SARGENT & LUNDY
ENGINEERS
FOUNDED 1891
55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780
(312) 269-2000

184086

S&L Letter No. Q1443E
April 10, 1992
Project No. 8913-73

Commonwealth Edison Company
Quad Cities Station - Unit 2

Transmittal of "Evaluation of DG 2
Cooling Water Pump Cooler Fan A & B
Minimum Starting Voltage Calculation"
W.O. No.: N/A
Mod. No.: N/A
System Codes: N/A

Mr. M. L. Reed
Electrical/I&C Design Superintendent
Commonwealth Edison Company
Nuclear Engineering Department
1400 Opus Place, Suite 400
Downers Grove, Illinois 60515

Dear Mr. Reed:

Enclosed is a copy of Design Input Transmittal (DIT) QC-EXT-0056 which transmits the following Sargent & Lundy calculation:

> Calculation 8913-73-19-2, Revision 0, dated April 3, 1992, "Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage."

The locations of the calculation purpose, methodology, assumptions, and any engineering judgements are referenced in the enclosed DIT.

Should you have any questions, please call me at (312) 269-6246.

Yours very truly,

R. M. Schiavoni
Senior Electrical
Project Engineer

RMS:mco
qdqc2672.ep
In duplicate
Enclosure - Addressee Only
Copies: See page two

184086

SARGENT & LUNDY
ENGINEERS
CHICAGO

Copies:

BWR Systems Design Superintendent (H. L. Massin)	(1/1/0)
CHRON Systems	(1/1/0)
Acting BWR Systems Design Supervisor (B. M. Wong)	(1/1/0)
Site Engineering Supervisor (C. A. Moerke)	(1/1/0)
Assistant Supt. of Work Planning (W. McGaffigan)	(1/0/0)
R. H. Jason	(1/0/0)
T. J. Ryan	(1/0/0)
E. Schumacher/File	(1/1/0)
S. Z. Haddad	(1/1/1)

184086

SARGENT & LUNDY
ENGINEERS

DESIGN INFORMATION TRANSMITTAL

X	SAFETY-RELATED		NON-SAFETY-RELATED	DIT No. - QC-EXT-0056

Page 1 of 1

To M. L. Reed

CLIENT Commonwealth Edison Company

STATION Quad Cities UNIT(S) 2

PROJECT NO(S) 8913-73

SUBJECT Transmittal of Calculation 8913-73-19-2, Rev. 0, Dated 4/3/92 "Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage."

MODIFICATION OR DESIGN CHANGE NUMBER(S) N/A

R. M. Schiavoni	EPED	[signature]	4/10/92
PREPARER (PLEASE PRINT NAME)	DIVISION	PREPARER'S SIGNATURE	ISSUE DATE

STATUS OF INFORMATION (This information is approved for use. Design information, approved for use, that contains assumptions or is preliminary or requires further verification (review) shall be so identified.)

This information is approved for use. One assumption used in the calculation listed below requires 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 DIT transmits to Commonwealth Edison Company (CECo) the following calculation:

Calculation 8913-73-19-2, Rev. 0, dated 4-3-92, "Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage."

The purpose, methodology, and assumptions can be found in the following calculation sections and pages:

Purpose: Section II, page 3
Methodology: Section VI, Page 8
Assumptions and Engineering Judgements: Section IV, Pages 5 and 6
Comparison of Results with Acceptance Criteria: Section VIII, Page 20

SOURCE OF INFORMATION

Calc. No. 8913-73-19-2 — 0 4-3-92 (Rev. and/or date) — Report No. N/A — (Rev. and/or date)

Other

DISTRIBUTION See Letter Q1443E, Dated April 10, 1992

Form GQ-3.17.1 Rev. 2

184086

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage				Calc. No. 8913-73-19-2	
	X	Safety-Related		Non-Safety-Related	Rev. 0	Date 4/3/92
					Page 1	of 24

Client Commonwealth Edison Company	
Project Quad Cities - Unit 2	
Proj. No. 8913-73	Equip. No.

Prepared by [illegible]	Date [illegible]
Reviewed by Nedal Deeb	Date 4/3/92
Approved by [illegible]	Date 4/3/92

I. REVISION SUMMARY AND REVIEW METHOD

A. REVISION SUMMARY

Revision 0, First Issue, Pages 1 Through 24

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage			Calc. No. 8913-73-19-2	
	X	Safety-Related	Non-Safety-Related	Rev. 0	Date
				Page 2	of 24

Client Commonwealth Edison Company	
Project Quad Cities - Unit 2	
Proj. No. 8913-73	Equip. No.

