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NUCLEAR PRODUCTION DEPARTMENT

April 18, 1984

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Attention: Mr. Harold R. Denton, Director

Dear Mr. Denton:

SUBJECT: Grand Gulf Nuclear Station
Unit 1
Docket No. 50-416
File: 0272/L-860.0
Diesel Generator and Gas Turbine Reliability
AECM-84/0241

MP&L met with the NRC Staff in Bethesda, Maryland on April 5, 1984, to discuss emergency on-site power sources. During this meeting, MP&L committed to provide responses to NRC concerns regarding (1) gas turbine/diesel generator and AC power reliability, (2) LOCA and loss of offsite power loading of the Division I and II diesel generators, (3) loss of offsite power loading on the gas turbine generators, assuming two and three gas turbine unit operation, and (4) gas turbine/diesel generator reliability assuming no credit is taken for the Division III diesel generator.

Our responses to concerns one through four above are provided in Attachments 1 through 4, respectively, to this letter.

Please advise us if you require further information on these concerns.

Yours truly,

J. P. McGaughy

SWK/SHH:daz
Attachments: 1. Response to NRC Questions on Gas Turbine and Diesel Generator Reliability
2. LOCA and LOSP Loads on Division I and Division II ESF Buses
3. Load Profile for Gas Turbine Generators
4. Gas Turbine/Diesel Generator Reliability Evaluation

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Washington, D.C. 20555

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RESPONSE TO NRC QUESTIONS ON
GAS TURBINE AND DIESEL GENERATOR RELIABILITY

The following are in response to NRC questions from the meeting on gas turbine and diesel generator reliability held in Bethesda on April 5, 1984.

Question 1

Discuss effect of increased suppression pool level during station blackout conditions on hydrodynamic pool loads.

Response

Evaluation assumptions and methodology:

a. Maximum pool elevation equal to the top of weir wall (El. 117'-4").

b. Maximum pool temperature equals 176°F (80°C). [GESSAR formula gives acceptable values up to 80°C]

c. Reactor pressure equals 300 psig

d. Credit taken for load reduction based on CAORSO inplant tests

The hydrodynamic quencher bubble loads generated during reactor shutdown without AC power were evaluated against static and dynamic structural design loads. The evaluation indicates that: For static loading, the evaluated loads (based on elevated pool level, elevated pool temperatures, and decreased reactor pressure), are bounded by the existing design. For dynamic loading, the evaluated loads exceed the existing design. However, in our judgement as long as they do not occur concurrently with earthquake loads, no problem is anticipated.

Also, to reduce dynamic loads on the suppression pool, an instruction is provided in the SBO procedure (ONEP 05-1-02-I-6) to sequentially operate the safety relief valves to maintain reactor pressure below the relief valve setpoint and distribute heat uniformly in the suppression pool. The instruction also states to operate the 12 relief valves first, and then operate ADS valves.

Question 2

Confirm RCIC pump suction valves are DC powered.

Response

The RCIC pump suction valves (F010A for the condensate storage tank and F031A for the suppression pool) and their associated logics are powered from the Class 1E batteries.

Question 3

Confirm the Class 1E batteries are capable of sustaining all required station blackout loads for a minimum of six hours.

Response

To verify a six hour battery life during station blackout conditions, the Battery A lifetime was calculated while supplying the following loads:

Standby Core Cooling Equipment:

a. Primary relief valve (ADS)

b. RCIC control system

c. RCIC isolation valves

d. RCIC turbine and valve

e. RCIC air compressor

f. RHR control

g. LPCS control

Diesel generator flashing

Indicator lamps and annunciators

ESF support system control

Reactor protection system

Load sequencing control

Seismic instrumentation

Switchgear

Uninterruptible power supplies

Since Battery B is more lightly loaded than Battery A, the calculated battery life is the worst case analysis.

The major difference between the present calculation and the one upon which the FSAR is based is that the FSAR calculation assumed the viability of only 58 of the battery's 60 cells. However, when the calculation is performed assuming all 60 cells are viable, the battery life is extended to six hours. The assumption of 60 viable cells is justified since the assumption of 58 cells is made for convenience and flexibility of operations and maintenance.

Question 4

Where in the FSAR are the capabilities of the ADS air receivers discussed?

Response

FSAR Section 5.2.2.4.1 and FSAR Figure 5.2-8 provide a description of the capability of the ADS air receivers.

Question 5

Can the diesel-driven fire pump be aligned to pump water into vessel? Can it pump into vessel and pool simultaneously? How long can the diesel driven fire pumps operate during station blackout conditions?

Response

The system operating instruction (SOI) for the fire protection system contains instructions for aligning the system to add water to the reactor vessel. Water can be added simultaneously to the pool and reactor vessel.

Based on vendor supplied fuel consumption data, each of the two diesel driven fire pumps can run for 20 hours without AC power when the day tanks are filled to their capacity of 550 gallons. When the day tanks are maintained at 300 gallons, as required by Technical Specification 3/4.7.6.1, each of the pumps can run for 11 hours without AC power.

Question 6

Provide temperature profile curves for the control room and RCIC pump room during station blackout conditions.

Response

Analyses are underway to determine the control room and RCIC pump room temperature profiles during station blackout conditions.

Question 7

In the event of a loss of offsite power, are loads stripped from their buses? Provide the loads on the Division I and Division II ESF buses during post LOCA and loss of offsite power (LOSP) conditions.

Response

A discussion of load shedding and sequencing on ESF buses is found in Section 8.3.1.1.3 of the GGNS FSAR. Upon loss of preferred power source, all incoming and motor feeder breakers except those to the 480 volt load centers are automatically tripped. At the load center level, all feeders are tripped except those supplying power to motor control centers (MCCs) feeding Class 1E loads.

Attachment 2 provides Division I and Division II LOCA and LOSP loading curves and a listing of the different loads that are required for each condition.

Question 8

Provide the loading on the gas turbine generators during station blackout conditions.

Response

Attachment 3 provides anticipated gas turbine generator loading curves and a listing of loads during station blackout conditions for both three gas turbine generator unit and two gas turbine generator unit operation.

Question 9

Provide a reliability evaluation of the extent to which the gas turbine generators can offset a postulated degradation in the reliability of the TDI diesel generators.

Response

Attachment 4 provides the evaluation.

Question 10*

Provide discussion of any credit which can be given for the seismic capability of the gas turbines, e.g., an experience of plant with seismic activity. Include components between the turbines and on-site power distribution system.

Response

The Allison Model No. 501-K15 is capable of withstanding accelerations in the range of 10-16g's. This information is taken from the Allison Report No. AR. 0001-001 titled "501-K15 Earthquake Capabilities." The manufacturer has indicated during telecons that the gas turbines have passed Navy Barge Tests, which subject the turbines to depth charge originated accelerations up to 23g's while operating.

Connection between the gas turbines, their auxiliary trailers and fuel supply and electrical distribution, is provided by flexible connections and cable. This allows for movement between the components and, therefore, should be able to withstand a seismic event.

Question 11*

Given no severe weather protection for the gas turbines, provide a discussion of the precautionary operating procedures to follow in case of a severe weather watch in the area.

Response

The gas turbines are classified as an additional offsite power source; therefore, the severe weather precautions described below are applied.

