LIC-95-0177
Attachment 2

FORT CALHOUN STATION UNIT NO. 1

CALCULATION #FC05916
Revision 3

"Operating Temperature Limits for DG-1 and DG-2"

BES [illegible]

CALCULATION COVER SHEET

Calculation Preparation, Review and Approval
Form PED-QP-3.1 Form Page No. 1 of 2
Calculation Cover Sheet

* Short Term Calc: ☒ YES ☐ NO

CALCULATION NUMBER
o FCØ 5916

Calc. Page No. 1
*TOTAL PAGES ~~33~~ ~~37~~ 47

QA Category: ☒ CQE ☐ LIMITED CQE ☐ FIRE PROT. ☐ NON CQE

o FILE NO.

PED DEPARTMENT 357

CALCULATION TITLE

OPERATING TEMPERATURE LIMITS FOR DG-1 AND DG-2

VENDOR CALC. NO.

☐ MR NO.
☒ ENGR. ANALYSIS 90-062
☐ DBD NO.
☐ ECN NO.
☐ OTHER

* APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	*REV. NO.	SUPERSEDES *CALC. NO.	CONFIRMATION *REQUIRED (✓) YES	NO
[signature] 4-20-92	[signature] 4-20-92	[signature] 4-20-92	A			✓
[signature] 8-7-92	[signature] 8-7-92	[signature] 8/10/92	B	A		✓
[signature] 11-2-92	[signature] 11-2-92	[signature] 11/9/92	C	B	✓	
As-Built [signature] 8/12/9[illegible]	N/A	N/A	0	C		✓
[signature] 7/18/95	[signature] 7/18/95	[signature] 7/18/95	1	Ø		✓
[signature] 8/9/95	[signature] 08/09/95	[signature] 08/09/95	2	1		✓
[signature] 8/15/95	[signature] 08/15/95	[signature] 08/15/95	3	2		✓

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CALCULATION PREPARATION, REVIEW AND APPROVAL FORM PED—QP—3.2 Form Page No. 1 of 1

CALC. PAGE NO. 2K 1A

PRODUCTION ENGINEERING DIVISION
CALCULATION REVISION SHEET

CALCULATION NO. FC05916

REV. NO.	DESCRIPTION / REASON FOR CHANGE
B	P3 OPPD MAY SUPERCEDE EA-FC-90-062 r 2 INSTEAD OF REVISING, FOR THE PURPOSE OF CLARITY AND DOCUMENT CONTROL
B	p 5a PROVIDED ADDED JUSTIFICATION OF THE 1 DEGREE ΔT FAN INLET / AMBIENT
B	p 6 MWO 92 2346 WAS DONE TO REMEASURE DG-2 AIR FLOW
B	p 7 REMOVED NONESSENTIAL INFORMATION AND ADDED STATEMENT CONCERNING GENERATOR CAPACITY
B	p 10, 11 UTILIZED DATA FROM MWO ADDED ON p 6
B	p 12 REDREW GRAPH IN A MORE PROFESSIONAL FORMAT AND USED DATA FROM p 6
B	p 13 WORDING CHANGE FOR CLARITY
B	p 14-17 ADDED CLARITY TO TABLE ~~TITLES~~ 8-3-92 TITLES WITH RESPECT TO AMBIENT AIR AND FAN INLET TEMPERATURES. A MISTAKE WAS NOTED WHERE TURBOCHARGER INLET TEMPERATURES FOR 110 °F WERE USED FOR ALL CASES. THIS WAS CORRECTED TO THE PROPER TURBOCHARGER INLET TEMPERATURE AND THE NEW DERATION NUMBERS WERE THEN USED. THIS RESULTED IN OVERCONSERVATISM IN THE CALCULATION
B	p 18 REMOVED UNNECESSARY WORDING
B	p 19, 20 REDREW GRAPHS WITH NEW DERATION CURVES
B	p 25, 26 INSERTED TEST DATA FROM MWO 922346
B	p 34 ADDED LETTER TO EXPLAIN GENERATOR LIMIT
B	p 35 ADDED FAX FOR 208 °F WATER COOLANT AIR FLOW REQUIREMENTS

CALCULATION PREPARATION, REVIEW AND APPROVAL
FORM PED-QP-3.2 Form Page No. 1 of 1

PRODUCTION ENGINEERING DIVISION
CALCULATION REVISION SHEET

CALCULATION NO. FC-05916

REV. NO.	DESCRIPTION /REASON FOR CHANGE
C	DSN MECHANICAL WAS NOTIFIED THAT MT-00077 "VELOCICALC PORTABLE AIR VELOCITY METER" WAS OUT OF CALIBRATION - LOW READING BY 12%. A NEW SET OF FAN FLOW READINGS WAS THEN TAKEN AND DRAMATICALLY NEW RESULTS MEASURED. THIS CALCULATION THEN REQUIRED REVISION ALSO UPDATED CALCULATION TO REDUCE FLOW MEASURED BY 3% TO ACCOUNT FOR INSTRUMENT INACCURACY ALSO UPDATED TO PREDICT EFFECTS OF USING PORTABLE FANS TO BLOW AWAY THE EXHAUST AIR FROM THE GENERATOR
0	No changes from Rev. C
1	REVISED TEXT AND TABLES TO REFLECT HOT WEATHER TESTING PERFORMED IN JULY OF 1995
2	REVISE CURVES AND CONCLUSIONS BASED ON POST TEST INSTRUMENT CALIBRATION ALSO INCLUDE ADDITIONAL INFORMATION FROM EA-90-062 RELATED TO EXCITER CABINET TEMP. ON DG-2
3	REVISE FIGURES AND TEXT BASED ON REVISION 8 OF FC03382

CALCULATION COVER SHEET

Calculation Preparation, Review and Approval Form PED-QP-3.1 Form Page No. 2 of 2 Calculation Cover Sheet	CALCULATION NUMBER FC-05916	Calc. Page No. 24
	FACILITY/SYSTEM DG	
	KEYWORD o DIESEL GENERATOR	

CALCULATIONS USED AS INPUT IN THE ANALYSIS		EQUIPMENT TAGS		
CALC./REV. NO.	DEPT	SYSTEM	ADDED	DEPT. NO.
FC03382 R 8		DG - JW	JW-3-1	
EA-FC-90-062 R 2		DG - JW	JW-3-2	
		DG	DG-1	
		DG	DG-2	

1. OBJECTIVE

The objective of this calculation is to determine the maximum ambient air temperature limits for operation of the Fort Calhoun Station Emergency Diesel Generators within the bounds of the 2000 hour deration curve.

2. METHODS

1 Determine the KW capacity of the diesel generator without considering the effects of elevated air temperature on jacket water temperature or turbocharger intake temperature.

2 Predict the turbocharger intake temperature at elevated conditions.

3 Predict jacket water temperatures at elevated conditions:

i. Determine fan flow rates at elevated temperatures.

ii. Compare fan flows to required flows to maintain jacket water at 190 °F and 208°F.

4 Determine deration factors from the predicted jacket water and turbocharger temperatures.

5 Compare derated power to post LOCA demands from calculation FC03382.

3. ASSUMPTIONS

1 Ambient air pressures are considered constant.

2 The diesels are in a cold shutdown condition with the jacket water at a temperature of 125 °F prior to the start of the accident. Test results indicate that the temperature is 120 °F at the time of start. This assumption is conservative.

3 Turbocharger inlet air temperature delta T with ambient air does not change dramatically with outside air temperature increases, ie. the outside air temperature to turbocharger intake delta T from 95°F ambient can be used to predict turbocharger intake temperature at 110°F ambient conditions.

4 The radiator fan intake is equivalent to outdoor temperature + 1 °F. This is validated by test data gathered during the last test performed on DG-2.

5 The maximum amount of emergency safeguards equipment started by SIAS is considered to be the required load for the diesels. Additional optional loads that may be desired to assist operations in accident response, such as station air compressors, are not included in the required electrical load calculations.

6 Although the new fans draw more air, the air flow in the room is such that the turbocharger inlet air temperature is assumed to be unaffected.

4. INPUT / REFERENCES

1 Letter from Ted Frayer to Randy Muellar, Dated 2/10/80 contained in EA-FC-90-062 R2 Attachment 8.2-b
2 MWO 913677 Replace Fan with Substitute Replacement Item per ECN 91-306
3 MWO 913676 Replace Fan with Substitute Replacement Item per ECN 91-306
4 MWO 922345 Hot Weather Testing for DG-1
5 MWO 922870 Hot Weather Testing for DG-2
6 Diesel Generator derating Curves from EA-FC-90-062 R2 Attachment 8.2-a
7 Fax Transmission from Young Radiator Comp. to Dan Borcyk dated 4/8/91
8 Fax Transmission from Young Radiator Comp. to Dan Borcyk dated 4/15/91 found in EA-FC-90-062 R2 Attachment 8.9a
9 FC03382 R7 Diesel Generator LOCA Loads
10 Mechanical Engineering Review Manual Seventh Edition
11 EA-FC-90-062 R2 Diesel Generator Upper Temperature Operation Limits
12 OP-ST-DG-0002 Diesel Generator 2 Check for Oct, 92
13 OP-ST-DG-0001 Diesel Generator 1 Check for Oct, 92
14 Stone & Webster report 16472.8009-AV1 'Torque Measurement on the Take-Off Shaft of Emergency Diesel Generator...' (Attached)

5. CONCLUSIONS

DG-1 may be operated under the following conditions and will operate within its 2000 hr derating curve limits during post LOCA conditions.

50% Ethylene Glycol/ Water coolant Mixture,
Ambient air ≤ 110°F
Turbocharger air Temp ≤ 116°F
Jacket Water Temp. ≤ 208°F

DG-2 may be operated under the following conditions and will operate within its 2000 hr deration curve limits during post LOCA conditions.

50% Ethylene Glycol/ Water coolant Mixture,
Ambient air ≤ 114°F
Turbocharger air Temp ≤ 132°F
Jacket Water Temp. ≤ 208°F

Discussion:

DG-1

Above 101°F ambient air temperature, DG-1's jacket water temperature is expected to exceed 190°F. Per conversations with Morrison Knudsen, the 200-210 curve must then be used for determining the deration factor. This accounts for approximately 7% reduction in diesel generator derated capacity. If the present turbocharger inlet temperatures predicted for this ambient air temperature condition are used while requiring the emergency load to be maintained less than the 2000 hr rating, 110°F becomes the upper ambient air temperature limit for DG-1. Per figure 2 it can be seen that the estimated load does not exceed the Diesel Generator 2000 hr rating. In addition significant margin exists if the event is initiated from the prewarmed condition (ie. JWOT at 125°F). If the event is initiated immediately following a surveillance test and the diesel is already heated up to a steady state condition, the margin is 1 KW. This has been determined to be acceptable based on the conservatism associated with calculation FC03382 and the likelihood of event initiation during this period.

EA-FC-90-062 evaluates the ambient temperature limits based on generator rating and cooling temperatures as well as exciter cabinet cooling limits. The results of this EA justify operation at 110°F.

Previous revisions of this calculation resulted in a limiting ambient temperature of 107° F. This value has been revised based on the results of hot weather testing performed on July 11, 1995 at 96°F.

One identified method for achieving a higher limiting temperature is to replace the 50% Ethylene Glycol/Water mixture with treated water which result in a higher heat removal rate. Based on existing historical information it is not expected that these measures will be required.

DG-2

Due to the load reduction performed during the 1992 Refueling outage, DG-2 is in a satisfactory configuration up to 115°F with 50% Ethylene Glycol/Water Mixture as a coolant media. Above 105°F ambient air temperature, DG-2's jacket water temperature is expected to exceed 190°F. Per conversations with Morrison Knudsen, the 200-210 curve must then be used for determining the deration factor. This accounts for approximately 7% reduction in diesel generator derated capacity. Although the jacket water temperature exceeds 190°F it remains below 208°F in this temperature range. Because the demand was reduced on this diesel generator, the derated power, even with the 7% reduction based on the jacket water temperature, exceeds the most severe accident demand load.

EA-FC-90-062 evaluates the ambient temperature limits based on generator rating and cooling temperatures as well as exciter cabinet cooling limits. The results of this EA justify operation at 114°F based on the rating of the generator and the associated cooling limits. The ambient temperature limit associated with the exciter cabinet cooling was established at 110°F. This limit was based on a 9°F delta with the air conditioning unit operating at a 50% duty cycle and 89°F room temperature. Based on the analytical method used for DG-1 cooling unit, the duty cycle for VA-759B is 67.2% with an ambient temp = 114°F, Room Temp. = 132°F. (50%+(132-89)*0.40) [ref. 4.11, Paragraph 6.12.3.1&2] This duty cycle is considered adequate to maintain the exciter cabinet within the required temperature range (80°F to 122°F). Based on these results, the temperature limit for operation of DG-2 will be established at 114°F. The tables and figures associated with DG-2 will therefore be revised in revision 2 of this calculation to reflect an ambient temperature of 114°F.

Previous revisions of this calculation resulted in a limiting ambient temperature of 110 deg F. This value was increased based on the results of hot weather testing performed July 12, 1995 @ 99°F.