Prepared by	Date
Reviewed by	Date
Approved by	Date

B. METHOD OF REVIEW

QA CALCULATION REVIEW CHECKLIST
TYPE OF CALCULATION

☒ Hand-Prepared Design Calculation Only

☐ Computer-Aided Design Calculation Only

☐ Both hand-Prepared and Computer Aided Design Calculation

FOR HAND-PREPARED DESIGN CALC
(check the appropriate items)

☒ Detailed review of the original calculation.

☐ Review by an alternate, simplified or approximate method of calculation.

☐ Review of a representative sample of repetitive calculations.

☐ Review of the calculation against a similar calculation previously performed.

FOR COMPUTER-AIDED DESIGN CALC
(check the appropriate items)

☐ A review to determine if the engineering design and analysis computer program(s) used have been validated and documented and that the calculation, regardless of the program used, contains all the necessary documentation for reconstruction at a later date. (MUST BE PERFORMED)

☐ A review to verify that the computer program is suitable to the problem being analyzed. (MUST BE PERFORMED)

☐ A review to determine if the input data as specified for program execution is consistent with the design input, correctly defines the problem for the computer program algorithm and is sufficiently accurate to produce results within any numerical limitation of the program. (MUST BE PERFORMED)

☐ A review to verify that the results obtained from the program are correct and within stated assumptions and limitations of the program and are consistent with the input. (MUST BE PERFORMED)

☐ Validation documentation for temporary changes to listed programs or developmental programs or unique single application programs shall be reviewed to assure that methods used adequately validate the program for the intended application. (WHERE APPLICABLE)

REVIEWER: Nedal Deeb DATE: 4/3/92

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage				Calc. No. 8913-73-19-2	
	X	Safety-Related		Non-Safety-Related	Rev. 0	Date
					Page 3	of 24

Client Commonwealth Edison Company	
Project Quad Cities - Unit 2	
Proj. No. 8913-73	Equip. No.

Prepared by	Date
Reviewed by	Date
Approved by	Date

II. PURPOSE/SCOPE

A. Purpose

The purpose of this calculation is to demonstrate that the DG 2 Cooling Water Pump Cooler Fan A & B at Quad Cities Unit 2 will start with minimum voltage of 75% of the motor rated voltage at the motor terminal without tripping its protective device or exceeding its thermal capability limit.

B. Scope

The scope of this calculation is to determine the motor starting time at 75% of the motor rated voltage, the thermal overload heater minimum tripping time and the motor thermal capability limit.

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler				Calc. No. 8913-73-19-2	
	Fan A & B Minimum Starting Voltage				Rev. 0	Date
	X	Safety-Related		Non-Safety-Related	Page 4	of 24

Client Commonwealth Edison Company		Prepared by	Date
Project Quad Cities - Unit 2		Reviewed by	Date
Proj. No. 8913-73	Equip. No.	Approved by	Date

III. INPUT DATA

Motor Data		Reference	Assumption
HP	1.5	XI.7	
NEMA class	B		IV.A.1
RPM	1740	XI.7	
Full load current	2.5	XI.7	
Rated voltage	460	XI.7	
Frame	145T	XI.7	
Locked rotor torque (% of FLT)	250	XI.1	IV.A.1
Pull-up torque (% of FLT)	175	XI.1	IV.A.1
Breakdown torque (% of FLT)	280	XI.1	IV.A.1
Motor inertia (WK^2)-lb-ft^2	0.1	XI.6	IV.B.5
Load inertia (WK^2)-lb-ft^2	4.0	XI.12	IV.B.4

Thermal Overload Heater

Manufacturer	GE	XI.8
Size	C301A	XI.8
Ampere range	1.99-2.15	XI.5

184086

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage	Calc. No. 8913-73-19-2
	X Safety-Related / Non-Safety-Related	Rev. 0 Date
		Page 5 of 24

Client Commonwealth Edison Company	Prepared by / Date
Project Quad Cities - Unit 2	Reviewed by / Date
Proj. No. 8913-73 Equip. No.	Approved by / Date

IV. ASSUMPTIONS

A. **Assumptions Requiring Verification:**

1. It is assumed that the motor being analyzed in this calculation is NEMA class B motor. A verification of this assumption is required.

