvement of 40%.

6.2.6 Characteristics of the General Solution:

As presented, Equation (10) appears somewhat complex due to the presence of numerous terms and auxiliary definitions. The purpose of this section is to demonstrate that this solution is fairly straightforward and further, that for easily visualized transients, Equation (10) yields physically acceptable results.

The solution gives the time dependence of the basin temperature for the specific case where both the load and the tower characteristic are approximated by continuous piecewise linear functions. Transitions from one linear segment to another, for both functions, are accomplished by evaluation of the initialization constant C_{ij}. To demonstrate the characteristics, (i.e. nature), of the solution we first discuss the governing time constant and then examine the system response to two idealized loads.

For the present discussion assume that both the LOCA load and tower response are given by single linear segments:

$$\Delta TL = mt + b$$

$$T_c = MT_h + B$$

where m, b, M and B are constants. The overall system time constant, given in Equation (16), is comprised of three factors all of which relate to global tower performance:

$$\tau = \tau_T/(1 - M)f$$

First, the time required for all of the system water to pass through the tower is given by $\tau_T = M_B/\dot{m}$. Intuitively, the larger the system inventory or the smaller the mass flow rate, the longer the time for the tower to respond to a changing load. The term containing M, (with typical values of 0.3 - 0.5), reflects the rate of change of T_c with respect to changing T_h. Lower values of M indicate that even for large changes in the hot water temperature, the corresponding cold water temperature change is less than the change in T_h. As a result, the time for the tower to respond decreases. The third term specifies the fraction of the tower which is operable and available for heat removal. For example, if only two of the four cells are functioning, the heat removal rate is decreased significantly from that of a fully operational tower, and the response time, accordingly, is increased. In the discussions that follow, f is set to unity to simplify the analysis.

The extreme case of a step change in the load is now considered. Assume that a non-zero steady state load is present and that at time t equals zero, the load instantly increases to a new steady state value:

$$\begin{aligned} \Delta TL &= b_0, \quad t < 0 \\ &= b, \quad t \geqq 0 \end{aligned}$$

Equation (9) then simplifies to the following

$$T_B(t) = T_{B0}\exp(-t/\tau) + [(Mb + B)/(1 - M)][1 - \exp(-t/\tau)] \qquad (21)$$

where T_{B0} is the steady state basin temperature corresponding to the initial load b_0. The final steady state basin temperature is given by

$$T_{B1} = (Mb + B)/(1 - M)$$

This is easily verified by using Equations (2) and (3) and recognizing that T_c and T_B are equal at times much longer than τ. Employing this expression for T_{B1} in the above solution yields the following

$$T_B(t) = T_{B1}[1 - \exp(-t/\tau)] + T_{B0}\exp(-t/\tau) \qquad (22)$$

In this form the basin temperature response is recognized as that of a classical first order system with a time constant τ.

The second most easily visualized example is that of ramp load. Assume that a steady state load of b has been applied to the towers for a long time, and that the basin temperature is T_{BO}. At time t equals zero, a linearly increasing load is then imposed on the system:

$$\Delta TL = b, \quad t < 0$$

$$= mt + b, \quad t \geqq 0$$

Equation (9) can then be arranged as follows:

$$T_B(t) = [m(t - \tau) + b]M/(1 - M) + B/(1 - M) + C\exp(-t/\tau)$$

$$\text{where} \quad C = T_{BO} + M(m\tau - b)/(1 - M) - B/(1 - M)$$

As was the case in the example of the step change in load, for time larger than τ, the exponential terms in the response to the ramp rapidly decay away: this is the expected response of a first order system. The basin temperature thereafter is linearly increasing with slope $Mm/(1-M)$ and delayed in time by the characteristic time τ.

The preceding discussion demonstrates, that in principle, the system response to specified loads is easily evaluated. Further, interpretation of the responses is fairly straightforward. For more accurate, and therefore more complex, characterizations of the load and tower performance, the solutions become burdensome. In particular, it is the evaluation of initialization constant C_{ij}, at each transition, (typically more than 30 times), which prompted development of a computer code to complete the calculations.

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Appendix A: Derivation of Equation (8)

- The equations which have to be manipulated are:

$$(6) \quad \frac{dT_B}{dt} = \frac{T_c - T_B}{\tau_T}$$

$$(7) \quad T_c = M_i(T_B + m_j t + b_j) + B_i$$

- Evaluate: $T_c - T_B = M_i(m_j t + b_j) + B_i - (1-M_i)T_B$

- Re-arranging: $\frac{dT_B}{dt} + \frac{(1-M_i)T_B}{\tau_T} = \frac{M_i(m_j t + b_j)}{\tau_T} + \frac{Bi}{\tau_t}$

- Define new time constant:

$$\tau_i = \tau_T/(1-M_i)$$

$$\text{or} \quad \tau_T = (1-M_i)\tau_i$$

- Substituting: $\frac{dT_B}{dt} + \frac{T_B}{\tau_i} = \left[\frac{M_i}{1-M_i}\right]\frac{m_j t + b_j}{\tau_i} + \frac{B_i}{(1-M_i)\tau_i}$

- Define new term: $K_i = \frac{M_i}{1-M_i}$

- Obtain final differential Equation (8):

$$\frac{dT_B}{dt} + \frac{T_B}{\tau_i} = \frac{K_i\ (m_j t + b_j)}{\tau_i} + \frac{B_i}{(1-M_i)\tau_i}$$

Appendix B: Solution to Cooling Tower Differential Equation

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- Reformulate Equation (8) as follows:

$$\frac{dT_B}{dt} + aT_B = k_1 t + k_0 \qquad (B.1)$$

with: $a = 1/\tau_i$

$k_1 = K_i m_j/\tau_i$

$k_0 = K_i b_j/\tau_i + B_i/(1 - M_i)\tau_i$

- Equation (B.1) is a first order linear differential equation and several methods are available for determining the required solution, (e.g., Method of Undetermined Coefficients, Laplace Transforms, etc.)

- The left-hand side of the equation, with constant coefficient "a", requires that the solution include a term of the form e^{-at}. Further, the right-hand side of (B.1), with k_1 & k_0 as constants, suggests that the solution include terms in powers of "t".

- Consider the following general solution for (B.1):

$$T_B(t) = Ce^{-at} + At + B \qquad (B.2)$$

where the constants A and B can be determined by reformulating (B.1) by use of (B.2)

- Take first derivative of (B.2):

$$\frac{dT_B}{dt} = -aCe^{-at} + A \qquad (B.3)$$

- Formulate the left hand side of (B.1) using (B.2) and (B.3):

$$\begin{aligned}\frac{dT_B}{dt} + aT_B &= [-aCe^{-at} + A] + a[Ce^{-at} + At + B]\\ &= (aA)t + (A + aB)\\ &= k_1 t + k_0, \text{ from (B.1)}\end{aligned}$$

- Equating coefficients:

$$aA = k_1 \longrightarrow A = k_1/a$$

$$A + aB = k_0 \longrightarrow B = \frac{1}{a}(k_0 - A) = \frac{k_0}{a} - \frac{k_1}{a^2}$$

Appendix B, (cont'd)

- The following general solution is then obtained:

$$T_B(t) = Ce^{-at} + \frac{k_1}{a}t + \left(\frac{k_0}{a} - \frac{k_1}{a^2}\right) \qquad (B.4)$$

- The constant C will now be determined. Recall that the three constants k_1, k_0 and a, defined in (B.1), incorporate the LOCA load for the $j^{\underline{th}}$ time interval, and tower heat removal for the $i^{\underline{th}}$ T_h interval.

- Assume that the initial basin temperature is T_{BO}. The temperature rise across the LOCA load is characterized by m_1 and b_1 and these apply over the interval 0 - 45 sec. The T_h interval characterizing the tower heat removal is determined by evaluating $T_h = T_B + \Delta TL$. As T_h increases or decreases, different linear segments, $T_{i-1} \leqq T_h \leqq T_i$, will be encountered, and re-initialization of the solution is required at each crossover. At a minimum then, re-initialization is required at 45 seconds, although it is likely that earlier re-initializations will be required due to crossing into new T_h intervals. At this re-initialization, new values of m_j & b_j, or M_i and B_i, will have to be incorporated, and in doing this the value of C must be updated as well.