Calculate the net KW available for each diesel generator.

Radiator filled with 50/50 Ethylene Glycol Coolant, 2000 hour and 4 hour ratings.

2000 hour Rating		4 hour Rating	Reference
3950 HP	Rating	4150 HP	1
- 120 HP	Radiator Fan Drive	-120 HP	2, 14
-20 HP	Generator Cooling	-20 HP	
-180 HP	50/50 EG Coolant	-180 HP	
3630 HP	**Available Horsepower**	**3830**	

Convert KW to Generator Output

3630	Mech Horsepower	3830	
X 0.746	BHP/KW	X 0.746	
2708 KW		2857 KW	1,pg 8.2b-3
X 0.97	Gen Efficiency	X 0.97	
2627 KW	**Available Generator Output**	**2771 KW**	1,pg 8.2b-3

From fan flow data, predict fan flows at elevated Temperatures

JW-3-1 (DG-1) Radiator Fan

Flow = 124,241 scfm at 98.5°F (average of north quadrant readings)

Kd = (460 + 98.5)/530 = 1.0538

$Flow_{corrected}$ = (flow-2%)*Kd = 128,304 cfm

Correcting back to SCFM on the following Table 1B

$Flow_{predicted}$ = 128,304/Kd

Likewise for DG-2:

JW-3-2 (DG-2) Radiator Fan

Flow = 114,121 scfm at 99.2°F (average of all inlet readings)

Kd = (460 + 99.2)/530 = 1.0551

$Flow_{corrected}$ = (flow-2%)*Kd = 118,000 cfm

Correcting back to SCFM on the following Table 1B

$Flow_{predicted}$ = 118,000/Kd

Based on the calculated air flows (presented in table 1B) and the comparison of these values with calculated required flows using Ethylene Glycol coolant (presented in figure 1) it is concluded that the cooling system should be capable of maintaining a jacket water outlet temperature (JWOT) of less that 190°F at ambient temperatures of 112°F (for DG-1) and 108°F (for DG-2) if the generators are run at rated output. In addition, radiator capacity is sufficient to maintain the JWOT below 208°F with ambient temperatures in excess of 120°F.

	Temp	*Fi (scfm)*	*F-e (scfm)*	*Kd*	*Fc (cfm)*	
DG-1	98.5	124,241	121,756	1.0538	128,304	See Tbl 2B-1
DG-2	99.2	114,121	111,839	1.0551	118,000	See Tbl 2B-2

Table 1A
Air Flow Correction for Test Data

Temp1	*Temp2*	*Kd*	*Corrected DG-1 Air Flow (scfm, Fc1)*	*Corrected DG-2 Air Flow (scfm, Fc2)*
70	70	1	128,304	118,000
75	75	1.009	127,159	116,948
80	80	1.019	125,911	115,800
85	85	1.028	124,809	114,786
90	90	1.038	123,607	113,681
95	95	1.047	122,544	112,703
100	100	1.057	121,385	111,637
102	102	1.06	121,041	111,321
104	104	1.064	120,586	110,903
106	106	1.068	120,134	110,487
108	108	1.072	119,686	110,075
110	110	1.075	119,352	109,768
112	112	1.079	118,910	109,361
114	114	1.083	118,471	108,957
124	124	1.102	116,428	107,078

Table 1B
Correction for Air Flow at Elevated Temperature

Table 2A-1
DG-1 AIR FLOW MEASUREMENTS
Tested October 13, 1992
Standard Velocity,Measured/Standard Flow,Calculated/Temperature,Measured

		1	2	3	4	5	6	7	8	9	AVG Velocity	Total SCFM	Avg Tmp
6"	Vel	2550	2775	2245	2320	2020	2665	2685	2655	2505	2491		
	scfm	2833.3	3083.3	2494.4	2577.8	2244.4	2961.1	2983.3	2950	2783.31		24910.862	
	Temp	140	139	139	138	135	136	136	136	138			137
18"	Vel	2920	3320	2450	2650	1900	2880	2880	3180	3060	2804		
	scfm	3244.4	3688.9	2722.2	2944.4	2111.1	3200	3200	3533.3	3399.97		28044.164	
	Temp	137	132	138	137	137	132	133	128	130			134
30"	Vel	2790	2965	2295	2450	1770	2415	2470	2965	2755	2542		
	scfm	3100	3294.4	2550	2722.2	1966.6	2683.3	2744.4	3294.4	3061.08		25416.413	
	Temp	125	127	132	133	134	127	132	120	120			128
42"	Vel	2550	2785	2300	2570	1390	2465	2640	2980	2487	2463		
	scfm	2833.3	3094.4	2555.5	2855.5	1544.4	2738.9	2933.3	3311.1	2763.31		24629.754	
	Temp	121	124	128	127	125	120	125	118	114			122
54"	Vel	1830	1780	2165	2600	1755	2050	1952	2411	1692	2026		
	scfm	2033.3	1977.8	2405.5	2888.9	1950	2277.8	2168.9	2678.9	1879.98		20260.909	
	Temp	118	117	122	118	119	115	116	110	110			116

Average Temp 128
Total Flow 123262.1

Table 2A-2
DG-2 AIR FLOW MEASUREMENTS
Tested October 28, 1992
Standard Velocity,Measured/Standard Flow,Calculated/Temperature,Measured

		1	2	3	4	5	6	7	8	9	AVG Velocity	Total SCFM	Avg Tmp
6"	Vel	2660	2480	2380	2720	1190	2660	2400	2550	2640	2409		
	scfm	2955.5	2755.5	2644.4	3022.2	1322.2	2955.5	2666.6	2833.3	2933.3		24088.648	
	Temp	127	126	127	129	130	128	122	125	130			127
18"	Vel	2650	2645	2410	2470	1050	2370	2700	3000	2550	2427		
	scfm	2944.4	2938.9	2677.8	2744.4	1166.7	2633.3	3000	3333.3	2833.31		24271.98	
	Temp	126	119	123	126	127	124	116	118	128			123
30"	Vel	2860	2960	2590	2460	1050	2340	2380	2630	2480	2417		
	scfm	3177.7	3288.9	2877.7	2733.3	1166.7	2600	2644.4	2922.2	2755.53		24166.425	
	Temp	110	114	120	118	120	122	113	115	112			116
42"	Vel	2597	3000	2575	2350	1110	2130	2100	2130	2350	2260		
	scfm	2885.5	3333.3	2861.1	2611.1	1233.3	2366.6	2333.3	2366.6	2611.09		22601.996	
	Temp	105	106	112	109	110	110	105	105	105			107
54"	Vel	2350	2440	2240	2060	1120	2000	1990	2300	2250	2083		
	scfm	2611.1	2711.1	2488.9	2288.9	1244.4	2222.2	2211.1	2555.5	2499.98		20833.125	
	Temp	99	98	100	102	105	103	100	100	102			101

Average Temp 115
Total Flow 115962.17

Table 2B-1
DG-1 AIR FLOW MEASUREMENTS
Tested July 10, 1995
Standard Velocity, Measured/Standard Flow, Calculated/Temperature, Measured

		1	2	3	4	5	6	7	8	9	AVG flow	Total SCFM	Avg Tmp
6"	Vel	1618	2050	2096	2215	1555	1867	2032	2479	1738	1961		
	scfm	1798	2278	2329	2461	1728	2074	2258	2754	1931.11		19611.111	
	Temp	161.8	159.7	161.9	157.2	154.3	163	161.5	163.3	161			160
18"	Vel	2392	2795	2465	2500	1722	2567	2691	2701	2616	2494		
	scfm	2658	3106	2739	2778	1913	2852	2990	3001	2906.67		24943.333	
	Temp	164.3	162.9	165.5	160.5	156.7	166.2	167.1	167.3	161.6			164
30"	Vel	2828	2769	2673	2665	2290	2483	2513	2779	2991	2666		
	scfm	3142	3077	2970	2961	2544	2759	2792	3088	3323.33		26656.667	
	Temp	165.5	163.9	167.2	162.9	160.2	167.3	168.3	166.9	162.8			165
42"	Vel	2838	2994	2855	2600	2311	2620	2733	2990	2992	2770		
	scfm	3153	3327	3172	2889	2568	2911	3037	3322	3324.44		27703.333	
	Temp	170.2	166.8	168.1	163.4	161.3	168.3	167.9	168.5	166.6			167
54"	Vel	2598	2807	2866	2287	1967	2576	2583	2497	2613	2533		
	scfm	2887	3119	3184	2541	2186	2862	2870	2774	2903.33		25326.667	
	Temp	172.1	170	169.3	167	158.9	167.4	170.6	172.2	170.8			169

Average Temp 165

Flow (scfm)=Vel*50/45

Total Flow (scfm) 124241.11

Table 2B-2
DG-2 AIR FLOW MEASUREMENTS
Tested July 11, 1995
Standard Velocity, Measured/Standard Flow, Calculated/Temperature, Measured

		1	2	3	4	5	6	7	8	9	AVG flow	Total SCFM	Avg Tmp
6"	Vel	2113	2179	1910	1930	939	1891	2210	2175	2146	1944		
	scfm	2348	2421	2122	2144	1043	2101	2456	2417	2384.44		19436.667	
	Temp	161	159.6	156.5	159.1	155.6	163	162.9	166	165.7			161
18"	Vel	2480	2290	2190	2037	917	2270	2753	2795	2506	2249		
	scfm	2756	2544	2433	2263	1019	2522	3059	3106	2784.44		22486.667	
	Temp	162.4	161.6	158.3	161.3	157.8	167.4	168.2	169.6	167.2			164
30"	Vel	2683	2621	2475	2395	1327	2481	2541	2717	2754	2444		
	scfm	2981	2912	2750	2661	1474	2757	2823	3019	3060		24437.778	
	Temp	164.5	163.6	159.7	162.5	159.7	169.2	169.5	171.2	167.2			165
42"	Vel	2604	2785	2712	2312	1330	2115	2345	2670	2333	2356		
	scfm	2893	3094	3013	2569	1478	2350	2606	2967	2592.22		23562.222	
	Temp	168.5	165	161.7	162.8	161.4	169.6	170.6	173	172.1			167
54"	Vel	2580	2507	2400	2633	1845	2525	2331	2417	2540	2420		
	scfm	2867	2786	2667	2926	2050	2806	2590	2686	2822.22		24197.778	
	Temp	168.5	167.2	162.9	162.1	162	170.5	173.4	173.5	173.2			168

Average Temp 165

Flow (scfm)=Vel*50/45

Total Flow (scfm) 114121.11

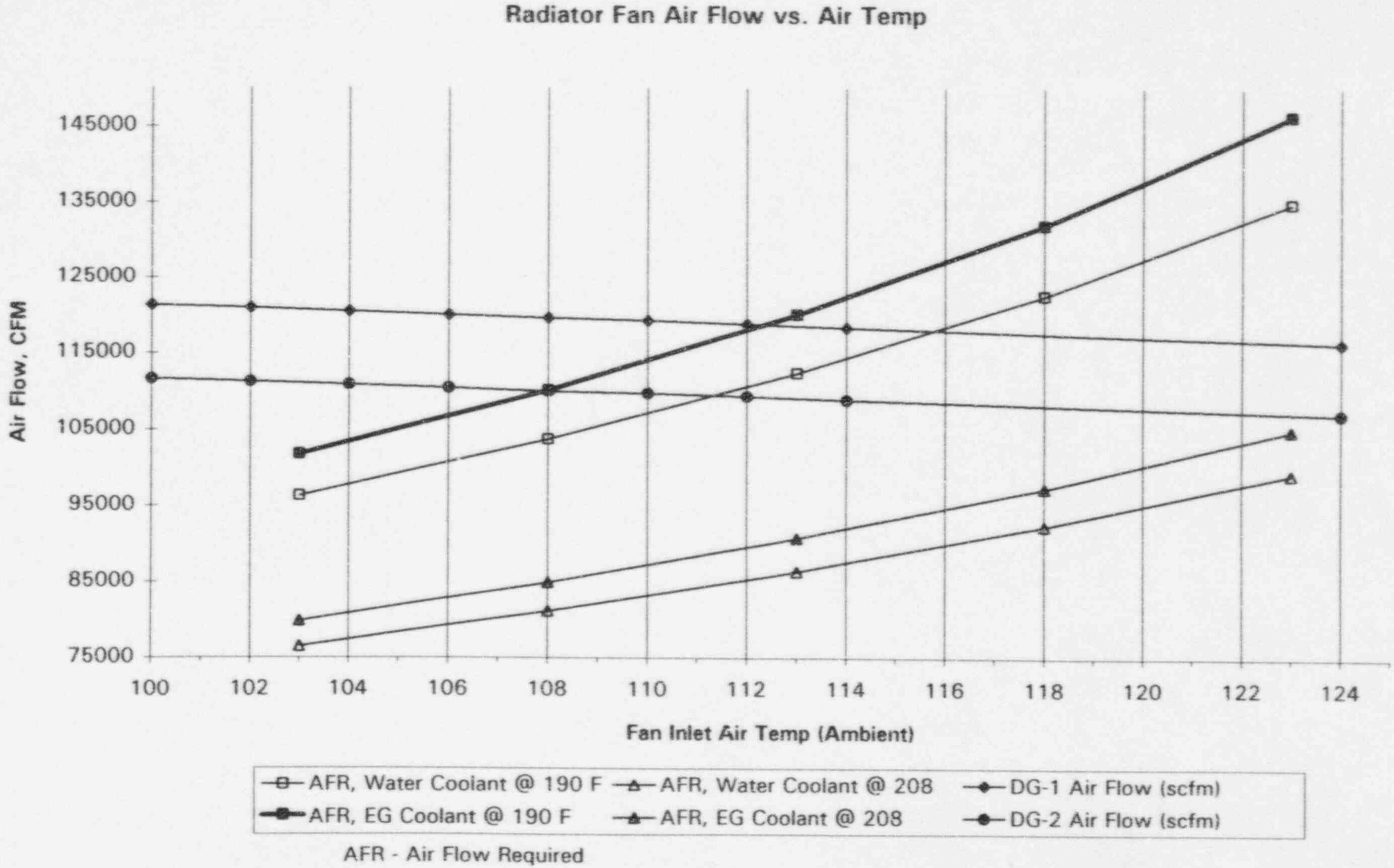


Figure 1
Radiator Fan Air Flow vs. Air Temperature

FC05916

The following pages show Tables 3 thru 8 and Figures 2 to 5. The tables show the results of the calculations used to determine the derating of the diesel generators. Tables 3 and 5 and figures 3 and 5 also show the demand power required during accident conditions as determined in calculation FC03382. Tables 7 and 8 are a tabulation of selected data taken from the test documentation. A discussion of the calculations is provided below. Figures 2 thru 5 are graphical presentations of the calculation results.

