RIVER BEND STATION

PRELIMINARY EQUIPMENT SURVIVABILITY REPORT

GULF STATES UTILITIES COMPANY

RIVER BEND STATION, UNIT 1

JULY, 1985

TABLE OF CONTENTS

1.0 SUMMARY

This report identifies and locates the essential equipment which must survive a degraded core hydrogen burn transient. Representative pieces of this equipment have been analyzed to demonstrate that either the casing surface temperature or the sentive internal component temperature does not exceed the known qualification temperature limit. This report provides further evidence to support interim operation at full power until a final analysis is completed.

2.0 INTRODUCTION

2.1 SURVIVABILITY ANALYSIS GOAL

In the unlikely event of a degraded core accident, certain pieces of equipment would be required to function in order to monitor the course of the accident, return the core to a safe condition, maintain containment integrity, and mitigate the consequences of the event. The containment and drywell environments during a degraded core event are characterized by high concentrations of hydrogen produced by the zirconium-water reaction in the reactor core region. The hydrogen igniter system is designed to ignite the hydrogen atmosphere at low hydrogen concentrations to prevent threats to containment structural integrity. Equipment which is required to survive a hydrogen burn and which is located in containment or drywell may be exposed to high temperatures. Therefore, the goal of the River Bend Station (RBS) essential equipment survivability analysis is to demonstrate that the essential equipment will perform its necessary safety functions during or following exposure to the degraded core hydrogen burn thermal conditions.

All essential equipment must be shown to survive the hydrogen burn environment. Equipment which is located in areas of high temperature and which cannot be shown to survive may require thermal shielding, relocation, or replacement with a higher rated piece of equipment.

2.2 APPROACH

The approach toward demonstrating equipment survivability involves four distinct steps. The first and most basic step is the determination of the list of equipment to be considered. The second step is the determination of the hydrogen burn thermal environment. The third step is the analytic prediction of the thermal response of the equipment. The final step is the determination of survivability.

Selection of the equipment to be considered as essential equipment is discussed in Section 2.4 of this report. The selection criteria, also described in Section 2.4, are consistent with those specified by the Hydrogen Control Owners' Group (HCOG) in the April 27, 1984, Survivability Guide (Reference 2).

The definition of the thermal environment to be considered for each piece of equipment is dependent upon the accident scenario and the in-plant location of the equipment. The hydrogen burn thermal environment for RBS is described in Section 3.0.

Section 4.0 describes the equipment thermal response analyses and the development of the equivalent thermal models for the essential equipment. The thermal models include the heat sensitive components and appropriate geometric features of the equipment.

The survivability of individual pieces of equipment is ensured if the surface temperature of the equipment remains below the

qualification temperature. If the outer surface temperature exceeds the qualification temperature, focus will be placed on the temperature-sensitive nonmetallic internal materials or subcomponents. These materials have also been exposed to the maximum qualification temperature during the typical 3-hr to 6-hr soak time in qualification testing. In this case, equipment survivability is ensured if the predicted temperature of the most thermally sensitive internal material is less than either the maximum qualification temperature or the maximum service temperature identified by the material manufacturer.

2.3 ACCIDENT DESCRIPTION

River Bend analyses of design basis accidents, conducted in accordance with 10CFR50, predict that the maximum metal-water reaction after a LOCA will involve less than 1 percent of the outer 23 mils of active fuel cladding. However, the TMI event demonstrated that nondesign basis scenarios can produce much more extensive metal-water reactions. To account for the TMI experience, the NRC's final rule, published in 10CFR50, requires consideration of a 75-percent metal-water reaction and the associated hydrogen release. The rule specifies the quantity of hydrogen to be considered but did not specify the accident scenario postulated to produce the hydrogen.

Task 1 of the HCOG program plan evaluated several degraded core accident scenarios (Reference 3). The accidents selected for consideration as hydrogen generation events are based upon both deterministic and probabilistic considerations. One objective for accident selection was to determine the most likely accident scenario which would produce a significant hydrogen release without core melt. In addition, accident scenarios which would challenge the structural integrity of both the drywell and the containment were investigated. Based upon these considerations, the following two accident scenarios are considered.

The first accident considered is a transient-initiated stuck open relief valve (SORV) event, with core cooling delayed until significant hydrogen is produced. Core cooling would be delayed until the operator has depressurized the reactor vessel using the automatic depressurization system (ADS) valves. This accident represents one of the dominant event sequences which could lead to a degraded core condition. The SORV event would challenge the integrity of the containment because all hydrogen produced would be released by the SORV and ADS valves through the suppression pool and into the containment atmosphere.

The second accident scenario selected is a small or intermediate size steam line break. This scenario is similar to the SORV case in that the operator would depressurize the reactor vessel using the ADS before core cooling water is restored. In this case, hydrogen is released directly to the drywell from the pipe break and to the containment through the ADS valves. Consequently, this scenario challenges the integrity of the drywell.

2.4 ESSENTIAL EQUIPMENT

Essential equipment is defined as systems and components that are exposed to a hydrogen burn event and are required to function during or after the burn event. The RBS essential equipment list was developed in accordance with the HCOG generic criteria, which are restated below. Plant systems and components were compared to the criteria; systems and components meeting one or more of the criteria were placed on the essential equipment list (Table 2.4-1).

The following are the criteria for inclusion on the survivability list:

1. Equipment and systems required to mitigate the consequences of the event.

2. Equipment and structures required to maintain the integrity of the containment pressure boundary.

3. Systems and components required to recover the core.

4. Instrumentation and systems required to monitor the course of the accident.

The effects of hydrogen combustion are limited to the containment and drywell. Only equipment located in these two compartments has been evaluated for inclusion on the survivability list. Figure 2.4-1 shows the approximate locations of the RBS essential equipment with the exception of the hydrogen igniters and hydrogen recombiners.

In addition, some components have been excluded from the essential equipment list based on their failure mode or active safety function prior to exposure to the hydrogen burn environment. Degraded core accidents evolve over a relatively long period of time before zircaloy oxidation begins. Many components will have performed their safety function before hydrogen combustion can begin. If these components are not required to function during or after hydrogen combustion, and if failure of the component will not compromise plant safety, then the component is not required to survive these accidents.

Specific exclusions used in developing the RBS equipment list are as follows:

1. Components which have performed their active safety function prior to a hydrogen burn.

2. Isolation valves which remain in the closed position, i.e., fail closed or "as is."

3. Isolation valves which are open during post-LOCA, fail in the "as is" position and have a redundant motor-operated isolation valve outside containment for functional backup.

4. Check valves which are qualified for reactor pressure and temperature with no safety-related instrumentation or electrical function are assumed to survive a hydrogen burn mechanically.

5. Equipment and/or components which fail in a safe condition with no subsequent functional requirement.

6. Manually operated valves or dampers which remain in the "as is" position (i.e., normally open or normally closed).

TABLE 2.4-1

EQUIPMENT REQUIRED TO SURVIVE A HYDROGEN BURN

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
DRYWELL								
Automatic Depressurization System (ADS)								
1B21*RVF041B	Main Steam Safety/	Crosby 8 x R x 10,	DW-1	132' 5"	278°	23' 10"	330°F	340°F
1B21*RVF041C	Relief Valves (ADS)	Style HB-65-DF	DW-1	132' 5"	88°	21' 7"		340°F
1B21*RVF041D			DW-1	132' 4"	309°	19' 0"		340°F
1B21*RVF041F	Depressurize Reactor		DW-1	132' 4"	297°	25' 6"		340°F
1B21*RVF047A	Vessel		DW-1	132' 3"	34° 30'	19' 8"		340°F
1B21*RVF047C			DW-1	132' 4"	70° 30'	24' 9"		340°F
1B21*RVF051G			DW-1	132' 4"	57° 30'	25' 2"		340°F
HCS Hydrogen Igniter System								
1HCS*IGN49A	Hydrogen Igniter	Power Systems Model 6043	DW-1	116' 8"	354.5°	26' 0"	330°F	340°F
1HCS*IGN49B	Ignite Hydrogen/Air		DW-1	116' 6"	66.8°	20' 11"	330°F	340°F
1HCS*IGN50A	Combustible Mixture		DW-1	116' 7"	113.4°	21' 2"	330°F	340°F
1HCS*IGN50B	During Degraded Core		DW-1	116' 7"	180°	21' 0"	330°F	340°F
1HCS*IGN51A	Event		DW-1	115' 2"	247.3°	20' 10"	330°F	340°F
1HCS*IGN51B			DW-1	116' 6"	292.9°	21' 2"	330°F	340°F
1HCS*IGN40B			DW-1	133' 1"	359.2°	18' 10"	330°F	340°F
1HCS*IGN41A			DW-1	139' 10"	60.4°	21' 9"	330°F	340°F
1HCS*IGN41B			DW-1	135' 5"	129.9°	21' 10"	330°F	340°F
1HCS*IGN42A			DW-1	138' 11"	179.0°	23' 0"	330°F	340°F
1HCS*IGN42B			DW-1	135' 10"	240°	22' 0"	330°F	340°F
1HCS*IGN40A			DW-1	138' 8"	293.3°	25' 0"	330°F	340°F
1HCS*IGN28A			DW-1	156'	0°	24' 8 1/2"	330°F	340°F
1HCS*IGN28B			DW-1	156'	58.5°	23' 0"	330°F	340°F
1HCS*IGN29A			DW-1	156'	125°	21' 6"	330°F	340°F
1HCS*IGN29B			DW-1	156'	180°	25' 0"	330°F	340°F
1HCS*IGN30A			DW-1	156'	233°	22' 0"	330°F	340°F
1HCS*IGN30B			DW-1	156'	306°	21' 0"	330°F	340°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
CMS Drywell Temperature Instruments								
1CMSXRTD41A	Resistance Thermal Detectors	Pyco, Inc.	DW	141' 0"	28°	34.47'	330°F	430°F
1CMSXRTD41B			DW	141' 0"	243°	34.47'	330°F	430°F
1CMSXRTD41C			DW	141' 0"	138°	34.47'	330°F	430°F
1CMSXRTD41D			DW	141' 0"	300°	34.47'	330°F	430°F
CONTAINMENT								
CMS Containment Atmosphere Monitoring								
1CMS*SOV33E	Containment Atmosphere Sampling	Solenoid Valve, Target Rock TRCP 77KK-003	CT-G	190' 9"	56° 30'	58' 9"	165°F	385°F
1CMS*SOV33F			CT-G	190' 9"	235°35'	59' 6"	165°F	385°F
1CMS*SOV34A	Drywell Atmosphere Sampling	Solenoid Valve, Target Rock TRCP 77KK-003	CT-G	154' 3 1/2"	140°	40' 6"	165°F	385°F
1CMS*SOV34B	Drywell Atmosphere Sampling	Solenoid Valve, Target Rock TRCP 77KK-003	CT-G	154' 1 1/2"	319° 30'	40' 9"	165°F	385°F
CPM Containment Hydrogen Mixing								
1CPM*FN1A	Mixing Fan	Fan Motor, Buffalo Forge West TBFC 145T	CT-G	163' 9"	50°	33' 5"	165°F	212°F
1CPM*FN1B	Mixing Fan	Fan Motor, Buffalo Forge West TBFC 145T	CT-G	163' 9"	228°	35'	165°F	212°F
1CPM*MOV1A	Exhaust Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	163' 9"	53° 30'	35' 10"	165°F	340°F
1CPM*MOV1B	Exhaust Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	163' 9"	231° 15'	37' 4"	165°F	340°F
1CPM*MOV2A	Supply Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	117' 6"	176° 30'	42' 11"	165°F	340°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
CPM Containment Hydrogen Mixing (Cont)								
1CPM*MOV2[illegible]	Supply Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	129' 5 3/8"	328°	42' 3"	165°F	340°F
1CPM*MOV3A	Exhaust Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	163' 9"	56°	37' 11"	165°F	340°F
1CPM*MOV3B	Exhaust Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	163' 9"	233° 30'	39' 2"	165°F	340°F
1CPM*MOV4A	Supply Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	117' 6"	173°	43' 2"	165°F	340°F
1CPM*MOV4B	Supply Valve	Motor-Operated Valve, Posi-Seal LMTQ SMB-000-2	CT-G	129' 5 3/8"	325° 15'	41' 6"	165°F	340°F

NOTE: Hydrogen mixing system is only required in long term for removal of residual hydrogen from drywell.

