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POOL COOLING

ALUATION

020

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10/29/92

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LOSS OF FUEL POOL COOLING
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ABSTRACT

This document evaluates the various accident scenarios identified by EDR G20020 for which a loss of fuel pool cooling is currently not discussed in the FSAR or other design calculations. In addition to evaluating these events, this document provides pertinent design basis information with regard to the Fuel Pool Cooling system and recovery from a loss of fuel pool cooling event.

For each event a design basis and a realistic evaluation is performed in order to assess the impact of the environment that results from a boiling spent fuel pool on safety-related equipment in Zones I & II. These evaluations also describe how the plant would recover from a loss of spent fuel pool cooling. The report also identifies what actions are required by the operators in order to assure recovery without compromising the operability of safety-related equipment in Zones I & II.

This report concludes that for all DBA LOCA events it is possible to recover without compromising the operability of safety related equipment required to mitigate the events, and assure that the spent fuel will remain sufficiently cooled. Therefore, it can be concluded that the plant is operable with regard to the concerns raised in EDR G20020.
This report draws no conclusions with regard to the reportability of this EDR since this was outside the scope of this evaluation.

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ACKNOWLEDGMENT

The author wishes to recognize the numerous individuals without whose efforts this report would not be possible. These individuals are commended for their efforts in providing timely quality information under adverse conditions.

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1.0 PURPOSE

The purpose of this evaluation is to examine the various scenarios and configurations under which fuel pool cooling could be lost and to determine the resulting impact on the plant. For each scenario, an evaluation is performed under both design basis and current realistic operability assumptions. Particular emphasis is placed on how cooling to the fuel pool can be restored.

2.0 ASSUMPTIONS

For each scenario, the following assumptions are made concerning the design basis and realistic evaluations:

Design Basis:

- DBA accident event scenarios.
- Zone I, II, & III HVAC operate/isolate as currently designed.
- Use of only safety-related or otherwise reliable equipment to recover from the event.
- Use of existing procedures as of 9-23-92.
- Current in-plant dose evaluations in the FSAR for contained sources.
- Extended loss of offsite power (≥24 hours).
- Time to boil is 25 hours. (Ref. 14)
- Systems not hydrodynamic /seismic designed are unavailable.
- Hydrodynamic loads act as originally analyzed affecting the non-LOCA unit with the same loading as the LOCA unit.

Realistic:

- Both units reactor buildings will remain accessible after 12 hours post-accident.
- The probability that offsite power can be restored in 24 hours is 99.53% per the SSES IPE.
- Plant procedures are changed to direct the use of all available means of cooling the pool prior to

of Fuel Pool Cooling. The FSAR assumes a seismic event causes the loss of Fuel Pool Cooling (the system is not seismically designed). It is further postulated in the FSAR that the earthquake occurs during a refueling outage, 10.5 days after shutdown, at a time when the heat load is 9.8 MBtu/hr. In this situation, the pools are isolated and assumed to boil in 25 hours with make-up provided by ESW. The resulting radiological release was well within offsite dose limits specified by 10CFR100. The impact of a boiling pool on reactor building (Zone I & II) equipment was not evaluated.

Note that the current heat load is much lower and thus the time to boil is longer than the original design assumptions as delineated in Table 1 and Figures 1 and 3.

3.2 FUEL POOL INSTRUMENTATION (Ref. 17)

Note that Unit 1 is discussed here. Unit 2 is identical.

The skimmer surge tank level (LT-15312), fuel pool level (LE-15332), and fuel pool temperature (TE-15333) instrumentation strings would be utilized in a potential loss of pool cooling event. These instruments are powered from UPS units. UPS units maintain power to the instrument strings on loss of power until the diesels pick up the load. Therefore, in a LOOP scenario, these instruments will remain powered.

Skimmer surge tank level is alarmed and indicated in panel 1C206 and alarmed on panel OC211. 1C206 is located at elevation 749' and OC211 is located on elevation 818'. Several other alarms also exist in these panels (pump low flow, pump low pressure etc.). When one of the local panel alarms trip, group alarms in control room panels 1C651 and OC653 respectively also alarm. Thus the operators must go to the local panels to determine which alarm has actually come in.

The fuel pool level and temperature instrument strings are similarly configured. These, however, only alarm locally on the OC211 with a group alarm on control room panel 1C653. Fuel pool temperature indication is additionally provided on the local OC211 panel (818' elevation).

Fuel pool level can be determined visually on elevation 818. The acceptable minimum level would be above the bottom of the weir. The bottom of the weir is above the level minimally required to maintain 22 feet of water above the top of the fuel bundles per technical specifications. When on the 749 elevation, fuel pool level can be determined even though fuel pool level is not indicated on the 749 elevation. When makeup is being provided to the fuel pool (via ESW, etc), the temperatures which exceeded EQ limits. A justification for interim operation was prepared (Ref. 22) and transmitted to the NRC demonstrating operability.

This mixing of the ventilation zones raises an additional concern. With cooling to the fuel pool during a LOCA and/or LOOP moisture will be spread throughout secondary containment with reactor building recirculation in operation. Calculations (ref. 13) indicate that the evaporation rate for both pools ranges from 60 gallons per hour at a pool temperature of 125°F with cooling in operation to 480 gallons per hour at a pool temperature of 210°F (no pool cooling). It is possible that high humidity conditions will be experienced in the ECCS pump rooms and switchgear rooms even without a loss of fuel pool cooling. Boiling the pool may greatly increase the moisture content and heat load in the reactor building. This may have an adverse affect on the environmental conditions experienced by safety-related equipment in Zones I and II.

The environmental impact on Zone I and II can be averted by implementing actions to isolate these zones from the high humidity environment on elevation 818. This can be accomplished by implementing the actions for Zone III Venting described in Attachment 3.

3.4 DBA ACCIDENT DOSE

DESIGN BASIS

Another important aspect of the original design basis relative to EDR# G20020 is postulation of fuel failure and its impact on equipment and access to the reactor buildings post accident. The current design accessibility evaluation for SSES is contained in FSAR Chapter 18. It uses methodology for determining "offsite" dose to establish in-plant dose levels.

