CONTROL ROOM HVAC SYSTEM
VALUE IMPACT ASSESSMENT
SEP TOPIC II-1.C, OFFSITE HAZARDS
NUREG-0737, ITEM III.D.3.4
CONTROL ROOM HABITABILITY
SAN ONOFRE UNIT 1
DOCKET NO. 50-206

REVISION 1

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I. EXECUTIVE SUMMARY

This report provides an evaluation of the cost-benefit of possible upgrades to the San Onofre Nuclear Generating Station Unit 1 Control Room HVAC system for the resolution of SEP Topic II-1.C, Offsite Hazards and TMI Action Plan Item III D.3.4, Control Room Habitability. This evaluation is performed by calculating the incremental value and impact of successive design enhancing features or requirements on the control room HVAC system.

The current design is a single train system. It has no toxic gas monitoring capability at the present time. It is assumed that it does not meet a .67g earthquake level, and it is not specifically designed to meet design basis tornado missile protection requirements. Supplemental capability is currently provided, however, by two possible backups to the existing system. These are:

- A ventilation path from the control room to the Technical Support Center (via one door)
- A ventilation path from the control room to outside environment (proven by operation)

A stepwise (i.e., added one at a time to evaluate individual effectiveness) set of system enhancements to bring the existing system into conformance with the latest requirements has been defined. Possible enhancements are shown in Table 1 and include:

- Addition of a new toxic gas monitoring system

- o Enhancement of the radiation monitoring system
- o Replacement of the existing HVAC with new redundant trains
- o Provision for improved seismic survivability of HVAC
- o Provision for design basis tornado survivability of the existing HVAC system

Each stepwise modification or enhancement has been evaluated in terms of both the cost and the effect on risk to the operators. In order to properly evaluate the risk reduction and cost associated with each stepwise modification, the incremental value is determined. That is, analyses are performed assuming that previous effects or values have already been incorporated.

The analyses conclude that the control room HVAC system, including all backup ventilation schemes, is reliable and unlikely to fail during an accident scenario. None of the design changes evaluated have a positive value-impact. The alternative designs have a low risk reduction per unit dollar cost, and should not be implemented. The cost factor is particularly true of the addition of a redundant HVAC train. The addition of another HVAC train requires the construction of a new structure to house the new equipment at considerable cost. The study shows this expense to be unwarranted even on a conservative assessment basis.

II. QUALITATIVE EVALUATION OF LOSS OF CONTROL ROOM HABITABILITY

A. Existing Control Room HVAC System

The HVAC system at Unit 1 is a single train system consisting of ducts, dampers, fans, a heat pump, and filters. Figure 1 is a simplified schematic diagram of the system. During normal operation, air from the normal outside fresh air intake is fed through a usually open damper and compressor/fan unit (A-31) supplying conditioned air into the control room. Upon receipt of containment high pressure or containment isolation signal, the emergency mode of operation is required. Initiation of the emergency mode of operation is a manual action. The HVAC is aligned such that Unit A-31 functions as a recirculation unit; air from the emergency outside air intake is fed through the emergency supply fan and air filter unit (A-33), providing filtered makeup air to the control room. The air filter unit (A-33) contains a pre-filter for normal dust collection, a high efficiency filter for fine radioactive particle collection, and two charcoal filters for radioactive gas adsorption. The HVAC system only depends on AC electric power to provide the motive power for the heat pumps, compressors, and fans. No auxiliary cooling water is required. Table 1B summarizes the dependency of the HVAC system on other systems.

B. Existing Backup Capability

1. TSC Connection

In case the control room HVAC system fails, the operator can gain access to the TSC HVAC system by opening a door between the two rooms. Figure 2 depicts a simplified schematic diagram for the TSC HVAC system. During normal operation, filtered and conditioned air is supplied by the TSC air conditioning unit (A-51). A separate filtering system (A-50) is provided for the outside air supply to A-51 through damper FCD/2519B. The emergency outside air intake filter unit A-50 contains a pre-filter for normal dust collection, two high efficiency filters for fine radioactive particle collection, and two charcoal filters for radioactive gas adsorption. Cooling is separate from the normal control room HVAC.