- Assume that at time t_{ij} a transition from one LOCA or tower interval to another is required. The basin temperature at this time is $T_B(t_{ij})$, which was evaluated in the previous interval. Because for $t \geqq t_{ij}$, the LOCA is in the $j^{\underline{th}}$ time interval and the tower response is in the $i^{\underline{th}}$ temperature interval, the basin temperature is given by (B.4), with C yet to be determined. Requiring that $T_B(t)$ be a continuous function yields:

$$T_B(t=t_{ij}) = T_B(t_{ij})$$

$$= Ce^{-at_{ij}} + \frac{k_1}{a}t_{ij} + \left(\frac{k_0}{a} - \frac{k_1}{a^2}\right)$$

Solving for C:

$$C = \left[T_B(t_{ij}) - \frac{k_1}{a}t_{ij} - \left(\frac{k_0}{a} - \frac{k_1}{a^2}\right)\right]e^{at_{ij}}$$

$$= C_{ij}$$

Note that C has been redefined as C_{ij} because it is to be used only for the $j^{\underline{th}}$ time and $i^{\underline{th}}$ tower intervals.

Appendix B, (cont'd)

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- Transform the solution to the original constants, M_iB_i, m_jb_j, etc;

$$a = 1/\tau_i$$

$$k_1 = K_i m_j/\tau_i$$

$$k_0 = K_i b_j/\tau_i + B_i/(1-M_i)\tau_i$$

$$\frac{k_1}{a} = k_i\tau_i = K_i m_j \,, \qquad \frac{k_1}{a^2} = K_i m_j \tau_i$$

$$\frac{k_0}{a} = k_0\tau_i = K_i b_j + \frac{B_i}{1-M_i}$$

$$C_{ij} = [T_B(t_{ij}) - K_i m_j t_{ij} - (K_i b_j + \frac{B_i}{1-M_i} - K_i m_j \tau_i)]e^{t_{ij}/\tau_i}$$

$$= [T_B(t_{ij}) - m_j K_i \tau_i(-1 + \frac{t_{ij}}{\tau_i}) - K_i b_j - \frac{B_i}{1-M_i}]e^{t_{ij}/\tau_i}$$

This is the initialization constant given by Equation (10).

Evaluate the remaining two terms of (B.4):

$$\frac{k_1}{a}t + \frac{k_0}{a} - \frac{k_1}{a^2} = K_i m_j t + K_j b_j + \frac{B_i}{1-M_i} - K_i m_j \tau_i$$

$$= m_j K_i \tau_i(-1 + t/\tau_i) + K_i b_j + \frac{B_i}{1-M_i}$$

Equation (B.5) is then given by:

$$T_B(t) = C_{ij}e^{-t/\tau_i} + m_j K_i \tau_i(-1 + t/\tau_i) + K_i b_j + \frac{B_i}{1-M_i}$$

This is the general equation for the basin temperature as a function of time when the LOCA is characterized by m_j & b_j and the tower by M_i & B_i: Equation (9).

Appendix C: System Response with No Cooling

167695

- This appendix gives the solution to Equation (11), which is a differential equation describing the heat-up of the ESW water inventory when subjected to a LOCA load when no heat is removed by the cooling tower:

$$\frac{dT_B}{dt} = (m_j t + b_j)/\tau_T \qquad (11)$$

- Integrating both sides of this equation with respect to time yields:

$$T_B(t) = (m_j t^2/2 + b_j t)/\tau_T + C_j \qquad (C.1)$$

where C_j is a constant to be determined by initial conditions. This is Equation (12).

- Assume that at LOCA onset the basin temperature is T_{BO}. The constants m_1 and b_1 characterize the LOCA during the first interval:

$$T_B(t) = (m_1 t^2/2 + b_1 t)/\tau_T + C_1$$

- Evaluate this expression at time equals zero:

$$T_B(t=0) = T_{BO} = C_1$$

$$T(t) = (m_1 t^2/2 + B_1 t)/\tau_T + T_{BO}$$

where this expression applies only for the first time interval.

- Equation (C.1) describes the basin temperature heatup during the $j^{\underline{th}}$ time interval, and C_j is yet to be determined. The basin temperature at the beginning of this interval, at time t_{j-1}, is $T_B(t_{j-1})$, and is determined by evaluating (C.1) with the LOCA constants of the $j\text{-}1^{\underline{th}}$ interval.

$$T_B(t=t_{j-1}) = T_B(t_{j-1})$$
$$= (m_j t^2{}_{j-1}/2 + b_j t_{j-1})/\tau_T + C_j$$

- Solving for C_j gives Equation (13):

$$C_j = T_B(t_{j-1}) - [m_j t^2{}_{j-1}/2 + b_j t_{j-1}]/\tau_T$$

Appendix D: Tower Response to Step and Ramp Loads

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- This appendix provides the arithmetic manipulations required to produce equations (21) and (22). These equations give the basin temperature as a function of time when subjected to a step change in load, and a ramp load, respectively.

- As stated, the tower temperature response is approximated by a single linear relation:

$$T_c = MT_h + B$$

Figure 2 shows the quality of fit when using a single versus several linear segment approximation: over the 48 degree interval of T_h shown, the single segment approximation introduces no more than a one degree error.

- With f = 1, Equations (16) and (17) then yield:

$$\tau_i \text{------>}\ \tau = \tau_T/(1-M)$$

$$K_i \text{------>}\ K = M/(1-M)$$

- For the tower response to a step change in load:

$$t_{ij} \text{----->} t = 0,$$

$$m_j \text{------>}\ m = 0,$$

$$b_j \text{------>} b,$$

$$T_B(t_{ij}) \text{---->}\ T_{Bo}$$

and Equation (10) yields:

$$C_{ij} \text{----->}\ C = T_{BO} - Kb - B/(1-M)$$

$$= T_{BO} - (Mb+B)/(1-M)$$

- Using the preceding, Equation (9) yields:

$$T_B(t) = C\ [\exp(-t/\tau)] + Mb/(1-M) + B/(1-M)$$

$$= T_{BO} \exp(-t/\tau) + [(Mb+B)/(1-M]\ [1-\exp(-t/\tau)],$$

and this is Equation (21).

Appendix D: Tower Response to Step and Ramp Loads (Con't.)

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- For the tower response to a ramp load, with a non-zero value of m_j, the above identifications, (K_i, t_{ij}, b_j, etc.), are unchanged with the following exception:

$$m_j \text{------}\!> m \neq 0.$$

- The initialization constant given in Equation (10) is then:

$$C_{ij} \text{------}\!> C = T_{B0} - Mm\tau\,(-1)/(1-M) - Mb/(1-M) - B/(1-M),$$

and Equation (9) then yields:

$$T_B(t) = Ce(-t/\tau) + Mm(-1 + t/\tau) + Mb/(1-M) + B/(1-M)$$

$$= [m(t-\tau) + b]\ M/(1-M) + B/(1-M) + Ce(-t/\tau),$$

and this is Equation (22).