This approach is specified by NUREG-0737 (Ref. 19) which states that radiation levels should be determined on the basis of contained sources, and core damage source terms equivalent to those used for 10CFR100. The NUREG further states that airborne radioactivity from leakage of systems outside containment is not required to be analyzed for personnel access. While the NUREG is silent with regard to leakage from other containment penetrations (i.e. hatches, airlocks, flanges, etc. which are 10CFR50 Appendix J "Type B" tested) it does recognize that intermittent access to the reactor building is necessary and requires that shielding for personnel access need only be considered. It can be inferred from this point that airborne leakage from "Type B" permitted by Technical Specifications (Reference Tech Spec 3/4.4.5).

In order to perform a realistic, yet conservative in-plant accessibility evaluation for a DBA LOCA, an analysis was performed assuming 1% fuel cladding damage and consideration of airborne radiation (Ref. 18). The results of this evaluation indicate that at 12 hours post-accident an airborne exposure of 1.4 R/hr would be expected on the refueling floor, while the reactor building will have an exposure of 47 mR/hr. Gross airborne activity concentrations tend to rise to a maximum at around 12 hours post-accident and holds constant until about 24 hours post-accident. The contained source exposure experienced by operators manipulating valves for the RHR Fuel Pool Cooling Assist mode would be 2-3 R/hr. Therefore, doses will be within the legal limits (Ref. 16).

3.5 RHR FUEL POOL COOLING ASSIST

A key element of the realistic evaluation of this document is taking credit for the use of RHR as a substitute for normal Fuel Pool Cooling. Original design of the RHR Fuel Pool Assist mode was intended to supplement Fuel Pool Cooling during refueling operations rather than replace it as the sole source of cooling, although it is fully capable of functioning by itself. This explains why numerous manual operator actions required to place RHR in the Fuel Pool Assist mode. It also explains why the piping connections to RHR prevent use of both Fuel Pool Cooling Assist mode and shutdown cooling simultaneously.

The Ultimate Heat Sink (UHS) analyses performed to date do not account for the additional heat load resulting from the use of RHR FPC Assist coincident with a DBA LOCA. These analyses can accommodate the additional heat load as long as two loops of spray arrays are available to dissipate the heat. These analyses will need to be updated formally to account for such capability in the future. This will, however, require additional operator actions to obtain optimum spray efficiencies. See Attachment 7.

Notwithstanding the preceding, the RHR Fuel Pool Cooling Assist mode exists as a viable option for use with a reactor at power. There are numerous drawbacks to its use but they can be overcome with prompt operator action and clear procedures that provide for adequate make-up and control of the RHR pumps.

3.8 RECOVERY FROM LOSS OF FUEL POOL COOLING

As a result of the evaporation/boiling caused by a loss of fuel pool cooling, it will be necessary to take numerous corrective actions. These actions are identified in Figure 5. While the following event evaluations do not proceed down each branch of the event tree, they do identify all of the actions listed on Figure 5. The actions are discussed herein relative to plant scenarios rather than loss of Fuel Pool Cooling scenarios discussed in the event tree of Figure 5.

Besides providing makeup or cooling to the pool, one of the key elements to recovery is to provide isolation of HVAC Zone III from the recirculation plenum and provide a means of relieving pressure buildup from a boiling pool. This will require access to Zone III and power to the Zone III ventilation equipment.

NOTE: The evaluation which follows identifies the use of venting HVAC Zone III. For the purposes of this evaluation, **Zone III Venting** is defined as follows:

> **Isolating the connections between Zone III and the recirculation plenum and providing Zone III ventilation by running filtered exhaust only <u>or</u> unfiltered exhaust and supply if radiation levels permit.**

Consequently, many of the assumptions in the realistic evaluations regarding accessibility and power restoration will be directed to the isolation of Zone III.

Therefore, in this evaluation, success is considered to occur when the pool is prevented from boiling <u>or</u> by permitting boiling and preventing the environmental consequences of a boiling fuel pool on equipment in secondary containment.

This success criteria can be expanded to the following:

1. Do not allow pool boiling/evaporation to adversely affect proper function of safety-related equipment in the reactor buildings.

2. Pursue all available means for maintaining adequate pool cooling before using pool boiling and make-up.

3. Provide filtered exhaust to the Zone III environment.

4. Keep operator actions required in the reactor building at a minimum.

under the assumption that the corrective actions listed in Section 5.2 can be taken credit for.

The evaluations for each event contained in this section address all of the conditions identified in Figure 5 except for a seismic event. This case is omitted from this evaluation, since recovery from this event was not a concern in the EDR and it is already evaluated in Chapters 9 & 9A of the FSAR. It is also bounded by the following event evaluations.

- Status of ECCS Keepfill will depend on the magnitude of the hydrodynamic loads from the LOCA unit.

- RHR would be available for Fuel Pool Cooling Assist since Alternate Shutdown Cooling could be used to cool the vessel. Additionally, the "A" loop of RHR would have to be used for FPC Assist in order to allow for suppression pool cooling via the "B" loop. This is due to the piping configuration which requires the discharge to the fuel pool through the "A" loop only.

CONCERNS:

1. For design basis purposes, access to some areas of the reactor building could be limited for several days post-accident. The refueling floor will remain accessible at all times post-accident per chapter 18 of the FSAR.

   From a realistic standpoint, access to the LOCA unit reactor building and the refueling floor will be possible based on the amount of fuel failure expected from realistic LOCA analysis.

2. Loss of the keepfill system requires the use of an alternate system to fill the Fuel Pool to allow use of RHR Fuel Pool Assist mode (ESW could fulfill this function).

3. The skimmer surge tank is marginally sized for the use of RHR at the flow rate prescribed by procedures. Potential is real for a loss of suction to the RHR pumps in this mode of operation. This in fact, happened at SSES during the test program where flows greater than 2000 gpm could not be attained without running the skimmer surge tank dry. (Ref. 4)

4. The time to boil is a key factor since it may allow for sufficient time to take actions necessary to place RHR into service for fuel pool cooling.