Instrument uncertainty

Post test calibration was conducted on equipment used in gathering data for the July, 1995 testing. The results of these calibrations showed that the instrumentation used for temperature measurement during the testing were in error. Jacket water temperature readings used in the evaluation of this data (see tables 7 and 8) were adjusted to account for the instrument error. All other instrumentation was found to be accurate. No additional error corrections were made based on this information.

DG-1

Turbo Inlet Temperature

This temperature is based on the ambient air temperature. The differential temperature is determined using data from the July 11, 1995 testing. The test results indicate that the initial inlet temperature is 1°F above the outside temperature and increases to 5°F above over the first 50 minutes. The remainder of the test the 5°F differential was maintained. The temperatures between zero and fifty minutes were linearly interpolated.

JW Outlet Temperature

This temperature is based on the ambient air temperature. The differential temperature is determined using data from the July 11, 1995 testing. The test results indicate that the initial inlet temperature is 120°F (125°F used, see assumption 3.2) and increases to 89°F above ambient over the first 10 minutes. The remainder of the test the 89°F differential was maintained. The temperatures between zero and 10 minutes were linearly interpolated.

Initial KW (2000 Hr)

The initial KW available is 2627 KW as previously calculated.

Initial KW (4 Hr)

The initial KW available is 2771KW as previously calculated.

Derate Factor

The derating factor is determined based on the Turbocharger inlet temperature and the engine coolant outlet temperature. (see Derating Curve attached)

Demand KW

The demand KW value was taken from calculation FC03382 Rev 8

Margin

Margin is the derated KW available from the diesel minus the demand value.

"OK"

If margin is less than zero this column will indicate "exceeds Avail". For a margin of zero or greater "OK" will be indicated.

DG-2

Turbo Inlet Temperature

This temperature is based on the ambient air temperature. The differential temperature is determined using data from the July 12, 1995 testing. The test results indicate that the initial inlet temperature is 2°F above the outside temperature and increases to 16°F above over the first 60 minutes. The remainder of the test the 16°F differential was maintained. The temperatures between zero and 60 minutes were linearly interpolated.

JW Outlet Temperature

This temperature is based on the ambient air temperature. The differential temperature is determined using data from the July 12, 1995 testing. The test results indicate that the initial inlet temperature is 120°F (125°F used, see assumption 3.b) and increases to 85°F above ambient over the first 30 minutes. The remainder of the test the temperature varied with load. Under the conditions of the emergency scenario the differential temperature would be less than 85°F due to the reduction of load. A differential temperature of 85°F will be used in this calculation to be conservative. The temperatures between zero and 30 minutes were linearly interpolated.

Initial KW

The initial KW available is 2627 KW as previously calculated.

Derate Factor

The derating factor is determined based on the Turbocharger inlet temperature and the engine coolant outlet temperature. (see Derating Curve attached)

Demand KW

The demand KW value was taken from calculation FC03382 Rev 8.

Margin

Margin is the derated KW available from the diesel minus the demand value.

"OK"

If margin is less than zero this column will indicate "exceeds Avail". For a margin of zero or greater "OK" will be indicated.

DG-1 Derating Calculation
Outside Air Temp 110
Radiator Inlet Temp 111

Time (min)	Turbo Inlet Temp	JW Outlet Temp	KW Initial (4 Hr)	KW Initial (2000 Hr)	Derate Factor	Derated KW (4 Hr)	Derate KW (2000 Hr)	Demand KW	Margin	Results
0	112	125	2,771	2,627	100.00%	2,771	2,627	2,439	188	OK
4.17	112	156	2,771	2,627	100.00%	2,771	2,627	2,439	188	OK
10	113	199	2,771	2,627	93.75%	2,598	2,463	2,427	36	OK
20	114	199	2,771	2,627	93.51%	2,591	2,456	2,400	56	OK
33.33	115	199	2,771	2,627	93.18%	2,582	2,448	2,372	76	OK
40	116	199	2,771	2,627	92.91%	2,575	2,440	2,361	79	OK
50	116	199	2,771	2,627	92.91%	2,575	2,440	2,349	92	OK
62.50	116	199	2,771	2,627	92.91%	2,575	2,440	2,349	92	OK
70	116	199	2,771	2,627	92.91%	2,575	2,440	2,349	92	OK
90	116	199	2,771	2,627	92.91%	2,575	2,440	2,349	92	OK
120	116	199	2,771	2,627	92.91%	2,575	2,440	2,349	92	OK

all temperatures in deg F.

Table 3
DG-1 Derating Calculation
Temp/Derating/Demand vs. Time

Ambient Temp	Turbo Inlet Temp	JW Outlet Temp	KW Initial (2000 hr rating)	Derate Factor	Derate KW
84	90	173	2,627	100.00%	2,627
86	92	175	2,627	100.00%	2,627
88	94	177	2,627	100.00%	2,627
90	96	179	2,627	100.00%	2,627
92	98	181	2,627	100.00%	2,627
94	100	183	2,627	100.00%	2,627
96	102	185	2,627	100.00%	2,627
98	104	187	2,627	100.00%	2,627
100.9	106.9	189.9	2,627	100.00%	2,627
101	107	190	2,627	95.36%	2,505
103	109	192	2,627	94.82%	2,491
104	110	193	2,627	94.55%	2,483
106	112	195	2,627	94.00%	2,469
107	113	196	2,627	93.73%	2,462
110	116	199	2,627	92.91%	2,440
112	118	201	2,627	92.36%	2,426

all temperatures in deg F.

Table 4
DG-1 Derating Calculation
Temp/Derating/Demand vs. Ambient Temp.

DG-2 Derating Calculation
Outside Air Temp 114
Radiator Inlet Temp 116

Time (min)	Turbo Inlet Temp	JW Outlet Temp	KW Initial	Derate Factor	Derate KW	Demand KW	Margin	Results
0	116	125	2,627	99.72%	2,619	2,145	474	OK
4.17	117	134	2,627	99.41%	2,611	2,145	466	OK
10	119	147	2,627	98.99%	2,600	2,135	465	OK
20	121	169	2,627	98.27%	2,581	2,110	472	OK
33.33	125	199	2,627	90.58%	2,379	2,086	293	OK
40	126	199	2,627	90.12%	2,367	2,078	289	OK
50	129	199	2,627	89.42%	2,349	2,068	[illegible]	OK
62.50	132	199	2,627	88.55%	2,326	2,068	258	OK
70	132	199	2,627	88.55%	2,326	2,068	258	OK
90	132	199	2,627	88.55%	2,326	2,068	258	OK
120	132	199	2,627	88.55%	2,326	2,068	258	OK

all temperatures in deg F.

Table 5
DG-2 Derating Calculation
Temp/Derating/Demand vs. Time

Ambient Temp	Turbo Inlet Temp	JW Outlet Temp	KW Initial	Derate Factor	Derate KW
90	108	175	2,627	100.00%	2,627
94	112	179	2,627	100.00%	2,627
96	114	181	2,627	100.00%	2,627
97	115	182	2,627	100.00%	2,627
98	116	183	2,627	99.72%	2,619
100	118	185	2,627	99.15%	2,604
102	120	187	2,627	98.58%	2,590
104.9	122.9	189.9	2,627	97.76%	2,568
105	123	190	2,627	91.00%	2,390
106	124	191	2,627	90.73%	2,383
107	125	192	2,627	90.45%	2,376
108	126	193	2,627	90.18%	2,369
110	128	195	2,627	89.64%	2,355
112	130	197	2,627	89.09%	2,340
114	132	199	2,627	88.55%	2,326
116	134	201	2,627	88.00%	2,312

all temperatures in deg F.

Table 6
DG-2 Derating Calculation
Temp/Derating/Demand vs. Ambient Temp.

DG-1 Test Data from 7-10-95								
Time	16:53	17:02	17:36	18:07	18:26	18:53	19:15	
minutes		0:09	0:43	1:14	1:33	2:00	2:22	
KW	2510	2450	2200	2200	2500	2500	2500	
Air Temp (air)		96.9	97	97.8	97.4	96.7	94.8	
Inlet 1		99.7	101	103.3	103.4	102.9	103.2	
Inlet 2		99	101.1	100.8	102	102.2	101.2	
Inlet 3		99.3	99.4	99.5	101	101.7	102.7	
Inlet 4		104.5	108.5	109.5	102.5	117.2	100.7	
Inlet 5		102.5	102.8	105.4	102.2	101.7	101.2	
Inlet 6		100.3	100.2	99.1	100.5	100	102.6	
Inlet 7		102.8	103.3	110.7	108.7	104.1	108.6	
Inlet 8		100.5	102	101	102.5	101.1	103.2	
Inlet 9		99.5	99.3	99.3	99.9	99.3	104	Average
Average (aia)		100.9	102.0	103.2	102.5	103.4	103.0	102.5
DT, (aia-air)		4.0	5.0	5.4	5.1	6.7	8.2	5.7
JW In**		173	177	175	170	177	178	175.0
JW Out (jwo)*		185	189	186	180	189	190	186.5
DT,(jwo-air)		88.1	92	88.2	82.6	92.3	95.2	89.73