2. Outside air

A second "backup" for the control room HVAC system is an option of opening the door connecting the TSC to outside air. A portable fan and ducting is used to enhance the ventilation. The TSC HVAC upgrade is relatively new. Prior to its availability, connection to the outside was used by the operators to maintain reasonable control room conditions during maintenance on the normal control room HVAC unit. These occurrences in the past showed that this is an effective means of maintaining adequate ventilation in the control room in case of the loss of both the control room and TSC HVAC systems.

C. Possible Upgrades

In response to the NRC TMI Action Plan Item III.D.3.4, Control Room Habitability, and SEP Topic II-1C, Offsite Hazards, a number of possible system upgrades have been identified to meet current design criteria. Table 1 summarizes present features and alternative designs for a series of potential hazards. These are described below.

1. Toxic Gas Monitoring

Unit 2/3 has installed a monitoring system for the detection of butane, gasoline, chlorine, propane, and anhydrous ammonia. Although Unit 1 does not have a toxic gas monitoring system, it is expected that an alert from Unit 2/3 (for any substance drifting to Unit 2/3) will warn the operators in Unit 1 to take protective actions.

A possible enhancement is to add a monitoring system to Unit 1 which includes sensors, alarms and isolation devices. The new monitoring system would be able to detect the presence of certain toxic gases and isolate the control room HVAC.

2. Upgraded Radiation Monitoring

The current radiation monitoring system consists of a sensor and an alarm in the control room. Upon receipt of a high radiation signal, a manual switchover to the emergency supply fan and filter is performed by operations personnel. A possible modification is to provide for an earlier indication and automatic switchover system so that manual operator action is not required for control room isolation.

3. Redundant Trains

The existing control room HVAC system has a single train of components. Alternatives rely upon non-HVAC, non-control room equipment. This does not strictly meet the single failure criterion. Redundant upgraded HVAC trains could be provided and would consist of adding fans, filters, and HVAC units. As a result of this enhancement, a new control room HVAC building would need to be constructed to accommodate the new equipment.

4. Seismic Enhancement

Unit 1 HVAC system is assumed to be designed to withstand earthquake levels up to 0.25g level. A possible enhancement would involve strengthening the structures, components, and equipment supports to withstand earthquakes up to the 0.67g level.

5. Tornado Enhancement

The current HVAC system is primarily housed within concrete walls. That is, the air intake is not through a single pipe or duct riser, but through a labyrinth of walls leading to a "filter wall". Thus, a high degree of tornado protection is provided for the normal system. A possible upgrade would involve the redesign to provide assurance of tornado protection. An alternative would involve provision of missile proof air intakes for the new redundant system.

D. Scenarios Leading to the Loss of Control Room Habitability

The accident scenarios leading to the loss of control room habitability depend on the nature of the initiating events. The following initiating events are considered: loss of offsite power, random failure of the control room HVAC, presence of toxic gas, presence of radiation, earthquakes, tornadoes, and fires. Each of these initiating events may lead to undesirable control room conditions causing the loss of control room habitability.

1. Loss of Offsite Power

In case of a loss of offsite power, the control room HVAC system would not function due to lack of AC electric power. It is possible to manually connect the control room HVAC heat pump to the emergency 4KV bus if either diesel generator successfully starts and provides backup electric power. In case the diesel generator is not available, a station blackout event ensues. This represents a much more significant challenge to other plant systems than to the control room HVAC system. A calculational thermodynamic model of the control room indicates that the control room temperature rises to 97 ^{o}F within 10 minutes and 104 ^{o}F within 30 minutes. The temperature then stabilizes at approximately 105 ^{o}F and rises slowly to 109 ^{o}F eight hours following the total loss of HVAC. The calculation assumes an outside temperature of 85 ^{o}F (a design basis day occuring less than 1 percent of the time) and no introduction of TSC or outside air into the control room. This is the most conservative condition and represents a bounding case.