EVALUATION:

Design Basis/Current Procedures:

Under the strict design basis assumptions identified in Section 2 and the concerns identified above, it may not be possible to prevent the LOCA Unit's Spent Fuel Pool from boiling. This is primarily because the normal fuel pool cooling system is assumed to be lost and the RHR Fuel Pool Cooling Assist mode procedure

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Operators must be made aware of the need to provide pool cooling by other than boiling if at all possible. Additionally, the operators will need to perform Zone III venting. Procedures need to be changed to reflect the need to place RHR into fuel pool cooling as early as possible and to identify ESW, Fire Protection and RHRSW as safety-related sources to fill the pool. Time to boil, thus time to take these actions are in excess of 60 hours for the upcoming operating cycle as shown in Figures 1-3. Time to makeup is estimated in Attachment 4.

The non-LOCA unit should be able to cool its pool via the normal Fuel Pool Cooling system, since hydrodynamic loads would be significantly less than the analytical model indicates. Also, the operators would have sufficient time to put RHR in Fuel Pool Cooling Assist mode if necessary. The operators should be made aware of the need to use Alternate Shutdown Cooling to permit the use of RHR in Fuel Pool Cooling Assist.

If the pools can be connected, time to boil will be extended. Additionally, it will allow use of the LOCA units pool cooling systems to cool both pools. This will alleviate the problem of swapping the NON-LOCA units RHR system between shutdown cooling and fuel pool cooling.

Therefore, it appears that the plant could prevent the pools from boiling, however, accessibility (Ref. 16) and the time it will take for the pools to boil (Table 1) are key factors in this judgement.

Note that should it not be possible to provide cooling to the pools, it would be possible to allow the pool to boil and vent zone III.

boil and have an adverse effect on the emvironmental conditions experienced by safety related equipment.

Realistic/Operability

The evaluation for the LOCA unit remains the same as event #1. The non-LOCA unit will lose normal Fuel Pool Cooling until power is restored (within 24 hrs). Since calculated time to boil exceeds the LOOP duration, operators can be expected to adequately restore normal Fuel Pool Cooling.

If normal Fuel Pool Cooling cannot be restored, operators must use Alternate Shutdown Cooling, to enable use of RHR FPC Assist. If this mode of RHR is not available, operators can establish a makeup source and allow the pool to boil. Initiation of Zone III venting will be necessary to prevent building pressurization and to provide a path for removal of moisture buildup on the refueling floor. Due to the three zone mixing during the LOOP, the non-LOCA unit must be isolated from the recirculation plenum to prevent the spread of moisture to its reactor building.

Therefore, it appears that the plant would adequately prevent pool boiling. However, the LOOP has the potential to further complicate the plant response to this event for the non-LOCA unit.

EVENT #4: ONE UNIT OPERATING, OTHER UNIT IN A REFUELING OUTAGE; LOCA/LOOP

Note: A LOCA/LOOP for the refueling scenario is the bounding event since it potentially disables more equipment than other accident events. Therefore, LOCA/LOOP is the only event being evaluated.

As documented in Table 1, the U2-5RIO evolution bounded the FSAR Appendix 9A design basis loss of fuel pool cooling event. During an outage, the fuel pools are at times crosstied to each other and to the RX well, and at times isolated.

For a brief period during the U2-5RIO outage, both loops of RHR were out of service for maintenance. During this period however, one loop of Core Spray remained in service providing a safety-related source of make-up. Additionally, the non-outage unit's FPC system and RHR system would be available to provide cooling to the crosstied pools. Furthermore, the probability of a LOCA/LOOP, concurrent with both loops of RHR out of service in an outage, is sufficiently small so as not to be considered.

During outages, the outage unit reactor building is normally isolated from the recirculation plenum, effectively isolating the outage unit from a potential LOCA environment. This allows accessibility to the outage unit reactor building should anything happen in the non-outage unit or on the refuel floor. With the pools crosstied, both pools can be cooled by either units pool cooling systems (via a Fuel Pool Cooling system or an RHR Fuel Pool Cooling mode). Since time to boil is relatively long and the outage units reactor building is accessible, the actions necessary to mitigate the loss of pool cooling event during a LOCA\LOOP will be more readily achievable in an outage situation than during non-outage situations. Therefore, the previous event evaluations present more challenging situations than does an outage event.

Zone III venting can be achieved under certain key assumptions:

- Both reactor buildings will remain accessible for a DBA LOCA to enable performance of operator actions.

- Offsite power can be restored within 24 hours.

- Plant procedures are changed as indicated below.

<u>5.2 Recommendations</u>

The following enhancements to the SSES plant procedures and design are deemed necessary to assure mitigation of the events evaluated herein. These actions are categorized into "Immediate" and "Short Term" actions, based in part on the relative timeframe in which they can be accomplished. "Short term" actions generally represent modifications which will require some time to design and install. For each "short term" action noted below, interim measures have been identified to enable time for implementation of a permanent design modification. Additional evaluations will be performed to determine the need for additional actions.

Immediate Actions:

1. Procedure changes to ON-135(235)-001, "Loss of Fuel Pool Cooling/Coolant Inventory" and OP-149(249)-003, "RHR Operation in Fuel Pool Cooling Mode". These procedure changes are necessary to identify all available options and important parameters to be considered during mitigation of a loss of fuel pool cooling resulting from SSES design basis events (i.e., LOCA/LOOP). The following changes should be considered as a minimum:

   ON-135(235)-001;

   1. Identify the potential need to isolate Zone III, as described herein, with reference to the appropriate implementing instructions.
   2. Identify ESW and fire water as a potential source of fuel pool makeup.
   3. Place greater emphasis on the importance of providing cooling to the pools rather than allowing the pools to boil.
   4. General recognition of this evaluation.
   5. Identify the potential need to periodically drain the skimmer surge tank to provide a means of gross fuel pool level indication.

   OP-149(249)-003;

   1. Identify fire water as a potential source of fuel

for these valves. This is not considered an "Immediate" action, because alternate means of fuel pool makeup will be available (i.e., fire hose).