* Recorded Value +3 due to instrument error

** Recorded Value -1 due to instrument error

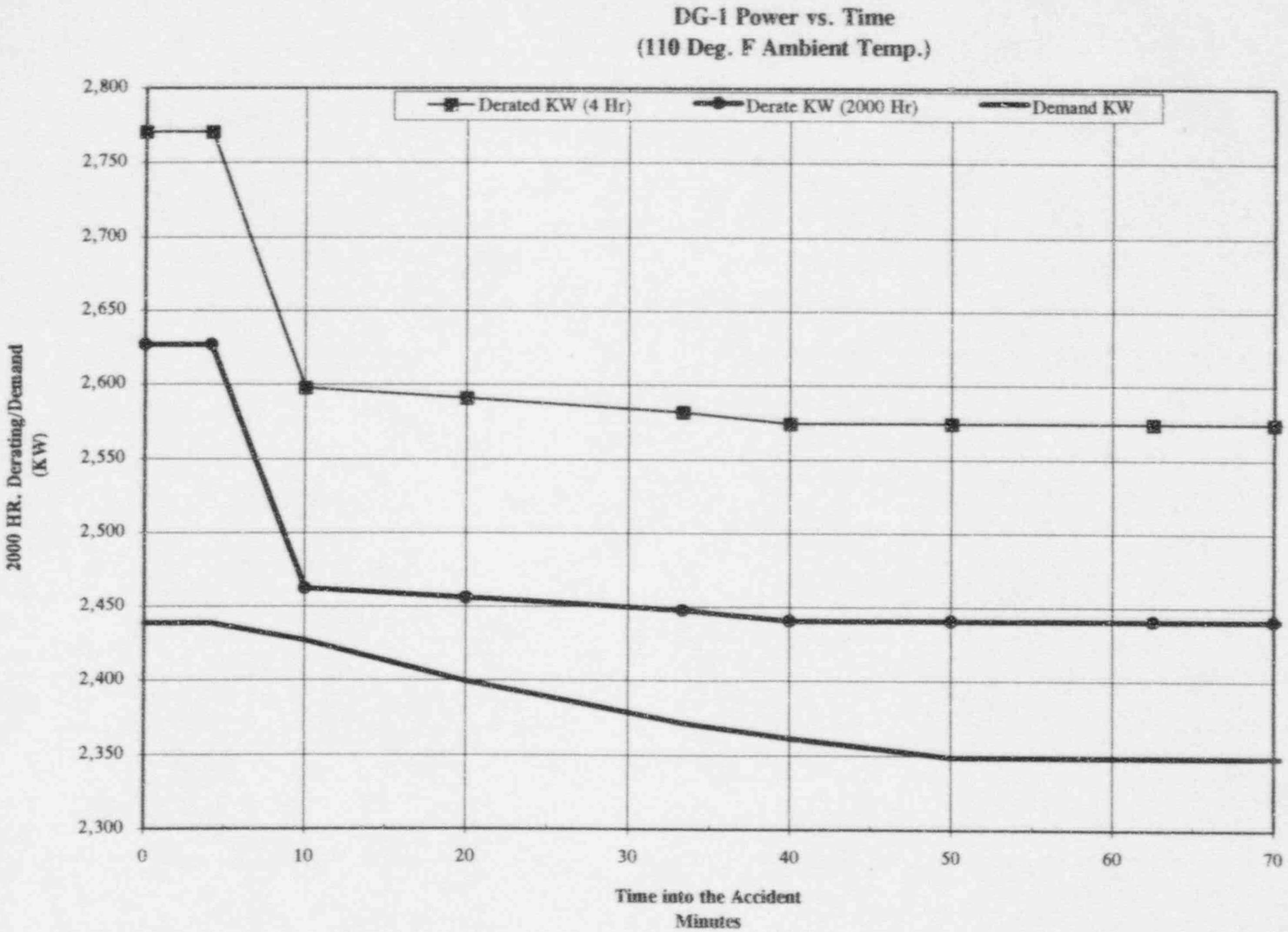
Table 7
Tabulation of Test Data
DG-1

DG-2 Test Data from 7-11-95										
Time	16:22	16:30	16:40	16:51	17:05	17:21	17:33	17:49	18:01	18:20
minutes				0	0:14	0:30	0:42	0:58	1:10	1:29
KW				2356	2250	2237	2334	2037	2533	2516
Air Temp (air)	99.4	99.4	99.4	99.4	99.5	99.7	99.3	99.8	99.5	98.4
Inlet 1	97.1	103.2	106.6	107.6	109.3	112.1	117.8	110.8	113.9	117.8
Inlet 2	100.2	107.1	109.3	108.1	109.5	108.7	112.3	111.2	111.1	112.1
Inlet 3	102.1	103.5	109.6	109.7	113	109.1	116.8	112.8	113.2	114.9
Inlet 4	99.5	103.4	105.2	106.5	110.2	111.7	113.9	115.7	115	112.5
Inlet 5	98.4	101.3	109.5	106.1	108.5	112.6	112.8	111.9	112.1	112.8
Inlet 6	98.4	101.7	103.7	106.1	108.5	110.6	116.7	111	111.7	113.6
Inlet 7	100.4	105.7	108.9	111.5	113	115.6	117.3	117.8	113.9	109.5
Inlet 8	98.8	101.9	103.9	105.2	111	109.7	112.9	113.1	110.6	110.1
Inlet 9	98.4	101.1	104.1	105.2	108	107.6	110	119.8	110.4	114.2
Average (aia)	99.3	103.2	106.8	107.3	110.1	110.9	114.5	113.8	112.4	113.1
DT, (aia-air)	-0.1	3.8	7.4	7.9	10.6	11.2	15.2	14.0	12.9	14.7
JW In**	172	172	172	172	172	170	168	168	168	178
JW Out (jwo)*	175	179	180	185	185	182	181	181	181	193
DT,(jwo-air)	75.6	79.6	80.6	85.6	85.5	82.3	81.7	81.2	81.5	94.6

* Recorded Value +3 due to instrument error

** Recorded Value -2 due to instrument error

Table 8
Tabulation of Test Data
DG-2



Ethylene Glycol Coolant

Note: Per calculations FC05916 and FC03382, DG-1 will provide power to supply post-LOCA load requirements up to a maximum ambient outdoor temperature of 110 deg. F

Figure 2

FCØ5916

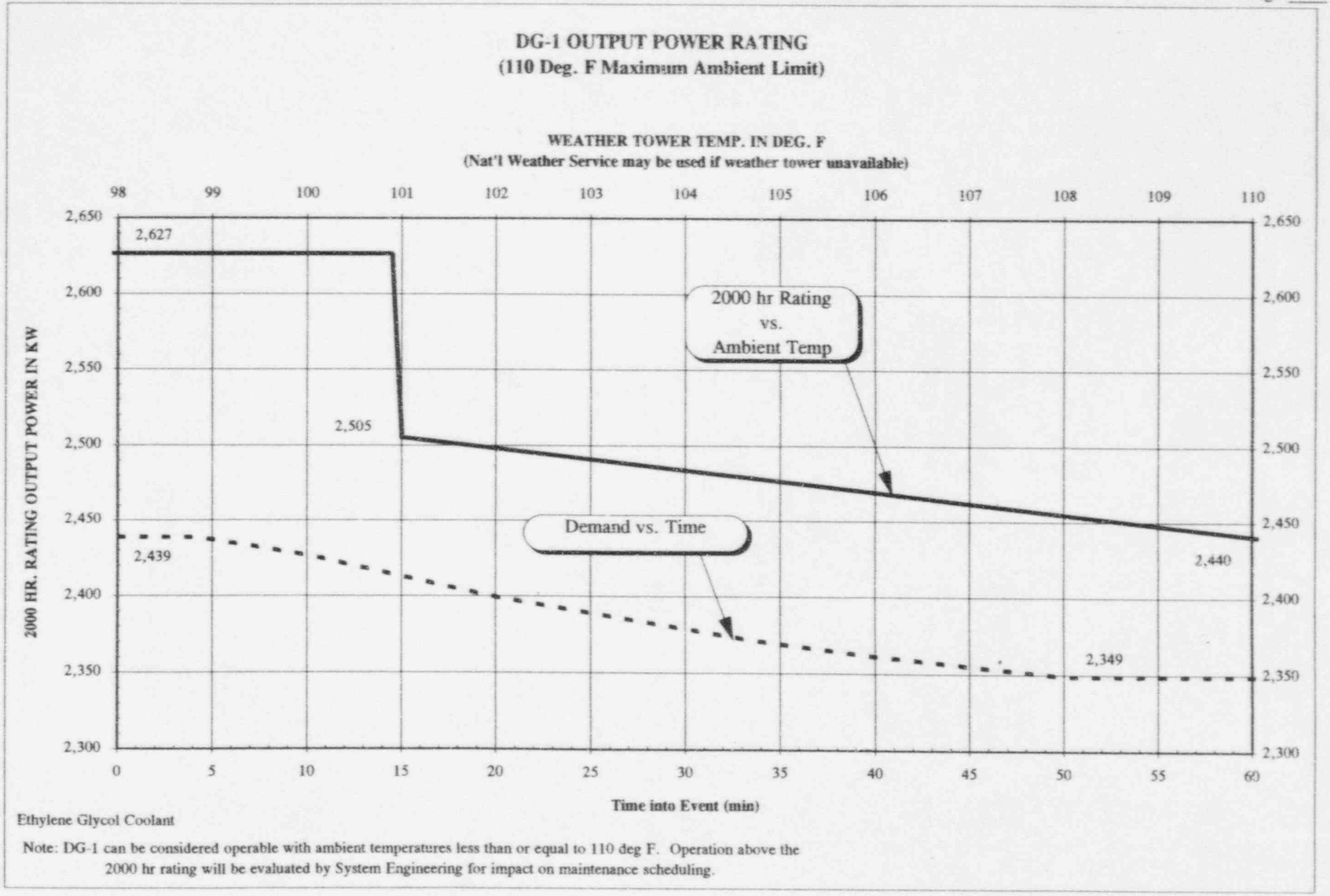
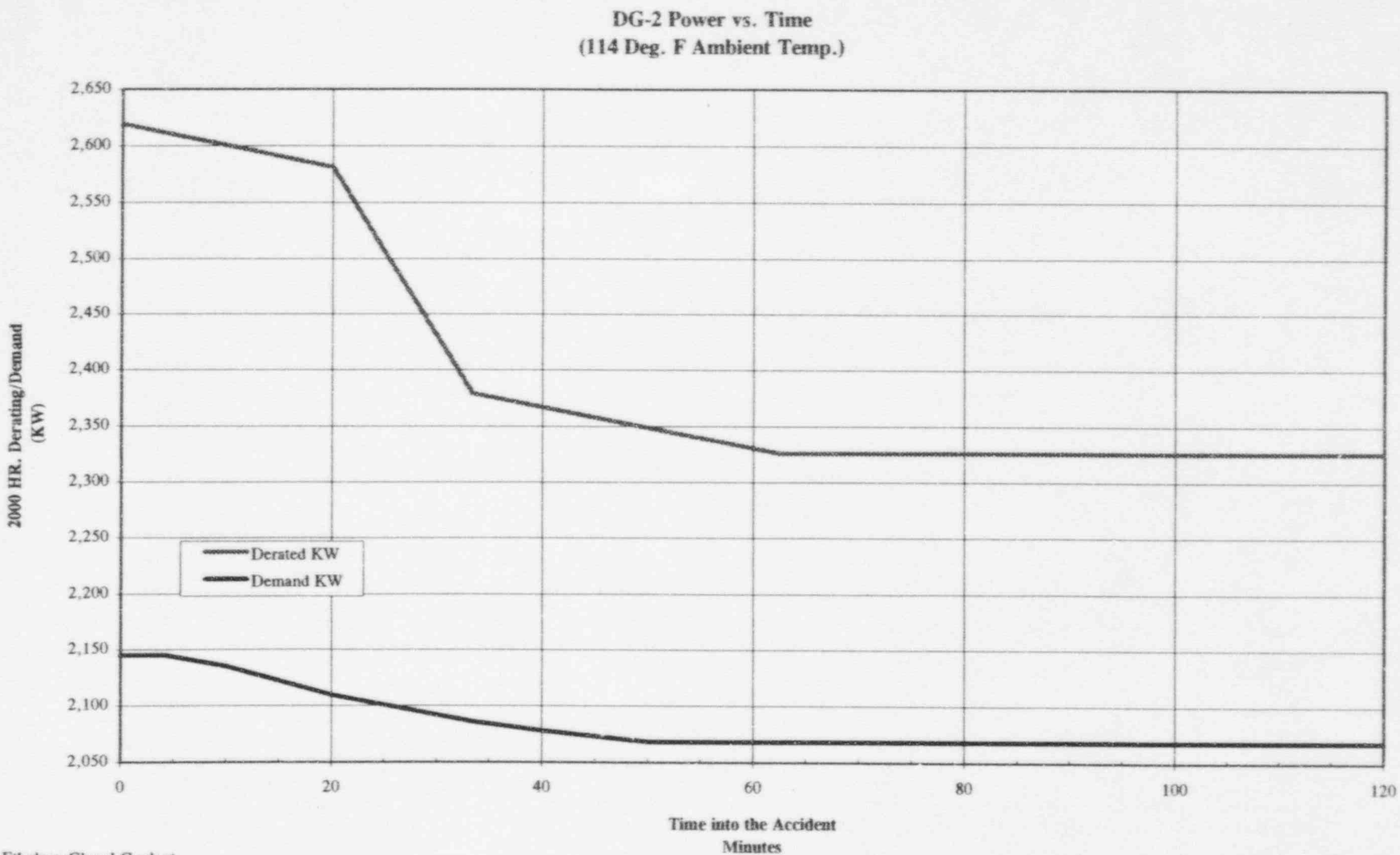