Off Normal Event Procedure 05-1-02-VI-2, "Hurricane, Tornados, and Severe Weather" provides instructions to start the diesel generators and bring them to operating voltage and speed when a tornado warning is received or severe weather is in effect. The Division III D/G may run four hours unloaded and then must be loaded to 50 percent load for at least 30 minutes prior to returning to no-load condition. This instruction is contained in the system operating instruction for HPCS. Division I and II D/Gs may run unloaded for seven days. These conditions are met by paralleling to the respective bus and loading and then returning to no load. If two or more diesels are connected to their respective bus and carrying loads, they are separated from the grid. The respective SOIs do not allow running two D/Gs in parallel.

The Off-Normal Event Procedure applies during a tornado warning or period of severe weather. A tornado warning is issued by the National Weather Bureau once a tornado has been sighted in an area. A tornado watch is issued when weather conditions would support the formation of a funnel cloud. Tornado watch conditions may occur frequently during the spring months and are not always elevated to Warnings. Starting and running the diesel generators during a tornado warning provides an appropriate safety precaution and minimizes the potentially unnecessary demands and challenges on the diesels if they were to be started during each tornado watch.

Per telecons with Allison, the Allison Gas Turbines have been subjected to water and ice ingestion tests up to 10 gpm to simulate severe weather operation. The test showed that the gas turbines produce higher output power due to the increase of mass flow and cooling effects.

Question 12*

If the diesels are challenged because of a seismic event, would the reliability change because of the problems experienced?

Response

The standby diesel generators are seismically qualified using low impedance testing to ensure frequencies of response greater than 35 Hz. Even if the earthquake was capable of exciting the engine, the earthquake loads are small compared to the dynamic loads that the engine components experience during operation. Therefore, earthquake loads will not contribute to or initiate a failure of any engine component. In addition, all replacement components have been exact duplicates or qualified components, therefore, should not change the capability of the diesel generators to resist seismic events.

Component repairs and replacements were performed considering possible effects on seismic performance. The most significant change, replacement of piston skirts, was determined to have an insignificant impact on the inertial mass and seismic operability of the engines.

Question 13*

Provide available testing data on the TDI D/G including information on failures (whether valid or not).

Response

The NRC has similarly requested the TDI D/G Owners Group to provide additional test data for the TDI D/G performed by the individual utilities (reference letter from G.H. Berlinger to J. P. McGaughy, dated March 19, 1984). In accordance with this request, MP&L has forwarded test data on TDI engines 74033 and 74034 to the Owners Group for compilation and presentation to the NRC.

Question 14*

Provide a copy of GGNS Station Blackout - related procedures. Include those for gas turbine generator hook-up, HPCS D/G cross-connect and Division I and II D/G load reduction.

Response

The SBO related procedures include:

1.	Station Blackout	ONEP 05-1-02-I-6
2.	Fire Protection Water System	SOI 04-S-01-P64-1
3.	Hurricanes, Tornados, and Severe Weather	ONEP 05-1-02-VI-2
4.	Loss of Offsite Power	ONEP 05-1-02-I-4
5.	Gas Turbine Generator System; Maintenance and Operation Procedure	Job Bulletin 456

(NOTE: In the case of the Fire Protection System SOI only Section 6, which addresses the addition of water to the reactor vessel and suppression pool is relevant.)

There is currently no procedure developed for cross-connecting the Division III (HPCS) D/G to Division I or II loads. While this alternative is considered technically feasible, a detailed design review is needed to support procedure development and to ascertain its feasibility from the standpoint of required operator actions and maintaining plant safety.

Load reduction of the Division I and II buses as a means of reducing stresses on the diesel engines is not required. The load rating is significantly greater than the loss of offsite power (LOSP) loading.

The SBO ONEP addresses the steps to be taken in order to feed division I and/or loads from the gas turbine generators.

*Note: These questions came from J. B. Richard's discussion with the NRC on AC power reliability.

Question 15

What effect would the shutdown of GGNS have on grid reliability? Is a problem promoted by shutting down the plant?

Response

The shutdown of GGNS does not promote any problems relating to grid reliability. The grid will continue to operate in a reliable manner. The stability analyses performed for the GGNS FSAR and discussed in Section II of the attachment to AECM-84/0113 include an evaluation of GGNS tripping off line.

Question 16

Has MP&L had an extensive loss of or serious threat to losing the system?

Response

Threats to a grid breakup have occurred to the MP&L system, but all three instances occurred over 18 years ago and all prior to the time the 500 KV South Central Electric Companies' bulk power transmission system was put in-service.

In 1955, there were two blackouts, both involving the No. 6 unit at the Sterlington, Louisiana plant.

In 1966, there was an islanding situation in which the system came close to a blackout situation.

Question 17

What actions would be taken to restore offsite power to GGNS in the event of a system blackout?

Response

Assuming a blackout condition, MP&L's black start unit (No. 5 at Rex Brown), an 11 MW combustion turbine, would initially be used to start a unit or units at the Rex Brown SES in Jackson. Then these units would be used to energize lines to the Baxter Wilson and/or Gerald Andrus SES in order to put these units back in service. Once this amount of system generation is established; power could be supplied to Grand Gulf.

LOCA AND LOSP LOADS ON
DIVISION I AND DIVISION II ESF BUSES

The loads fed from the Division I and Division II ESF buses during a loss of offsite power (LOSP) are significantly different from those required during a LOCA. The specific differences are outline below. Some loads are required for both LOCA and LOSP conditions. FSAR Tables 8.3-1 and 8.3-2 provide a listing of all loads connected to the ESF buses.

For Division I, the load required during LOCA is roughly 1,000 KW higher than that of a LOSP. This is due largely to the 2,000 HP LPCS pump which is required only for LOCA.

1) Division I loads required only for LOCA

   LPCS Pump
   Hydrogen Recombiner
   Control Room Emergency Ventilation
   SLCS Pump
   Enclosure Building Recirc. Fan
   Drywell Purge Compressor
   SGTS

2) Division I loads required only for LOSP

   Plant Lighting
   Non-1E Battery Chargers
   CRD Pump
   Drywell Coolers
   Fuel Pool Cooling Pump
   Inverter Backup Transformers
   RPS Backup Transformer
   SLCS Heaters