FUEL POOL

e. FF10451 SHT 4201
f. E167 SHT 6
g. J453 SHT 3
h. J5AC-142 SHT 1
i. E331 SHT 11
j. E371 SHT 19
k. E25 SHT 4

GENERAL REFERENCES:

l. SEIS INSTRUMENT INDEX
m. P&ID M153

18. PLI-72696
19. NUREG 0737
20. ET-0871
21. PLA-1132 (NUREG 0803 SUBMITTAL)
22. PLI-20806 (NUREG 0803 JIO)
23. ET-0870
24. Calculations E-AAA-718 AND E-AAA-719

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TABLE 1

UNIT 2 5RIO HEAT LOADS

AND

TIME TO BOIL

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TABLE 1: U2 5RIO HEAT LOADS AND TIME TO BOIL

TIME (DAYS)	HEAT LOAD (MBTU/HR)	TIME TO BOIL (HOURS) 110	125
0 - 9/14/92 * Pools are isolated. No fuel is offloaded.	U2 = .75 U1 = .8	>340 >340	340 340
18 - 9/30/92 * U1 FPC cooling both pools. U2 defueled. Pools crosstied and connected to RX well.	20	57	45
38 - 10/19/92 * RPV refueled. 1/3 of U2 core left in U2 pool. Pools are isolated.	U2 = 5.65 U1 = .8	53 >340	45 340
57 - 11/7/92 * U2 S/U. Pools are isolated.	U2 = 4.65 U1 = .8	64.5 >340	55 340

NOTES:

1. Time in days from U2-5RIO outage schedule 8/28/92.

2. Heat load based on measured values to the extent available at the time of this evaluation and on calculated projections. Measured values from TP-235-011 and calculated values from NFE-B-NA-048, rev. 3 which provided the heat load of 1/3 of the core as a function of time. See M-FPC-010.

3. Time to boil from M-FPC-010 assuming initial pool temperatures of 125 and 110 F. Values identified should be viewed as the minimum time to boil. Due to conservative nature of the calculation methodology, actual time to boil will be in excess of the values provided.