Figure 3

FC05916

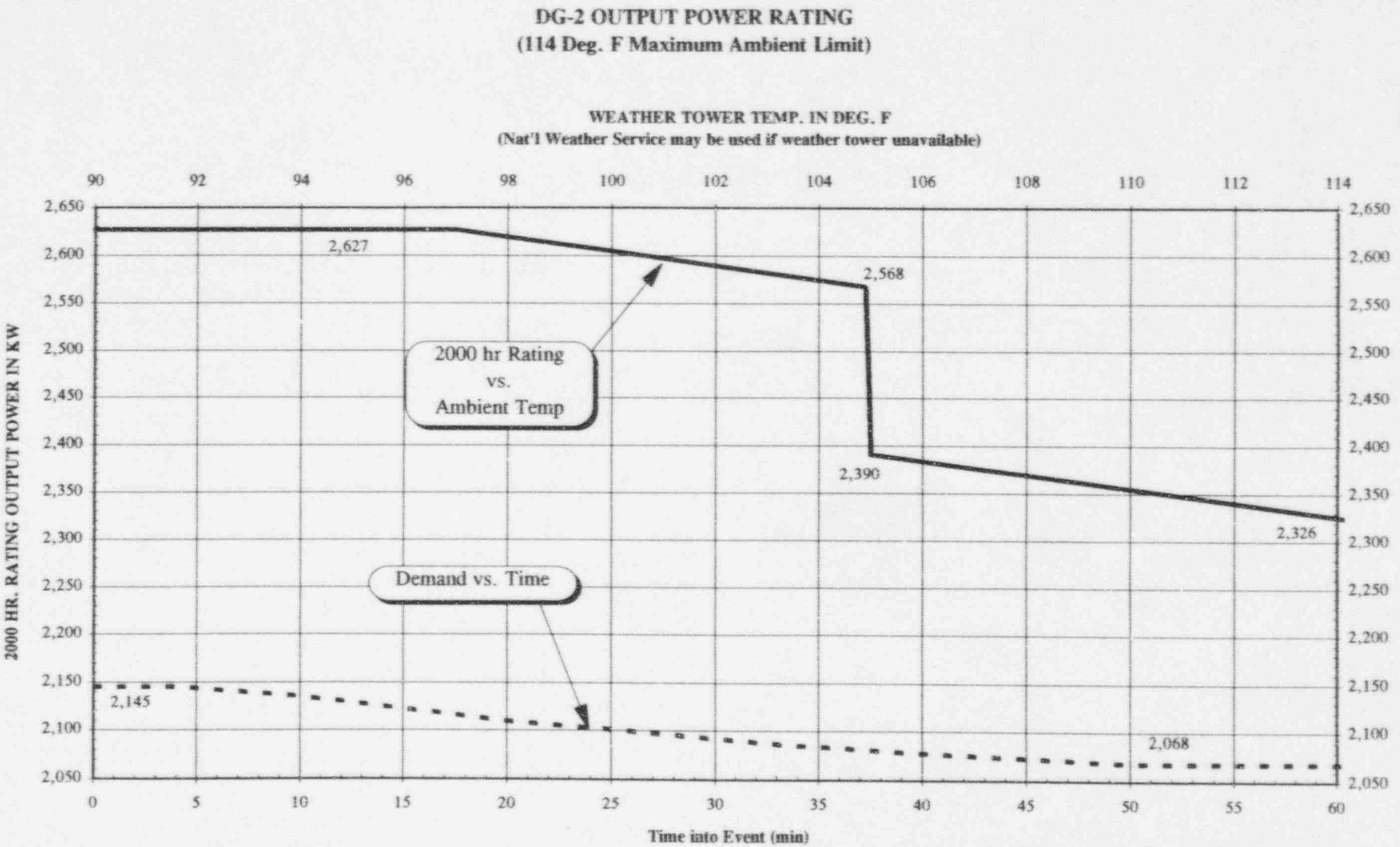


Ethylene Glycol Coolant

Note: Per calculations FC05916 and FC03382, DG-2 will provide power to supply post-LOCA load requirements up to a maximum ambient outdoor temperature of 114 deg. F, based on a cold start.

Figure 4

FCØ 5916



Ethylene Glycol Coolant

Note: DG-2 can be considered operable with ambient temperatures less than or equal to 114 deg F. Operation above the 2000 hr rating will be evaluated by System Engineering for impact on maintenance scheduling.

Figure 5

FCØ5916

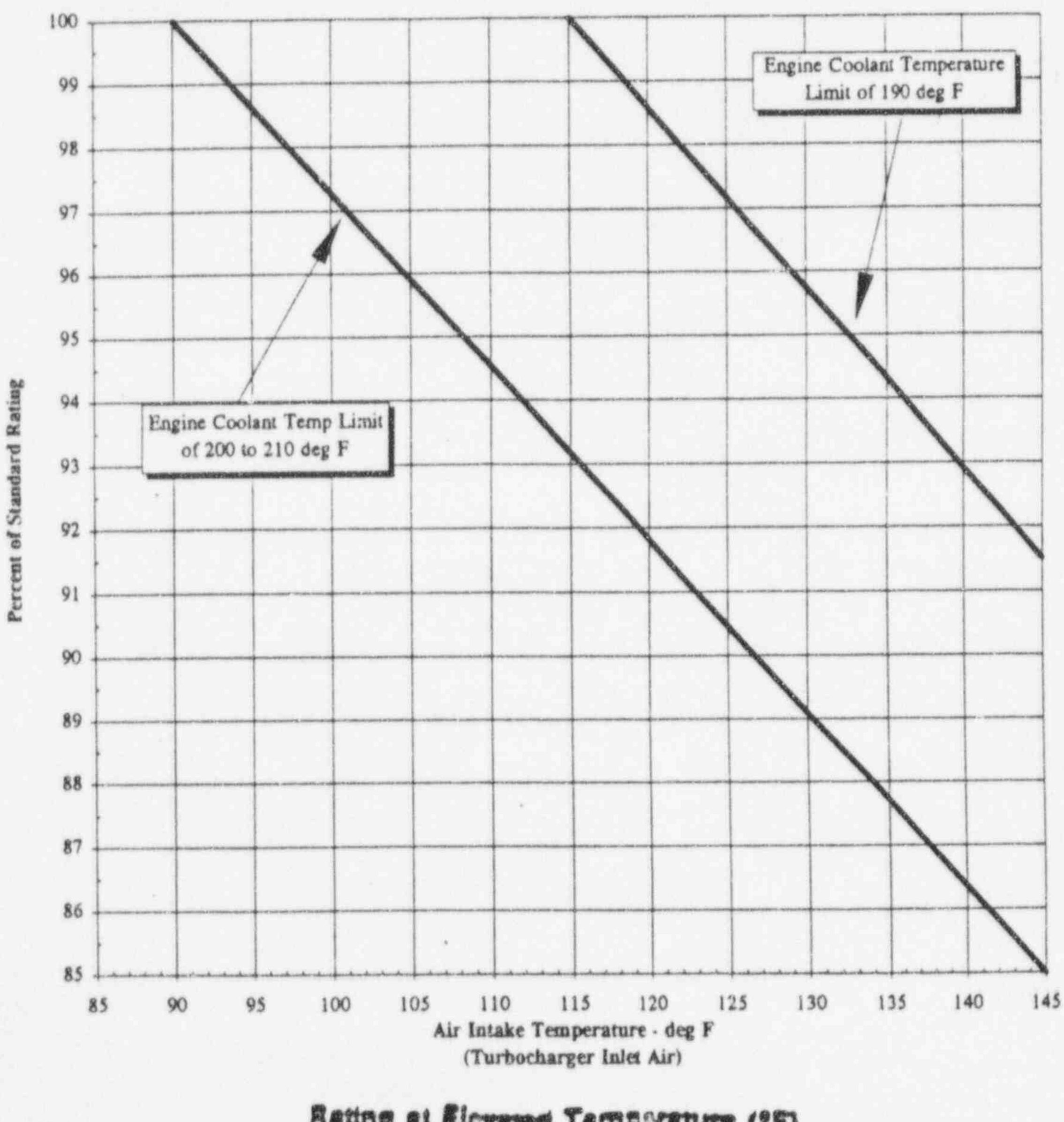
DIESEL GENERATOR DERATION CURVES

ENGINE TEMPERATURE SWITCH NOMINAL SETTINGS

Switch	Pickup	Dropout
ETS 1	208° F.	198° F.
ETS or ETS 2	215° F.	205° F.

ETS 1 — Hot engine alarm SC. HC. S.
ETS — Hot engine alarm MD. LD.
ETS 2 — Hot engine shutdown SC. HC. S.

The D/G @ Omaha is equivalent to an "S" UNIT



Rating at Elevated Temperature (°F)
For EMD 645E4

TOTAL P.06

FC-05916 2/8

Young Radiator Company

2825 Four Mile Road, Racine, Wisconsin 53404
Telephone: 414-639-1010 • EasyLink: 627-83631
TWX: 910-271-2397 • Telex: 26-4435
Telefax: 414-639-1013

FACSIMILE TRANSMISSION

TRANSMIT TO: FAX NO. 402-636-3946 C.C.

NAME DAN BORCYK TITLE

COMPANY OMAHA PUBLIC POWER CITY OMAHA STATE ZIP

NUMBER OF PAGES BEING TRANSMITTED, INCLUDING THIS COVER

HEAT LOAD: 120,970 Btu/m

COOLANT, FLOW, TEMP IN: 50% EG-WATER, 1100 GPM, 208°F

ALTITUDE: 1007 ft

RADIATOR FACE AREA: 105.1 ft²

RADIATOR TUBE LENGTH: 12.25 ft.

°F T AIR IN	AIRFLOW REQ. SCFM	IWG SP	fpm FACE VEL.	EST. TOTAL SYST. RESISTANCE IWG SP std. air
103	79,777	.42	759	1.30
108	84,873	.47	807	1.42
* 113	90,658	.52	862	1.57
118	97,279	.59	926	1.78
123	104,933	.67	998	2.00
128	113,934	.76	1084	2.29
133	124,539	.89	1185	2.60
138	137,294	1.05	1306	3.10

THE 9 ft dia, 8 blade fan @ 600 rpm is probably limited to 2.00 iwg ACTUAL ~~iwg~~ static pressure which leaves no room for de-rating. As you have suggested, purchase of a fan to overcome the system resistance appears to be a logical approach. THE system resistance shown on the attached sheet yield the following operating point on the un-derated fan curve: (Approx.) 8° pitch, 100,000 SCFM, 1.3 iwg; 10° pitch, 105,000 SCFM, 2.00 iwg; 12° pitch, 113,000 SCFM, 2.20 iwg; 14° pitch, 120,000 SCFM, 2.40 iwg.

TRANSMISSION FROM:

NAME TOM TILLER TITLE

☑ RACINE, WI 414-639-1013 ☐ LEXINGTON, TN 901-968-3617 ☐ CENTERVILLE, IA 515-856-8834

FORM NO. 3613 REV 6/88

FC 05916 R02
PG-26

Young RADIATOR COMPANY

2825 Four Mile Road, Racine, Wisconsin 53404
Telephone: 414-639-1010 • EasyLink: 627-83631
TWX: 910-271-2397 • Telex: 26-4435
Telefax: 414-639-1013

FACSIMILE TRANSMISSION

TRANSMIT TO: FAX NO. 402-636-3946 C.C. ______

NAME DAN BORCYK TITLE ______

COMPANY OMAHA PUBLIC POWER CITY OMAHA STATE NE ZIP ______

NUMBER OF PAGES BEING TRANSMITTED, INCLUDING THIS COVER 1

HEAT LOAD : 120,970 Btu/m
COOLANT, FLOW, TEMP IN : WATER, 1100 GPM, 220°F
ALTITUDE : 1007 ft
RADIATOR FACE AREA : 105.1 ft² RAD TUBE LENGTH: 12.25 ft

°F TAIR IN	-WATER- AIRFLOW REQ SCFM	IWG S.P.	fpm FACE VEL	ESTIMATED SYSTEM TOTAL RESISTANCE IWG STD AIR
103°	76,457	.39	727	1.22
108°	81,097	.43	771	1.30
113°	86,336	.48	821	1.45
118°	92,294	.54	878	1.65
123°	99,200	.61	943	1.85

TRANSMISSION FROM:

NAME TOM TILLER TITLE ______

☒ RACINE, WI 414-639-1013 ☐ LEXINGTON, TN 901-968-3617 ☐ CENTERVILLE, IA 515-856-8634

FC-05916 rev 2 Pg 27

28

Young Radiator Company

2825 Four Mile Road, Racine, Wisconsin 53404
Telephone: 414-639-1010 • EasyLink: 627-63631
TWX: 910-271-2397 • Telex: 26-4436
Telefax: 414-639-1013

FACSIMILE TRANSMISSION

TRANSMIT TO: FAX NO. 402-636-3946 C.C.