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
E12 Residual Heat Removal								
1E12*MOVF042A	LPCI Injection	Motor-Operated Valve, Velan LMTQ SB-2-60	CT-G	121' 7"	35°	48' 0"	165°F	340°F
1E12*MOVF042B	LPCI Injection	Motor-Operated Valve, Velan LMTQ SB-2-60	CT-G	122' 0"	321°	44' 8"	165°F	340°F
HCS Hydrogen Recombiner								
1HCS*RBNR1A	Hydrogen Recombiner	Hydrogen Recombiner, Westinghouse West Model 4B	CT-G	186' 3"	80°	54'	165°F	330°F
1HCS*RBNR1B	Hydrogen Recombiner	Hydrogen Recombiner, Westinghouse West Model 4B	CT-G	186' 3"	315°	51'	165°F	330°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Hydrogen Igniter System								
1HCS*IGN52A	Hydrogen Igniter	Power Systems Model 6043	CT-G	179' 3"	80° 30'	30' 3"	165°F	340°F
1HCS*IGN52B	Ignite Hydrogen/Air		CT-G	179' 3"	138° 50'	33' 2"	165°F	340°F
1HCS*IGN43B	Combustible Mixture		CT-G	108' 6"	5°	39' 6"	165°F	340°F
1HCS*IGN44A	During Degraded Core		CT-G	112' 5"	39°	44' 6"	165°F	340°F
1HCS*IGN44B	Event		CT-G	109' 0"	65°	39' 6"	165°F	340°F
1HCS*IGN45A			CT-G	110' 0"	95°	39' 6"	165°F	340°F
1HCS*IGN45B			CT-G	112' 5"	117°	42' 2"	165°F	340°F
1HCS*IGN46A			CT-G	112' 5"	155°	44' 6"	165°F	340°F
1HCS*IGN46B			CT-G	112' 5"	176°	41' 6"	165°F	340°F
1HCS*IGN47A			CT-G	112' 5"	204°	41' 6"	165°F	340°F
1HCS*IGN47B			CT-G	112' 5"	244°	43' 0"	165°F	340°F
1HCS*IGN48A			CT-G	109' 6"	268°	39' 6"	165°F	340°F
1HCS*IGN48B			CT-G	108' 6"	297°	39' 6"	165°F	340°F
1HCS*IGN43A			CT-G	108' 9"	330°	39' 6"	165°F	340°F
1HCS*IGN32B			CT-G	126' 0"	30°	60' 0"	165°F	340°F
1HCS*IGN34A			CT-G	126' 0"	180°	47' 0"	165°F	340°F
1HCS*IGN32A			CT-G	130' 0"	69°	60' 0"	165°F	340°F
1HCS*IGN33B			CT-G	126' 0"	90°	60' 0"	165°F	340°F
1HCS*IGN33A			CT-G	124' 0"	115°	60' 0"	165°F	340°F
1HCS*IGN24B			CT-G	128'	145°	51' 1"	165°F	340°F
1HCS*IGN35A			CT-G	136' 0"	155.1°	46' 7"	165°F	340°F
1HCS*IGN36A			CT-G	136' 0"	166.3°	56' 4"	165°F	340°F
1HCS*IGN34B			CT-G	139' 4"	209°	54' 2"	165°F	340°F
1HCS*IGN35B			CT-G	136' 0"	178.7°	45' 0"	165°F	340°F
1HCS*IGN36B			CT-G	136' 0"	185.6°	57' 3"	165°F	340°F
1HCS*IGN37A			CT-G	135' 0"	202.1°	39' 11"	165°F	340°F
1HCS*IGN37B			CT-G	134' 0"	201.3°	49' 5"	165°F	340°F
1HCS*IGN34B			CT-G	139' 4"	209°	54' 2"	165°F	340°F
1HCS*IGN38A			CT-G	139' 4"	240.5°	54' 0"	165°F	340°F
1HCS*IGN38B			CT-G	126' 0"	270°	60' 0"	165°F	340°F
1HCS*IGN39A			CT-G	126' 6"	298.5°	60' 0"	165°F	340°F
1HCS*IGN39B			CT-G	130'	328°	55' 5"	165°F	340°F
1HCS*IGN31A			CT-9	126'	341.9°	51' 6"	165°F	340°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Hydrogen Igniter System (Cont)								
1HCS*IGN31B	Hydrogen Igniter	Power Systems Model 6043	CT-9	126'	17.4°	53' 6"	165°F	340°F
1HCS*IGN22A	Ignite Hydrogen/Air		CT-G	150'	21.7°	51' 4"	165°F	340°F
1HCS*IGN22B	Combustible Mixture		CT-G	154'	63°	60' 0"	165°F	340°F
1HCS*IGN23A	During Degraded Core		CT-G	159' 6"	84°	60' 0"	165°F	340°F
1HCS*IGN23B	Event		CT-G	152' 0"	115°	60' 0"	165°F	340°F
1HCS*IGN24A			CT-G	154' 0"	153°	60' 0"	165°F	340°F
1HCS*IGN25A			CT-G	159' 6"	210°	50' 0"	165°F	340°F
1HCS*IGN25B			CT-G	151'	238°	60' 0"	165°F	340°F
1HCS*IGN26A			CT-5	157' 6"	247.5°	49' 6"	165°F	340°F
1HCS*IGN26B			CT-5	149' 0"	275.9°	48' 10"	165°F	340°F
1HCS*IGN27B			CT-G	152' 7"	294.8°	52' 3"	165°F	340°F
1HCS*IGN27A			CT-G	153' 4"	321.1°	46' 2"	165°F	340°F
1HCS*IGN21B			CT-7	167' 6"	4.0°	43' 5"	165°F	340°F
1HCS*IGN11A			CT-7	166' 6"	20.8°	50' 6"	165°F	340°F
1HCS*IGN11B			CT-G	173'	27°	48' 3"	165°F	340°F
1HCS*IGN13A			CT-G	167' 3"	52.1°	29' 2"	165°F	340°F
1HCS*IGN12A			CT-G	173' 6"	64°	57' 0"	165°F	340°F
1HCS*IGN12B			CT-G	176' 6"	88.9°	53' 0"	165°F	340°F
1HCS*IGN14A			CT-G	173'	115°	60' 0"	165°F	340°F
1HCS*IGN13B			CT-G	167' 3"	123.5°	32' 5"	165°F	340°F
1HCS*IGN14B			CT-G	169' 9"	153.9°	52' 3"	165°F	340°F
1HCS*IGN15B			CT-G	183' 6"	212°	56' 7"	165°F	340°F
1HCS*IGN18A			CT-11	173' 0"	235.3°	31' 7"	165°F	340°F
1HCS*IGN15A			CT-G	183' 6"	238°	56' 7"	165°F	340°F
1HCS*IGN17B			CT-5	172' 0"	240.5°	38' 6"	165°F	340°F
1HCS*IGN16A			CT-5A	173' 0"	249.3°	53' 6"	165°F	340°F
1HCS*IGN18B			CT-11	173' 0"	260.1°	23' 3"	165°F	340°F
1HCS*IGN19B			CT-11	174' 6"	282.3°	23' 6"	165°F	340°F
1HCS*IGN16B			CT-5A	172'	290.9°	53' 0"	165°F	340°F
1HCS*IGN17A			CT-5	170' 6"	298.4°	40' 0"	165°F	340°F
1HCS*IGN20A			CT-G	168'	293.9°	54' 1"	165°F	340°F
1HCS*IGN19A			CT-11	175' 6"	303.9°	31' 3"	165°F	340°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Hydrogen Igniter System (Cont)								
1HCS*IGN20B			CT-G	170'	319°	50' 10"	165°F	340°F
1HCS*IGN21A			CT-7	167' 4"	338°	48' 0"	165°F	340°F
1HCS*IGN1A			CT-G	255'	0°	20'	165°F	340°F
1HCS*IGN7B			CT-G	239'	0°	56'	165°F	340°F
1HCS*IGN3B			CT-G	250'	22.5°	38'	165°F	340°F
1HCS*IGN8A			CT-G	239'	45°	56'	165°F	340°F
1HCS*IGN4A			CT-G	250'	67.5°	38'	165°F	340°F
1HCS*IGN1B			CT-G	255'	90°	20'	165°F	340°F
1HCS*IGN8B			CT-G	239'	90°	56'	165°F	340°F
1HCS*IGN4B			CT-G	250'	112.5°	38'	165°F	340°F
1HCS*IGN9A			CT-G	239'	135°	56'	165°F	340°F
1HCS*IGN5A			CT-G	250'	157.5°	38'	165°F	340°F
1HCS*IGN2A			CT-G	255'	180°	20'	165°F	340°F
1HCS*IGN9B			CT-G	239'	180°	56'	165°F	340°F
1HCS*IGN5B			CT-G	250'	202.5°	38'	165°F	340°F
1HCS*IGN10A			CT-G	239'	225°	56'	165°F	340°F
1HCS*IGN6A			CT-G	250'	247.5°	38'	165°F	340°F
1HCS*IGN2B			CT-G	255'	270°	20'	165°F	340°F
1HCS*IGN10B			CT-G	239'	270°	56'	165°F	340°F
1HCS*IGN6B			CT-G	250'	292.5°	38'	165°F	340°F
1HCS*IGN7A			CT-G	239'	315°	56'	165°F	340°F
1HCS*IGN3A			CT-G	250'	337.5°	38'	165°F	340°F
HVR Ventilation - Reactor Plant								
1HVR*UC1A	Unit Cooler Mitigate Temperature Increase During Event and Return Temperatures to Normal Following Event	Unit Cooler Motor, Buffalo Forge West 445TCZ	CT-G	162' 3"	107°	47' 6"	165°F	212°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
HVR Ventilation - Reactor Plant (Cont)								
1HVR*UC1B	Unit Cooler	Unit Cooler Motor, Buffalo Forge West 445TCZ	CT-G	162' 3"	75°	47' 8"	165°F	212°F
JRB Superstructure - Reactor Building								
1JRB*DRA1	Cont. Personnel Airlock	Door Access, Graver Woolley	CT-G	175'	315°	73' 6"	165°F	342°F
1JRB*DRA2	Cont. Personnel Airlock	Door Access, Graver Woolley	CT-G	117' 10"	135°	73' 6"	165°F	342°F
1JRB*DRA3	Drywell Personnel Airlock	Door Access, Graver Woolley	CT-6/DW1	130' 7"	163° 30"	39' 6"	165°F/330°F	342°F
1JRB*DRA4	Drywell Equipment Hatch	Door Access, Graver Woolley	CT-6/DW1	95' 9"	225°	39' 6"	165°F/330°F	342°F
1JRB*DRA7	Cont. Equipment Hatch	Door Access, Graver Woolley	CT-G	95' 9"	225°	70'	165°F	342°F

NOTE: Airlock and hatches are required to maintain containment integrity during and after event.

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Instrumentation								
1B21*LTN07[illegible]C (1H22*P005)	Monitor Course of Transient	Reactor Pressure Vessel Level Trans Rosemount Model 1152	CT-G	114'	135°	44'	165°F	232°F
1B21*LTN073G (1H22*P005)			CT-G	114'	135°	44'	165°F	232°F
1B21*LTN080A (1H22*P005)			CT-G	114'	135°	44'	165°F	232°F

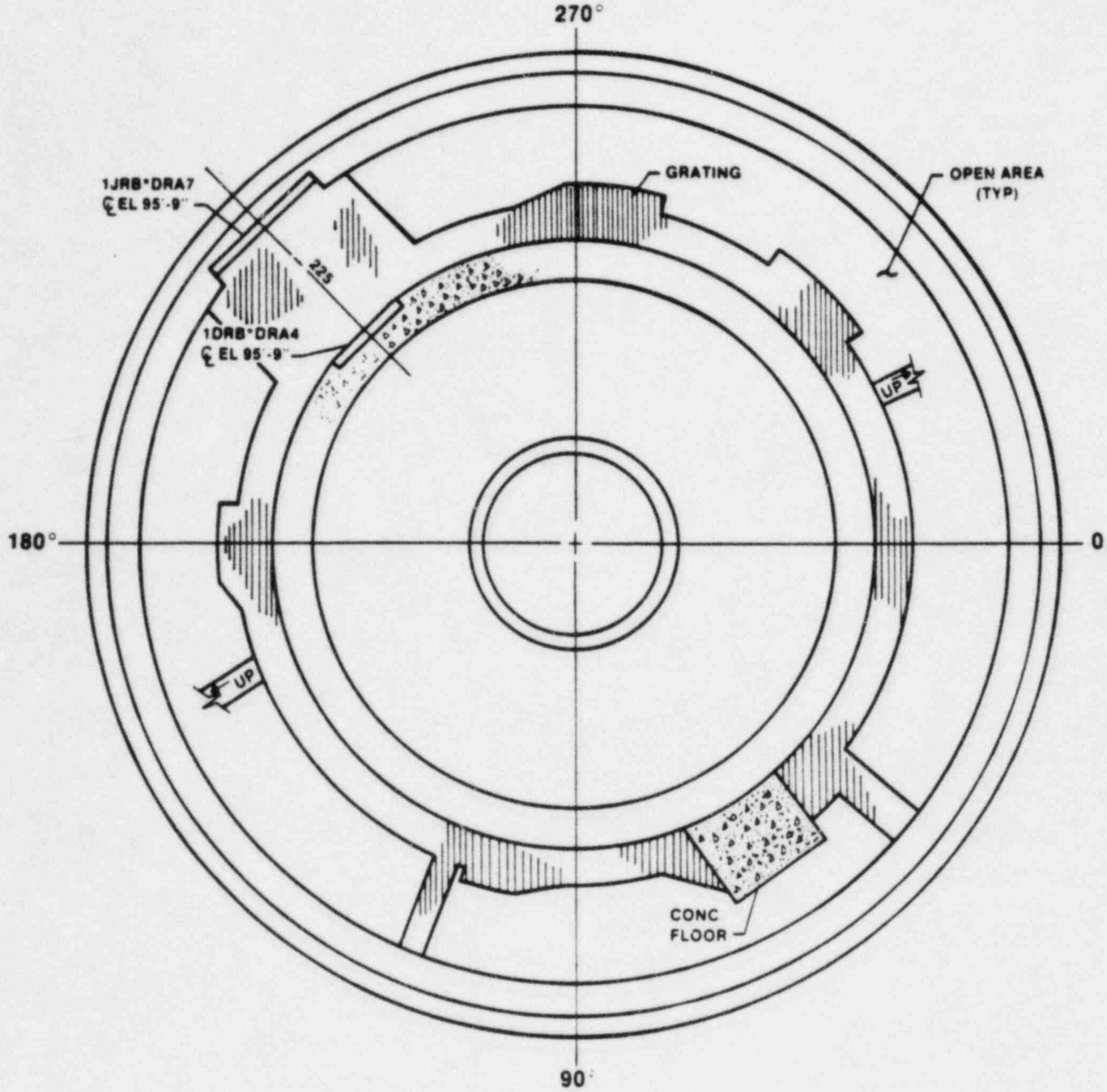
Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Instrumentation (Cont)								
1B21*LTN080B (1H22*P027)			CT-G	114'	185°	46'	165°F	232°F
1B21*LTN080C (1H22*P005)			CT-G	114'	135°	44'	165°F	232°F
1B21*LTN080D (1H22*P026)			CT-G	114'	300°	48'	165°F	232°F
1B21*LTN081A (1H22*P004)			CT-G	114'	45°	50'	165°F	232°F
1B21*LTN081B (1H22*P027)			CT-G	114'	185°	46'	165°F	232°F
1B21*LTN091A (1H22*P004)			CT-G	114'	45°	50'	165°F	232°F
1B21*LTN091B (1H22*P027)			CT-G	114'	185°	46'	165°F	232°F
1B21*LTN091E (1H22*P004)			CT-G	114'	45°	50'	165°F	232°F
1B21*LTN091F (1H22*P027)			CT-G	114'	185°	46'	165°F	232°F
1B21*LTN095A (1H22*P004)			CT-G	114'	45°	50'	165°F	232°F
1B21*LTN095B (1H22*P027)			CT-G	114'	185°	46'	165°F	232°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Instrumentation (Cont)								
1C71*PTN050A (H22*PNLP004)	Monitor Course of Accident	Drywell Pressure Rosemount 1152	CT-G	114'	45°	50'	165°F	232°F
1C71*PTN050B (H22*PNLP027)			CT-G	114'	185°	46'	165°F	232°F
1C71*PTN050C (H22*PNLP005)			CT-G	114'	135°	44'	165°F	232°F
1C71*PTN050D (H22*PNLP005)			CT-G	114'	300°	48'	165°F	232°F
1B21*PTN068A	RHR/LPCI Permissive Instrumentation	Rosemount 1152	CT-G	114'	45°	50'	165°F	232°F
1B21*PTN068B			CT-G	114'	185°	46'	165°F	232°F
1B21*PTN068E			CT-G	114'	45°	50'	165°F	232°F
1B21*PTN068F			CT-G	114'	185°	46'	165°F	232°F
Containment Pressure - Instrument located in auxiliary building								
1CMS*RTD42A	Resistance Thermal Detectors	Pyco, Inc.	CT-G	166'9"	72°	52'4"	165°F	430°F
1CMS*RTD42B	Resistance Thermal Detectors	Pyco, Inc.	CT-G	166'9"	108°	33'4"	165°F	430°F
1CMS*RTD42C	Resistance Thermal Detectors	Pyco, Inc.	CT-G	166'9"	37°	37'4"	165°F	430°F
1CMS*RTD42D	Resistance Thermal Detectors	Pyco, Inc.	CT-G	119'	15°	39'6"	165°F	430°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
1CMS*RTD42E	Resistance Thermal Detector	Pyco, Inc.	CT-G	118'6"	66°	39'6"	165°F	430°F
1CMS*RTD42F	Resistance Thermal Detector	Pyco, Inc.	CT-G	118'6"	117°	39'6"	165°F	430°F
1CMS*RTD42G	Resistance Thermal Detector	Pyco, Inc.	CT-G	122'2"	170°	39'6"	165°F	430°F
1CMS*RTD42H	Resistance Thermal Detector	Pyco, Inc.	CT-G	118'6"	219°	39'6"	165°F	430°F
1CMS*RTD42J	Resistance Thermal Detector	Pyco, Inc.	CT-G	118'6"	270°	39'6"	165°F	430°F
1CMS*RTD42K	Resistance Thermal Detector	Pyco, Inc.	CT-G	119'	322°	39'6"	165°F	430°F
Containment Electrical Penetrations								
1RCP*LVC05	Containment Integrity	Electrical Penetration Assy Conax Corp/Unique	CT-G	Various	Various	60'	165°	255°F
1RCP*LVC10A			CT-G				165°	255°F
1RCP*LVC11A			CT-G				165°	255°F
1RCP*LVC13A			CT-G				165°	255°F
1RCP*LVC18			CT-G				165°	255°F
1RCP*LVC18A			CT-G				165°	255°F
1RCP*LVC19A			CT-G				165°	255°F
1RCP*LVC20A			CT-G				165°	255°F
1RCP*LVC21			CT-G				165°	255°F
1RCP*LVI05A			CT-G				165°	393°F
1RCP*LVI11			CT-G	Various	Various	60'	165°	393°F
1RCP*LVI12			CT-G				165°	393°F
1RCP*LVI12A			CT-G				165°	393°F