IV. ASSUMPTIONS (continued):

B. Assumptions not Requiring Verification:

1. It is assumed that the motor full load power factor is 85%, efficiency is 90%, and the locked rotor current is 625% of the full load current. These values, which are typical for 460 V rated voltage power plant motors, are utilized in conjunction with the minimum torque constraints of NEMA class B requirement to develop the motor speed versus torque curves. Since minor variations in the above values have a relatively small impact on the speed versus torque curves, no special verification is required.

2. It is assumed in the development of speed versus torque curves that the pull-up torque occurs at the 50% of full load speed. This assumption conservatively reflects typical 460 V power plants class B motor designs and need not be separately verified.

3. Speed versus torque curve for the fan is developed using the formula taken from reference XI.3. This speed versus torque curve is typical for power plant 460 V motor fans and need not to be verified for the motor analyzed in this calculation. For additional discussion see section VII.A

4. It is assumed that the inertia (WK^2) for the fan is equal to 4.0 $lb\text{-}ft^2$. This assumption is reasonable and conservative based on reference XI.12. A verification of this assumption is not required

5. It is assumed that the inertia (WK^2) for the motor is equal to 0.1 $lb\text{-}ft^2$. This assumption is reasonable based on reference XI.6. Furthermore, any minor variation in it does not affect the result since the fan WK^2 is predominant factor. A verification of this assumption is not required

V. ACCEPTANCE CRITERIA

The motor starting voltage (75% of rated voltage) is considered acceptable if the following conditions are met:

1. The motor starting time is less than the thermal overload heater minimum tripping time.

2. The heater maximum tripping time does not exceed the motor thermal capability.

3. A minimum of 25% (based on motor load torque) margin between the motor torque and load torque shall be maintained during the acceleration period.

VI. METHODOLOGY

A. The minimum motor locked-rotor, pull-up and breakdown torque in percent of full load torque is taken from reference XI.1 for class B induction motors.

B. Using the above torque data and assumptions VI.B.1 & 2, conservative motor torque versus speed curve for the DG 2 Cooling Water Pump Cooler Fan A & B motor will be developed as shown in section VIII.A

C. The equation relating fan torque to motor/fan RPM is taken from reference XI.3.

D. The total inertia (WK^2) for fan is taken as the sum of the fan WK^2 and the motor WK^2.

E. The method outlined in ESC-307 (REF.XI.4), for calculating motor accelerating time will be used to calculate the accelerating time at the minimum expected motor starting voltage. The starting time will be compared against the time-current characteristics of the thermal overload heater to show if the motor will start before the protective device trips, and without exceeding the motor thermal capability.

F. A margin of 25% between the motor torque and load torque during the acceleration period will be conservatively considered acceptable to start the motor (Ref.XI.11)

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage			Calc. No. 8913-73-19-2	
	X	Safety-Related	Non-Safety-Related	Rev. 0	Date
				Page 9	of 24

Client Commonwealth Edison Company	Prepared by / Date
Project Quad Cities - Unit 2	Reviewed by / Date
Proj. No. 8913-73 Equip. No.	Approved by / Date

VII. CALCULATION AND RESULTS

A. MOTOR AND LOAD TORQUE VS SPEED

In this part of the calculation we will develop the motor and load torque versus speed curve based on the available data and assumptions outlined earlier. The curve developed is used to determine whether adequate accelerating torque exist by calculating the starting time

- The equation used to develop the load torque vs speed for a fan is taken from reference XI.3

$$T_{load}(RPM) = 5252.11 \times \frac{full\text{-}load\ hp}{full\text{-}load\ RPM} \times \left(\frac{RPM}{full\text{-}load\text{-}RPM}\right)^2 \quad ft\text{-}lb$$

- The equations used to develop the motor speed vs torque using the minimum motor locked-rotor, pull-up and breakdown torques (Ref XI.1) and assumptions VI.B.1 & 2 are taken from reference XI.2

$$I(slip) = \left|\frac{V}{Zeq(slip)}\right|$$

$$pf(slip) = \cos(arg[Zeq(slip)])$$

$$T(slip) = \left[\frac{0.7373}{\omega_s}\right] \times \left[3 \times V_{th}^2 \times \frac{\frac{r_2(slip)}{slip}}{\left[R_{th} + \frac{r_2(slip)}{slip}\right]^2 + (X_{th} + X_2(slip))^2}\right]$$