NAME DAN BORCYK TITLE

COMPANY OMAHA PUBLIC POWER CITY OMAHA STATE NE ZIP

NUMBER OF PAGES BEING TRANSMITTED, INCLUDING THIS COVER 3

HEAT LOAD: 120,970 Btu/m

COOLANT FLOW, TEMP. IN: 1100 GPM, 190°F

ALTITUDE: 1007 ft

RADIATOR FACE AREA: 105.1 ft² RAD TUBE LENGTH: 12.25 ft

°F TAIR IN	50% EG-WATER AIRFLOW REQ SCFM	iwg	fpm FACE VEL	iwg std air EST. TOTAL SYST. RESISTANCE
103	101,782	.63	968	1.85
108	110,184	.72	1048	2.17
113	120,144	.84	1143	2.50
118	131,986	.98	1255	2.90
123	146,384	1.16	1392	3.45
	WATER ONLY			
103	96,311	.58	916	1.75
108	103,766	.65	987	1.90
113	112,446	.75	1069	2.30
118	122,679	.87	1167	2.57
123	134,912	1.0?	1283	3.05

TRANSMISSION FROM:

NAME TOM TILLER TITLE

☑ RACINE, WI 414-639-1013 ☐ LEXINGTON, TN 901-968-3617 ☐ CENTERVILLE, IA 515-856-6634

FORM NO. 3613 REV. 6/89 DATE 4,8,91 TIME AM

MI-00011 FC05916 REV 2 PG 20 AS Found

TSI CERTIFICATE OF CALIBRATION AND TESTING

TSI Model 8350 TSI Serial No. 982

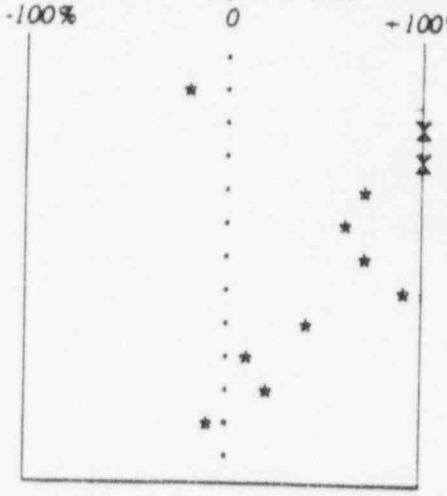
Description VELOCICALC PORTABLE AIR VELOCITY METER

Calibration Standard WIND TUNNEL CALIBRATION SYSTEM, SERIAL NO. 141

CALIBRATION VERIFICATION RESULTS

Calibration Standard Std Ft/Min	*Instrument Output* Std Ft/Min	*Percent Difference*
35.7	35.0	-1.9
65.2	69.0	5.9
150.4	159.5	6.1
325.0	332.2	2.2
648.9	664.8	2.5
997.6	1021.3	2.4
1477.2	1519.2	2.8
2514.0	2559.8	1.8
4483.6	4499.2	0.3
6993.2	7035.7	0.6
8205.9	8164.2	-0.5

Difference as a Percent of Tolerance



Indicated Temperature at 32°F 32.3 *140°F* 140.6

Standard Conditions
Ambient Temperature: 21.1°C
Barometric Pressure: 760.0 mmHg

Tolerance
±2.5% of reading ±2 f/m (30-500), 10 f/m (500-2000), 50 f/m (2000-6000), 100 f/m (6000-10000)

TSI Incorporated does hereby certify that all materials, components, and workmanship used in the manufacture of this equipment are in strict accordance with the applicable specifications agreed upon by TSI and the customer and with all published specifications. All performance and acceptance tests required under this contract were successfully conducted according to required specifications. Furthermore, all test and calibration data supplied by TSI has been obtained using standards whose accuracies are traceable to the National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants.

Applicable NIST Test Report		Report Number	Date	Date Last Verified
DC voltage		100061	7-30-92	7-30-92
Barometric Pressure		P-8077	5-13-87	5-26-92
Temperature	19-35°C	213426	3-19-80	10-19-91
	0°C	246369	9-13-90	9-24-91
	60°C	216642	9-13-90	9-24-91
Pressure		040J/34FB2:001-2	10-23-85	1-16-92
Velocity:	(Gage Blocks)	738/231633-84	6-25-84	10-23-91
	(Frequency)	84071101	7-11-84	6-11-92
Dewpoint		248330	6-10-91	11-21-91

Karen Kerrick
Calibrated by

Oct 16, 1992
Calibration Date

TSI Incorporated
Industrial Test Instruments Group

Mailing Address: P.O. Box 64394 St. Paul, MN 55164 USA
Shipping Address: 500 Cardigan Road St. Paul, MN 55126 USA
Phone: (800) 876-9874 or (612) 490-2888 Fax: (612) 490-2874

FC05416
R2
PG 29

Report No. 16472.8009-AV1 CQE

APRIL 1992

Nuclear Safety Related

TORQUE MEASUREMENT ON THE TAKE-OFF SHAFT OF EMERGENCY DIESEL GENERATOR EDG-4 FORT CALHOUN NUCLEAR STATION

PREPARED
FOR
OMAHA PUBLIC POWER DISTRICT

STONE & WEBSTER ENGINEERING CORPORATION
ADVANCED MEASUREMENT & DIAGNOSTIC SERVICES
BOSTON, MASSACHUSETTS

FCC5416 ~2

PO 2030

Report No. 16472.8009-AV1 CQE Apr. 1992

Nuclear Safety Related

TORQUE MEASUREMENTS ON THE TAKE-OFF SHAFT OF EMERGENCY DIESEL GENERATOR EDG-4 FORT CALHOUN NUCLEAR STATION

PREPARED FOR OMAHA PUBLIC POWER DISTRICT

Prepared by: E. Bercel Date: 4/17/92

E. Bercel
Senior Vibration Engineer

Approved by: J.R. Hall Date: 4-17-92

J.R. Hall
Senior Consulting Engineer

STONE & WEBSTER
ADVANCED SYSTEMS DEVELOPMENT SERVICES
ADVANCED MEASUREMENT AND DIAGNOSTIC SERVICES GROUP
a division of
STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS
(617) 589-1505

TABLE OF CONTENTS

SUMMARY

On March 16 and 18 1992, field measurements were performed to determine the power requirement of the cooling fan at various blade pitch settings. The power is delivered to the fan by a take-off shaft through a gear reducer. One end of the take-off shaft is coupled to the free end of the crankshaft of the Emergency Diesel Generator, the other end is coupled to a gear reducer. The Diesel engine is a General Motors Model 20-645-E4. The generator is rated at 3250 kVA.

The take-off shaft was instrumented using strain gages to serve as a torque transducer. Using radio telemetry, the torque signal was transmitted to a data acquisition system. Prior to the tests, the entire measuring system was calibrated end to end by applying known torque inputs to the shaft and recording the output of the data acquisition system.

Tests were performed at 500 rpm and 900 rpm engine speeds and at four blade pitch settings ranging from 12 to 26 degrees. In each test, the data acquisition system recorded the torque measurements and using the known rotational speed of the take-off shaft computed the engine power delivered to the fan drive. The results obtained show good repeatability and are reliable. This is a factual report to present the test results.

1.0 OBJECTIVES

The objective of the tests was to determine the engine power required to drive the fan at various blade pitch settings representing corresponding air flow rates.

2.0 CALIBRATION AND MEASUREMENT PROCEDURES

The take-off shaft was instrumented with meatal-foil strain gages arranged on the shaft in a manner to provide an output proportional to torsional strain and to be unaffected by bending or axial forces.

The following instrumentation was used in the tests:

Description	Make & Model	M&TE No.	Calibration Due Date
Strain Gages	Micro-Measurement	CEA-06-187UV-350	
Strain Amplifier	Vishay 2310	AMS02	10/02/92
Force Transducer	HBM USB-500	LC009	04/30/93
Radio Transmitter	PMD T-20/T-201	TEL07	CBU
Radio Receiver	Ark R-102BD	TEL02	CBU
LP Filter	Rockland 432	FLT05	07/18/92
A/D Board	Metrabyte DAS16F	DAS27	05/09/92
Digital Computer	Compaq 386/20	COM11	NCR

The torque measurement system is illustrated in Figure 1. An FM/FM radio transmitter equipped with strain gage conditioning circuitry was mounted on the take-off shaft and connected to the strain sensors. The transmitted radio signal was captured and demodulated in a receiver. The receiver provided a voltage output proportional to the torsional strain in the shaft. That output was connected to a data acquisition card in a portable computer for quantitative measurement. A spectrum analyzer and an oscilloscope were used for monitoring the quality of the received signal and that of the receiver output respectively. Both functions were qualitative. On command from the keyboard, the data acquisition was performed at a set sampling rate to obtain a desired number of data samples. The data collection parameters were preset in the data acquisition software to 2 samples/sec and 36 samples total for the static calibration and 10 samples/sec and 310 samples total for the fan test.

The torque measuring system was calibrated end to end, treating the instrumented shaft, the telemetry and data acquisition equipment as one system. The coupling between the take-off shaft and the gear reducer driving the fan was broken, and a rigid lever arm was attached to the coupling flange of the take-off shaft. The torque input to the shaft was applied by suspending dead weight from the end of the lever arm. The distance from the centerline of the shaft to the point of weight attachment, measured to reflect to effective moment arm, was 42.0". A precision force transducer was used as a link between the lever arm and the suspended dead weight and served to provide a precision measurement of the applied force. Figure 2 is a schematic illustration of the calibration set-up.

The output of the force measuring system was connected to a data acquisition channel. The force measuring system was also calibrated end-to-end. The calibration was performed using the precision shunt method to simulate input to the transducer and recording the output of the data acquisition system. The torque was applied in four increments up to 720 lb-ft, which was the anticipated torque range of the test. The actual maximum torque seen in the subsequent tests was 880 lb-ft. Both increasing and decreasing loads were applied. The output of the telemetry-based torque measuring system and that of the force measuring system were recorded simultaneously at each load. The calibration procedure was performed twice. At the completion of the calibration, the data acquisition software combined the two sets of results to compute the input-output relationship of the torque measuring system. The calibration data are given in Table 1 and have been plotted in Figure 3.

Before each test, the pitch of the fan blades was adjusted to the desired angle and before the engine was started up a set of zero torque readings were recorded. The engine was brought up to 500 rpm and then to 900 rpm and torque readings were taken. At each speed two to four sets of torque readings were taken. Taking the zero readings and the known engine speed into account, the torque and power flowing through the take-off shaft were determined for each set of data. Tests were performed at blade pitch settings of 12, 18, 22 and 26 degrees.

3.0 TEST RESULTS

The results of the torque measurements and the shaft power data computed from them have been summarized in Table 2. In Figure 4 the shaft power data have been plotted against blade pitch for both engine speeds.

4.0 CONCLUSIONS

The objective of determining the engine power required to drive the fan at various blade settings has been successfully accomplished. The results obtained show good repeatability and are reliable.

APPENDIX

TABLE 1

CALIBRATION DATA FOR TAKE-OFF SHAFT TORQUE MEASUREMENTS
EMERGENCY DIESEL GENERATOR EG4, FORT CALHOUN NUCLEAR STATION
MARCH 16, 1992

APPLIED FORCE lbs	MEASURED TORQUE lb-ft	TELEMETRY COUNT ###	BEST FIT TORQUE lb-ft *	ERROR Re. BFT lb-ft **	ERROR PER CENT FS
0.02	0.06	2	0	-0	-0.0
51.69	180.90	465	179	-2	-0.2
103.39	361.88	926	358	-4	-0.6
154.89	542.11	1383	535	-8	-1.1
205.56	719.46	1852	716	-3	-0.4
154.93	542.24	1399	541	-1	-0.2
103.45	362.08	952	368	6	0.8
51.72	181.02	476	183	2	0.3
0.01	0.04	-2	-1	-1	-0.2
-0.02	-0.06	0	-1	-1	-0.1
51.48	180.16	453	175	-5	-0.8
102.14	357.49	908	351	-7	-0.9
153.87	538.54	1382	534	-4	-0.6
205.57	719.49	1869	723	3	0.5
153.88	538.58	1415	547	8	1.2
102.14	357.50	942	364	6	0.9
50.68	177.36	466	180	2	0.3
-0.01	-0.04	2	-0	-0	-0.0

***** Best Fit CNTS/lb-ft 2.583 *****

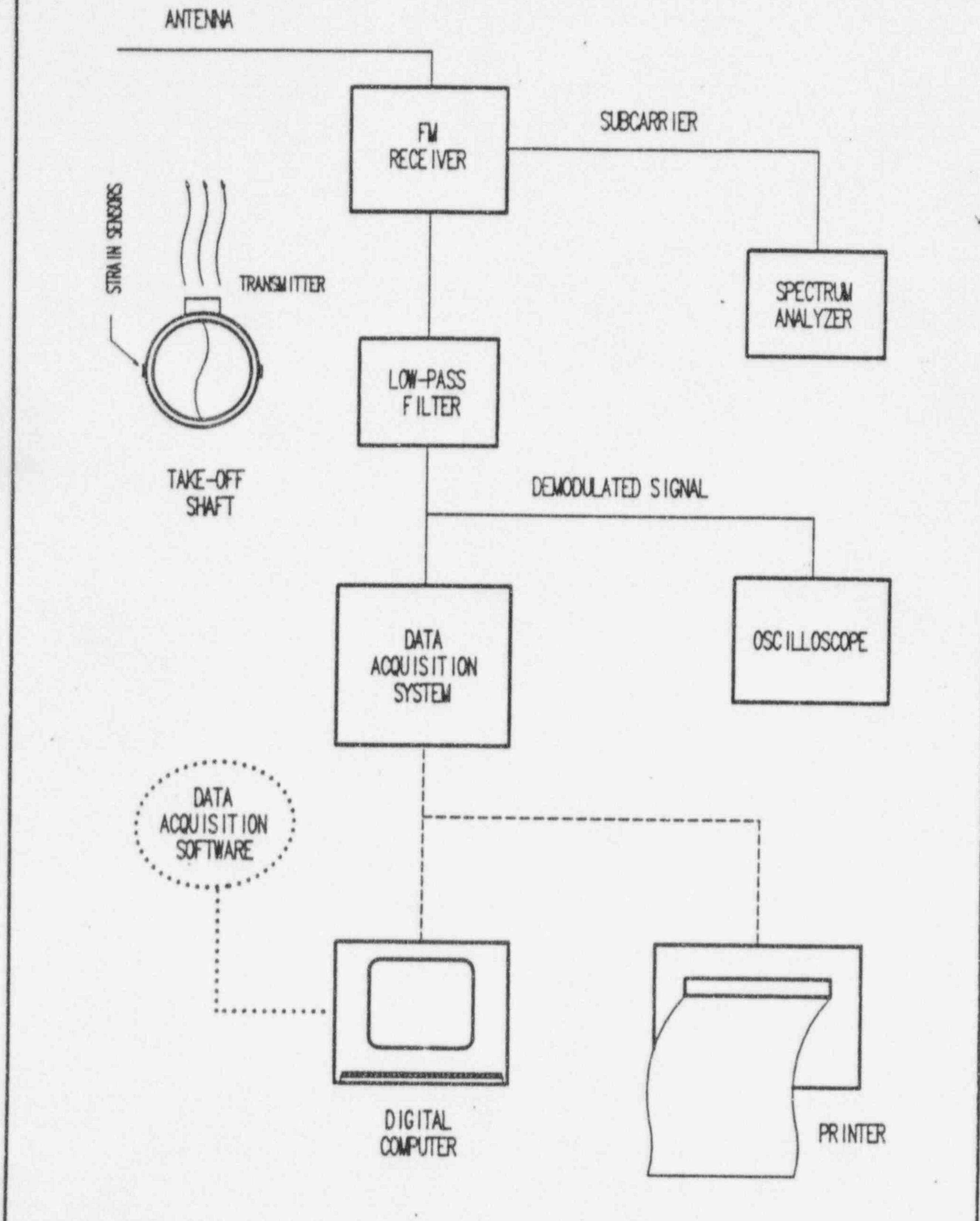
* THE 'BEST FIT' TORQUE WAS CALCULATED FROM THE TELEMETRY COUNTS AND THE COUNTS/TORQUE VALUE OBTAINED FROM THE 'LEAST SQUARE' FITTING OF THE CALIBRATION DATA POINTS.