Equipment Identification	Function	Equipment Description Make/ Manufacturer Vendor Model/ Catalog No.	EDC Zone Location	Elevation	Location Azimuth Degrees	Radius	Peak Accident EDC Temperature	Peak Accident Qualified Temperature
Containment Electrical Penetrations (Cont)								
1RCP*LVI14			CT-G				165°	393°F
1RCP*LVI14A			CT-G				165°	393°F
1RCP*LVI15			CT-G				165°	393°F
1RCP*LVI15A			CT-G				165°	393°F
1RCP*LVI17B			CT-G				165°	393°F
1RCP*LVI17C			CT-G				165°	393°F
1RCP*LVI21A			CT-G				165°	393°F
1RCP*LVP03			CT-G				165°	255°F
1RCP*LVP03A			CT-G				165°	255°F
1RCP*LVP07			CT-G				165°	255°F
1RCP*LVP07A			CT-G				165°	255°F
1RCP*LVP09			CT-G				165°	255°F
1RCP*LVP09A			CT-G				165°	255°F
1RCP*LVP16			CT-G				165°	255°F
1RCP*LVP16A			CT-G				165°	255°F
1RCP*LVP22			CT-G				165°	255°F
1RCP*LVP22A			CT-G				165°	255°F
1RCP*MVP01			CT-G				165°	405°F
1RCP*MVP02			CT-G				165°	405°F
1RCP*NMS10			CT-G				165°	393°F
1RCP*NMS13			CT-G				165°	393°F
1RCP*NMS19			CT-G				165°	393°F
1RCP*NMS20			CT-G				165°	393°F
1RCP*LVC06			CT-5A				165°	255°F
1RCP*LVI06A			CT-5A				165°	393°F
1RCP*LVP04			CT-5A				165°	255°F
1RCP*LVP04A			CT-5A				165°	255°F
1RCP*LVP08			CT-5A				165°	255°F
1RCP*LVP08A			CT-5A				165°	255°F
Cables and Terminal Blocks	Service All Equipment Listed Above	Various	Various	Various	Various	Various	165°/330°	Various

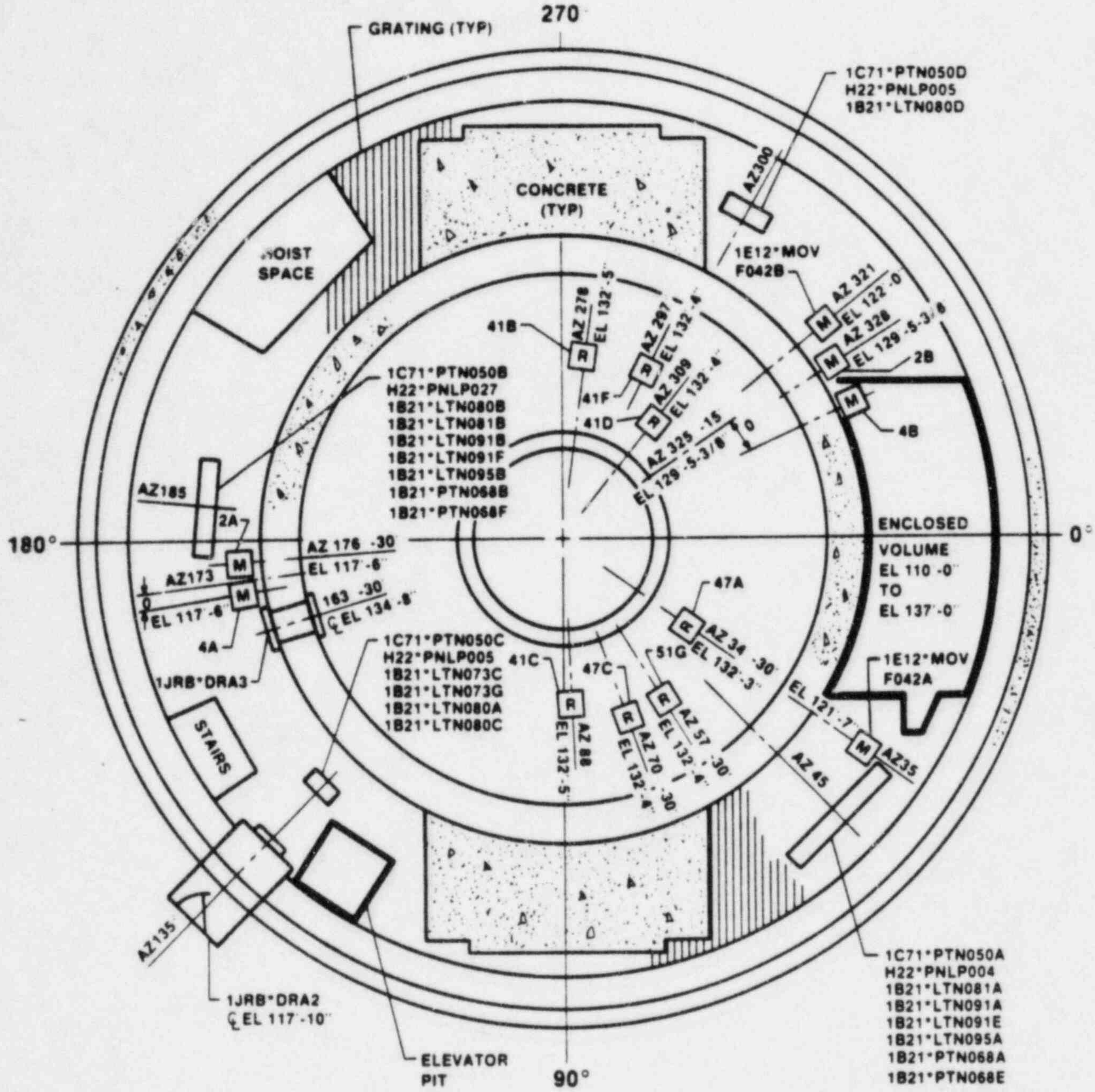
C4/14764/15A/4YH



REFERENCE DWG.
EM-2C. MACH. LOCATION PLAN

FIGURE 2.4-1

ESSENTIAL EQUIPMENT LOCATION PLAN EL 95'-9" (SHT 1 OF 6)
RIVER BEND STATION



LEGEND

R RELIEF VALVES

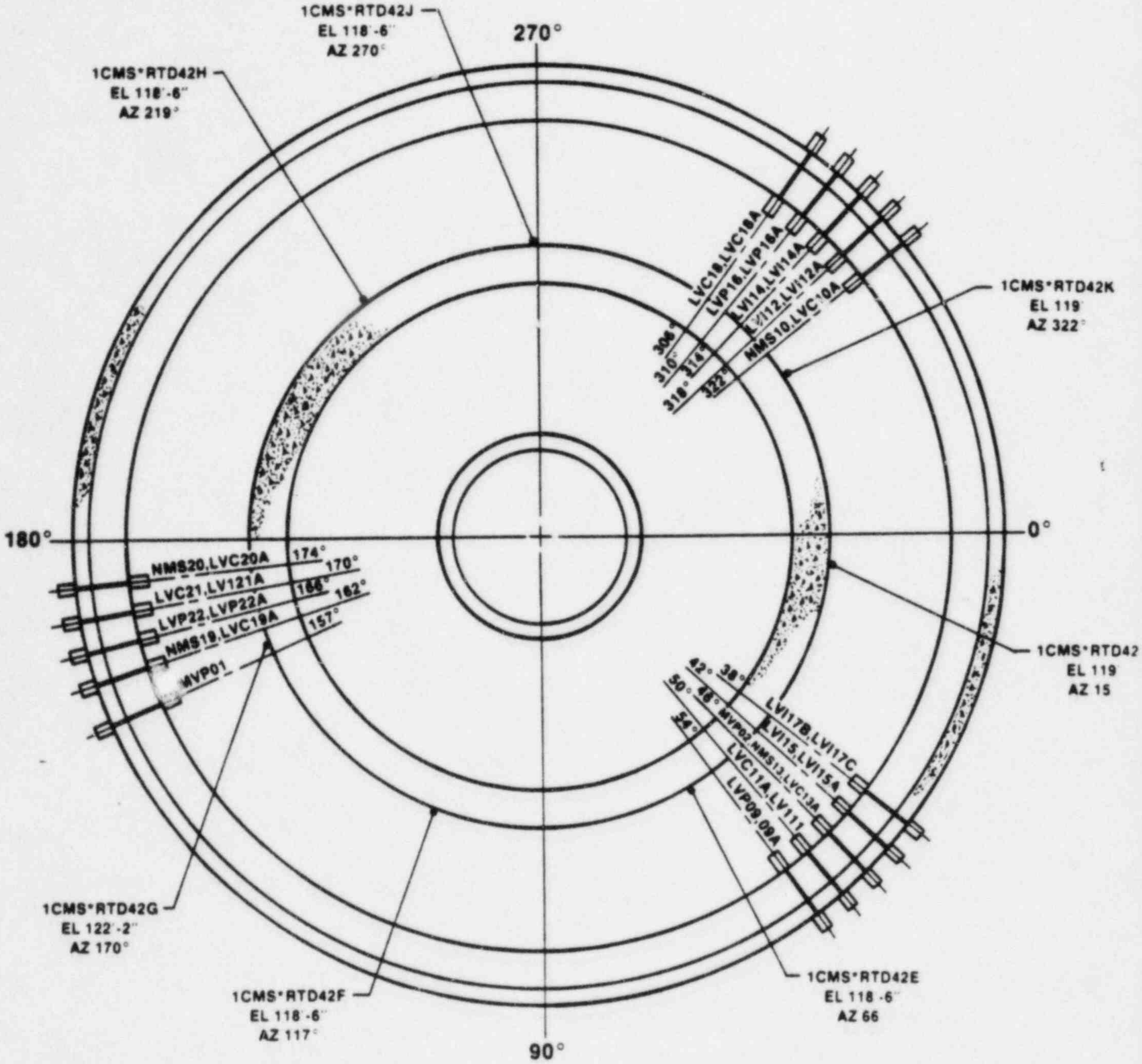
M MOTOR OPERATED VALVES

NOTES:
1. PREFIX RELIEF VALVE NUMBERS WITH 1B21*RVF0.
2. PREFIX MOTOR OPERATED VALVE NUMBERS WITH 1CPM*MOV.