2. Random Failure of the Control Room HVAC

The control room HVAC system may not provide sufficient ventilation and cooling to the control room due to a random failure of components such as heat pumps, chillers, fans, dampers, etc. In most cases, the loss of control room HVAC system does not cause the loss of control room habitability.

The calculational thermodynamic model of the control room for the design basis day indicates that the control room temperature rises at the same rate as in the total loss of AC power scenario until forced ventilation is established between the TSC and control room via the door separating the two rooms. The use of a portable fan and short piece of duct transfering 2000 cfm of TSC air to the control room results in a rapid drop in control room temperature to approximately 97 ^{o}F, and then a slow increase in control room at a rate of approximately 0.3 ^{o}F/hr. The temperature of both rooms rises steadily reaching 104 ^{o}F in the control room and 87 ^{o}F in the TSC after 24 hours.

3. Presence of Toxic Gas

There are two potential sources of toxic gas: onsite and offsite. The offsite source of toxic gas refers to the shipment of toxic gas on highway I-5. The onsite source consists of gases used to provide service of the plant such as chlorine, ammonia, and hydrazine. In order to have a significant concentration of the toxic gas at the control room air intake, the toxic gas must be released in sufficient quantities. In addition, the weather conditions must be such that diffusion to the control room air intake is favorable.

4. Presence of Radiation

The major radiation sources originate from extremely unlikely core melt occurrences at Unit 1, Unit 2, or Unit 3. Direct radiation from shine through the Unit 1 containment contributes to the whole body gamma dose to the operators. Airborne radioactive gases including iodine, krypton, and xenon can enter the control room HVAC fresh air intake and accumulate in the control room. Upon indication of high radiation inside, the operators manually realign the fresh air intake dampers to provide filtration of the intake air and start the emergency control room pressurization fan to prevent infiltration of unfiltered air into the control room.

A less significant radiation release might result from a steam generator tube rupture or LOCA, however, dose calculations indicate that the dose to the operators would be less than the limits defined in Design Criterion 19 of Appendix A 10 CFR 50 for these design basis accidents except for the whole body gamma dose. The whole body gamma dose for a LOCA accident at Unit 1 results in a calculated 6.2 rem to the operators from sources outside the control room and 0.4

rem from sources inside the control room over a period of 35 days. The total dose exceeds the criterion by only 1.4 rem. Therefore, from the standpoint of risk, only core melt is considered significant.

5. Earthquakes

Earthquakes represent a common cause initiator affecting the control room HVAC system and other plant systems. Earthquakes with stronger magnitudes occur with lower frequency than those with lower magnitudes.

An earthquake could result in a loss of the control room HVAC system by: (1) obstruction of air flow through ducts as a result of damage from falling structures, damage to HVAC fans, chillers, or dampers from failure of the structural mounts, or loss of electrical power supply to the electrical equipment.

The major impact of an earthquake may be more significant for electrical power systems (e.g. circuit breaker or relay chatter problems) than for the control room HVAC system. Such loss is described under the loss of offsite power scenario description. Loss of control room HVAC due to earthquakes may thus have negligible risk significance compared with the loss of other safety-related systems.

6. Tornadoes

The major impacts of a tornado include missiles and wind loadings. The wind loading affects the building and is thus not considered in current analysis. The missiles generated by the tornado may destroy the control room intake leading to a degraded performance of the control room HVAC.

The control room HVAC intake duct is shielded from the outside by structural walls and floors of the building. The TSC intake, fan, and chiller unit are situated on the top of the control building in a metal building.

The tornado analysis in this assessment is only intended to address design basis tornadoes and their associated probability of occurrence. Damage from more frequent wind storms with slower wind speeds than the design basis tornado are not addressed in this analysis. An ongoing tornado study is being conducted and will address the impact of wind storms on the Unit 1 control room HVAC system.

7. Fires

Fires in the mechanical equipment room housing the control room HVAC system may damage the control room HVAC system. However, fires in this region are not likely to induce plant transients. The major effect is the potential for loss of control room habitability due to the presence of smoke or the loss of ventilation and air conditioning capability. Fire dampers are included in the system. This risk could be increased by adding additional trains of HVAC equipment.