VII. CALCULATION (continued):

The full load torque (FLT) is calculated using the following equation

$$FLT = 5252.11 \times \frac{hp}{Full\ Load\ Speed}$$

$$FLT = 5252.11 \times \frac{1.5}{1740} = 4.53\ ft\text{-}lb$$

The values of equivalent circuit parameters of an induction motor are obtained by minimizing the erroı between the calculated and the available or typical values of torque, current and power factor with respect to slip.
The equivalent circuit used to model a specific induction motor takes in to account the variation of rotor resistance and rotor leakage reactance as a function of speed. This variation of rotor resistance and rotor leakage reactance are accounted for by defining piece wise linear multipliers CRs, and CXs for rotor resistance and rotor leakage reactance respectively.

184086

VII. CALCULATION (continued):

DG 2 COOLING WATER PUMP COOLER FAN A & B

- KVA = KVA of the motor
- V = Motor Voltage
- Sy_s = Rated Speed of the Motor
- R1 = Stator resistance
- X1 = Stator reactance
- R2 = Rotor resistance
- X2 = Rotor reactance
- RM = Magnetizing resistance
- XM = Magnetizing reactance

$V := \frac{460}{\sqrt{3}}$ $\quad Sy\_s := 1800$ $\quad IFLC := 2.5$ $\quad VA := 3 \cdot V \cdot IFLC$

$FLT := 4.53$ $\quad FLS := 1740$

$ZBASE := \frac{V}{IFLC}$ $\quad KVA := \frac{VA}{1000}$ $\quad ZBASE = 106.232$ $\quad KVA = 1.992$

$r1 := 5.544$ $\quad r20 := 3.876$ $\quad rm := 14600$

$x1 := 10.395$ $\quad x20 := 15.474$ $\quad xm := 300$

$CR_1 := 1.0$ $\quad CX_1 := 1.0$ $\quad CR_2 := 1.02$ $\quad CX_2 := 0.925$

$CR_3 := 1.06$ $\quad CX_3 := 0.9155$ $\quad CR_4 := 1.105$ $\quad CX_4 := 0.74$

$CR_5 := 1.75$ $\quad CX_5 := 0.5$ $\quad sl_0 := -1.0$

$sl_1 := 0.0$ $\quad sl_2 := 0.06$ $\quad sl_3 := 0.55$ $\quad sl_4 := 0.7$ $\quad sl_5 := 1.0$

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage			Calc. No. 8913-73-19-2	
	X	Safety-Related		Non-Safety-Related	Rev. 0 / Date
					Page 12 of 24

Client Commonwealth Edison Company	Prepared by / Date
Project Quad Cities - Unit 2	Reviewed by / Date
Proj. No. 8913-73 Equip. No.	Approved by / Date

VII. CALCULATION (continued):

$$r1pu := \frac{r1}{ZBASE} \qquad x1pu := \frac{x1}{ZBASE} \qquad r20pu := \frac{r20}{ZBASE} \qquad x20pu := \frac{x20}{ZBASE}$$

$$rmpu := \frac{rm}{ZBASE} \qquad xmpu := \frac{xm}{ZBASE}$$

r1pu = 0.052   x1pu = 0.098
r20pu = 0.036   x20pu = 0.146
rmpu = 137.434   xmpu = 2.824

cr(s) := linterp(sl,CR,s)   cx(s) := linterp(sl,CX,s)

$$\omega s := \frac{2 \cdot \pi \cdot Sy\_s}{60}$$

r2(s) := r20·cr(s)   x2(s) := x20·cx(s)

Calculate Thevenin quantities

$$Zth := \frac{1}{\frac{1}{r1 + j \cdot x1} + \frac{1}{rm} + \frac{1}{j \cdot xm}}$$