REFERENCE DWG.
EM-28: MACH. LOCATION PLAN

FIGURE 2.4-1

ESSENTIAL EQUIPMENT LOCATION PLAN EL 114'-0" (SHT 2 OF 6)
RIVER BEND STATION



ELECTRICAL PENETRATIONS

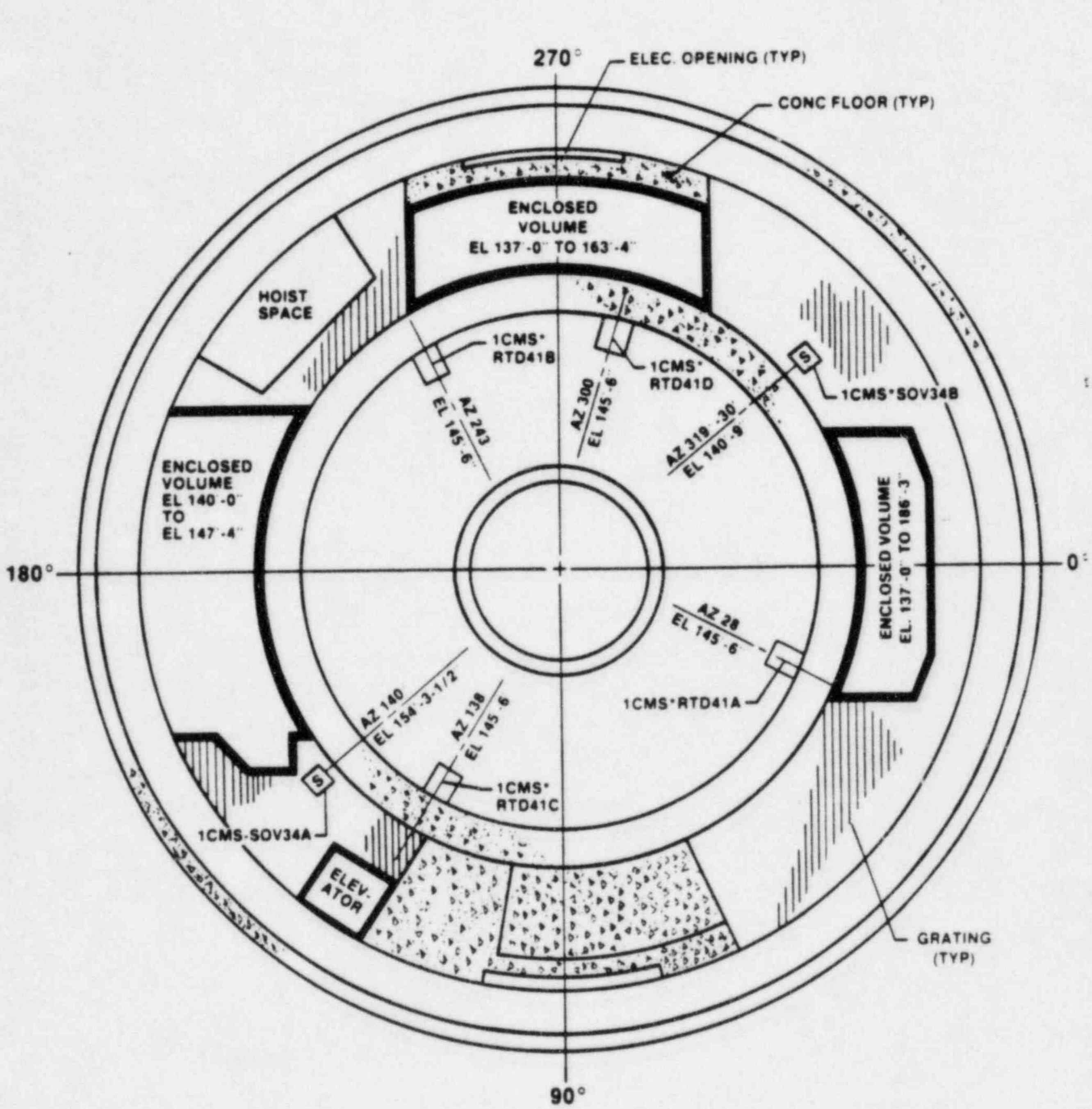
ASSY NO.	ELEV.	ASSY NO.	ELEV
MVP01	126'-3"	LVI15A	117'-0"
MVP02	133'-0"	LVP16	121'-0"
LVP09	121'-0"	LVP16A	117'-0"
LVP09A	117'-0"	LVI17B	121'-0"
NMS10	121'-0"	LVI17C	117'-0"
LVC10A	117'-0"	LVC18	121'-0"
LVI11	121'-0"	LVC18A	117'-0"
LVC11A	117'-0"	NMS19	121'-0"
LVI12	121'-0"	LVC19A	117'-0"
LVI12A	117'-0"	NMS20	121'-0"
NMS13	121'-0"	LVC20A	117'-0"
LVC13A	117'-0"	LVC21	121'-0"
LVI14	121'-0"	LVI21A	117'-0"
LVI14A	117'-0"	LVP22	121'-0"
LVI15	121'-0"	LVP22A	117'-0"

NOTES:
1. ALL ASSY NO'S. TO BE PREFIXED WITH 1RCP*.
2. SEE SHT. 2 FOR FL DESCRIPTION.

REFERENCE DWGS.
EE-35A: ARRGT ELEC PENETRATIONS
EK-303A,C,D,T,Z INST. PIPING

FIGURE 2.4-1

ESSENTIAL EQUIPMENT LOCATION PLAN EL 114'-0" (SHT 3 OF 6)
RIVER BEND STATION



LEGEND

S SOLENOID VALVE

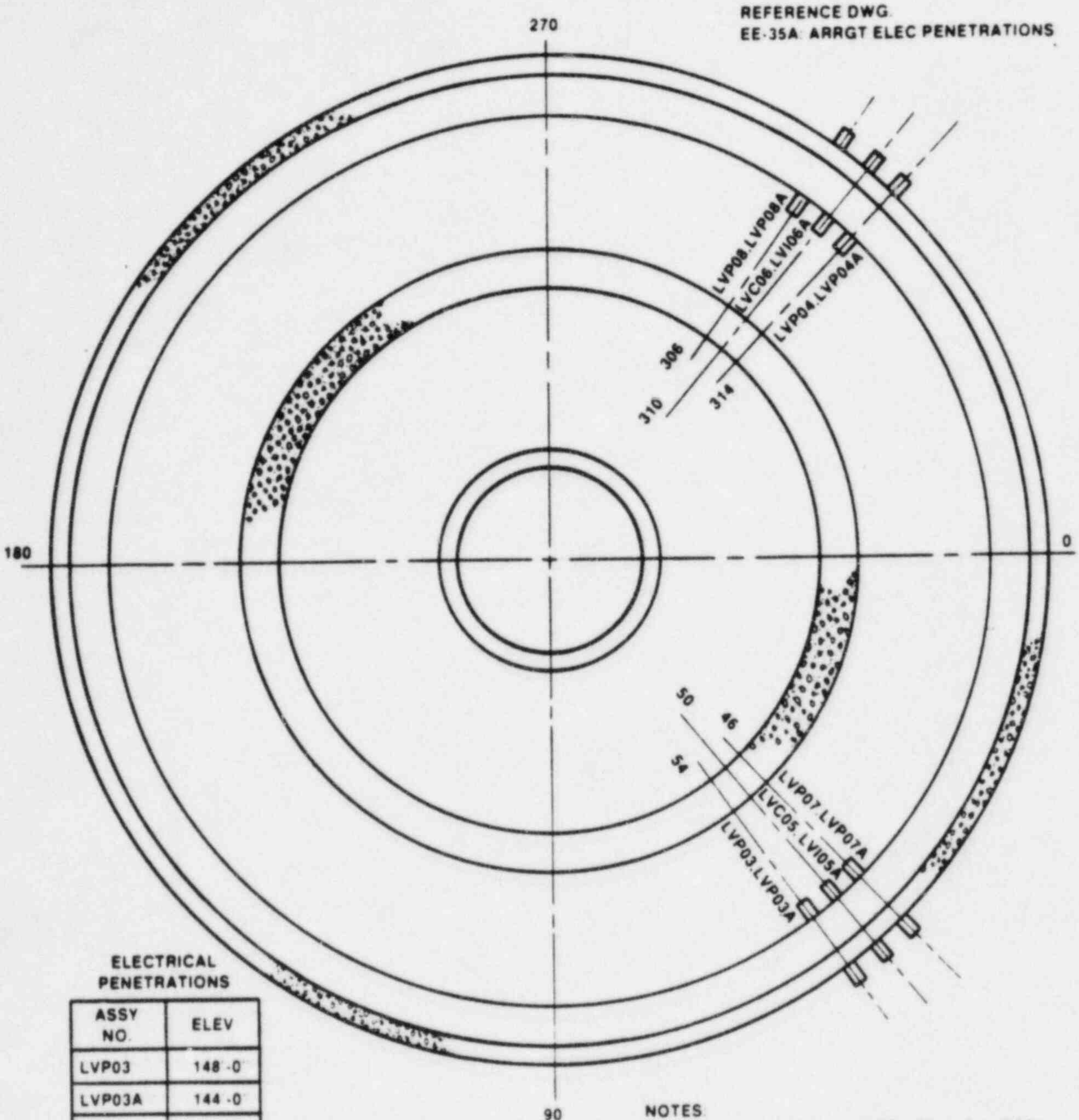
REFERENCE DWG.
EM-2B: MACH. LOCATION PLAN

FIGURE 2.4-1

ESSENTIAL EQUIPMENT LOCATION PLAN EL 141'-0" (SHT 4 OF 6)

RIVER BEND STATION

REFERENCE DWG.
EE-35A: ARRGT ELEC PENETRATIONS



NOTES:
1. ALL ASSY NO'S TO BE PREFIXED WITH 1RCP'
2. SEE SHT 4 FOR FL DESCRIPTION

ELECTRICAL PENETRATIONS

ASSY NO.	ELEV
LVP03	148'-0"
LVP03A	144'-0"
LVP04	148'-0"
LVP04A	144'-0"
LVC05	148'-0"
LVI05A	144'-0"
LVC06	148'-0"
LVI06A	144'-0"
LVP07	148'-0"
LVP07A	144'-0"
LVP08	148'-0"
LVP08A	144'-0"

FIGURE 2.4-1

ESSENTIAL EQUIPMENT LOCATION PLAN EL 141'-0" (SHT 5 OF 6)

RIVER BEND STATION

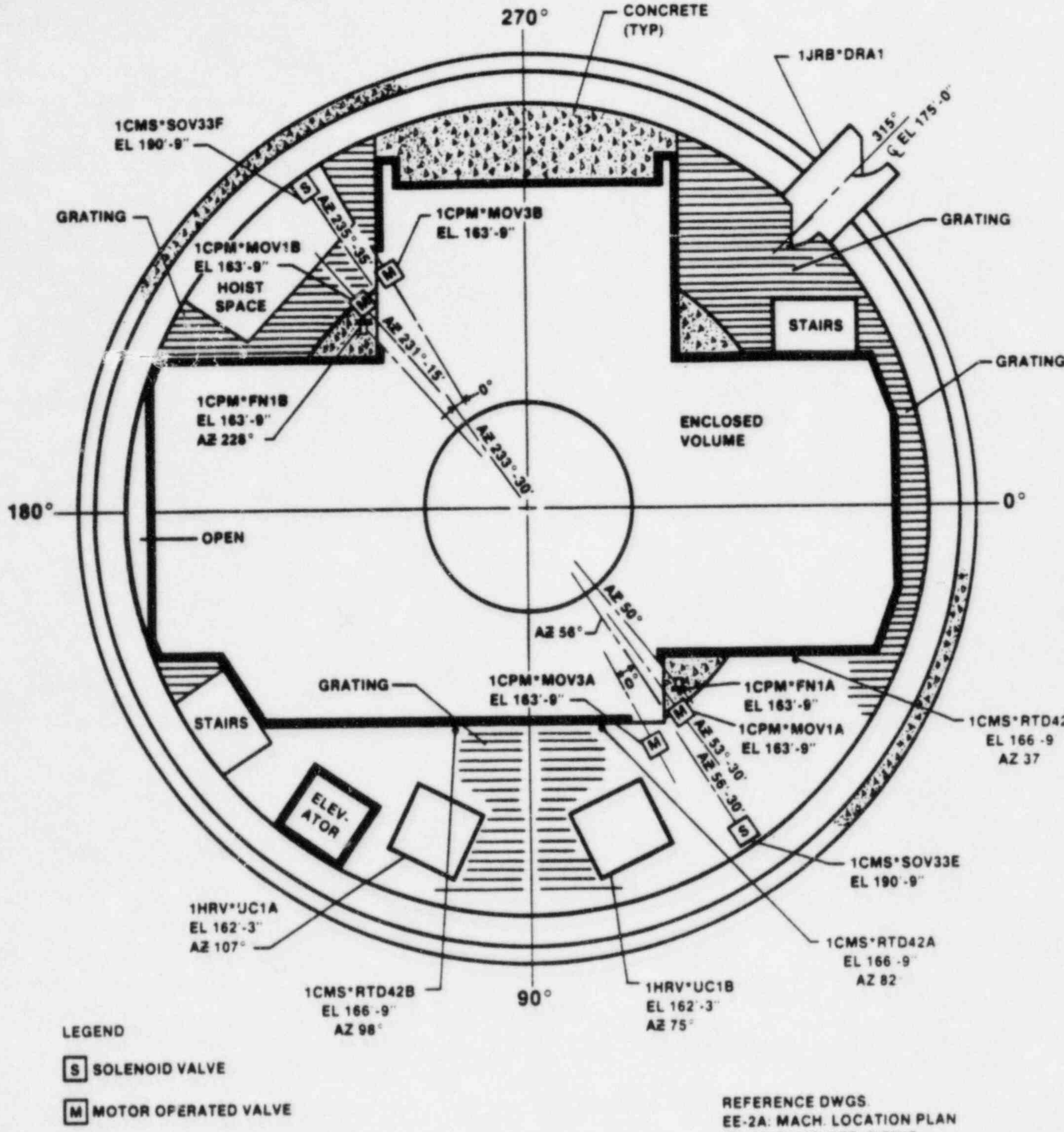


FIGURE 2.4-1

ESSENTIAL EQUIPMENT LOCATION PLAN EL 162'-3" (SHT 6 OF 6)

RIVER BEND STATION

3.0 THERMAL ENVIRONMENT

3.1 HYDROGEN BURN CHARACTERISTICS

Hydrogen combustion is categorized into several burn types based on observed flame behavior as a function of the concentration of hydrogen and oxygen in the gas mixture and as a function of geometry. Two types, deflagration and diffusion burning have been identified as possibly occurring in RBS following a degraded core hydrogen generation event. The other types of burning are impossible or very unlikely to occur in the RBS containment, since they require very specific geometry and hydrogen-oxygen mixture characteristics.