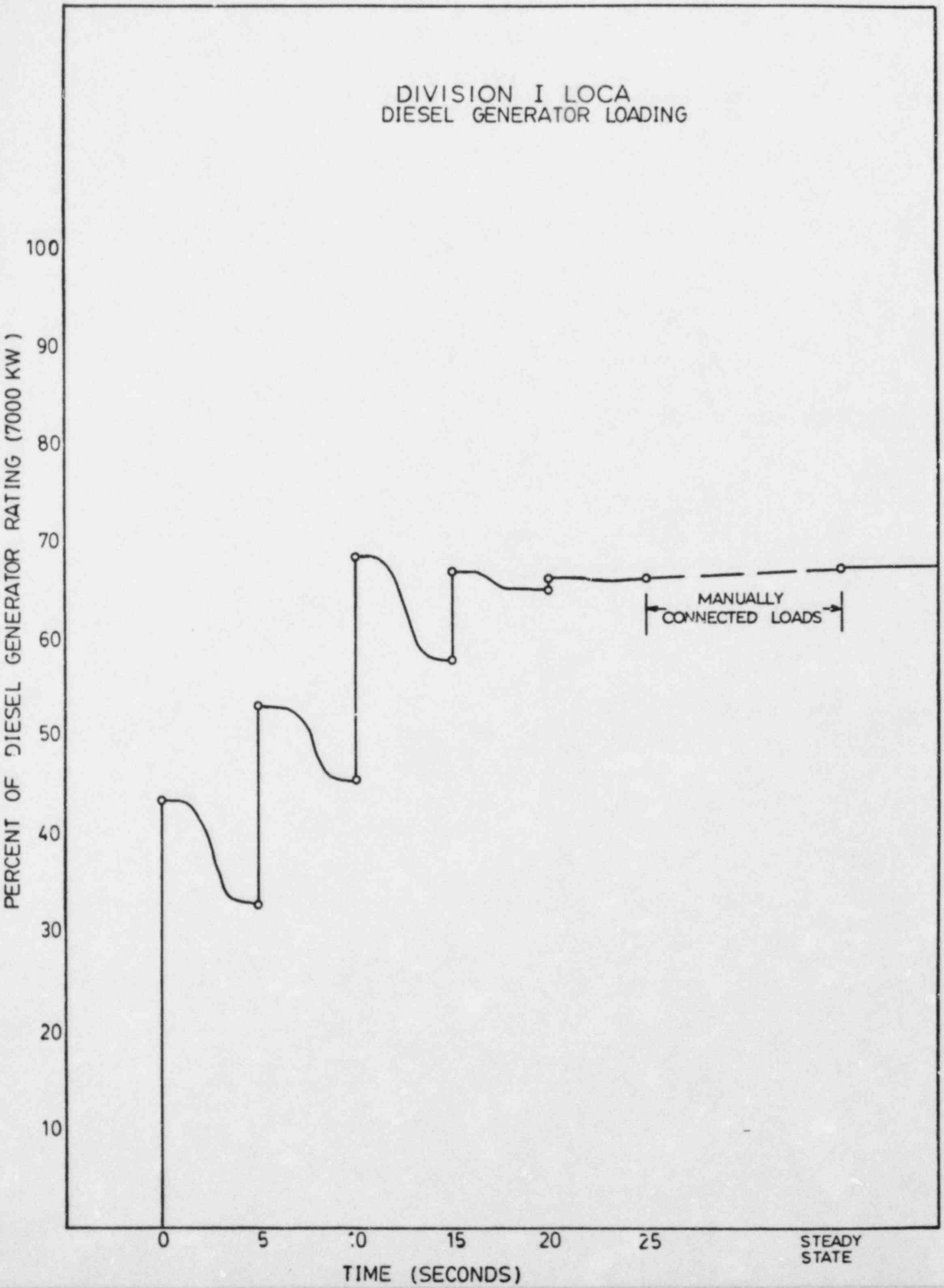
For Division II, the load required during LOCA is roughly 800 KW lower than that of a LOSP. This is due largely to the presence of several non-1E loads on the bus during a LOSP, such as instrument air, component cooling water, and drywell chillers.

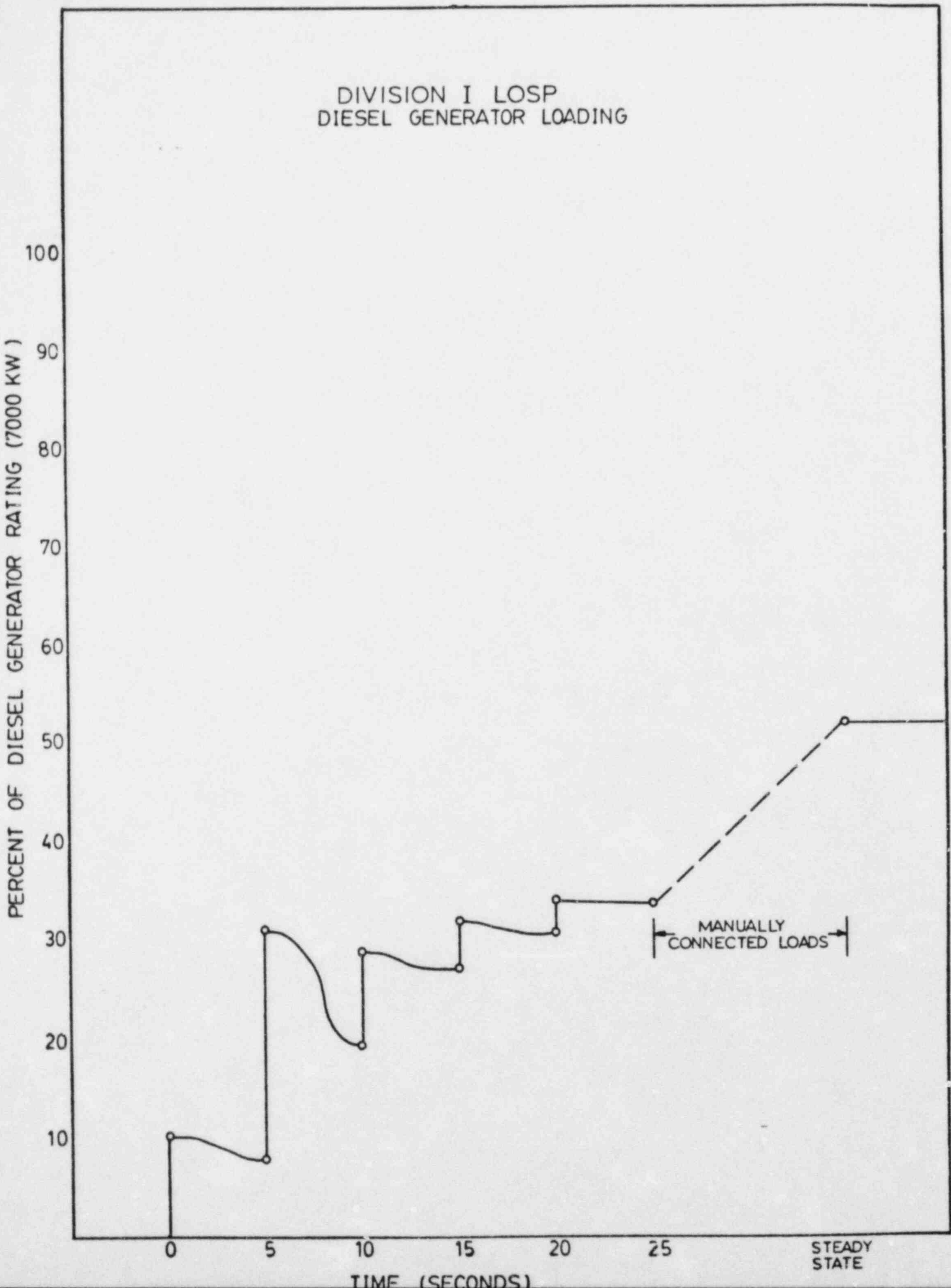
1) Division II loads required only for LOCA