FIGURE 1

SCHEMATIC OF BYRON ESW COOLING TOWER

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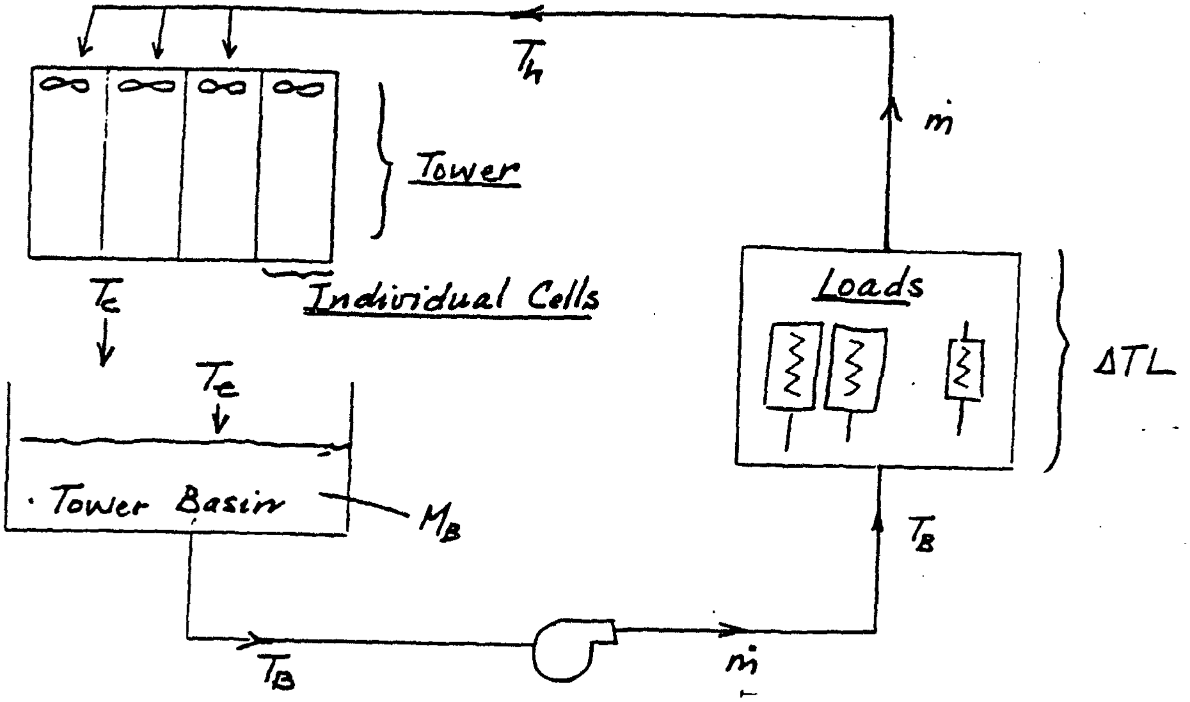

M_B = mass of water in the ESW system (lbm)

$\dot{m}$ = total mass flow rate to tower (lb/hr)

T_h = temperature of water entering tower (°F)

T_c = temperature of water leaving an operating cell (°F)

ΔTL = increase in ESW water temperature due to load (°F)

T_B = temperature of water leaving tower basin (°F)
Te = temperature of water entering tower basin (°F)

NOTE: The distinction is made between Te and Tc in order to simulate the effect of bypassing one or more cooling tower cells.

FIGURE 2

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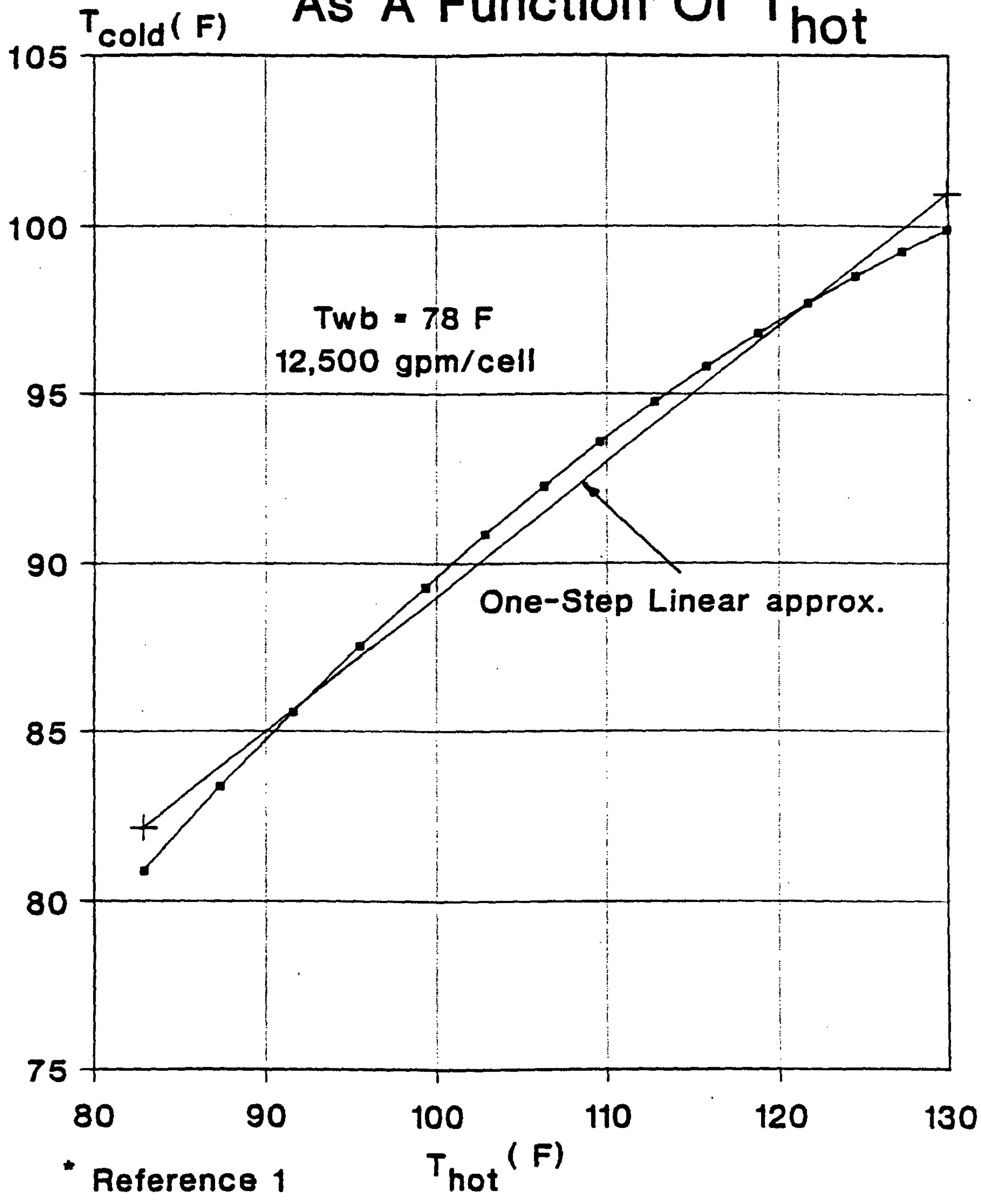

ESW Tower Performance*
As A Function Of T_{hot}

* Reference 1

FIGURE 3

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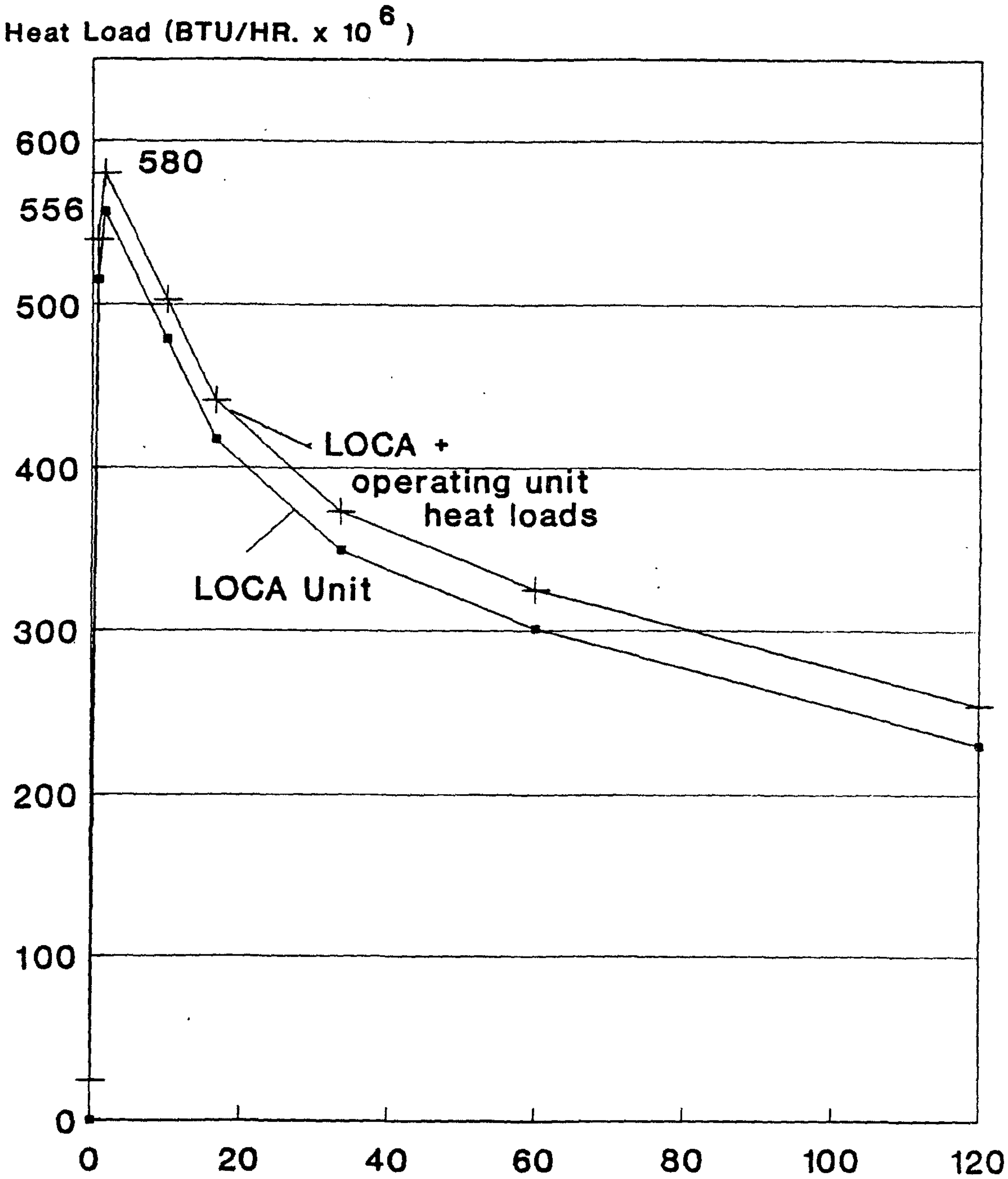
LOCA Load Profile vs Time