Diffusion burning consists of one or more steady flames anchored at the hydrogen source or other physical restrictions where the hydrogen-oxygen mixture can be maintained at combustible levels. Diffusion burning is expected to occur when the hydrogen release is continuous and remains at a rate equal to or greater than the threshold value.

If hydrogen is released at a rate less than the threshold value, the burning is likely to consist of a series of deflagration burns. Deflagration burning is characterized by a slow buildup of hydrogen, in the presence of excess oxygen, until a deflagration ignition limit is reached at an ignition source. Once ignited, a deflagration burn rapidly consumes most of the hydrogen in the volume.

The thermal environment in the containment resulting from a hydrogen burn is highly dependent upon the type of burning considered. Diffusion burning generally results in locally high temperatures. The region affected by the high temperatures is dependent upon the burn location, the rate of hydrogen release, and the resulting circulation patterns developed in the containment.

The deflagration burning thermal environment is characterized by a series of temperature spikes with a relaxation period between burns. Each subvolume in the containment may be subject to one or more deflagration burns. The thermal environment produced by a deflagration burn is assumed to directly affect the entire subvolume with high temperatures.

In both diffusion burning and deflagration burning, equipment located within the containment will be subject to convection and radiation heat transfer. The rate of heat transfer is dependent upon the type of burning, the location of burning, and the location of the equipment.

3.2 DEFLAGRATION BURN ENVIRONMENT

The thermal environment produced by deflagration burning in a Mark III containment can be estimated through the use of the CLASIX-3 computer program (Reference 4). The nodal arrangement used

in CLASIX-3 for RBS is shown in Figure 3.2-1. The RBS model is similar to the model used for Grand Gulf Nuclear Station (GGNS) as reported in Reference 5.

Because deflagration burning is volume-dependent, careful consideration of containment geometry must be made when developing the model to be used in CLASIX-3. The model used for RBS simulates the drywell, the wetwell, the intermediate containment region between the HCU and refueling floors, and the upper containment above the refueling floor. The model includes heat removal from the intermediate volume due to operation of the containment unit coolers.

The inclusion of the intermediate node, from the HCU floor (el 114 ft 0 in.) to the refueling floor (el 186 ft 3 in.), reflects the significant physical changes in flow area at these elevations. The HCU floor, consisting of concrete platforms and grating, represents approximately a 60-percent reduction in flow area from the wetwell volume. The flow area through the refueling floor consists primarily of the hoist area and two stairways. This limited flow area represents a significant restriction to flow between the intermediate node and the upper containment.

Results obtained from CLASIX-3 for RBS are included as Figures 3.2-2 through 3.2-4.

For a further description of the CLASIX-3 analysis and results, see Reference 6.

3.3 DIFFUSION BURN ENVIRONMENT

The diffusion burn environment specific to the RBS configuration will be determined by the 1/4 scale tests being conducted by the HCOG. These tests are currently scheduled for completion in 1985. Therefore, this report does not address essential equipment response to diffusion burn thermal conditions.