FIGURE 1

UNIT 2 TIME TO BOIL

POOLS ISOLATED

U2 FUELPOOL TIME TO BOIL

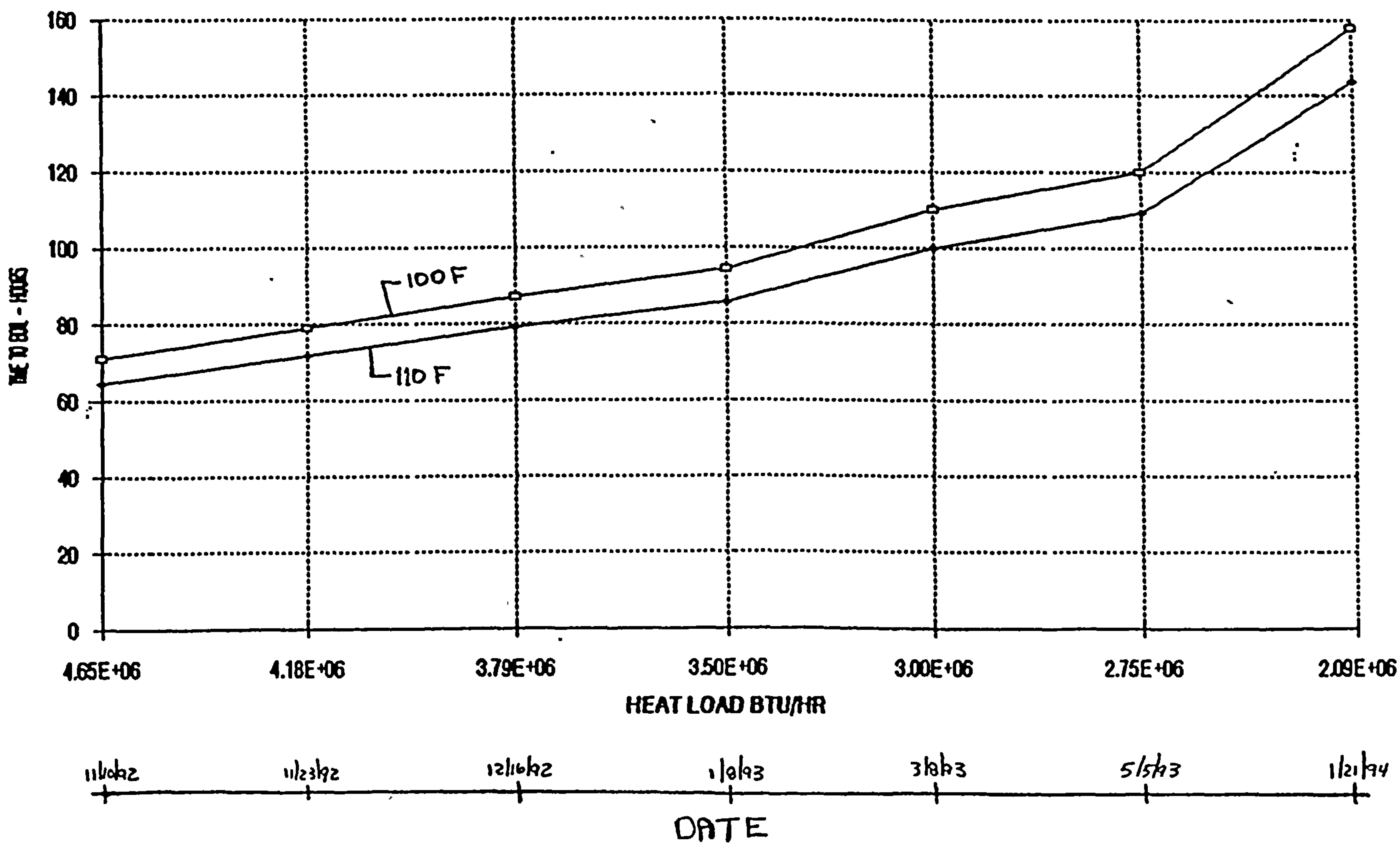

FIGURE 2

TIME TO BOIL

POOLS CONNECTED

TIME TO BOIL FUEL POOLS CONNECTED

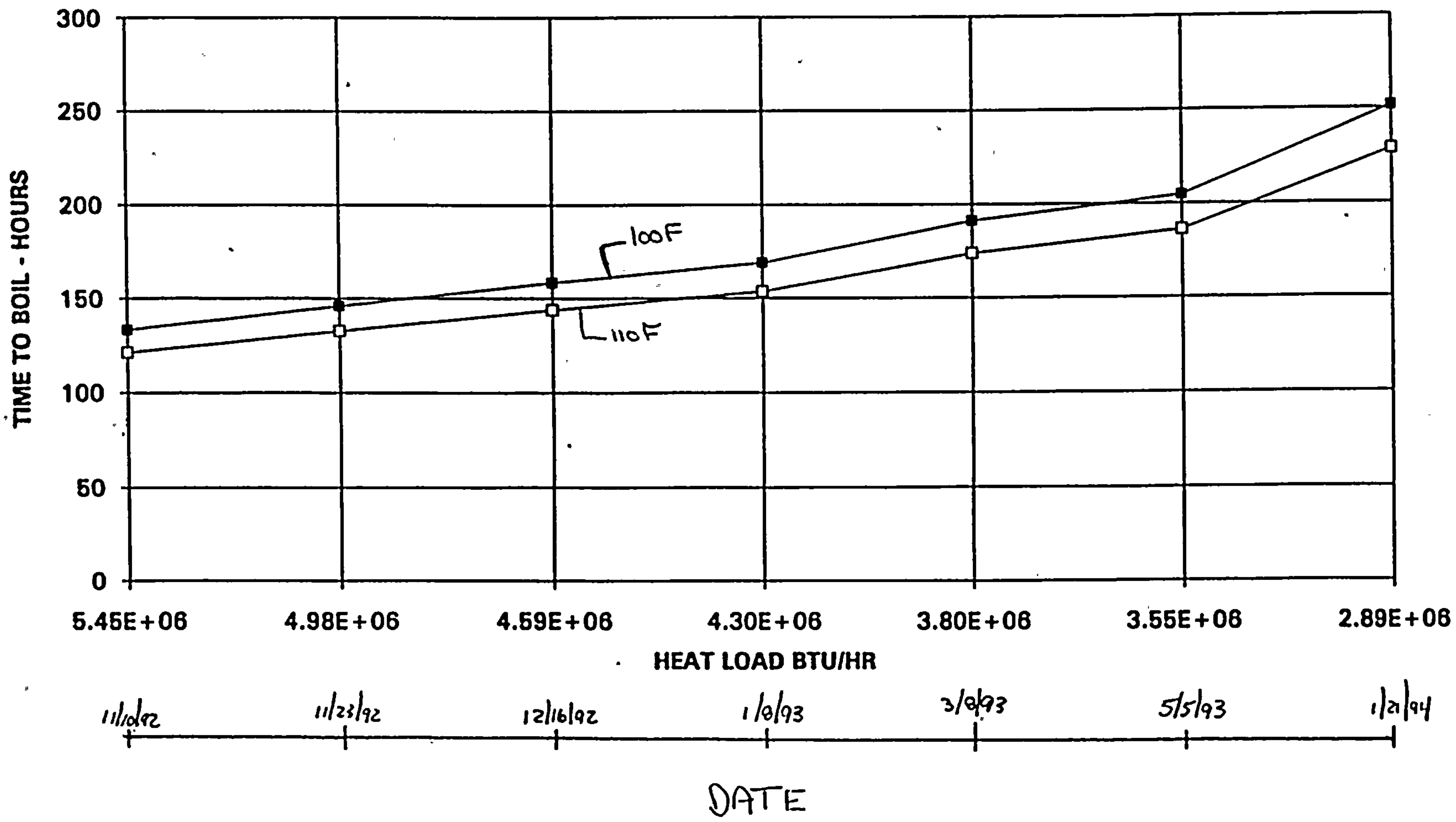

Figure 2

FIGURE 3