Reference:UFSAR Table 9.2-6
UFSAR Figure 9.2-7

ATTACHMENT 3
Additional References

5. Calculation NED-Q-MSD-6, "ESW Cooling Tower Transient Model: Part III"

Exhibit B
ENC-QE-51.D
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TITLE PAGE

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☒ SAFETY RELATED ☐ NON-SAFETY RELATED

CALCULATION TITLE
ESW COOLING TOWER TRANSIENT MODEL: PART III

EQUIP NUMBER(S)	STATION /UNIT	SYSTEM
0SX02AA and BB	Byron / 1 and 2	service water

REV.	CHRON#	PREPARER DATE	REVIEWER DATE	APPROVER DATE
1	210729	Sam Powers 10/19/94 S. Powers	Daniel Lee 10/24/94	Paul E. Dietz 10/26 Paul E. Dietz

210729

COMMONWEALTH EDISON COMPANY

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REVISION SUMMARY

CALCULATION NO: NED-Q-MSD-6	PAGE 3 OF

DESCRIPTION OF REVISIONS/REASONS FOR CHANGE

The reason for this change is to revise the analytical model to account for bypassed uncooled water in both towers.

AFFECTED PAGES

PAGES	REV.	DESCRIPTION
5	1	Purpose/Objective section revised to account for bypassed uncooled water in both towers/typographical correction.
6	1	Model Development includes discussion of faulted cells in one tower.
10	1	Bypass flow in both towers,cooling tower heat removal sections revised.
11,12	1	Time dependent cooling tower operation in both towers
12	1	Conclusion revised to account for bypassed, non-cooled water in bth towers.
14	1	Reference 5 added.
18	1	Figure 4 added to reflect bypass flow in both towers.

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CALCULATION SHEET

Exhibit E
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Revision 3
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CALCULATION NO: NED-Q-MSD-6	PAGE 4 OF

See attached

REVISION	1							

QE-51.D
EXHIBIT E
REV. 3

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4.0 Purpose/Objective:

To develop a model which predicts the same time dependent response of the ESW Cooling Towers basin temperature (Byron Station) to a time varying LOCA heat load. This calculation augments calculation # NED-Q-MSD-1, CHRON # 167695 and NED-Q-MSD-6, Rev. 0, CHRON # 172315. This calculation has been revised to account for the possibility of bypassing uncooled water in both towers.

4.1 Assumptions/Design Inputs:

Assumptions: All assumptions are indicated in each appropriate section of the calculation.

Design Inputs: The parameters used for modelling and generating the sample figures in the calculation were based on references shown.

4.2 Body of Calculation

4.2.1 Background

The time-dependent model of the ESW, (Essential Service Water), cooling towers developed in Reference (1) incorporated the basic assumption that the total water flow to the towers was equally partitioned amongst the cells receiving flow. The accident scenarios described in Reference (2), together with the accompanying expected flows given in Reference (3), demonstrate that this assumption is not always satisfied. Because tower performance is very dependent upon the water loading, the transient model of Reference (1) is extended to account for different cell flows in the present calculation. Additionally, allowance for an uneven distribution of the total heat load to the two towers is also addressed. Further, the model allows for bypassed flow in the cells of both towers. In fact, inclusion of bypass flow is the reason for revising this calculation.

The Byron Nuclear Generating Station ESW cooling towers consist of two four-cell, counter-flow, mechanical, induced draft tower sections. See Figure 1 for an overview. Although the flows through each of the cells of a given tower may be assumed to be equal, the flows to the two towers may be significantly different. Further, one or more cells of a given tower may be isolated, either for normal maintenance or for some component failure. One example from Reference (3) shows how large the flow disparity can be:

> Case 3A predicts a flow greater than 16,000 gpm being directed to a single cell of Tower A, and approximately 10,600 gpm being simultaneously directed to four cells of Tower B.

Figure 2 illustrates the importance of water flow on tower performance. At a wet bulb temperature of 80°F and a tower range of 23°F, the exiting cold water temperatures are approximately 90°F and 108°F, for water flow rates of 8,333 and 16,667 gpm, respectively. Clearly the impact of unbalanced flows to the two towers, resulting in such different thermal performance, must be carefully evaluated.

This calculation closely parallels the development given in Reference (1). The modelling of the LOCA heat loads and tower thermal performance is unchanged. Definitions of terms and symbols are also unchanged. The major difference between this "two-tower" model and the "single-tower" model of Reference (1) is that, because of the possible difference in flows and loads to the towers, the heat removal properties of each are separately factored into the analysis. The final differential equation describing the basin temperature, and its solution, are shown to be formally identical to that obtained in Reference (1).

4.3 Model Development: Faulted Cells in One Tower

Figure 3 schematically displays the ESW cooling towers and associated water flows and heat loads. Water is drawn from the common basin at temperature T_B, (°F), at the mass flow rates of $\dot{m}_1$, (lbm/hr), and $\dot{m}_2$, and supplied at those rates to towers T-1 and T-2, respectively. After passing through the heat load L_1 (Btu/hr), the resultant temperature of the water entering T-1 is T_{h1}. Similarly, water is supplied to tower T-2 at a temperature of T_{h2} after being heated by the load L_2.

Heat is removed at different rates in each of the towers due, primarily, to the different cell flows. Allowance is made for faulted cells in T-1, for which the overall thermal performance will be significantly reduced. All hot water entering T-2 is assumed to be cooled. The cooled water from both towers then enters the basin, and mixes to produce an overall average basin temperature, T_B.

4.3.1 Cooling Tower Heat Removal

As in Reference (1) the cooling tower heat exchange process is modelled as a linear function. Hot water enters the fill region of the tower at a temperature T_h, releases heat to the counter flowing air by both latent and sensible heat transfer, and enters the basin at the cold water temperature, T_c. The resultant rate of heat transfer, for a given mass flow rate, $\dot{m}$, is given by the product of $\dot{m}$ and the temperature decrease, or range, $R = T_h - T_c$. The dependence of T_c, upon T_h, (in turn, known to be Strong function of $\dot{m}$), is the relationship to be approximated as a linear function.

Figures (1) and (2) of Reference (4) give examples of the quality-of-fit of a straight line to this slowly varying function. For the present calculation a single segment linear approximation will be used. Note that the development of Reference (1) allowed for a multi-segment approximation. Because the water flows may be different for the two towers, each is modelled separately.