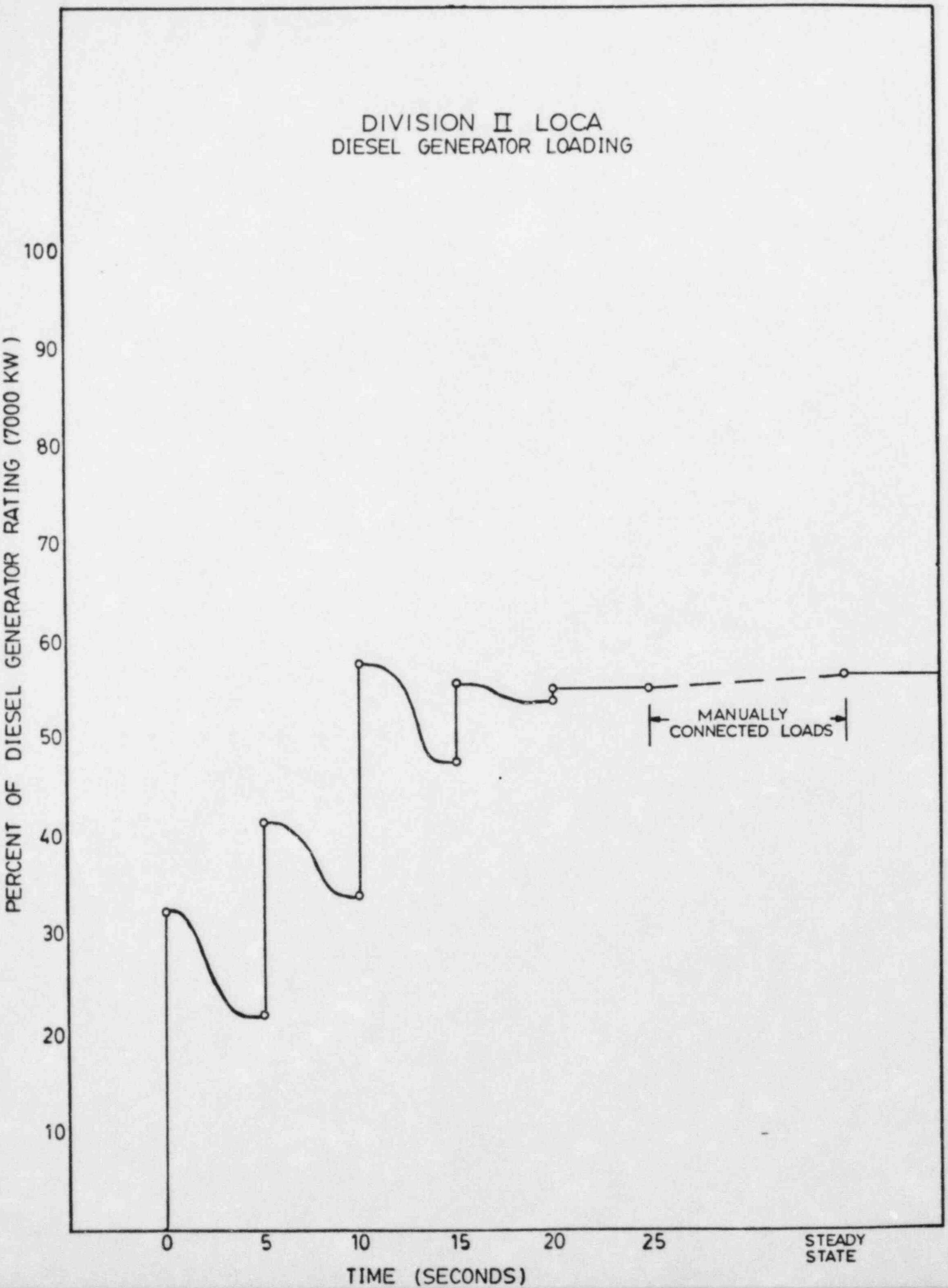
   RHR C Pump
   Control Room Emergency Ventilation
   Hydrogen Recombiner
   Enclosure Building Recirc Fan
   Drywell Purge Compressor
   SGTS
   SLCS pump

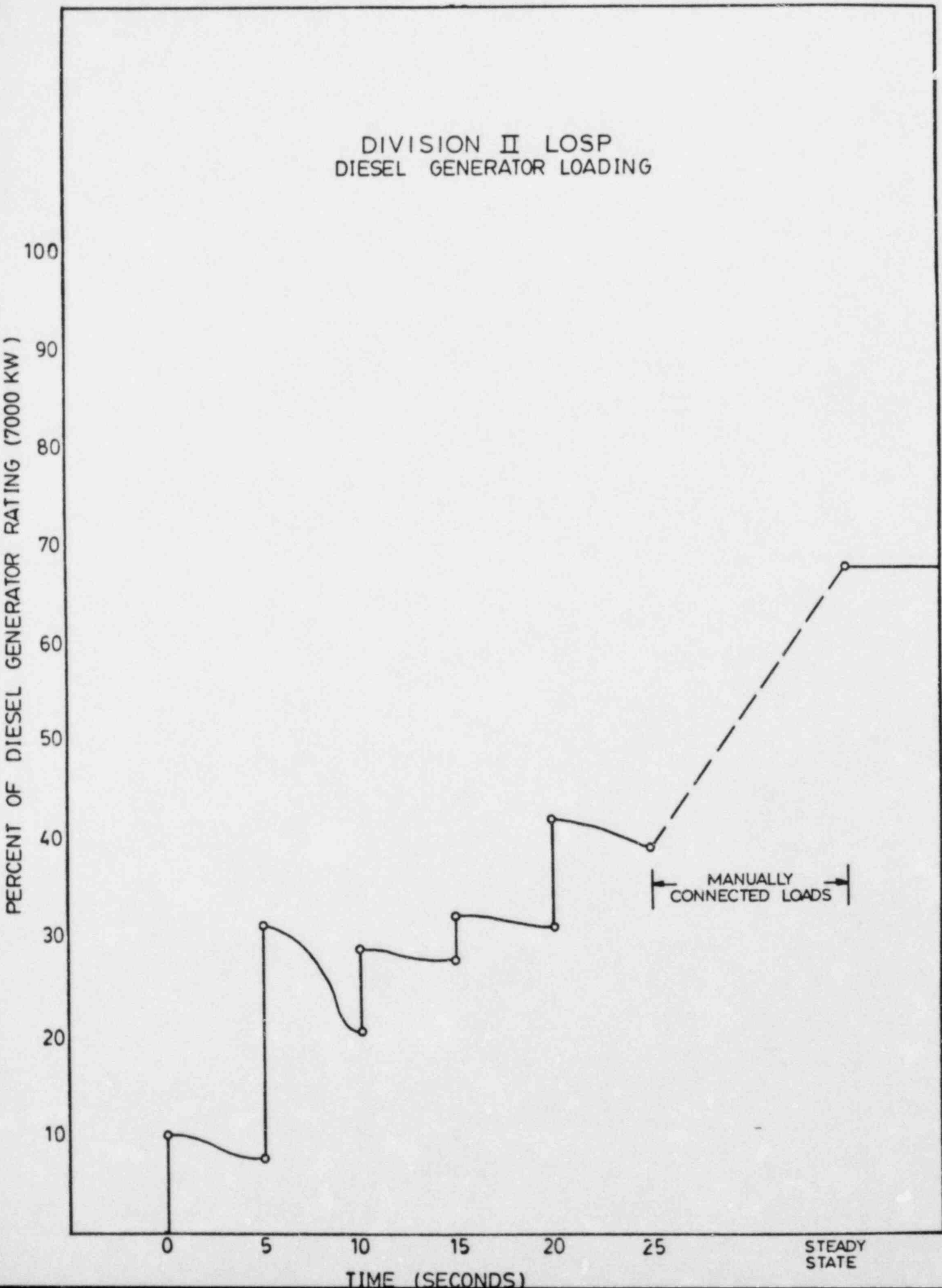
2) Division II loads required only for LOSP