Rth := Re(Zth)   Xth := Im(Zth)

$$Zm := \frac{1}{\frac{1}{rm} + \frac{1}{j \cdot xm}}$$

Z1 := r1 + (j ·x1)

$$Vth := V \cdot \left[\frac{Zm}{Z1 + Zm}\right] \qquad V1 := |Vth|$$

Calculate Speed dependent quantities

$$Z2(s) := \left[\frac{r2(s)}{s} + (j \cdot x2(s))\right] \qquad Zeq(s) := Z1 + \left[Zm \cdot \frac{Z2(s)}{Zm + Z2(s)}\right]$$

$$I(s) := \left|\frac{V}{Zeq(s)}\right| \qquad pf(s) := \cos(\arg(Zeq(s)))$$

VII. CALCULATION (continued):

$$T(s) := \left[\frac{.7373}{\omega s}\right] \cdot \frac{3 \cdot V1^2 \cdot \dfrac{\dfrac{r2(s)}{s}}{\left[Rth + \dfrac{r2(s)}{s}\right]^2 + (Xth + x2(s))^2}}{FLT}$$

$$Torque(speed) := T\left[1 - \left[\frac{speed}{Sy\_s}\right]\right] \qquad Current(speed) := I\left[1 - \left[\frac{speed}{Sy\_s}\right]\right]$$

$$P\_f(speed) := pf\left[1 - \left[\frac{speed}{Sy\_s}\right]\right]$$

m_data := READPRN(data)

$$m\_data = \begin{bmatrix} 0 & 15.6 & -0.359 & 11.3 \\ 870 & -10 & -0.51 & 7.9 \\ 1566 & -3 & -0.8 & 12.6 \\ 1740 & 2.5 & 0.85 & 4.5 \end{bmatrix}$$

(MOTOR DATA FROM REF XI.1)

$$sp := m\_data^{<0>} \quad cu := m\_data^{<1>} \quad mp\_f := m\_data^{<2>} \quad mt := m\_data^{<3>}$$

$$i := 0, 1 .. (rows(m\_data) - 1)$$

sp_i	$\frac{mt_i}{FLT}$	$Torque[sp_i]$	cu_i	$Current[sp_i]$	mp_f_i	$P\_f[sp_i]$
0	2.494	2.501	15.6	12.246	-0.359	0.553
870	1.744	1.773	-10	9.735	-0.51	0.469
1566	2.781	2.78	-3	6.247	-0.8	0.779
1740	0.993	1.277	2.5	2.309	0.85	0.859

VII. CALCULATION (continued):

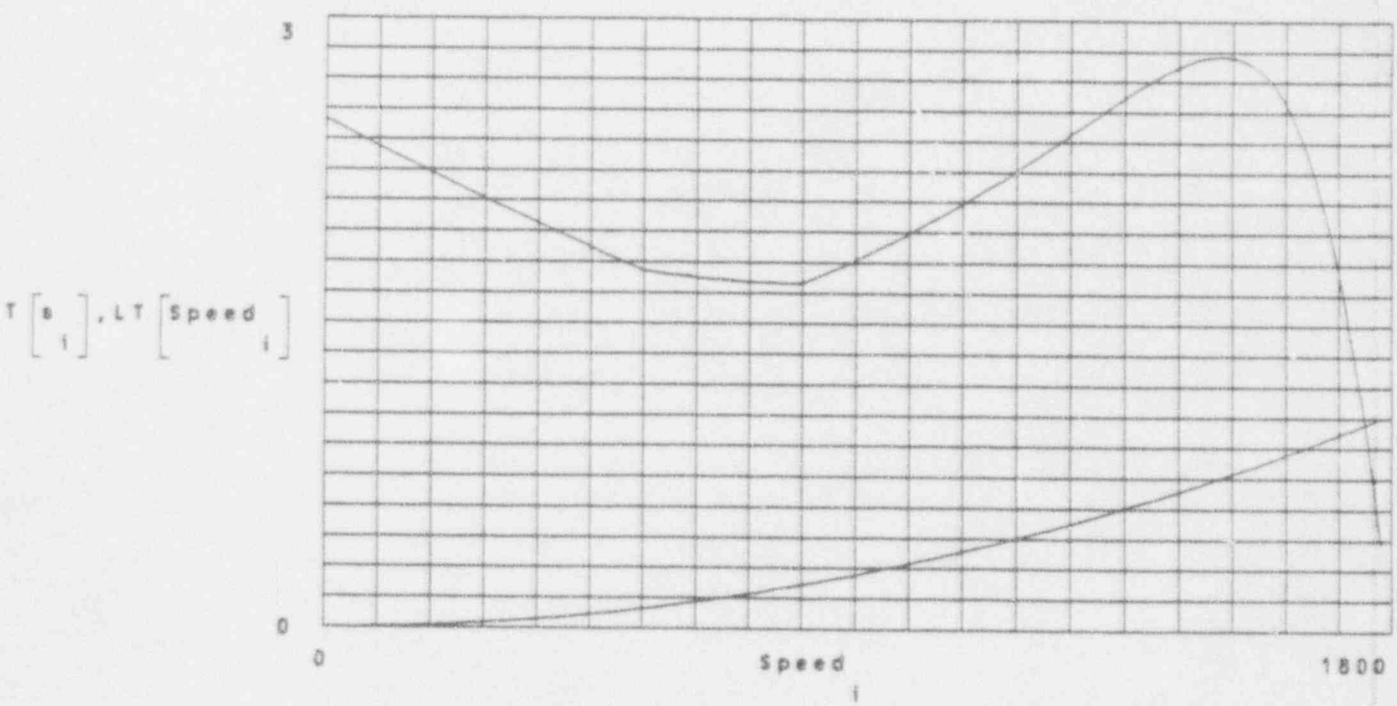
Load Torque Equation in P.U (Fan):