UNIT 1 TIME TO BOIL

POOLS ISOLATED

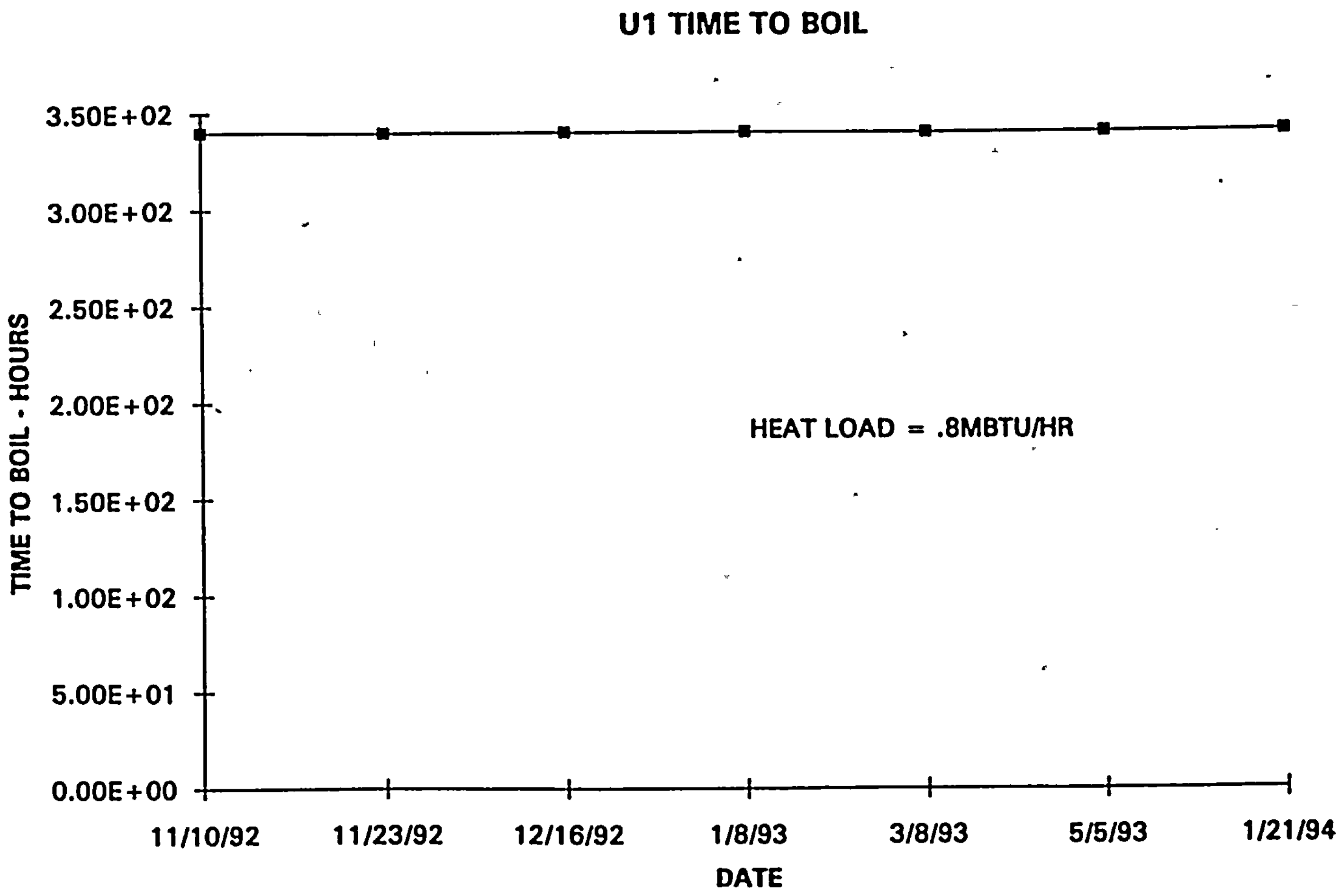
U1 TIME TO BOIL
TIME TO BOIL - HOURS
3.50E+02
3.00E+02
2.50E+02
2.00E+02
1.50E+02
1.00E+02
5.00E+01
0.00E+00
HEAT LOAD = .8MBTU/HR
11/10/92
11/23/92
12/16/92
1/8/93
3/8/93
5/5/93
1/21/94
DATE