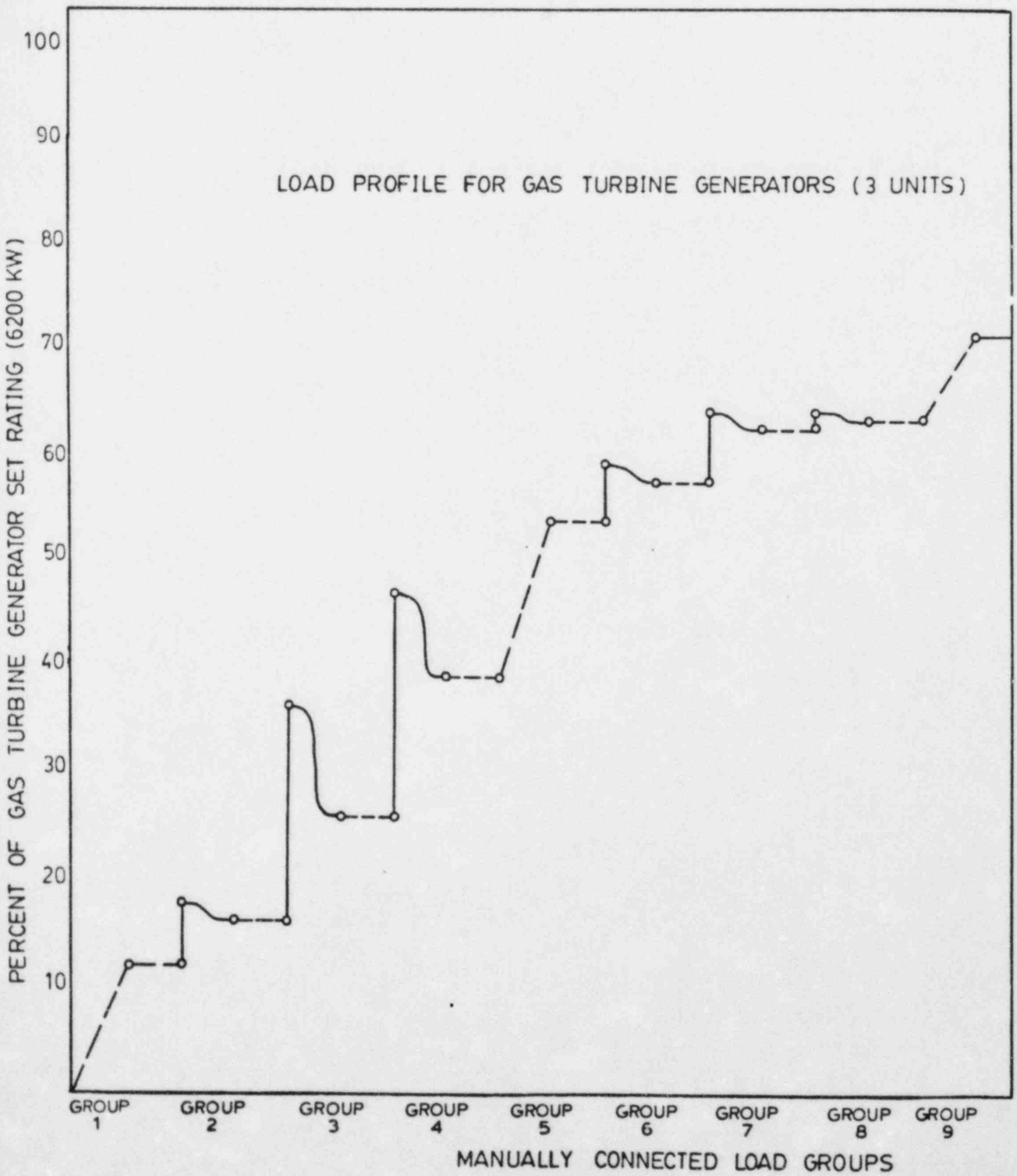
Instrument Air Compressor
Component Cooling Water Pump
Drywell Chillers
Plant Lighting
Non-1E Battery Chargers
CRD Pump
Drywell Coolers
Fuel Pool Cooling Pump
Switchyard Feeder
Inverter Backup Transformers
RPS Backup Transformers


DIVISION I LOCA
DIESEL GENERATOR LOADING
PERCENT OF DIESEL GENERATOR RATING (7000 KW)
100
90
80
70
60
50
40
30
20
10
MANUALLY
CONNECTED LOADS
0
5
10
15
20
25
STEADY
STATE
TIME (SECONDS)


DIVISION I LOSP
DIESEL GENERATOR LOADING
PERCENT OF DIESEL GENERATOR RATING (7000 KW)
100
90
80
70
60
50
40
30
20
10
MANUALLY CONNECTED LOADS
0
5
10
15
20
25
STEADY STATE
TIME (SECONDS)


DIVISION II LOCA
DIESEL GENERATOR LOADING
PERCENT OF DIESEL GENERATOR RATING (7000 KW)
100
90
80
70
60
50
40
30
20
10
MANUALLY CONNECTED LOADS
0
5
10
15
20
25
STEADY STATE
TIME (SECONDS)


DIVISION II LOSP
DIESEL GENERATOR LOADING
PERCENT OF DIESEL GENERATOR RATING (7000 KW)
100
90
80
70
60
50
40
30
20
10
MANUALLY CONNECTED LOADS
0
5
10
15
20
25
STEADY STATE
TIME (SECONDS)