$$LT(speed) := \left[\frac{speed}{FLS}\right]^2$$

$i := 1,2 \,..100$ $\quad s_i := 0.01 \cdot i$ $\quad Speed_i := Sy\_s \cdot \left[1 - s_i\right]$

$k := 0,1 \,..(rows(m\_data) - 1)$

$$V := \frac{460}{\sqrt{3}}$$



MOTOR AND LOAD TORQUE (FAN) VS SPEED AT 100% OF THE MOTOR RATED VOLTAGE

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage			Calc. No. 8913-73-19-2	
	X	Safety-Related	Non-Safety-Related	Rev. 0	Date
				Page 15	of 24

Client Commonwealth Edison Company	
Project Quad Cities - Unit 2	
Proj. No. 8913-73	Equip. No.

Prepared by	Date
Reviewed by	Date
Approved by	Date

VII. CALCULATION (CONTINUED):

B. ACCELERATION TIME REQUIRED TO START THE MOTOR

The longest starting time will occur at the lowest expected motor terminal voltage because less torque is available to accelerate the load. The acceleration time required to start the motor using the minimum starting voltage at the motor terminal will be calculated in the following tabulation.

Column No. 1 - beginning of speed interval in percent of full load rpm.

Column No. 2 - beginning of speed interval in rpm (Col. No. 1 times full load rpm)

Column No. 3 - end of speed interval in percent of full load rpm

Column No. 4 - the magnitude of speed interval in rpm

Column No. 5 - torque output by motor (Tm) during the rpm increment expressed as a percent of motor full load torque at 100% voltage, read from the motor torque vs speed developed in section VIII.A of this calculation

Column No. 6 - motor torque output in ft-lb at 100% voltage (Col. No. 5 times motor full load torque)

Column No. 7 - motor torque output in ft-lb at the motor minimum starting voltage (Col. No. 6 times the square ratio of the min. staring voltage divided by unity - 100% voltage)

Column No. 8 - load torque in percent of full load torque read from the load torque vs speed developed in section VIII.A of this calculation.

Column No. 9 - load torque in ft-lb (Col. No. 8 times the full load torque)

Column No.10 - net accelerating torque in ft-lb (Col. No. 7 minus Col. No. 9)

Column No.11 - time to accelerate through speed interval - this column is calculated using the following formula (REF.V.7)

$$t = \frac{(\Delta RPM)\times(WK^2)}{(308)\times T_N}$$

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler			Calc. No. 8913-73-19-2	
	Fan A & B Minimum Starting Voltage			Rev. 0	Date
	X	Safety-Related	Non-Safety-Related	Page 16	of 24

Client Commonwealth Edison Company		Prepared by	Date
Project Quad Cities - Unit 2		Reviewed by	Date
Proj. No. 8913-73	Equip. No.	Approved by	Date

VII. CALCULATION (CONTINUED):

where t = accelerating time in seconds
Δrpm = change in rpm (Col. No. 4)
T_N = net accelerating torque in ft-lb (Col. No. 10)
WK^2 = total inertia in lb-ft^2 (Ref.XI.6 & 12 and Assumptions IV.B.4 & 5)

SARGENT & LUNDY ENGINEERS	Calc. For Evaluation of DG 2 Cooling Water Pump Cooler Fan A & B Minimum Starting Voltage	Calc. No. 8913-73-19-2
	X Safety-Related / Non-Safety-Related	Rev. 0 Date
		Page 17 of 24