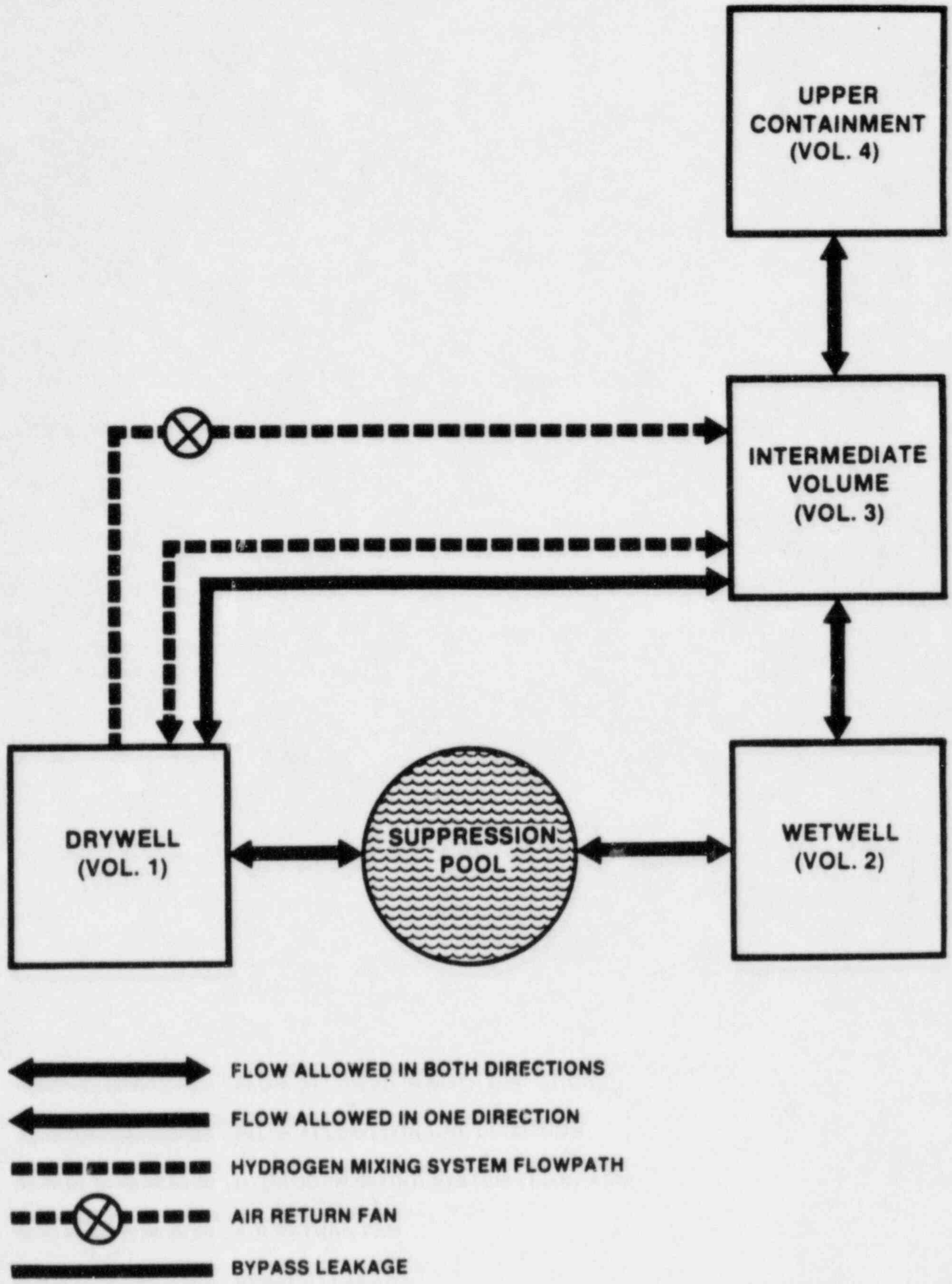


FIGURE 3.2-1

CLASIX-3 NODALIZATION
RIVER BEND STATION –

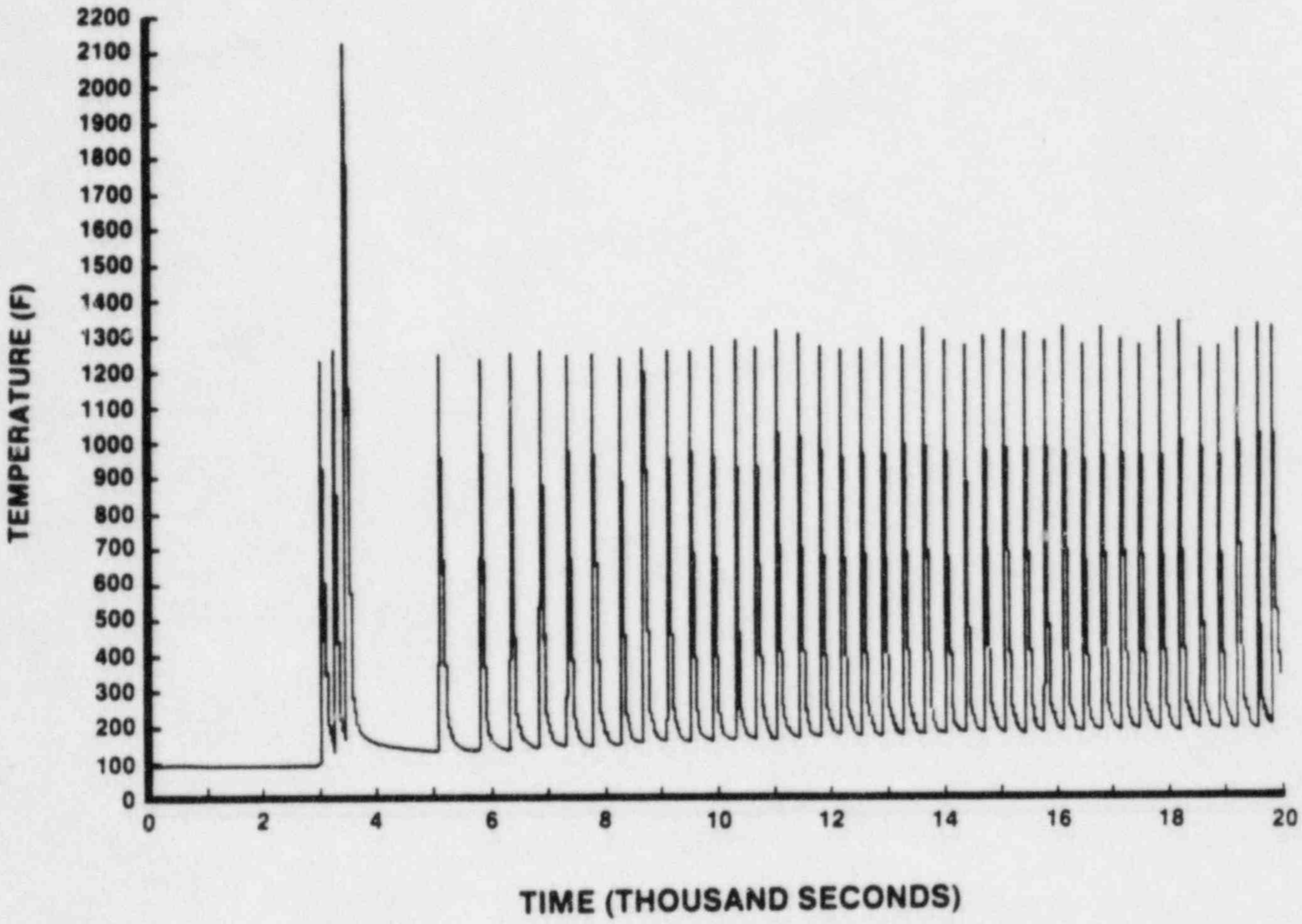


FIGURE 3.2-2

WETWELL TEMPERATURES
SORV CASE - RELEASE B
RIVER BEND STATION

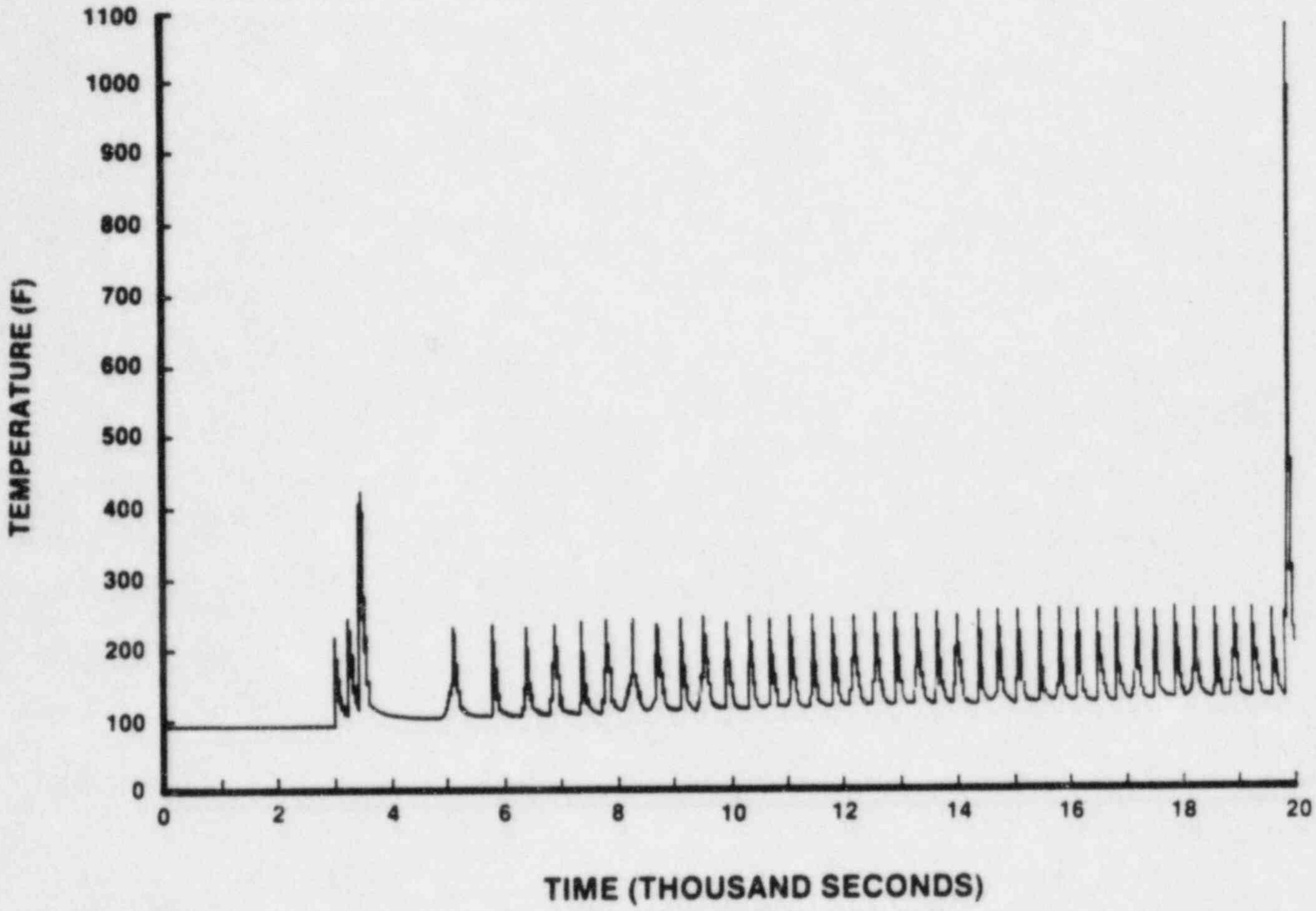


FIGURE 3.2-3

INTERMEDIATE NODE TEMPERATURE
SORV CASE - RELEASE B
RIVER BEND STATION

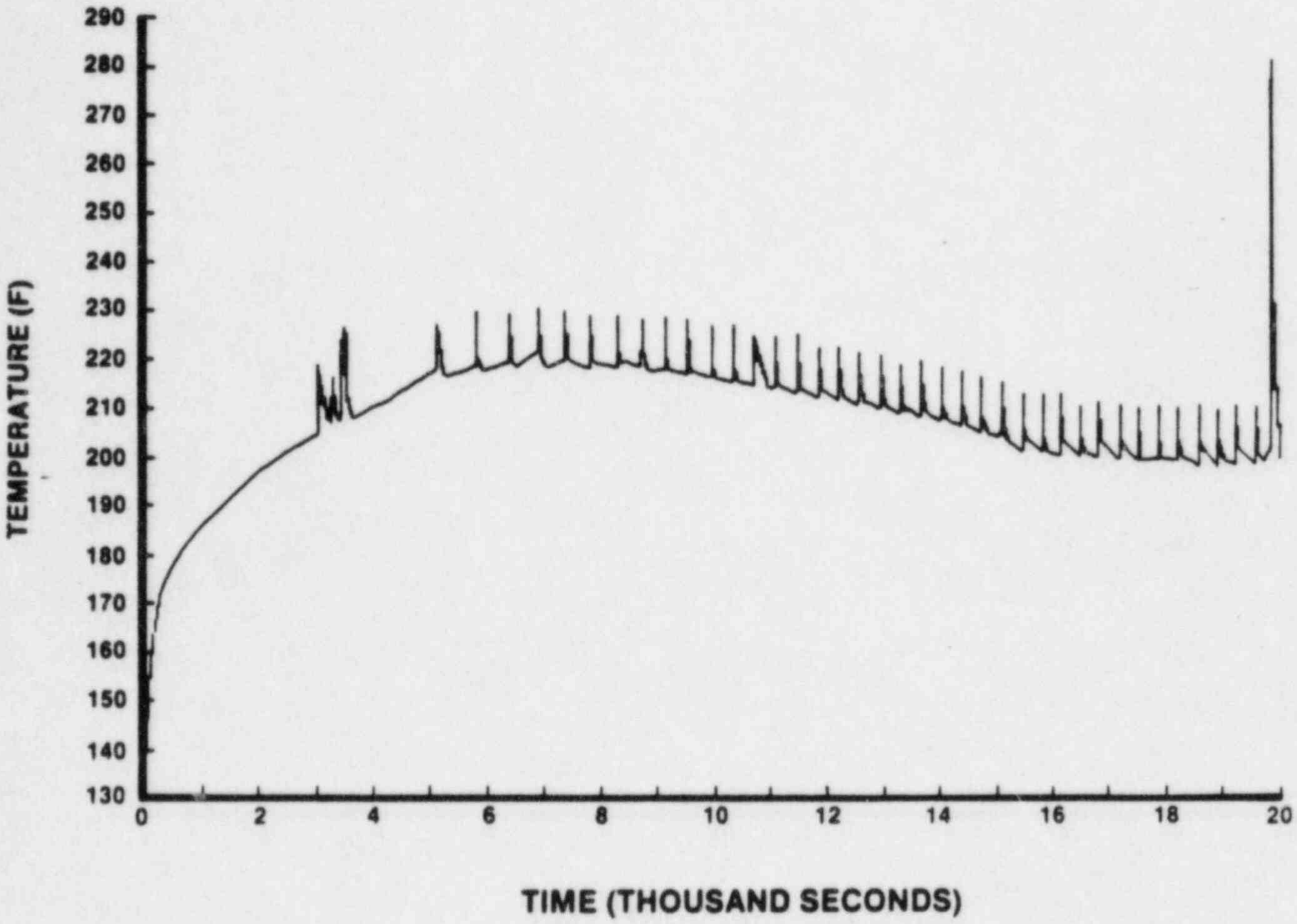


FIGURE 3.2-4

DRYWELL TEMPERATURES
SORV CASE - RELEASE B
RIVER BEND STATION

4.0 EQUIPMENT THERMAL MODELING

4.1 CODE SELECTION

The code selected for use in this analysis is HEATING6. HEATING6 is a multidimensional heat conduction analysis code using the finite-difference formulation and is the latest version of "The Heating Program," where HEATING is an acronym for Heat Engineering and Transfer in Nine Geometries. The code was prepared for the U.S. Nuclear Regulatory Commission by D. C. Elrod, G. E. Giles, and W. D. Turner under Interagency Agreements DOE 40-549-75 and 40-550-75. The code was selected for use in this project in order to maintain compatibility with other HCOG investigations currently being pursued.

4.2 ASSUMPTIONS

a. Two-dimensional modeling is assumed sufficiently exact for preliminary investigations. One-dimensional (radial) modeling is used to represent thin-walled elongated cylindrical objects (e.g., Crosby pilot valve solenoid coil) where the cylinder ends can be assumed to act as massive heat sinks, so that it is conservative to ignore them.

b. Where unit orientation with respect to vertical has not been verified, it is assumed that the unit is so oriented as to maximize convection to the most critical component.

c. Units being analyzed are assumed to be surrounded on exposed sides by hot vapor to a sufficient distance (of at least 10 ft) so as to maximize emissivity of the radiant cloud.

d. Convection of heat to the units is modeled by assuming forced convection at a velocity of 12 ft/sec.

e. Emissivity and absorptivity of the equipment component surfaces (internal and external) are set equal to conservatively high values, so as to maximize heat transfer to the equipment surface and within air spaces located inside the equipment outer surface.

f. Natural convection within free air spaces inside the equipment surface envelope is modeled by using enhanced heat conduction (Reference 7).

g. Critical unit nonmetallic subcomponents are determined by review of vendor data and equipment qualification reports. When two subcomponents have similar projected temperature sensitivity, alternate heat transfer models are developed to maximize heat flow to each potentially critical component. Each model is then subjected to the thermal forcing function for the unit being analyzed. This procedure avoids spurious qualification on the basis of the most thermally sensitive material occurring only in a well protected location (well insulated, attached to

most massive component heat sink, etc), while another material, with less inherent sensitivity to high temperature, may occur in a more exposed environment and thus be heated rapidly above its critical temperature.

h. Internal heat generation has been considered for the hydrogen igniter.

4.3 BOUNDARY CONDITIONS

All units are assumed to be maximally exposed to the elevated thermal environment as indicated in the diagrams in Section 4.4. Exposed surfaces are allowed to radiate to the heat sinks which have surface temperatures calculated by CLASIX-3. No credit is taken for any unit being in a convective "dead zone" and thus shielded from the assumed 12-ft/sec gas stream.

Unit internal air spaces (from the shell or case to the heat-sensitive component which is shielded by the shell or case) are assumed to transmit heat by natural convection, by conduction, and by radiation. Natural convection internal to the unit is modeled as an increase in the thermal conductivity of the air in these spaces. Thermal radiation across the air gap is modeled directly.

Credit is taken for heat flow by conduction into heat sinks, such as will occur from the hydrogen igniters into the wall (drywell, etc) upon which they are mounted. Conservative values of thermal contact resistance are employed so as not to overestimate the temperature reduction due to this effect.

4.4 MODEL DEVELOPMENT AND VERIFICATION

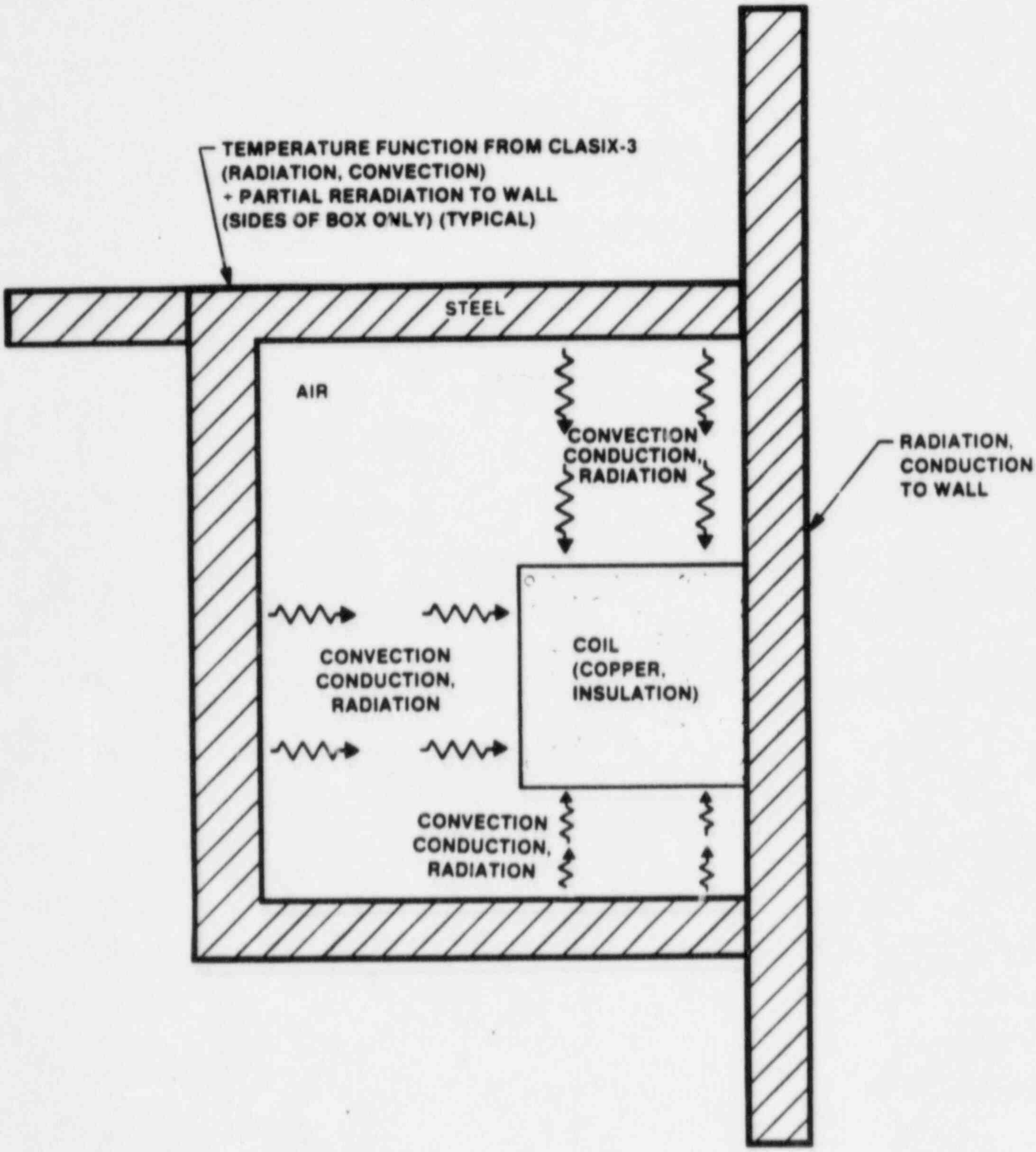
Models for component thermal analysis have been developed incorporating the assumptions and boundary conditions listed above. The study uses two-dimensional models, except where a one-dimensional (radial) model more conservatively represents an elongated cylindrical object (Crosby pilot valve solenoid coil).

These models will be verified by comparison of modeling techniques and assumptions with other similar analyses, by independent consultant review. The models used in the Grand Gulf preliminary survivability report are available (Reference 8). The techniques and assumptions used are generally similar.

In addition to the standard in-house calculation review procedures, SWEC has arranged for a review by Dr. J. R. Howell of the University of Texas at Austin. Dr. Howell is an expert in the field of radiant heat transfer and is well known as the coauthor with Dr. R. Siegel of the text Thermal Radiation Heat Transfer.