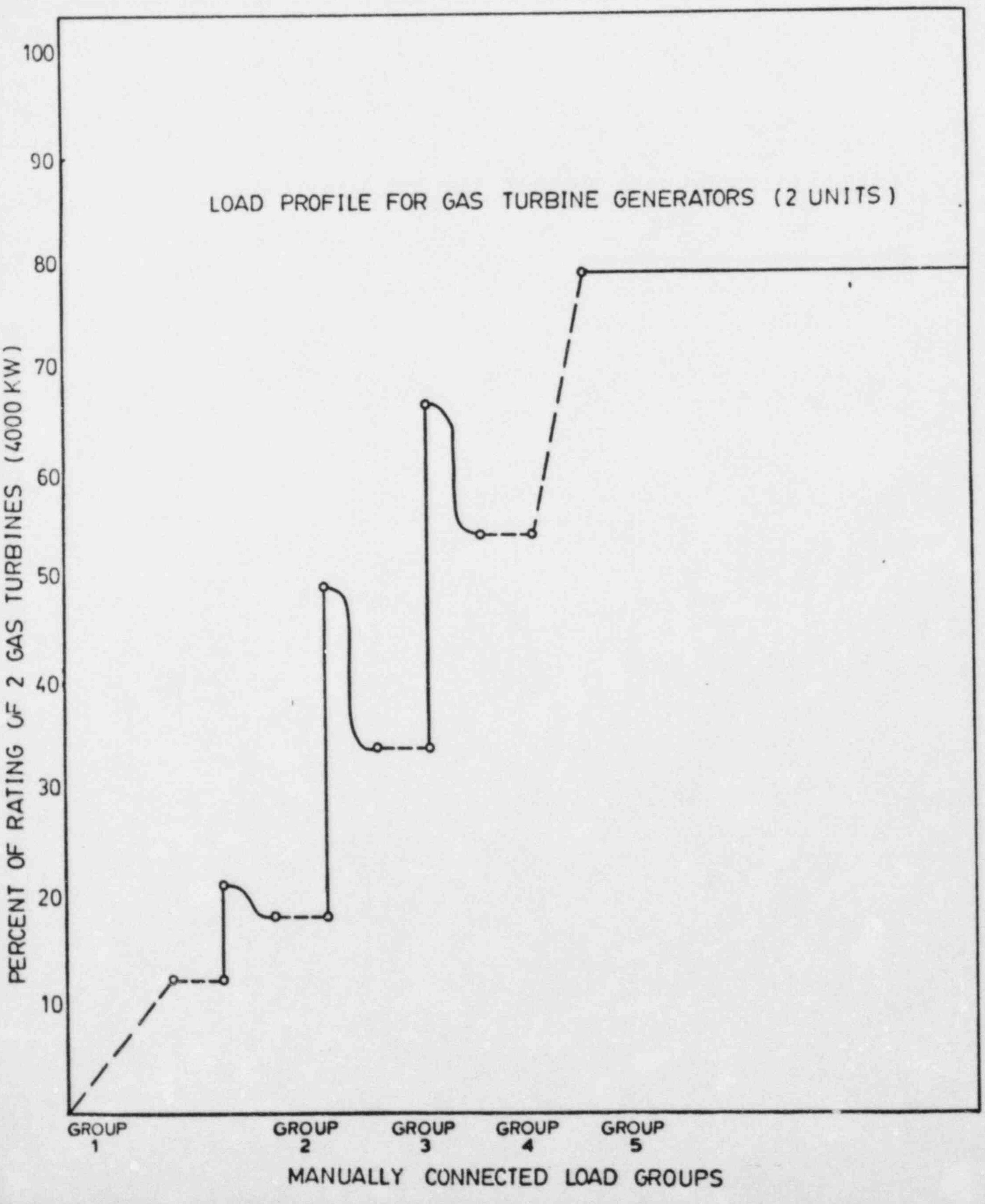

LOAD PROFILE FOR GAS TURBINE GENERATORS (3 UNITS)
PERCENT OF GAS TURBINE GENERATOR SET RATING (6200 KW)
100
90
80
70
60
50
40
30
20
10
GROUP 1
GROUP 2
GROUP 3
GROUP 4
GROUP 5
GROUP 6
GROUP 7
GROUP 8
GROUP 9
MANUALLY CONNECTED LOAD GROUPS

LOAD GROUPS FOR GAS TURBINE GENERATORS (3 UNITS)

	KW
Group 1	
Plant Lighting	15
Control Room Lighting	15
Class 1E Battery Chargers	55
Jockey Pumps	10
ECCS Pump Room Coolers	8
SSW O/A Fans	80
Switchgear Room HVAC	384
Power Panels	180
	747
Group 2	
SSW Cooling Tower Fans	244
Group 3	
SSW Pump	639
Group 4	
RHR Pump	803
Group 5	
Drywell Chillers	660
Drywell Coolers	120
Control Room HVAC	153
	933
Group 6	
Instrument Air Compressor	233
Group 7	
Control Rod Drive Pump	325
Group 8	
Component Cooling Water Pump	100
Group 9	
Switchyard Feeder	100
Non-1E Battery Chargers	165
RPS MG Backup Xfmr	25
Power Panel 16P42	30
Inverter Backup Transformers	90
	410

Total 4,434 KW

NOTE: Group 1 loads may be already connected when the bus is energized unless they have been manually disconnected prior to energization. The remaining groups are manually loaded in this order to prevent multiple pump starts at the same time.


LOAD PROFILE FOR GAS TURBINE GENERATORS (2 UNITS)
PERCENT OF RATING OF 2 GAS TURBINES (4000 KW)
100
90
80
70
60
50
40
30
20
10
GROUP 1
GROUP 2
GROUP 3
GROUP 4
GROUP 5
MANUALLY CONNECTED LOAD GROUPS

LOAD GROUPS FOR GAS TURBINE GENERATORS (2 UNITS)

	KW
Group 1	
Plant Lighting	15
Control Room Lighting	15
Class 1E Battery Chargers	55
Jockey Pumps	10
ECCS Pump Room Coolers	8
SSW O/A Fans	80
Switchgear Rooms HVAC w/o Htrs	134
Power Panels	180
	497
Group 2	
SSW Cooling Tower Fans	224
Group 3	
SSW Pump	639
Group 4	
RHR Pump	803
Group 5	
Drywell Chillers	660
Drywell Coolers	120
Control Room HVAC	153
RPS MG Backup Xfmr	25
Power Panel 16P42	30
	988

Total 3,171 KW

GAS TURBINE/DIESEL GENERATOR RELIABILITY EVALUATION

1.0 Objective

The purpose of the evaluation is to determine to what extent the gas turbines can offset a postulated degradation in the reliability of the TDI diesel generators.

2.0 Scope

In this limited evaluation, only the reliabilities of the major elements of the AC power system are addressed. That is, the diesel generator system, gas turbines, and gas turbine starting system. The reliabilities of circuit breakers, load sequencers, human error, are not addressed within this study. However, neglecting these contributions should not affect the basic conclusions since these elements would be present to some degree in both the diesel generator system and gas turbine systems.

There are two scenarios to be examined in determining the extent to which the gas turbines can compensate for the diesel generator. The two scenarios are loss of offsite power (LOSP) and a large LOCA. The most probable scenario is the LOSP which will be of primary interest. For the LOCA case, the performance and availabilities of the diesel generators or gas turbines are only relevant for the very improbable scenario of a large LOCA with a concurrent LOSP.

3.0 Assumptions and Data

This section includes a list of the assumptions and a tabulation of data used in the evaluation.

3.1 No credit is taken for using the HPCS-diesel generator to mitigate the loss of offsite power event.

3.2 The most likely value for gas turbine reliability is based on an evaluation of the data presented in Table 1 and on an examination of individual unit availabilities presented in Reference 6.3.

3.3 Each gas turbine has a separate auxiliary power unit (APU) for starting. However, a single APU can be used to start any of the gas turbines.

Table 1: Reliability of Gas Turbines

Identification	Size (MW)	Starting Reliability (%)	Availability (%)	Reference
Lilco/Holbrook (Top 25%)	27.5	93.6 (98.6)	93.4 (95.3)	6.1
Allison Gas Turbine Div.	≤2.2	~95	95+	6.2
All Gas Turbines in NERC Data base	1-19	84+	95.6*	6.3

+ Starting reliability tends to decrease with increasing unit size
* Calculated operating availability

4.0 Evaluation

The following reliability evaluation will first examine whether the gas turbines need to compensate for diesel generators in the large LOCA accident scenario. The evaluation will then investigate the reliability required from the TDI diesel generators as a function of gas turbine reliability for the loss of offsite power event.