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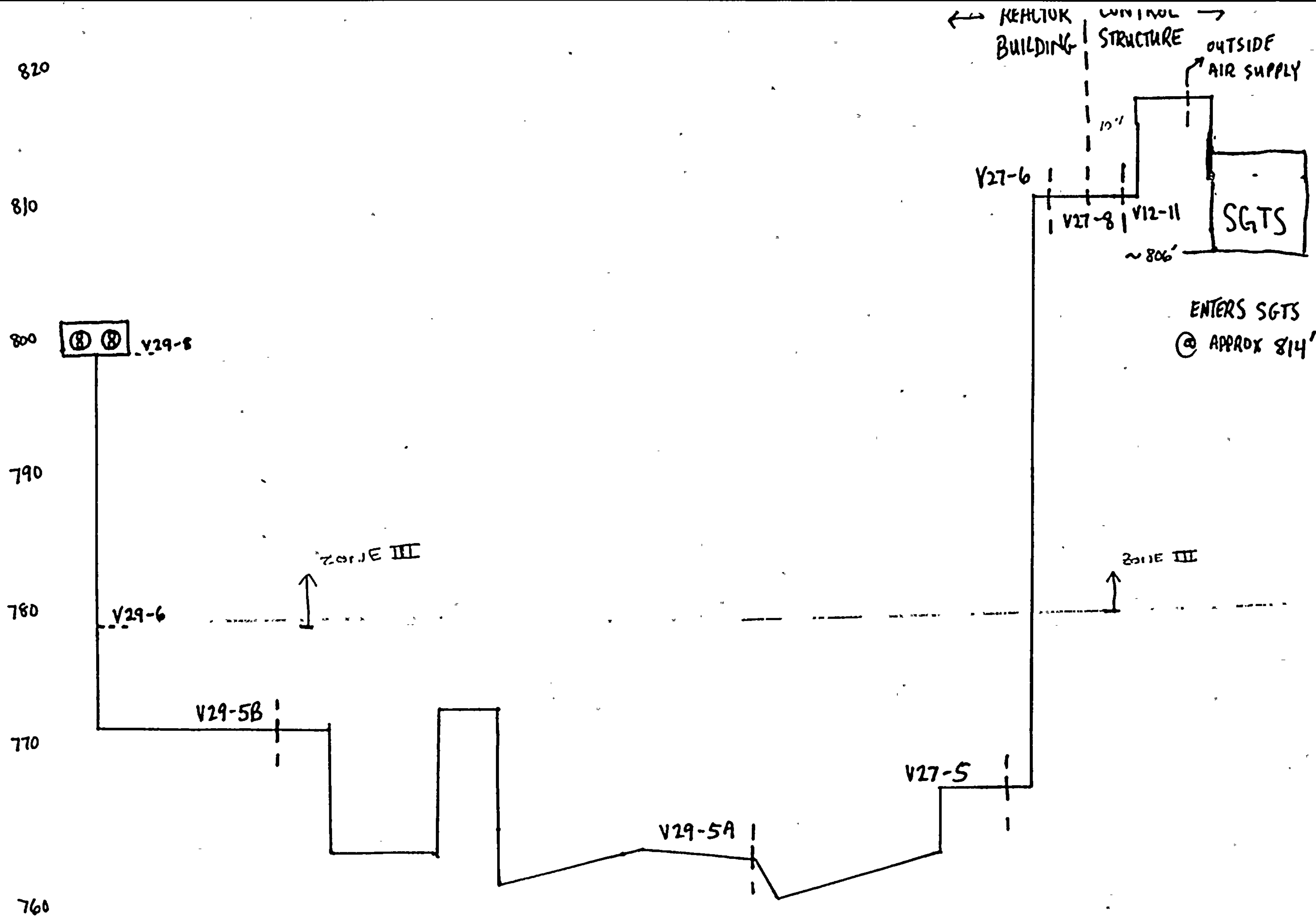
FIGURE 4

SGTS DUCT ROUTING



820
810
800
790
780
770
760
REACTOR BUILDING
CONTROL STRUCTURE
OUTSIDE AIR SUPPLY
10"
V27-6
V27-8
V12-11
SGTS
~806'
ENTERS SGTS @ APPROX 814'
V29-8
ZONE III
ZONE III
V29-6
V29-5B
V27-5
V29-5A