For T-1, for water passing through operating cells:

$$T_{c1} = M_1 T_{h1} + B_1 \qquad (1)$$

where, as defined in Reference (1), M_1 and B_1 are the slope, (°F/°F), and intercept, (°F), characterizing the dependence of T_{c1} an T_{h1}, the cold and hot water temperatures of T-1, respectively. The fraction of operable cells in T-1, characterized by "*f*", is allowed to be equal to or less than unity. If no heat is removed from non-operable cells, the average temperature of the water entering the basin from T-1 is then Tel;

$$T_{c1} = fT_{c1} + (1-f)T_{h1} \qquad (2)$$

The second tower, T-2, is assumed to be fully operational, with all water being cooled from T_{h2} to T_{c2}:

$$T_{c2} = M_2 T_{h2} + B_2 \qquad (3)$$

where M_2 and B_2 are the slope and intercept, respectively, of the single segment linear approximation.

4.3.2 LOCA Heat Loads

Under accident conditions the heat load supplied to the cooling towers is given by the sum of the load from the LOCA unit and a smaller contribution from the other, non-LOCA unit. Following the method given in Reference (1), this total load is expressed as a piecewise linear function:

$$L_T = M_j t + B_j \qquad (4)$$

where L_T is the total load, (Btu/hr), at time "t", (min), and M_j, (Btu/hr/min), and B_j ,(Btu/hr), are the slope and intercept constants for the jth time interval.

Each tower receives some fraction of this heat load:

$$L_1 = \beta L_T \qquad (5)$$

$$L_2 = (1-\beta) L_T \qquad (6)$$

where L_1 and L_2 are the heat loads supplied to towers T-1 and T-2, respectively. The load fraction, β, equals 0.5 when the load is equally divided to the two towers. Otherwise, $0 \leq \beta \geq 1$, and the appropriate value of β must be determined by the constraints of the accident scenario being examined.

For convenience, in this calculation the water flow rates to the towers are expressed as fractions of the total flow:

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$$\dot{m}_1 = \alpha\dot{m} \qquad (7)$$

$$\dot{m}_2 = (1-\alpha)\dot{m} \qquad (8)$$

where α is the fraction of flow directed to T-1, and $\dot{m}$ is the total flow rate supplied to the towers. The temperature rise across the heat load of the water supplied to tower T-1, L_1, (°F), is given as:

$$\mathrm{L}_1 = L_1/\dot{m}\mathrm{C}_p \qquad (9)$$

where C_p is the specific heat of water, taken as one Btu/(lbm°F) in this calculation. Combining Equations (9), (7), (5) and (4) yields:

$$\mathrm{L}_1 = \beta L_T/\alpha\dot{m}\mathrm{C}_p \qquad (10)$$

$$= \beta\mathrm{L}_T/\alpha$$

where:

$$\mathrm{L}_T = \mathrm{m}_j t + \mathrm{b}_j \qquad (11)$$

and L_T is the average temperature rise of the water passing through the heat loads for the j<u>th</u> time interval. The slope and intercept for L_T in this interval are, respectively:

$$\mathrm{m}_j = M_j/\dot{m}\mathrm{C}_p, \ (\text{°F/min})$$

$$\mathrm{b}_j = B_j/\dot{m}\mathrm{Cp}, \ (\text{°F})$$

Similarly, for tower T-2, the temperature increase is:

$$\mathrm{L}_2 = ((1-\beta)/(1-\alpha))\mathrm{L}_T \qquad (12)$$

Equations (12), (11), and (10) can now be used to relate the hot water temperatures to the basin temperature:

$$\mathrm{T}_{h1} = \mathrm{T}_B + \mathrm{L}_1 \qquad (13)$$

$$\mathrm{T}_{h2} = \mathrm{T}_B + \mathrm{L}_2 \qquad (14)$$

4.3.3 Time Dependent Cooling Tower Operation

4.3.3.1 Basin Heat Balance

Following Reference (1) a heat balance is applied to the basin water inventory as follows. In the interval of time Δt, the quantity of water $\dot{m}\ \Delta t$ both enters and exits the basin. The entering water temperatures are T_{c1} and T_{c2} for water from towers T-1 and T-2, respectively, and the flow rates, as defined above, are $\dot{m}_1$, and $\dot{m}_2$. Because the water exits the basin at the temperature T_B, the net heat added in this interval is ΔQ:

$$\Delta Q = (\dot{m}_1\ \Delta t)C_p(T_{c1} - T_B) + (\dot{m}_2\ \Delta t)C_p(T_{c2} - T_B)$$

The corresponding differential change in basin temperature is given by:

$$\Delta T_B = \Delta Q/(M_B C_p)$$

where M_B is the total basin inventory. Taking the limit as Δt goes to zero and using Equations (7) and (8) yields

$$\frac{dT_B}{dt} = [\alpha T_{c1} + (1-\alpha)T_{c2} - T_B]/\tau_T \qquad (15)$$

where, as used in Reference (1) again, τ_T is the recirculation time constant, equal to $M_B/\dot{m}$.

4.3.3.2 Time-Varying Basin Temperature

Equation (15), representing the time rate of change of the basin temperature, must now be manipulated into a usable differential equation. First, eliminate the intermediate temperatures, T_{c1} and T_{c2}, by using equations (2) and (3). Second, eliminate T_{h1}, and T_{h2} by, using equations (13) and (14). Finally, substitute for L_1 and L_2 with equations (9), (10) and (11), and re-arrange to obtain the following:

$$\frac{dT_B}{dt} + aT_B = k_1 t + k_o \qquad (16)$$

where:

$$a = [1-\alpha(1-f+f M_1) - (1-\alpha)M_2]/\tau_T$$

$$k_1 = m_j[\beta(1-f+f M_1) + (1-\beta)M_2]/\tau_T$$

$$k_o = \{b_j[\beta(1-f+f M_1) + (1-\beta)M_2] + \alpha f B_1 + (1-\alpha)B_2\}/\tau_T$$

This first order differential equation for T_B is now recognized as being formally identical to that developed in Reference (1). See Appendix B of this Reference, where Equation (B.1) is presented in the identical form to Equation (16) above. The solution to (16), given as Equation (B.4) of Appendix B is as follows:

$$T_B(t) = C_j e^{-at} + \frac{k_1}{a}t + \left(\frac{k_0}{a} - \frac{k_1}{a^2}\right) \qquad (17)$$

where the re-initialization constant, C_j, for the jth LOCA time interval, is given as:

$$C_j = \left[T_B(t_j) - \frac{k_1}{a}t_j - \left(\frac{k_0}{a} - \frac{k_1}{a^2}\right)\right] e^{at_j} \qquad (18)$$

and "t_j" is the time at the beginning of the jth interval.

4.4 Bypass Flow in Both Towers

This section extends the proceeding cooling tower model of Section 4.3 to account for the possibility of bypassing uncooled water in both towers. The mathematical development follows that given in Section 4.3, with one modification: the fraction of water being cooled in T-1 is now designated as f_1 (instead of "f"), and the corresponding fraction for T-2 is f_2. Figure 4 schematically displays the new model, and definitions for all of the system parameters are provided as well.

4.4.1 Cooling Tower Heat Removal

The average temperature of the water entering the basin from T-1 is now given by:

$$T_{e1} = f_1 T_{c1} + (1-f_1)T_{h1} \qquad (19)$$

Clearly, this equation reduces to Equation (2) when f_1 is replaced with f. Similarly, the temperature of the water entering the basin from T-2 is :

$$T_{e2} = f_2 T_{c2} + (1-f_2)T_{h2} \qquad (20)$$

For $f_2 = 1$, as implicitly used in Section 6.2, Equation (20) reduces to $T_{e2} = T_{c2}$, and Equation (3) gives the value of T_{c2}.

4.4.2 LOCA Heat Loads

The development and terminology of Section 4.3.2 is directly applicable to the extended model. That is, Equations (4) through (14) will be used , unchanged, in the following.

4.4.3 Time Dependent Cooling Tower Operation

4.4.3.1 Basin Heat Balance

Allowing for bypassed flow in both towers, the net heat added to the basin in the time interval Δt is now given by:

$$\begin{aligned}\Delta Q &= (\dot{m}_1\Delta t)C_p(T_{e1} - T_B) + (\dot{m}_2\Delta t)C_p(T_{e2} - T_B)\\ &= M_B C_p \Delta T_B\end{aligned}$$

Taking the limit as Δt goes to zero and using Equations (19) and (20) yields:

$$\frac{dT_B}{dt} = \frac{1}{\tau_T}[\alpha T_{e1} + (1-\alpha)T_{e2} - T_B] \qquad (21)$$

With $f_2 = 1$, $T_{e2} = T_{c2}$, and Equation (21) then reduces to (15).