4.1 Large LOCA

In the case of a large LOCA with concurrent loss of offsite power and the unavailability of the diesel generators, the gas turbine-supplied power could not be available in the short time period ($\leq$30 sec) required. However, because there is no evidence that the loss of GGNS from the grid would produce a LOSP, the following discussion will show the probability of this scenario is so small as to be considered incredible. Since it is conservatively estimated that it would take 30 minutes to start and synchronize the gas turbine, the exposure period for a LOCA with concurrent LOSP when the gas turbines would be incapable of mitigating the loss of Division I, II, and III diesel generators is 30 minutes.

The probability of LOSP in any one-half hour period can be extrapolated from the yearly frequency of loss of offsite power. From Reference 6.4, a conservative frequency of LOSP is .2/yr; therefore, assuming a flat probability distribution over a year, the probability of a LOSP in any 30 minute period is 1.14E-5. The following Boolean expression can be written to represent the core melt probability resulting from failures in the AC power system.

$$P(CM) = P(LOCA)*[P(LOSP; <.5\ hr.)*P(DG1)*P(DG2)*P(DG3)+ P(LOSP, >.5hr)*P(DG1)*P(DG2)*P(DG3)*P(2/3GT)] \quad (1)$$

Looking at the situation where offsite power is lost in the first half hour and even assuming the TDI diesels are completely unavailable (i.e., $P_{failure} = 1$).

$$P(CM) = (10^{-4})(1.14E-5)(1)(1)(3.6E-2)$$
$$P(CM)=4.1E-11$$

Therefore, the contribution to the core melt probability resulting from a LOCA concurrent with loss of offsite power is so small as to be considered an incredible event.

Clearly, this is not the true core melt probability since other component and system failures could result in a failure to cool the core. However, the goal in this evaluation is to determine the performance and reliability requirements for the gas turbines and diesel generators.

4.2 Loss of Offsite Power

The more probable LOSP event will be used to examine to what extent the gas turbines can offset a degradation in diesel generator reliability. Figure 1 represents a simple fault tree representation of the on-site AC power system if only Division I and II diesel generators were available. The top event is defined as failure of two out of two diesel generators (DG) to start and run for an hour (Note: One hour is consistent with testing requirements in Reg. Guide 1.108. Also, as used in this evaluation, the one hour duration is more conservative than a more encompassing four hour duration.). Based on Reference 6.5, the generic failure probability for a DG to start and run for one hour is .033 per demand. Therefore, using the Boolean expression for the fault tree logic represented in Figure 1, a conservative goal probability for the loss of on-site power (LOP) is:

$$P(LOP) = P(DG1)P(DG2) \qquad (2)$$

$$P(LOP) = (.033)^2 = 1\times10^{-3} \text{ per demand}$$

This is a conservative goal because the actual probability for loss of onsite power is closer to four times higher, Reference 6.1. The higher value is due to the contribution from other failures in the Division I and II emergency AC power supply (e.g., standby service water, human error, maintenance outage).

Case 1: Three out of Three (3/3) Gas Turbines

Figure 2 shows the fault tree representation of the failure logic for an on-site AC power system which includes the gas turbines. The fault tree shown in Figure 2 assumes that three out of three gas turbines would need to operate to compensate for the unavailability of Division I and II diesel generators. Again, no credit is taken for the HPCS-diesel generator. The following Boolean expression for the probability of loss of on-site power can be written for the configuration represented in Figure 2.

$$LOP = DG1*DG2*[(GT1+GT2+GT3)+(APU)^3] \qquad (3)$$

where

LOP = probability of loss of on-site AC power

DG1=DG2 = .033

GT1=GT2=GT3 = probability of failure (unavailability) of gas turbines

APU=APU1=APU2=APU3 = unavailability of starting units

The probabilities for the loss of gas turbines and auxiliary power units (APU) were based on an evaluation of data in References 6.1, 6.2, and 6.3. The $(APU)^3$ term is small enough to be neglected in further discussion.

Equation 3 can be solved to calculate a loss of on-site power probability. However, since we are interested in knowing how far the diesel generator reliability could degrade and still be able to meet the 10^{-3} probability goal for failure of on-site power, we solve this equation for the required DG reliability. Therefore, for the case of three out of three gas turbines required for success:

$$(DG)^2 = LOP/3GT$$

$$DG = \sqrt{LOP/3GT}$$

Case 2: Two Out of Three Gas Turbines Required for Success

In order to model the two out of three (2/3) case, the binomial equation is used:

$$P\binom{n}{x} = \sum_{s=x}^{n} \frac{n!}{s!(n-s)!} (A_{GT})^s (1-A_{GT})^{n-s} \qquad \text{(Ref. 6.6)}$$

$P\binom{n}{x}$ = probability of at least x successes in n trials

A_{GT} = availability of gas turbine

For this case, x=2 and n=3.

For A_{GT} = .90

$$P\binom{3}{2} = 3(.90)^2(.10)+1(.90)^3=.972$$

For A_{GT} = .95

$$P\binom{3}{2} = 3(.95)^2(.05)+1(.95)^3=.992$$

Using the same approach as in Case 1, the goal probability is assumed to be 10^{-3} per demand (i.e., LOSP).

$$DG = \sqrt{LOP/P(2/3GT)}$$

where

DG = unavailability of diesel generator

LOP = probability of LOP (10^{-3})

P(2/3GT) = unavailability of 2 out of 3 gas turbines, $1-P\binom{3}{2}$

Then, for A_{GT} = .95 → P(2/3GT) = .008, and

$$DG = \sqrt{10^{-3}/8.0E-3} = .35$$

The required diesel generator reliability (i.e., 1-DG) is then .65 or 65 percent.

5.0 Results and Conclusions

For the case of loss of offsite powcr and assuming no credit for the HPCS-diesel generator (Div. III), the reliability of the installed gas turbines would allow the reliability of the TDI diesel generators to degrade to the values shown in Table 2.

Table 2
Required Diesel Generator Reliability vs. Gas Turbine Reliability

Gas Turbine Reliability (%)	Required DG Reliability (%)
90 (3 out of 3)	94.2
95 (3 out of 3)	91.8
90 (2 out of 3)	81.0
95 (2 out of 3)	65.0
97 (2 out of 3)	34.0

If a more detailed evaluation were performed which accounted for Grand Gulf's station blackout capability, the other contributors to on-site power failures and the likelihood of rapid restoration of offsite power, the required diesel generator reliability could be significantly lower than the value given in Table 2.

Since the data in Table 1 supports assuming a gas turbine start and run reliability of 95 percent and since a two out of three success criteria appears to be supportable for the gas turbines, the TDI diesel generators need only have a reliability of 65 percent. Given the recent experience with the TDI diesels at GGNS, a reliability significantly higher than 65 percent can be supported for those diesel generators.

6.0 References

6.1 "High-Reliability Gas Turbine Combined-Cycle Development Program: Phase 1," EPRI AP-1599, October 1980 (Table 402).