Client Commonwealth Edison Company	Prepared by Date
Project Quad Cities - Unit 2	Reviewed by Date
Proj. No. 8913-73 Equip. No.	Approved by Date

TIME REQUIRED TO START THE DG 2 COOLING WATER PUMP COOLER FAN A & B @ 75% VOLTAGE

% OF FULL LOAD SPEED (1)	INITIAL SPEED (RPM) (2)	SPEED @ THE END OF INCREMENT (3)	SPEED INTERVAL (RPM) (4)	MOTOR FULL LOAD TORQUE IN % @ 100% V (5)	MOTOR TORQUE IN lb-ft @ 100% (6)	MOTOR TORQUE IN lb-ft @ 75% (7)	LOAD TORQUE IN % OF FLT (8)	LOAD TORQUE IN lb-ft (9)	NET ACCELERATING TORQUE (lb-ft) (10)	TIME TO ACCELERATE THROUGH SPEED INTERVAL (SEC) (11)
0	0.00	87.00	87	245.00%	11.10	6.24	0.00%	0.00	6.24	0.19
5	87.00	174.00	87	232.50%	10.53	5.92	1.00%	0.05	5.88	0.20
10	174.00	261.00	87	220.00%	9.97	5.61	2.00%	0.09	5.52	0.21
15	261.00	348.00	87	215.00%	9.74	5.48	4.00%	0.18	5.30	0.22
20	348.00	435.00	87	207.00%	9.38	5.27	5.00%	0.23	5.05	0.23
25	435.00	522.00	87	190.00%	8.61	4.84	7.50%	0.34	4.50	0.26
30	522.00	609.00	87	188.00%	8.52	4.79	11.00%	0.50	4.29	0.27
35	609.00	696.00	87	185.00%	8.38	4.71	15.00%	0.68	4.03	0.29
40	696.00	783.00	87	182.00%	8.24	4.64	19.00%	0.86	3.78	0.31
45	783.00	870.00	87	187.50%	8.49	4.78	23.00%	1.04	3.74	0.31
50	870.00	957.00	87	200.00%	9.06	5.10	30.00%	1.36	3.74	0.31
55	957.00	1044.00	87	210.00%	9.51	5.35	35.00%	1.59	3.77	0.31
60	1044.00	1131.00	87	225.00%	10.19	5.73	40.00%	1.81	3.92	0.30
65	1131.00	1218.00	87	237.50%	10.76	6.05	50.00%	2.27	3.79	0.31
70	1218.00	1305.00	87	255.00%	11.55	6.50	55.00%	2.49	4.01	0.29
75	1305.00	1392.00	87	270.00%	12.23	6.88	65.00%	2.94	3.94	0.29
80	1392.00	1479.00	87	280.00%	12.68	7.13	73.00%	3.31	3.83	0.30
85	1479.00	1566.00	87	265.00%	12.00	6.75	80.00%	3.62	3.13	0.37
90	1566.00	1653.00	87	225.00%	10.19	5.73	90.00%	4.08	1.66	0.70
95	1653.00	1740.00	87	100.00%	4.53	2.55	100.00%	4.53	-1.98	0.00
100	1740.00	0.00	-	-	-	-	-	-	-	-
									TOTAL TIME TO START	5.65

184086

VII. CALCULATION (continued):

C. MOTOR THERMAL PROTECTION AND PROTECTIVE DEVICES TIME TO TRIP

The motor is protected by General Electric thermal overload heater size C301A (reference XI.8)

Motor	Full Load (amps)	Locked Rotor @ 100% Voltage	Minimum Starting Voltage (% of 460V)	Locked Rotor @ Actual Voltage (amps)	Heater Size	Heater Rating	LRC in % of HTR Rating	Minimum Tripping Tim
DG 2 Cooling Water Pump Cooler Fan A & B	2.5	15.6	75	11.7	C301A	1.99	5.88	9.3

VII. CALCULATION (continued):

C. MOTOR THERMAL PROTECTION AND PROTECTIVE DEVICES TIME TO TRIP (continued):

The following table checks the locked rotor protection afforded to the motor by the existing protective device. The motor thermal capabilities are estimated based on data contained in reference XI.9.