** DEVIATION OF THE MEASURED TORQUE FROM THE 'BEST FIT' TORQUE.

TABLE 2

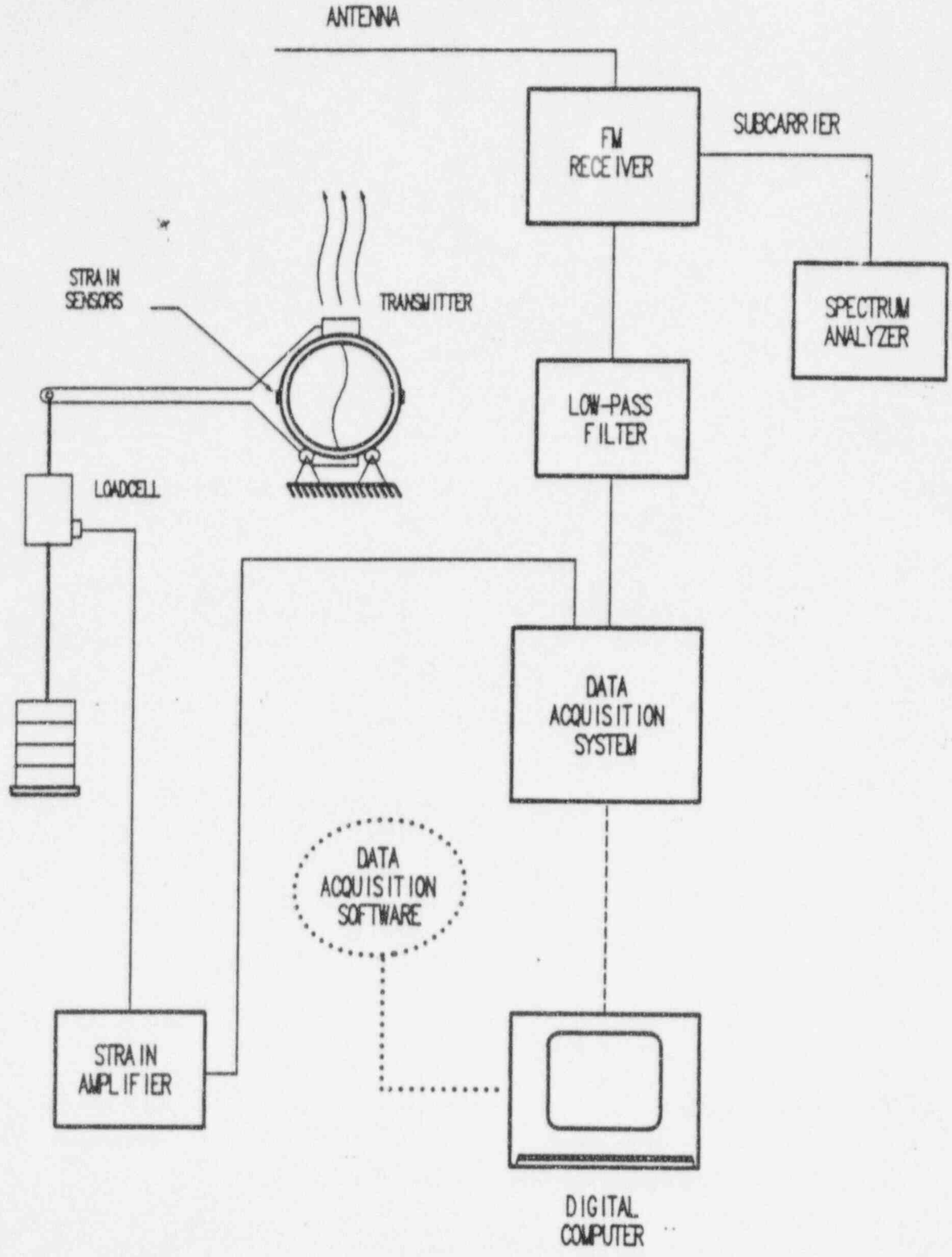
TAKE-OFF SHAFT POWER MEASUREMENTS
EMERGENCY DIESEL GENERATOR EDG4
FORT CALHOUN NUCLEAR POWER STATION
MARCH 18-19, 1992

500 rpm			900 rpm		
FAN BLADE PITCH deg.	DRIVE TORQUE lb-ft	DRIVE POWER hp	FAN BLADE PITCH deg.	DRIVE TORQUE lb-ft	DRIVE POWER hp
12	114	10.8	12	342	58.6
12	114	10.8	12	343	58.8
12			12	342	58.7
18	194	18.4	18	578	99.1
18	194	18.4	18	578	99.1
18	193	18.4	18	575	98.6
18			18	575	98.6
22	243	23.1	22	697	119.5
22	235	22.3	22	697	119.4
22	236	22.4	22	696	119.2
22			22	692	118.6
26	306	29.1	26	872	149.5
26	308	29.3	26	880	150.9
26	316	30.1	26	873	149.6
26			26	869	148.9
26			26	881	151.0



INSTRUMENTATION SCHEMATIC

Figure 1



CALIBRATION SET-UP

Figure 2

FORT CALHOUN NUCLEAR STATION EDG4 TEST

TAKE-OFF SHAFT TORQUE CALIBRATION

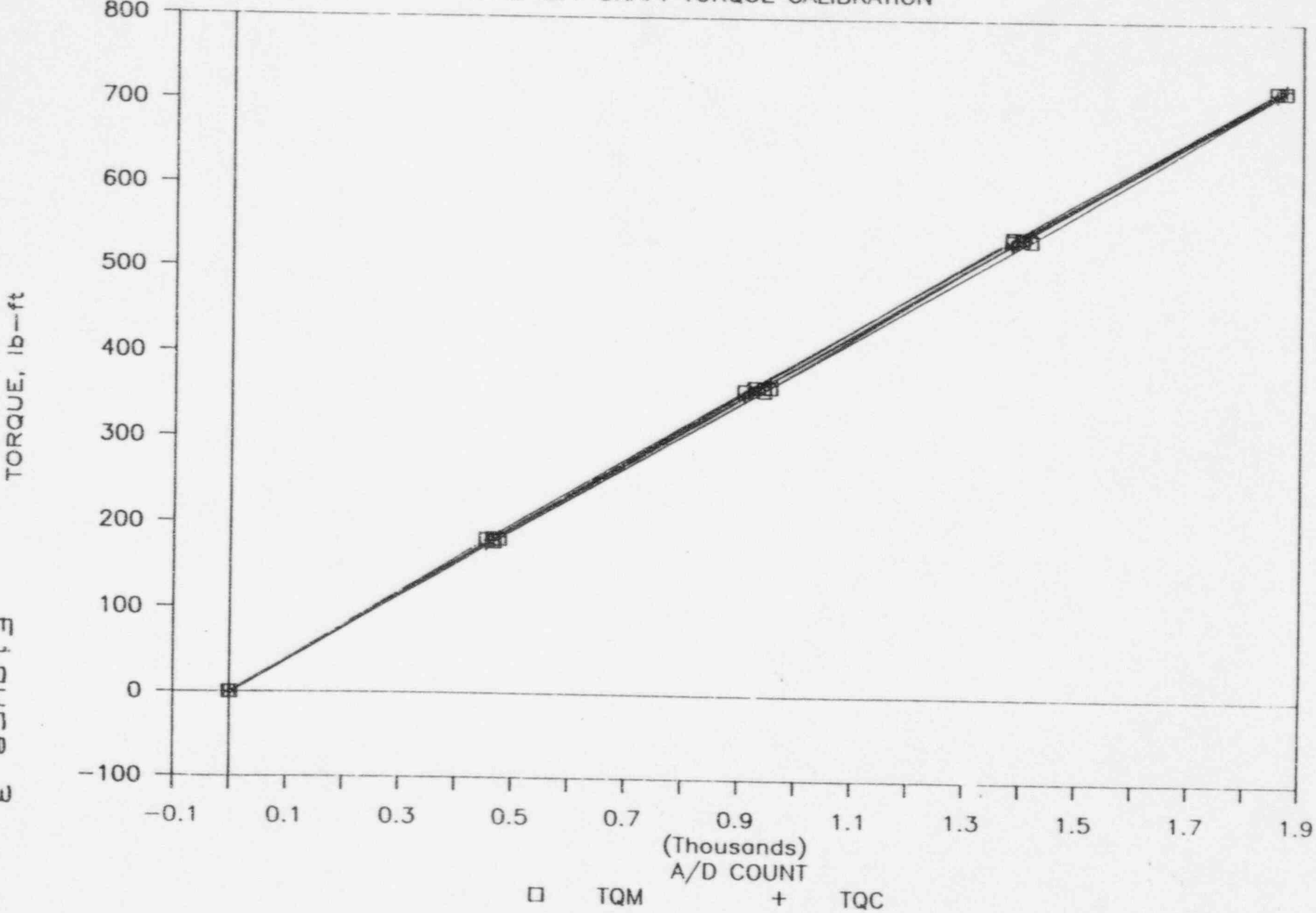


Figure 3

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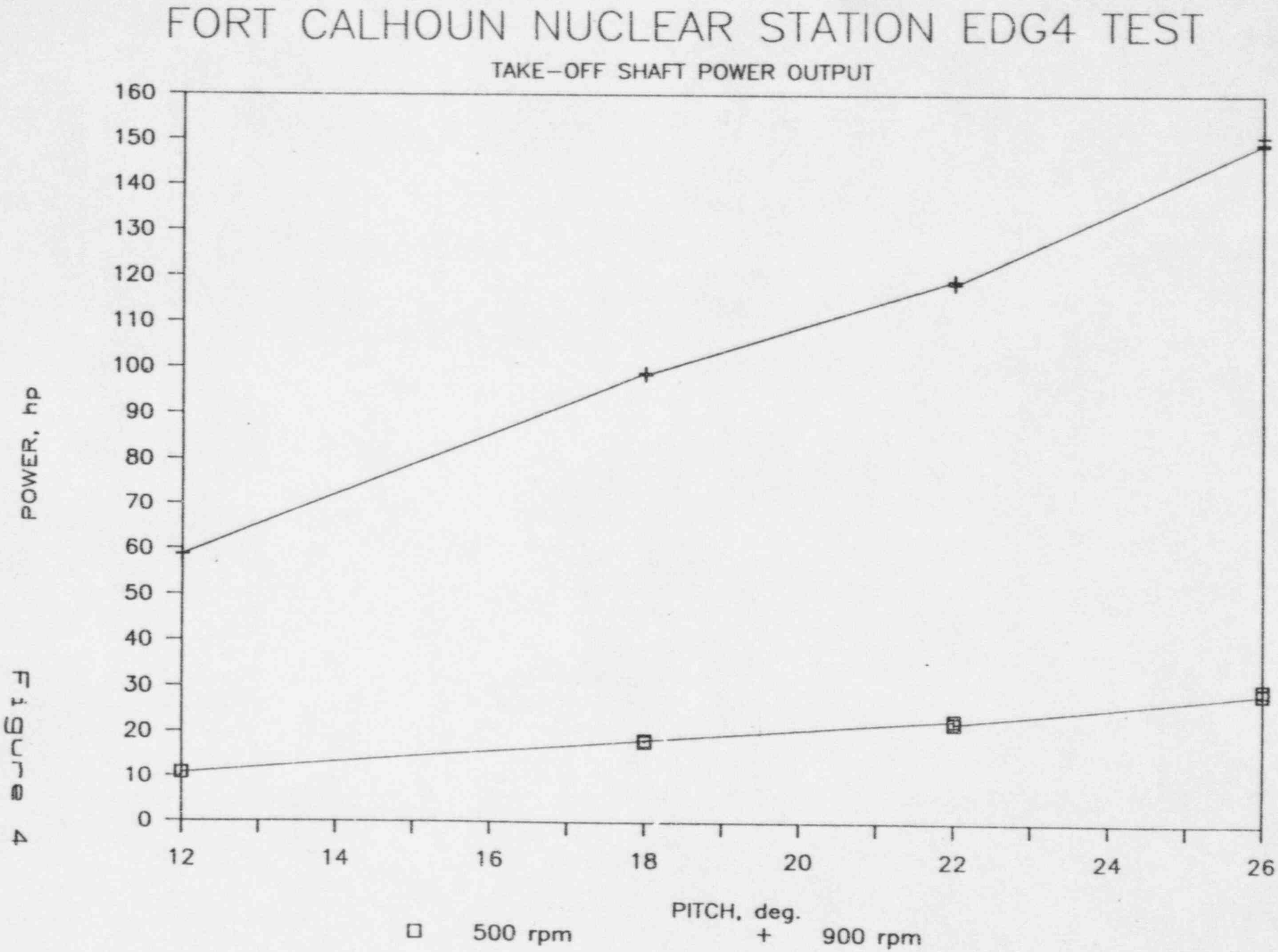