FIGURE 5

LOSS OF FUEL POOL COOLING

EVENT TREE

Figure 5a - Loss of Fuel Pool Cooling Due to Seismic Event

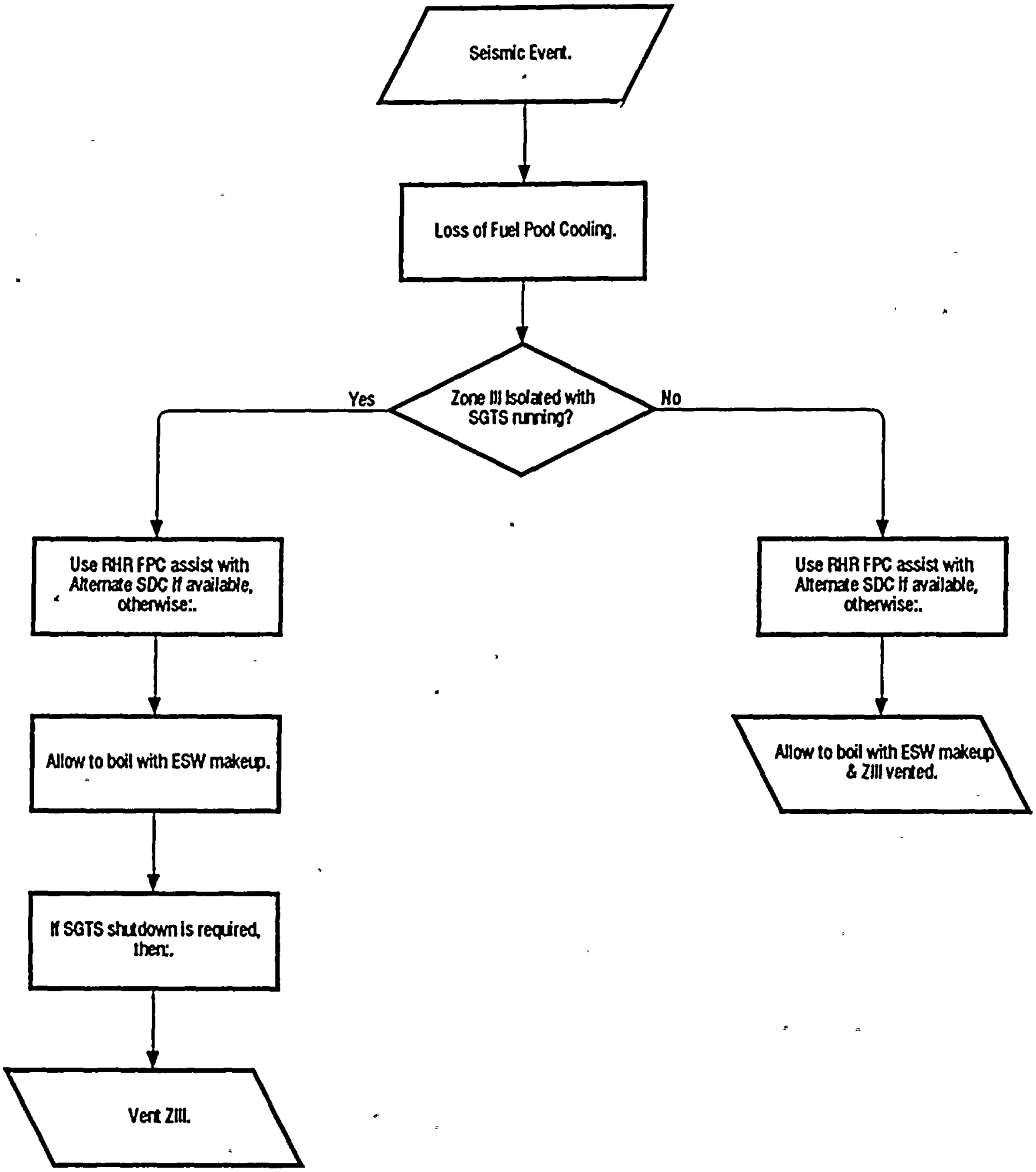


Figure 5b - Loss of Fuel Pool Cooling Due to LOCA

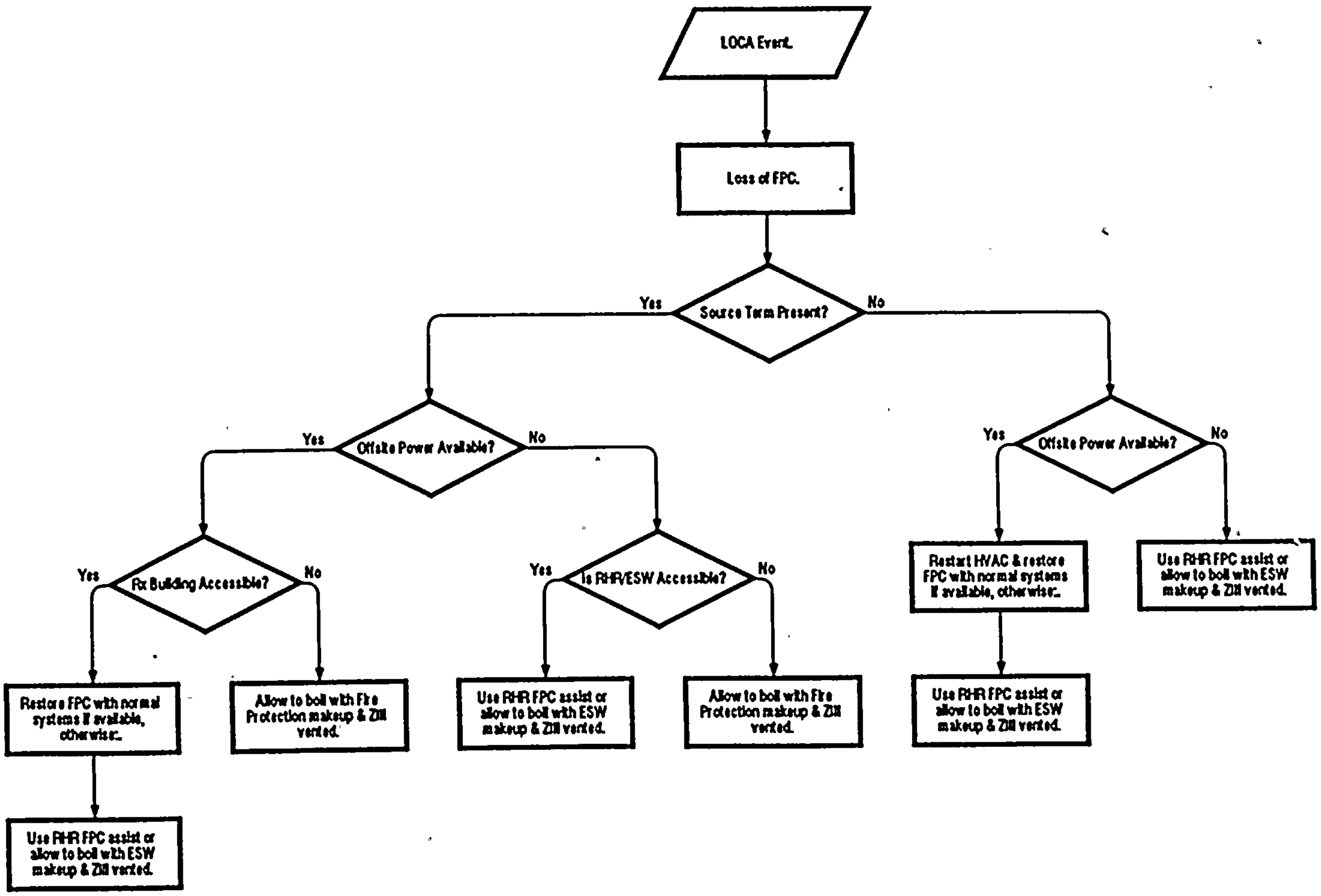
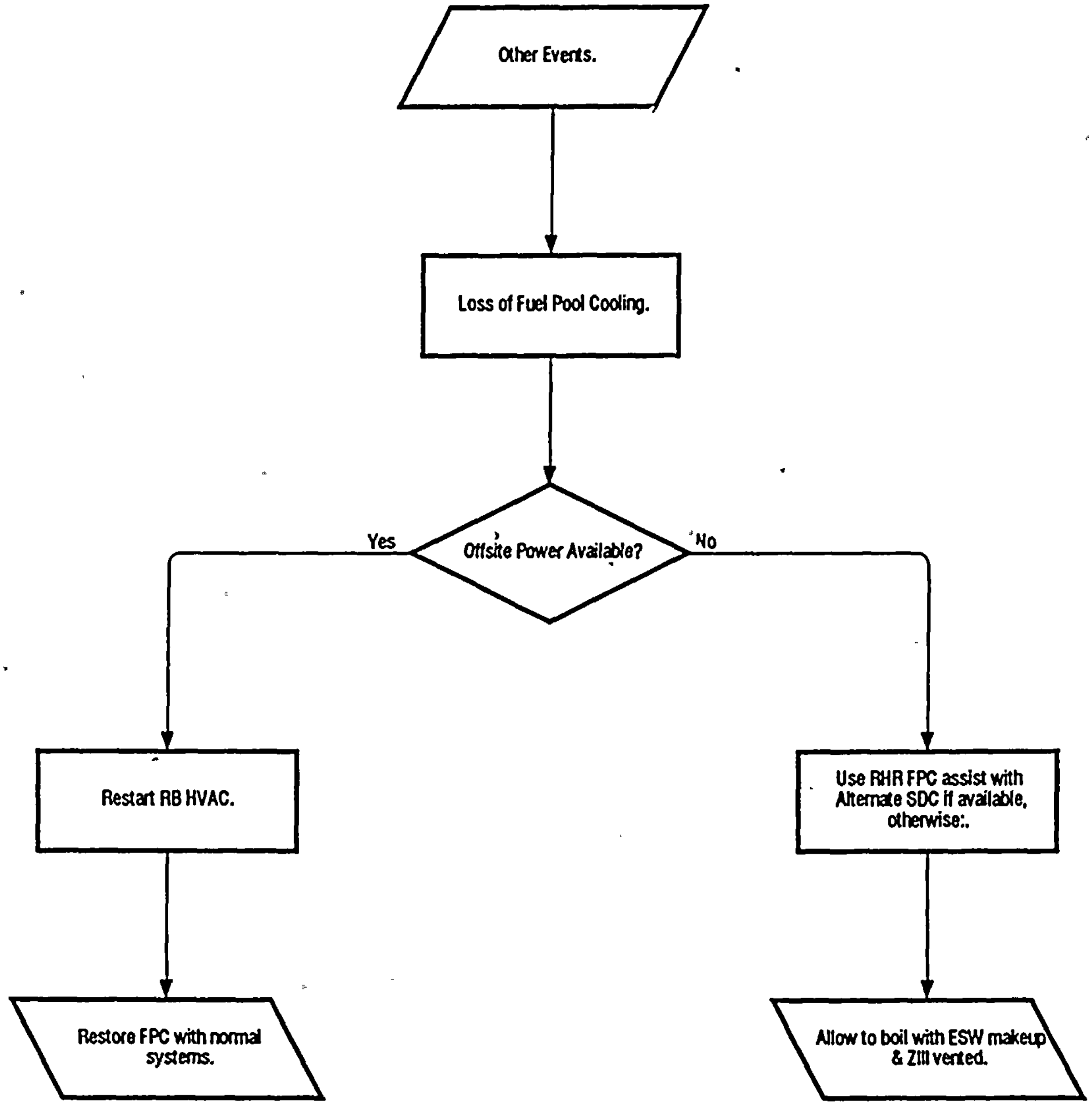


Figure 5c - Loss of Fuel Pool Cooling Due to Other Causes



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ATTACHMENT 1

ENGINEERING ASSESSMENT OF FUEL POOL COOLING PIPING

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