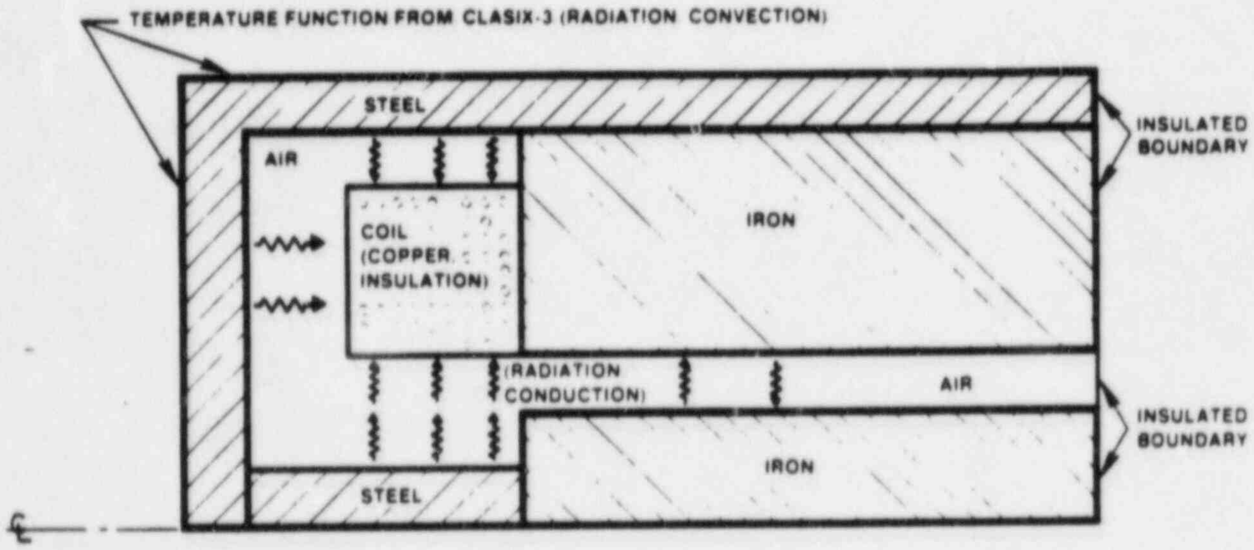
The following sketches show the models used for the hydrogen igniter, valve operator, solenoid valve, and pilot valve. These are derived from the manufacturer's documentation, samples of which are included as Figures 4.4-1 through 4.4-4, respectively.

HYDROGEN IGNITER

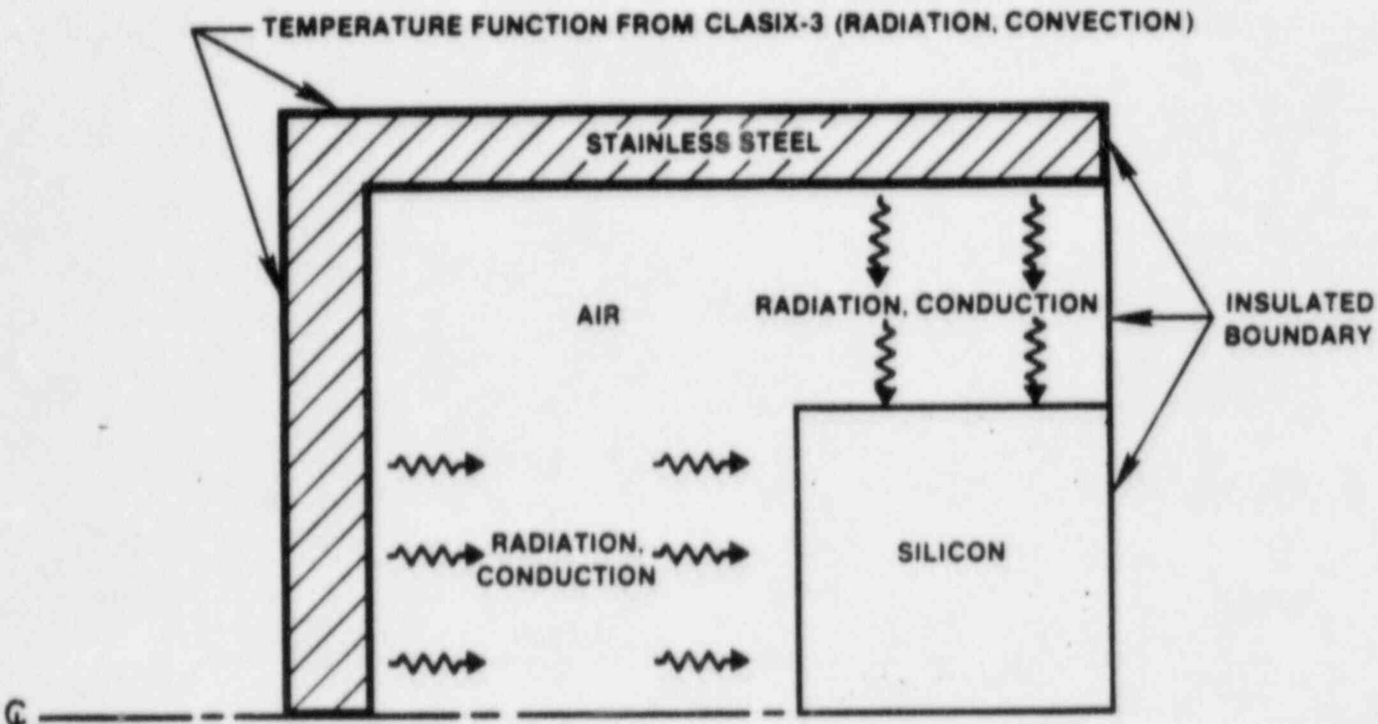


The above shows a two-dimensional model (rectangular coordinates) of the coil (mixture of copper and insulation), which is taken as the critical component.

LIMITORQUE VALVE OPERATOR
0.13-HP RELIANCE MOTOR

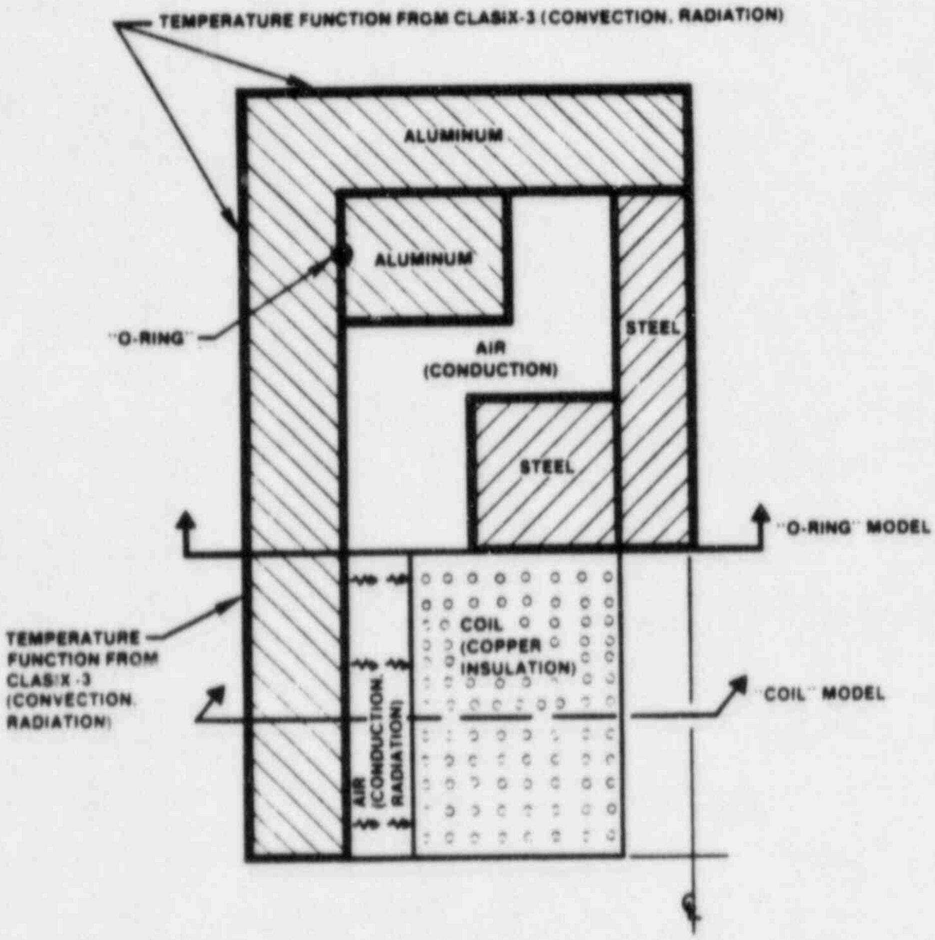


The above shows a two-dimensional model (cylindrical coordinates) of the stator coil (mixture of copper and insulation), which is taken as the critical component. An insulated boundary is used to separate the model from other elements assumed to follow the same temperature transient (typical).



The above shows a two-dimensional model (cylindrical coordinates) of the rectifier block, which is considered to be the critical component. The body of the valve is not considered as a heat sink as it is also subjected to the thermal transient.

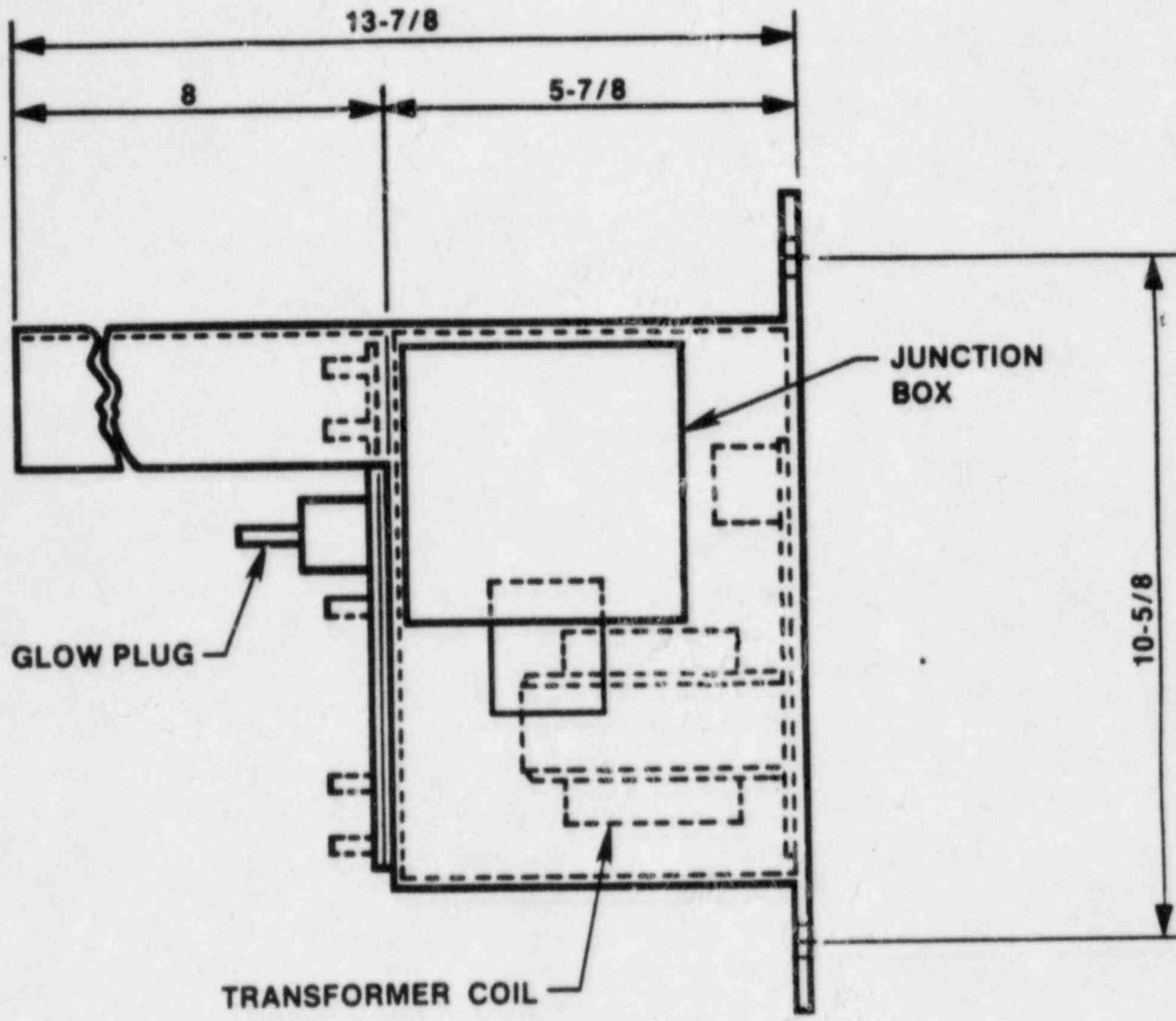
CROSBY PILOT VALVE (ADS SYSTEM)



Two models are used:

O-ring	Two dimensional (cylindrical)
Coil	One dimensional (cylindrical)

These units have two classes of temperature sensitive subcomponents, O-rings and a solenoid coil. It is not obvious which will be subjected to the most severe local conditions, so both are modeled. Coil temperatures are conservatively estimated by considering maximum thermal radiation from the aluminum case (i.e., emissivity = absorptivity = 1.0) while O-ring temperatures are maximized when the thermal radiation across the air gap is eliminated (i.e., emissivity = absorptivity = 0.0 on the inner surfaces only). A one-dimensional model is chosen for the coil as it conservatively avoids heat flow into the massive sinks at either extremity of the valve. Cylindrical coordinates are used as they fit the shape of the critical components and conservatively ignore significant thermal mass at these extremities.