4.4.3.2 Time-Varying Basin Temperature

The algebra required to produce a differential equation describing the time rate of change of T_B will be briefly described. Note that the approach is identical to that given in Section 6.2. The only difference is that f is replaced by f_1 and f_2 is introduced for Tower T-2.

Incorporating Equations (1), (13) and (10) into (19) leads to:

$$T_{e1} = [1 - f_1 + f_1M_1]T_B + [1 - f_1 + f_1M_1](\beta/\alpha)L_T + f_1B_1 \qquad (22)$$

The corresponding expression for T_{e2} is then developed in the same manner:

$$T_{e2} = [1 - f_2 + f_2M_2]T_B + [1 - f_2 + f_2M_2]((1-\beta)/(1-\alpha))L_T + f_2B_2 \qquad (23)$$

Substituting (22) and (23) into (21) leads directly to:

$$\frac{dT_B}{dt} + \hat{a}T_B = \hat{k}_1 t + \hat{k}_0 \qquad (24)$$

$$\hat{a} = \frac{1}{\tau_T} \quad [1 - \alpha(1 - f_1 + f_1M_1) - (1-\alpha)(1 - f_2 + f_2M_2)]$$

$$\hat{k}_1 = \frac{M_j}{\tau_T} \quad [\beta(1 - f_1 + f_1M_1) + (1-\beta)(1 - f_2 + f_2M_2)]$$

$$\begin{aligned}\hat{k}_0 = \frac{1}{\tau_T} \quad [b_j\{\beta(1 - f_1 + f_1M_1) + (1-\beta)(1 - f_2 + f_2M_2)\}\\ + \alpha f_1B_1 + (1-\alpha)f_2B_2]\end{aligned}$$

This differential equation is formally the same as that given in Equation (16). Further, it is straight forward to show that $\hat{a}$ reduces to " a " in (16), when the substitutions $f_1 = f$ and f_2=1 are made. Similarly, $\hat{k}_1$ and $\hat{k}_0$ reduce to k_1 and k_0, respectively, with the same substitutions for f_1 and f_2. It is clear, furthermore, that the solutions to Equation (16),(given by (17) and (18)),

apply as well to (24), provided the constants (a,k_1,k_0) are replaced by $(\hat{a},\hat{k}_1,\hat{k}_0)$.

4.5 Conclusions

This analytical model provides a method to determine the ESW basin temperature as a function of time under accident conditions. Required inputs are best estimate time dependent LOCA heat loads and actual tower performance characteristics. In addition the analytical model accounts for bypassed uncooled water in both towers.

The present model builds upon, and extends, the single tower model developed in Reference (1). Three additional features have been incorporated:

i) each of the two ESW towers may, have different thermal performance characteristics.
ii) the heat loads and flows supplied to each tower may be different.
iii) bypassed, non-cooled water is allowed for in both towers.

This two-tower, two-load model will provide a more realistic description of the ESW cooling response under accident conditions than previously available.

210729

Exhibit F
ENC-QE-51.D
Revision 3
Page 2 of 2

COMMONWEALTH EDISON COMPANY

REVIEW CHECKLIST

CALCULATION NO: NED-Q-MSD-6	REV. 1	PAGE 13 OF

REVIEWED BY:

DATE: 10/24/94

YES NO REMARKS

☑ ☐ 1. IS THE OBJECTIVE OF THE ANALYSIS CLEARLY STATED?

☑ ☐ 2. ARE ASSUMPTIONS AND ENGINEERING JUDGEMENTS VALID AND DOCUMENTED?

☐ ☑ 3. ARE THERE ASSUMPTIONS THAT NEED VERIFICATION?

☑ ☐ 4. ARE THE REFERENCES (I.E. DRAWINGS, CODES, STANDARDS) LISTED BY REVISION EDITION, DATE, ETC.?

☑ ☐ 5. IS THE DESIGN METHOD CORRECT AND APPROPRIATE FOR THIS ANALYSIS?

☑ ☐ 6. IS THE CALCULATION IN COMPLIANCE WITH DESIGN CRITERIA, CODES, STANDARDS, AND REG. GUIDES?

☑ ☐ 7. ARE THE UNITS CLEARLY IDENTIFIED, AND EQUATIONS PROPERLY DERIVED AND APPLIED?

☑ ☐ 8. ARE THE DESIGN INPUTS AND THEIR SOURCES IDENTIFIED AND IN COMPLIANCE WITH UFSAR & TECH SPECS?

☑ ☐ 9. ARE THE RESULTS COMPATIBLE WITH THE INPUTS AND RECOMMENDATIONS MADE? Calculation for model Development only

10\. INDICATE TYPE OF CALCULATION (HAND-PREPARED AND/OR COMPUTER-AIDED) AND METHOD OF REVIEW:

☐ HAND PREPARED DESIGN CALCULATION

THE REVIEW OF THE HAND-PREPARED DESIGN CALCULATION WAS ACCOMPLISHED BY ONE OR A COMBINATION OF THE FOLLOWING (AS CHECKED):

☑ A DETAILED REVIEW OF THE ORIGINAL CALCULATION

☐ A REVIEW BY AN ALTERNATE, SIMPLIFIED OR APPROXIMATE METHOD OF CALCULATION

☐ A REVIEW OF A REPRESENTATIVE SAMPLE OF REPETITIVE CALCULATIONS

☑ A REVIEW OF THE CALCULATION AGAINST A SIMILAR CALCULATION PREVIOUSLY PERFORMED

☐ COMPUTER AIDED DESIGN CALCULATION

YES NO

☐ ☐ 11. IS THE PROGRAM APPLICABLE TO THIS PROBLEM?

☐ ☐ 12. IS THE COMPUTER PROGRAM VALIDATED PER QP 3-54?

☐ ☐ 13. IS THE COMPUTER PROGRAM VALIDATED BY OTHER AE'S / ORGANIZATIONS AND HAS IT BEEN PREVIOUSLY APPLIED TO NUCLEAR PROJECTS?

☐ ☐ 14. IS THE INPUT DATA IN CONFORMANCE WITH THE DESIGN INPUTS?

YES NO

☐ ☐ 15. ARE THE RESULTS CONSISTENT WITH THE ASSUMPTIONS AND THE INPUT DATA?

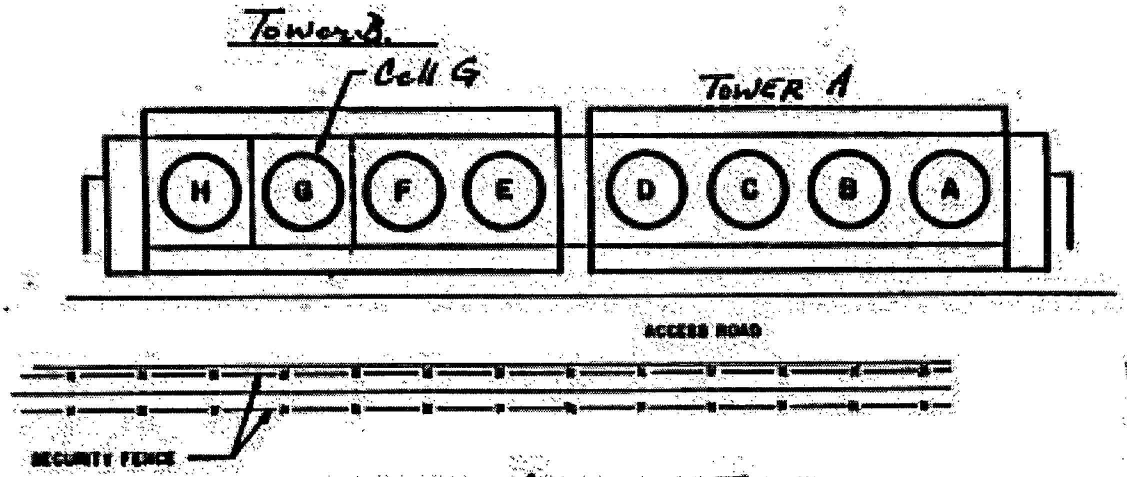
☐ ☐ 16. IS A LIST OF THE PROGRAMS USED AND DATE OF EACH COMPUTER RUN REFERENCED IN THE CALCULATION?