Motor	Minimum Starting Voltage (% of 460V)	Size (hp)	Allowable LR Time @ 100% Voltage		Minimum Allowable LR Time* @ Actual Voltage		Maximum Tripping Time @ the Minimum Voltage (sec)
			Cold (sec)	Hot (sec)	Cold (sec)	Hot (sec)	
DG 2 Cooling Water Pump Cooler Fan A & B	75	1.5	21	11	37.3	19.5	15

* Actual locked rotor time = locked rotor (100% V)/(starting voltage)^2

Therefore, it can be concluded that the existing protective devices protect the motors thermally and will not trip during the motor start at the postulated minimum voltage.

VIII. <u>COMPARISON OF RESULTS WITH ACCEPTANCE CRITERIA</u>

Motor	Minimum Starting Voltage (% of 460V)	Protective Device Minimum Tripping Time (sec)	Time it Takes the Motor to Start at Minimum Starting Voltage (sec)	Protective Device Maximum Tripping Time (sec)	Motor Thermal Capability (sec)
DG Cooling Water Pump Cooler Fans A & B	75	9.3	5.65	15	37.3 (cold start) 19.5 (hot start)

A. The above table summarizes the results of motor starting time calculations at the minimum starting voltage and it shows that spurious motor trips should not occur.

B. From section VII.B of this calculation (net acceleration torque - column No. 10 in the spreadsheet), the minimum margin between the motor torque and load torque is equal to

$$\frac{1.66}{4.08} = 40.6\% \quad (\textit{minimum margin})$$

which is much higher than the minimum acceptable margin of 25%.

IX. CONCLUSION

As demonstrated by this calculation, the DG 2 Cooling Water Pump Cooler Fans A & B motors will start at 75% of the motor rated voltage without tripping their protective devices or exceeding the motor thermal capabilities.

184086

X. RECOMMENDATIONS

We reccammend the verification of the following assumption:

Verify that the motor being analyzed in this calculation is NEMA class B motor.

184086

XI. REFERENCES

1. NEMA Standard MG1, Part 12 " Tests and Performance AC Motors", August 1975.
   - This reference provides the Locked Rotor, Breakdown, and Pull-up Torque in percent of full load torque for class B motors.

2. Text Book entitled " The Performance and Design of Alternating Current Machines", second edition, by M. G. Say
   - This reference provides the equations used to develop the torque versus speed curves.

3. Sargent & Lundy Q/A calculation No. 4266/19AZ18, Rev. 0, entitled " Demonstrating that RHR C/D SW pump room vent. fan IVY06C will start with 80% V", approved 10-31-91.
   - This reference provides the equation relating typical fan torque to motor/fan rpm.

4. Sargent & Lundy Standard ESC-307, section 11 "Accelerating time and losses"
   - This reference provides the method and formulas used to calculate the motor acceleration time

5. GE publication GEH-4821 "Thermal overload relays"
   - This reference provides the Time-Current characteristics for GE overload relays.

6. A Classified Collection of Manufacturers' Catalogs, 1987 Sweet's Catalog File, Buyline 2582
   - This reference provides the motor inertia

7. Sargent & Lundy Design Information Transmittal (DIT) No. QC-EPED-0532-00, dated 3-26-92.
   - This reference provides the motor data.

8. Sargent & Lundy Design Information Transmittal (DIT) No. QC-EPED-0491-01, dated 3-18-92.
   - This reference provides the thermal overload heaters data.

9. Electrical Analytical Division (S&L) General - Relay file, Inter-Office Memorandum by J. M. Pabich entitled "460V Motor Locked Rotor Protection" , August 18, 1978
   - This reference provides the typical motor thermal capabilities.

184086

XI. REFERENCES (continued):

10. Sargent & Lundy Q/A calculation No. 8986-15-04, Rev. 1, entitled " Evaluation of 460 V Motor Minimum Voltage Starting Requirement", approved 1-6-92.
    - This reference provides the inertia (WK^2) for fans.

11. Technical paper entitled "An Analytical Look at Squirrel-Cage Induction motors Starting". by R. C. Moore, Allis-Chalmers mfg Co. Nov. 1964.
    - This reference provides the conservative 25% accelerating torque margin criteria between the motor torque and load torque during the acceleration period.

12. Memorandum of telephone conversation between J. Wisniewski (S&L) and Dave Crockett (Buffalo Forge), dated 4-2-92.
    - This reference provides the inertia for the fan.