SIDE VIEW

FIGURE 4.4-1

HYDROGEN IGNITER
RIVER BEND STATION

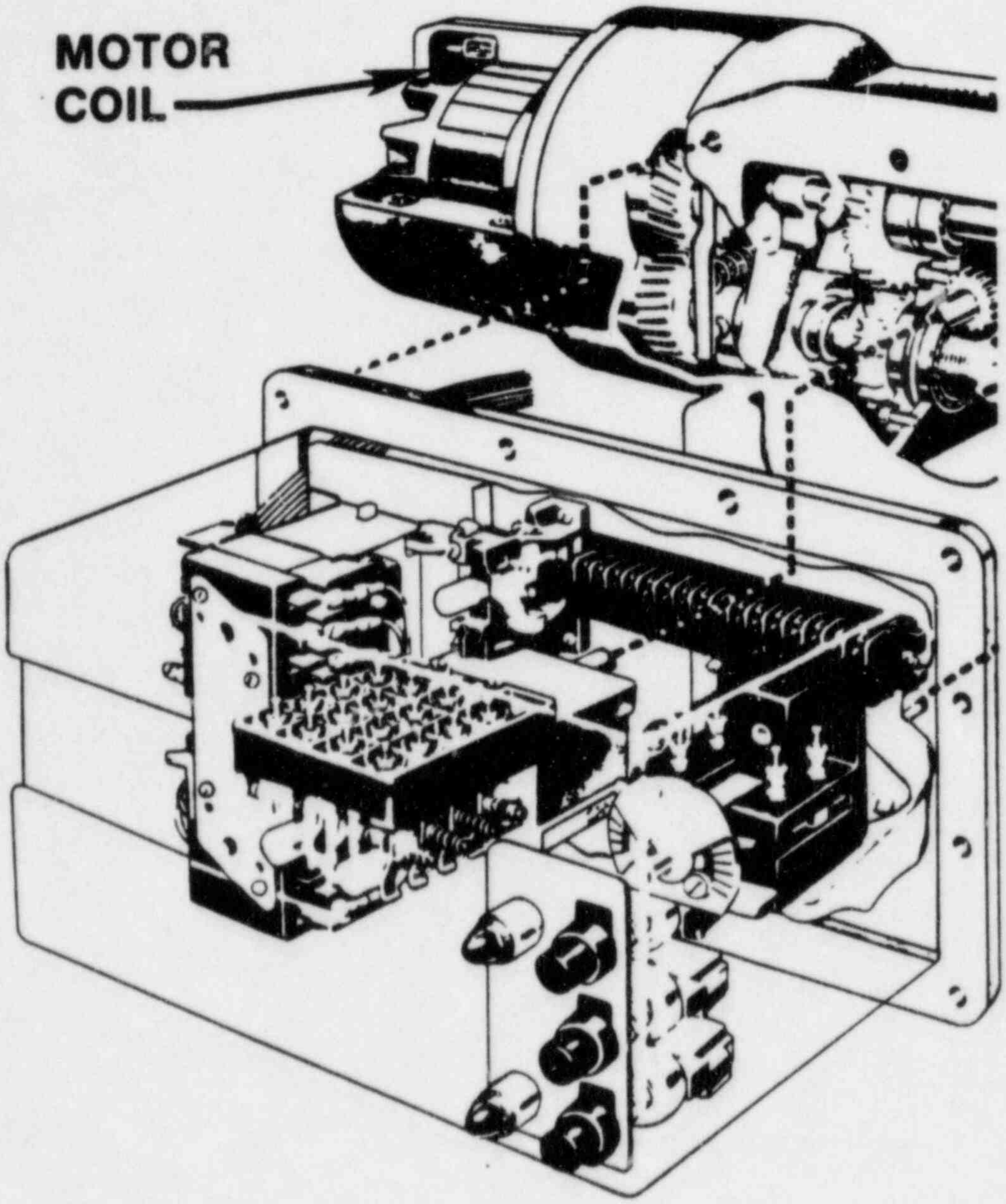


FIGURE 4.4-2

LIMITORQUE VALVE OPERATOR MOTOR
RIVER BEND STATION

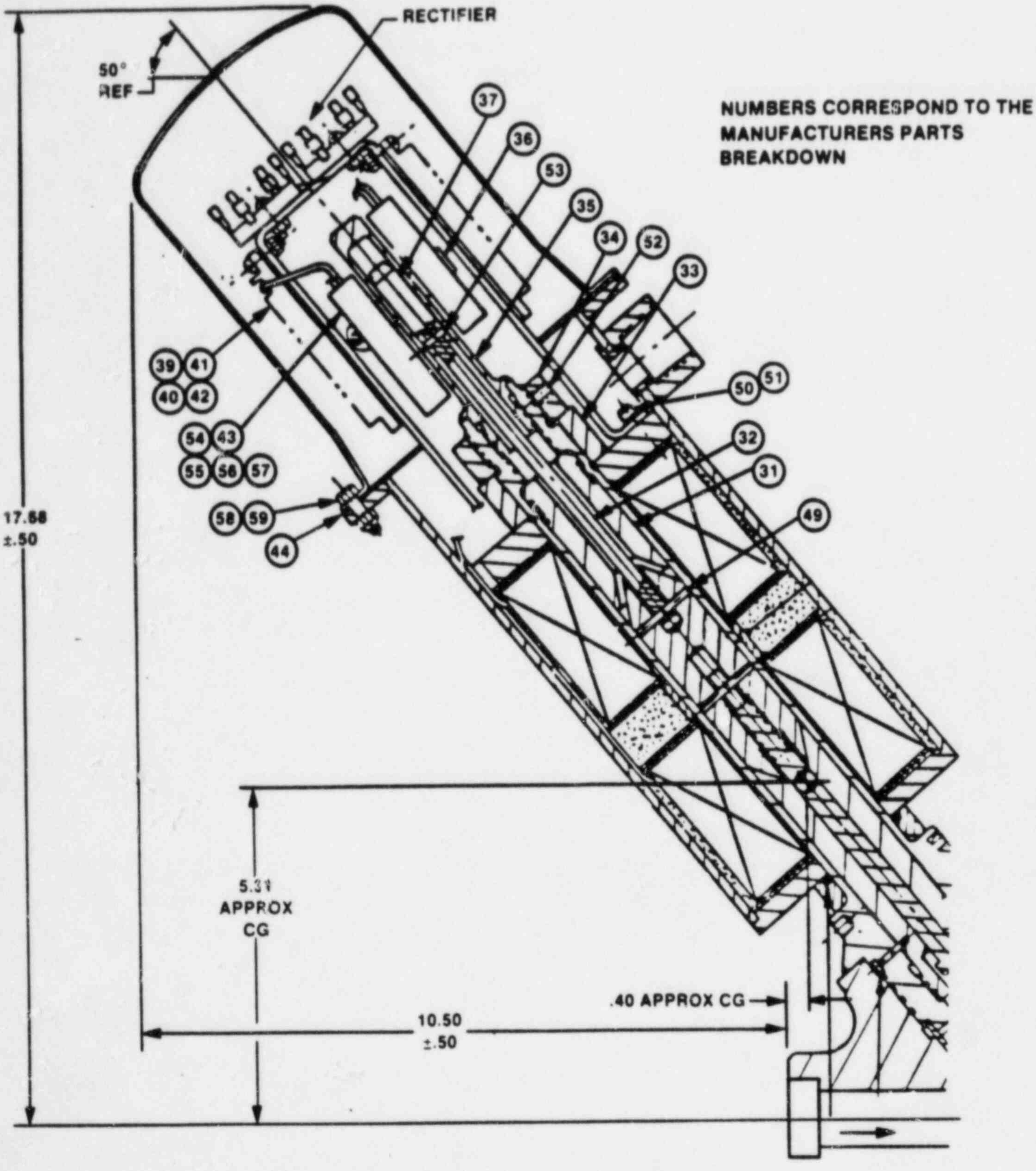


FIGURE 4.4-3

TARGET ROCK SOLENOID VALVE
RIVER BEND STATION

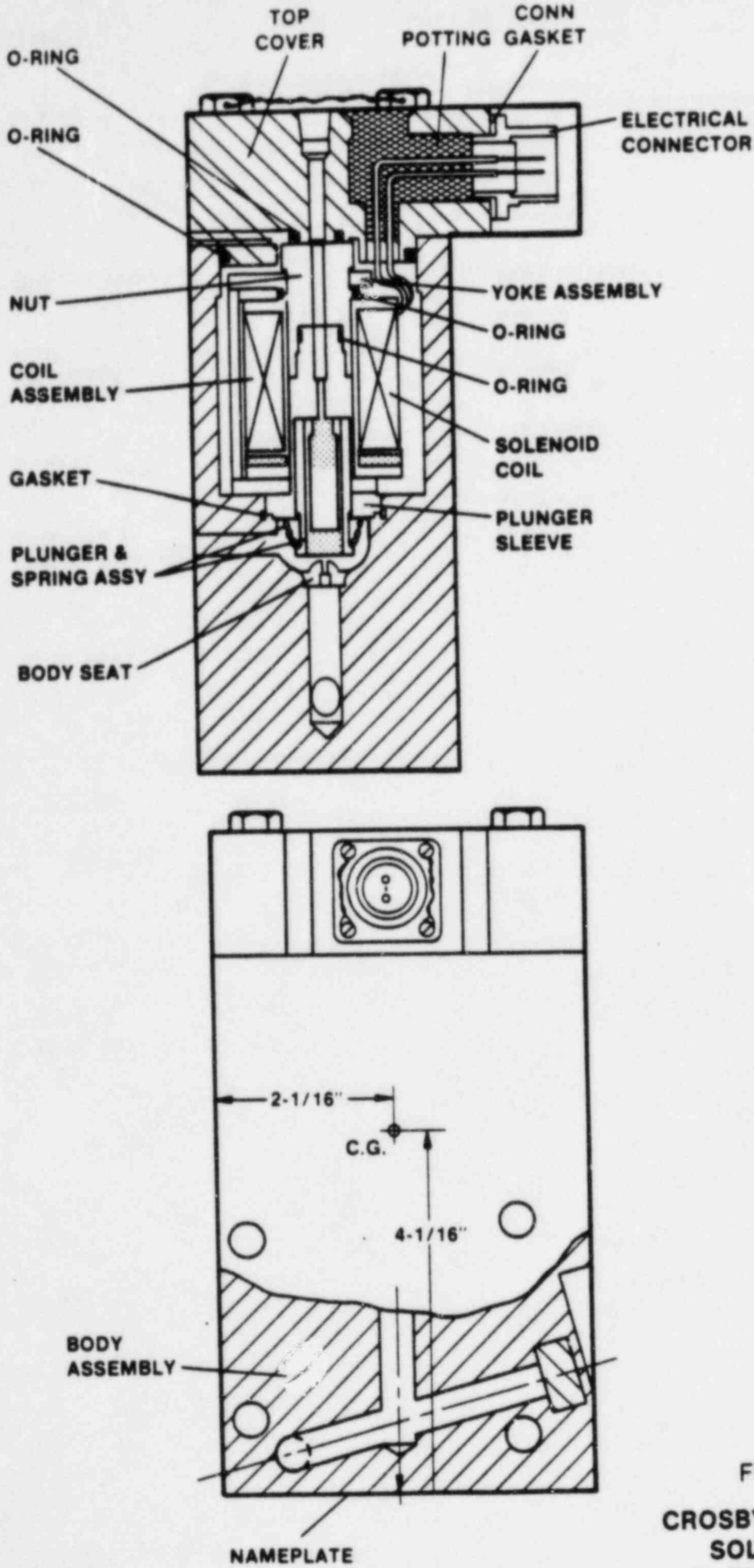


FIGURE 4.4-4

CROSBY (ADS) PILOT AIR SOLENOID VALVE

RIVER BEND STATION

5.0 RESULTS

The predicted maximum temperatures and qualification temperature for the essential equipment considered in this analysis are listed in Table 5.0-1. Both the maximum outside surface temperature of the equipment casing and the maximum temperature of the thermally sensitive nonmetallic internal component are given. The table also indicates the hydrogen generation event thermal environment applied as the driving condition to the HEATING6 thermal model of each unit.

TABLE 5.0-1

SUMMARY OF RESULTS

Unit	Hydrogen Generation Event	Equipment Location	Equipment Qualification Temperature	Predicted Temperature Casing	Predicted Temperature Sensitive Component	Material Maximum Service Temperature
Hydrogen igniter	SORV	WW (Fig. 3.2-2)	340°F (470°F)***	900°F*	600°F*	500°F
Hydrogen igniter	SORV	INT (Fig. 3.2-3)	340°F (470°F)	300°F	165°F	500°F
Hydrogen igniter	DWB	DW (Fig. 3.2-4)	340°F (470°F)	320°F	305°F	500°F
0.13 HP Reliance motor on Limitorque operator	SORV	INT (Fig. 3.2-3)	340°F	310°F	235°F	NA
Target Rock solenoid rectifier	SORV	INT (Fig. 3.2-3)	385°F	388°F	222°F	NA
Crosby (ADS) pilot valve						
O-ring	DWB	DW (Fig. 3.2-4)	340°F**	336°F	336°F	400°F
Coil	DWB	DW (Fig. 3.2-4)	340°F**	336°F	312°F	500°F

*Estimated value

**LOCA qualification currently in progress

***470°F predicted for sensitive component for 25 watts operating power and 340°F soak temperature

6.0 REFERENCES

1. 10CFR, Part 50, Hydrogen Control Requirements, Final Rule, January 25, 1985

2. A Guide to Preparation of Equipment Survivability Lists, Enercon Services, Inc., Revision 0, April 27, 1984

3. HGN-024, December 14, 1984, from S. H. Hobbs (Chairman, HCOG) to H. R. Denton (Director, NRC-NRR), "Hydrogen Control Program Plan"

4. Fuls, Dr. G. M., "The CLASIX-3 Computer Program for the Analysis of Reactor Plant Containment Response to Hydrogen Release and Deflagration," WCAP-10259 (proprietary) and WCAP-10260 (nonproprietary), March 1983

5. Enclosure to HCOG Letter No. HGN-001, January 15, 1982, "CLASIX-3 Containment Response Sensitivity Analysis"

6. RBS CLASIX-3 Analysis, February 1985

7. J. P. Holman, Heat Transfer, New York (McGraw-Hill, 1976), pg 255 to 259

8. RBG-21,218, June 7, 1985, from J. E. Booker to H. R. Denton, "Containment Pressure and Temperature Response to Hydrogen Combustion"