☐ ☐ 17. IS THE PROGRAM VERSION AND IT'S REVISION IDENTIFIED ON THE COMPUTER RUN?

REFERENCES:

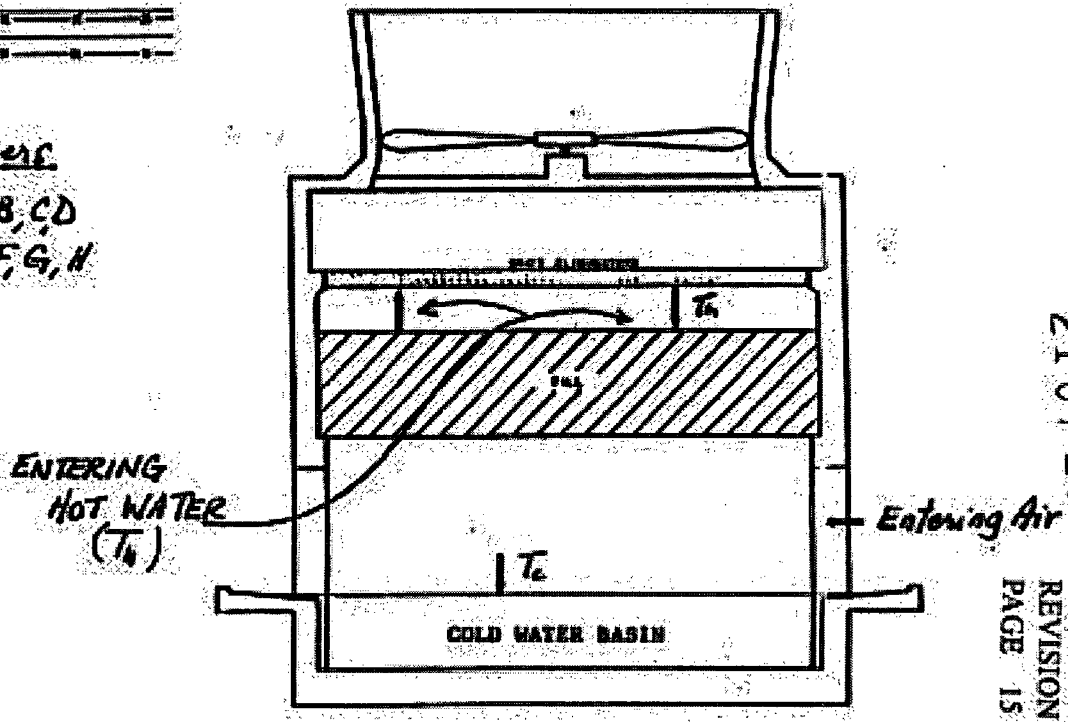
1. ESW Cooling Tower Transient Model: Part I, Calculation # NED-Q-MSD-1, CHRON # 167695, Rev. 0, dated 5/22/91.
2. Ultimate Heat Sink Design Basis LOCA Single Failure Scenarios, S&L calculation # UHS-01, Rev. 1, dated 8/5/91.
3. Cooling Tower Flows for UHS Analysis, S&L Calculation # 91-0121, Rev. 0, dated 8/16/91.
4. ESW Cooling Tower Transient Model: Part II, Calculation # NED-Q-MSD-5, CHRON # 168036, Rev. 0, dated 5/31/91.
5. ESW Cooling Tower Transient Model: Part III, Calculation # NED-Q-MSD-6, CHRON # 172315, Rev. 0, dated 9/3/91.

FIGURE 1 : ESW Cooling Towers



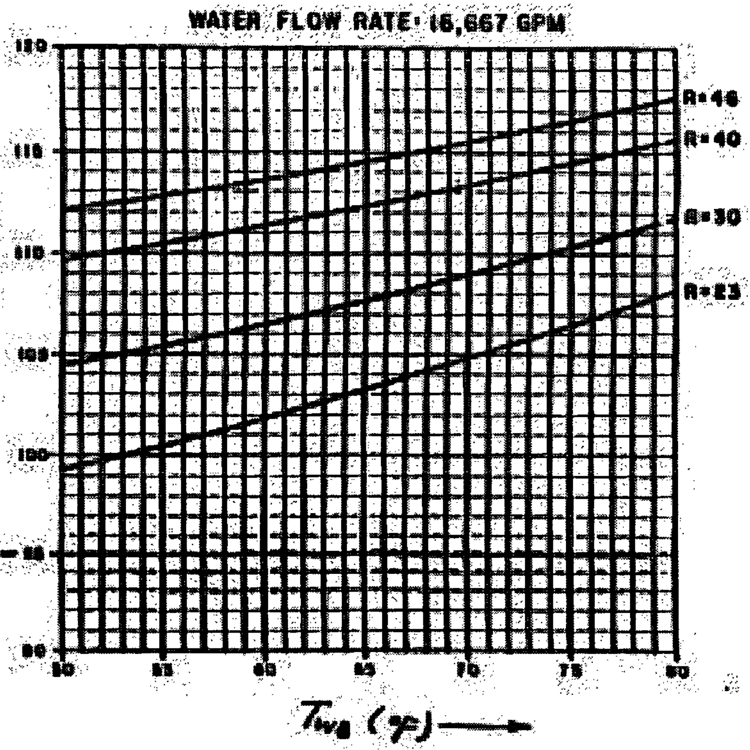
Top View of the Two Towers

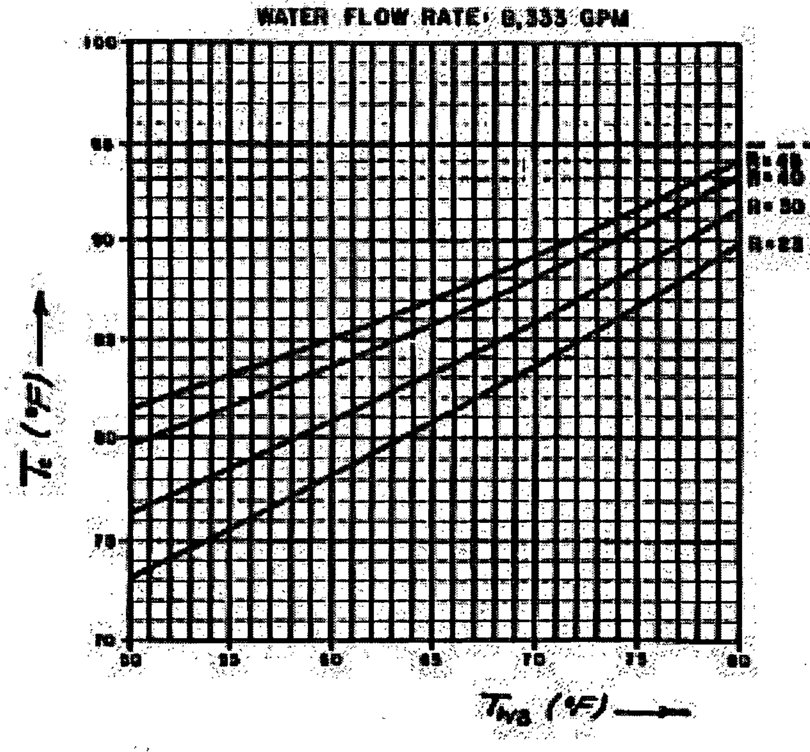
- Tower A, with Cells A, B, C, D
- Tower B, with Cells E, F, G, H