Figure 4

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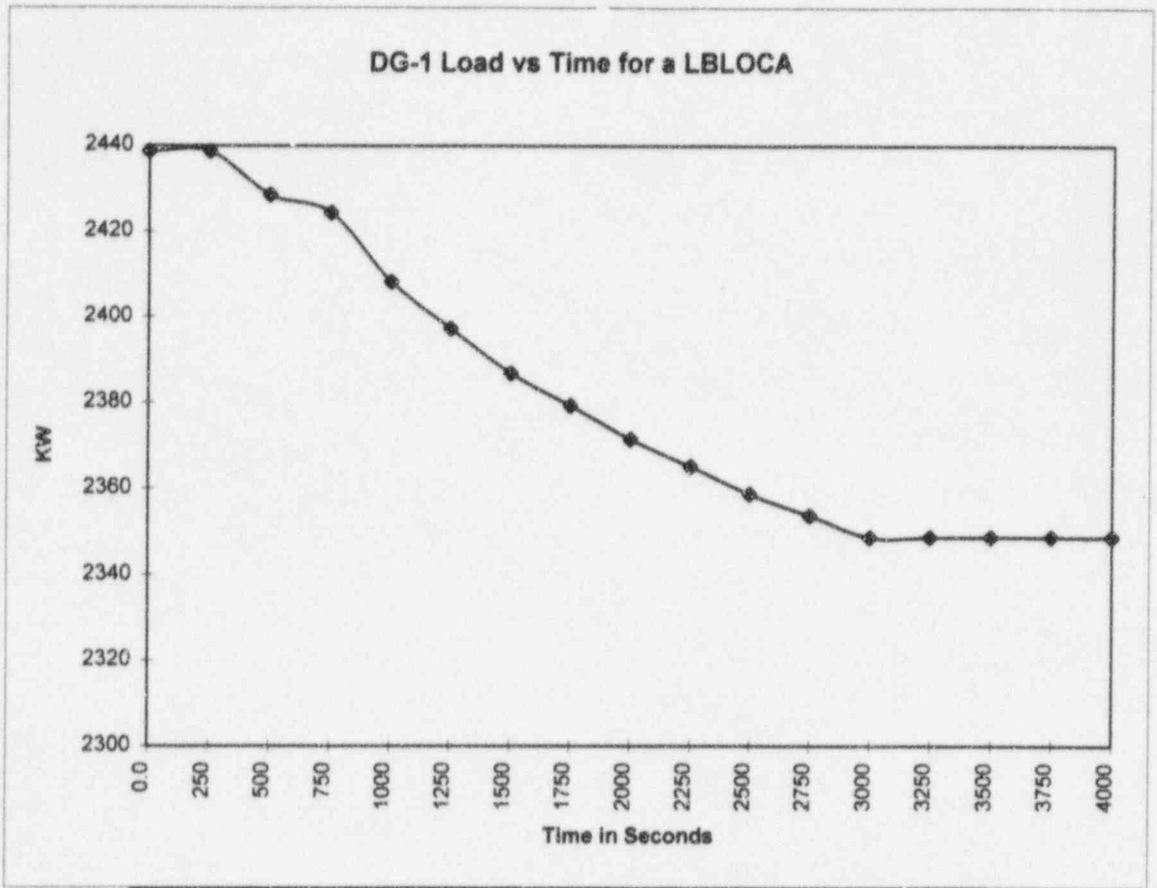
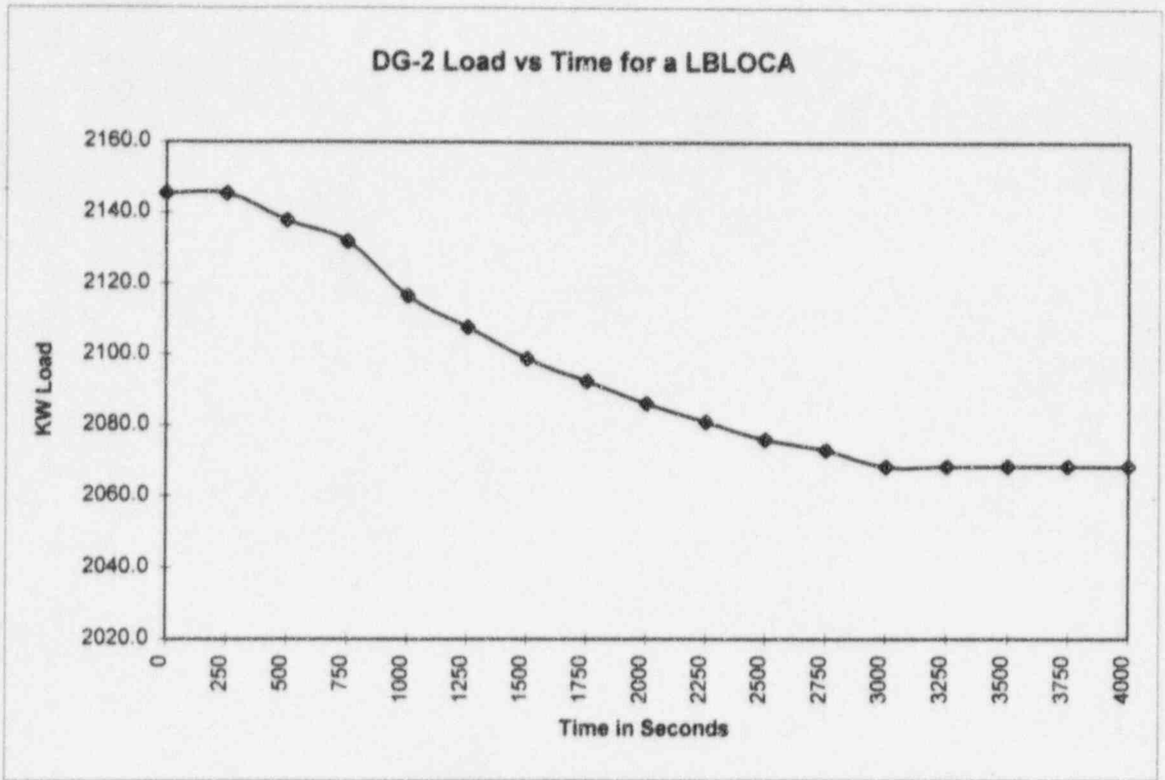


DG-1 Load vs Time for a LBLOCA					
Time Into Event Sec.	Fan Coolers Creditied				
	Containment Pressure psig	VA-3A&VA-7C Load KW	SI-3A Load KW	DG-1 Base Load	Total DG-1 Load KW
0	56.3	284.0	260.9	1893.8	2438.6
250	56.3	284.0	260.9	1893.8	2438.6
500	53.3	273.9	260.9	1893.8	2428.6
750	51.0	266.2	264.3	1893.8	2424.3
1000	45.0	246.1	268.4	1893.8	2408.3
1250	41.5	234.3	269.2	1893.8	2397.3
1500	38.0	222.6	270.4	1893.8	2386.8
1750	35.5	214.2	271.3	1893.8	2379.3
2000	33.0	205.8	271.9	1893.8	2371.5
2250	31.0	199.1	272.3	1893.8	2365.2
2500	29.0	192.4	272.6	1893.8	2358.8
2750	27.5	187.3	272.6	1893.8	2353.8
3000	26.0	182.3	272.6	1893.8	2348.7
3250	26.0	182.3	272.6	1893.8	2348.7
3500	26.0	182.3	272.6	1893.8	2348.7
3750	26.0	182.3	272.6	1893.8	2348.7
4000	26.0	182.3	272.6	1893.8	2348.7



DG-2 Load vs Time for a LBLOCA					
Time Into Event (sec)	Fan Coolers Creditied				
	Containment Pressure psig	DG-2 Base Load	Total Spray Pump Load KW	VA-3A&VA-7C Load KW	Total DG-2 Load KW
0	56.3	1380	481.4	284.0	2145.4
250	56.3	1380	481.4	284.0	2145.4
500	53.3	1380	483.8	273.9	2137.8
750	51.0	1380	485.7	266.2	2131.9
1000	45.0	1380	490.6	246.1	2116.7
1250	41.5	1380	493.4	234.3	2107.8
1500	38.0	1380	496.2	222.6	2098.9
1750	35.5	1380	498.2	214.2	2092.5
2000	33.0	1380	500.3	205.8	2086.1
2250	31.0	1380	501.9	199.1	2081.0
2500	29.0	1380	503.5	192.4	2075.9
2750	27.5	1380	505.5	187.3	2072.9
3000	26.0	1380	505.9	182.3	2068.3
3250	26.0	1380	505.9	182.3	2068.3
3500	26.0	1380	505.9	182.3	2068.3
3750	26.0	1380	505.9	182.3	2068.3
4000	26.0	1380	505.9	182.3	2068.3

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Calc Preparation, Review and Approval PED-QP-3.5 Page 1 of 2 Reviewer's Checklist-Calculations	CALCULATION NUMBER FC05916 REV 3

		YES	NO	N/A
1.	Is Calculation Cover Sheet attached and completed, as required, to the calculation?	✓		
2.	Is the calculation objective stated? Was this achieved?	✓		
3.	Are inputs correctly selected and incorporated into the analysis?	✓		
4.	Have inputs and/or assumptions which require confirmation at a later data, been identified on the Calculation Cover Sheet and in the calculation body?			✓
5.	Are the applicable codes, standards, regulatory requirements, and other references including issue and addenda identified such that they are traceable to source document?	✓		
6.	Was an appropriate calculation method used? Was the basic theory appropriate?	✓		
7.	Have assumptions been noted and justified?	✓		
8.	Are the calculations free of arithmetic errors?	✓		
9.	Is the calculation consistent with the design basis requirements?	✓		
10.	Is the conclusion stated?	✓		
11.	Is the calculation legible and suitable for microfilming?	✓		

Calc Preparation, Review and Approval PED-QP-3.5 Page 2 of 2 Reviewer's Checklist-Calculations	CALCULATION NUMBER
	FC05916 REV 3

		YES	NO	N/A
12.	Are all blocks on the Calculation Cover Sheet addressed correctly?	/		
13.	Have Forms PED-QP-3.2, 3, 4 and 5 been used and correctly completed?	/		
14.	If the calculation has been prepared to supersede another calculation, has all the valid information been transferred in the new calculation?	/		
15.	If the calculation determines that an existing or preexisting condition may be outside the design basis of the plant, are the results of a reportability evaluation performed in accordance with PED-QP-19 attached?			/

REVIEWER COMMENTS:

Doug Mof [signature] 08-15-95

Reviewer Date

Calc Preparation, Review and Approval
PED-QP-3.7 Page 1 of 1
Independent Reviewer's Checklist - Calculations

CALCULATION NUMBER

FC05916 REV 3

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		YES	NO	N/A
1.	Are the calculation methods accurate and appropriate?	/		
2.	Are input data sufficiently detailed?	/		
3.	Are the calculation assumptions reasonable?	/		
4.	Has the basis for engineering judgement been included in the calculation, when used?	/		
5.	Is the calculation documented sufficiently such that the analysis is understandable to someone competent in the discipline without recourse to the Preparer?	/		
6.	Have the design interface requirements been satisfied?	/		
7.	Are the results reasonable and do they resolve the calculation objective?	/		
8.	If an alternate calculation was used to verify the adequacy of the analysis, is it attached to the calculation? SUPPORTING DATA & CALC ATTACHED			/
9.	If qualification testing was used to verify the adequacy of the analysis, has it been documented using a retrievable source, or attached to the calculation?			/
10.	Are calculations involving Technical Specification values and associated margins of safety identified? REF TO T.S. 3.7(1) MADE	✓		

INDEPENDENT REVIEWER COMMENTS:

Doug Moffe 08-15-95
Independent Reviewer Date