6.2 Telephone conversation with Dan Marinacci of O'Brian Machinery. He obtained the information from calling Jim Strother (Application Engineer for 501 Unit) of the Allison Division. Mr. Strother's estimate of gas turbine availability was based on an assumption of "Good maintenance, clean air, and clean fuel." He thought the air power unit (or ground power unit), manufactured by Garrett Ind. had at least a 95 percent reliability.*

6.3 "Equipment Availability Report 1972-1981," Generating Availability Data System, North American Electric Reliability Council (NERC), 1983.

6.4 "Reactor Safety Study Methodology Applications Program: Grand Gulf No. 1 BWR Power Plant," by Sandia National Laboratories from US NRC, NUREG/CR-1659/4, October 1981.

6.5 "Interim Reliability Evaluation Program Procedures Guide," Sandia National Laboratories from US NRC, NUREG/CR-2728, January 1983.

6.6 Fault Tree Handbook, US NRC, NUREG-0492, January 1981.

*Dan Marinacci contacted Garrett Ind. and was informed that the auxiliary power unit (APU) has a MTBF of 500 hours. This translates to 3,000 starts (10 minutes each) before failure or a failure probability of 3.3E-4 per demand.

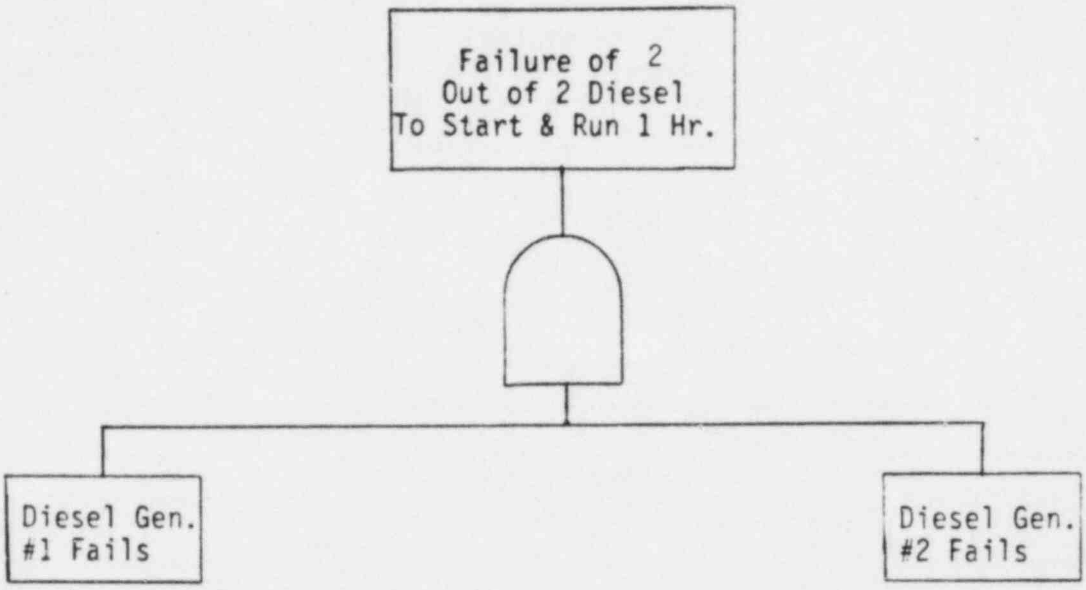

Failure of 2
Out of 2 Diesel
To Start & Run 1 Hr.
Diesel Gen.
#1 Fails
Diesel Gen.
#2 Fails

Figure 1

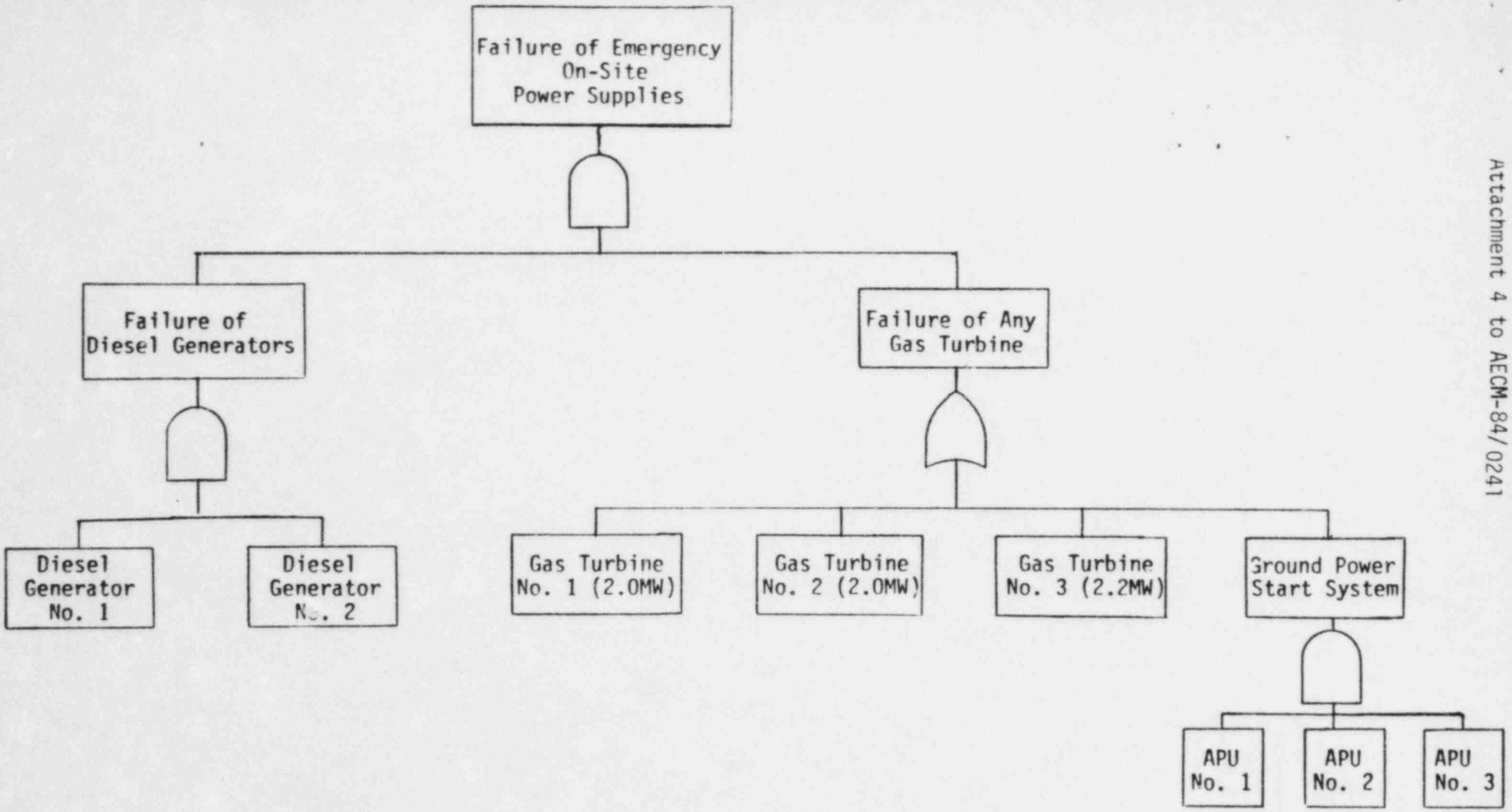


Figure 2
Simplified Fault Tree of On-Site AC Power