Side View of Single CELL

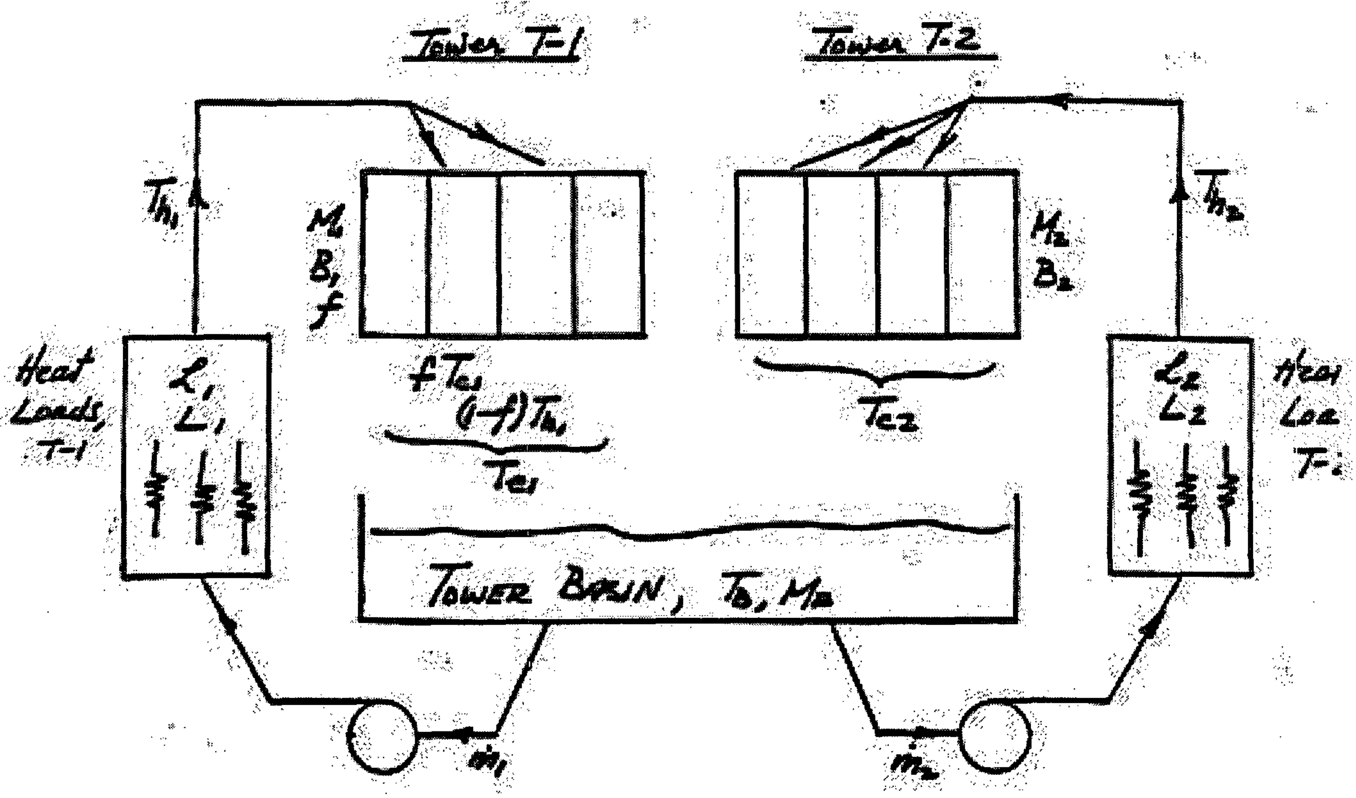
FIGURE 2: Typical ESW Cooling Tower Performance Curves.





Notes:
1. T_{WB} = wet bulb temperature
2. T_c = cold water temperature
3. $R = T_{hw} - T_c$, tower range

FIGURE 3: Schematic of BYRON ESW Cooling Towers.



Tower T-1:

T_{c_1} — cold water temperature, operational cells

T_{h} — hot water temperature

T_{e_1} — average temperature of water leaving T-1

$\dot{m}_1$ — flow to T1, (lbm/hr)

$\mathcal{L}_1$ — heat load to T1, (Btu/hr)

L_1 — temperature rise across $\mathcal{L}_1$

f = fraction of T-1 which is operable, cooling the hot water

Tower T-2:

T_{c_2} — cold water temperature of all water passing through cells of this tower

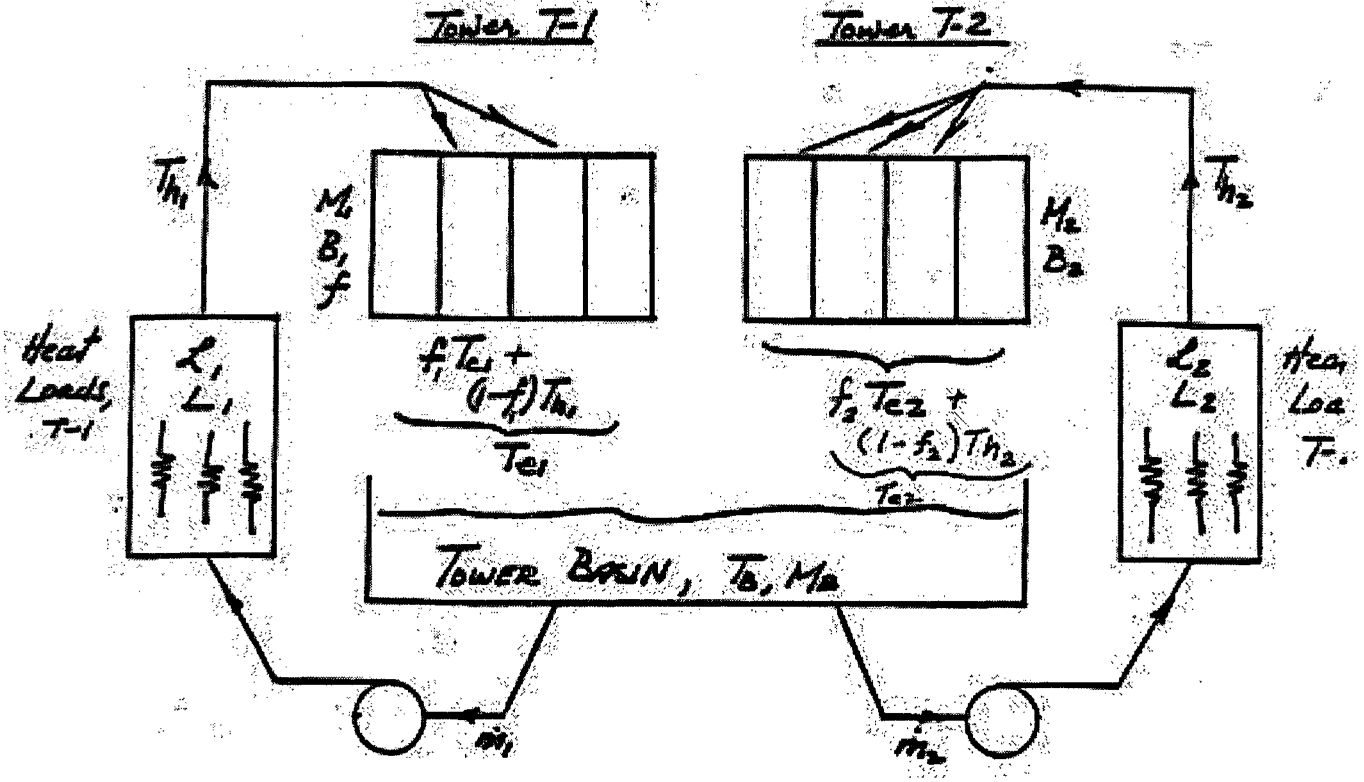
T_{h_2}, $\dot{m}_2$, $\mathcal{L}_2$, L_2 as defined for T-1

Basin:

T_B — average temperature of basin water inventory

M_B — mass of basin water

FIGURE 4: Schematic of BYRON ESW Cooling Towers.



Tower T-1:

T_{c1} — cold water temperature, operational cells

T_h — hot water temperature

T_{e1} — average temperature of water leaving T-1

$\dot{m}_1$ — flow to T-1, (lbm/hr)

$\mathcal{L}_1$ — heat load to T-1, (Btu/hr)

L_1 — temperature rise across $\mathcal{L}_1$

f_1 = fraction of T-1 which is operable, cooling the hot water

Tower T-2:

T_{c2} — cold water temperature of all water passing through cells of this tower

T_{h2}, $\dot{m}_2$, $\mathcal{L}_2$, L_2 as defined for T-1

f_2 = fraction of T-2 which operable, cooling the hot water

Basin: T_{e2} = average temperature water entering T-2.

T_B — average temperature of basin water inventory

M_B — mass of basin water