Since fires are treated by Appendix R considerations, and since no HVAC system can be fully fire proof, no further consideration of fire risk is provided.

III. ANALYSIS OF VALUE AND IMPACT

In evaluating the desirability of possible system upgrades, it is appropriate to evaluate the "safety" value of possible enhancements and compare this value to the cost or impact of providing the enhancement. In evaluating an older plant such as Unit 1, it is particularly appropriate to evaluate such factors when considering the applicability of new criteria for which the plant was not originally designed. Only those modifications with a significant value-to-impact ratio are considered appropriate. In this context:

- o Value is defined as the monetary worth of risk reduction.
- o Impact is the cost of the modification, any operations and maintenance costs, outage time (if any), and associated physical plant and personnel impact (i.e, man-rem exposures associated with the modification)

By evaluating the risk reduction based on probabilistic approaches and estimating the dollar cost associated with each stepwise upgrade, the value-impact is determined. To perform an incremental value-impact assessment, change in value is determined for each of a series of identified alternatives.

A base case is identified as follows:

- o Normal system hardware is analyzed as is
- o TSC HVAC system and outside air are included as

possible backups

For this base case, like other alternative cases, the risk to the control room operators from the following events are evaluated:

- o Excessive temperature
- o Toxic gas
- o Radiation
- o Earthquakes
- o Tornado

The loss of offsite power (including station blackout) and a fire are two events that are evaluated based on a bounding analysis and are not further considered for loss of offsite power, the impact on other plant safety systems outweighs effects of control room HVAC. For fire, only a fire in the area of the HVAC room would represent a significant challenge. The control of other fires is covered by responses to Appendix R and station procedures, including provision of a remotely operable dedicated safe shutdown system. Fires offsite would be identified and the control room notified prior to any serious condition.

Extensive use is made of published PRA results to facilitate judgment with respect to the risk associated with each hazard.

1. Base Case Analysis

The fault tree for the base case is illustrated in Figure 3. This shows that loss of control room HVAC can occur by five different types of conditions. The first is a normal system failure or malfunction leading to high control room temperature. Other failures require an external hazard to exist. The evaluated hazards include a toxic gas cloud, radiation release on-site, an earthquake, and a tornado.

The control room HVAC provides air to the control room for a variety of conditions. These evaluated hazards represent the envelope of such conditions. The continuing pages of the fault tree provide the full model of these events. The triangles and the letters in each tree are provided to connect these trees together.

It is seen that loss of control room habitability due to excessive temperature results from the simultaneous occurrence of three events: loss of normal control room HVAC, no air from TSC HVAC system, and no outside cooling.

The failure results from the loss of normal control room HVAC for an 8 hour period (assumed to be long enough to require some type of action by an operator). The value in the fault tree for this entry is a "per year" frequency. All other entries are for continued operation during the 8 hour period. The presence of either TSC air cooling and connection or outside air will extend the available time for corrective action long enough to achieve a variety of temporary solutions.

For a toxic gas hazard, the HVAC would not be isolated without either a detection of the presence of toxic gas or notice from outside the control room. The probability of toxic gas entering control room and causing loss of habitability is estimated using the results of a previous study for toxic gas occurrence frequency [1] and is taken to be 5.5×10^{-6}/year. The source of toxic gas is from offsite highway accidents on Interstate 5 involving vehicles transporting toxic chemicals. Onsite sources of toxic gas are being reviewed and will be addressed in a revision of this analysis.

Similarly, a typical value for radiation hazards, given no automatic actuation, is 2.1×10^{-7}/year. Seismic risk, using Seismic Safety Margin Research Program [2] methodology and considering different earthquake levels, is 9.3×10^{-8}/year. Table 4A summarizes data used for seismic hazard evaluation of the control room HVAC. The tornado hazard is ~ 10^{-8}/year [3], which is essentially negligible compared with other hazards. The total probability of loss of control room habitability for the base case is estimated to be 6.0×10^{-6}/year.

In evaluating the value of enhancements it is necessary to first review the base case to determine the most likely cost effective upgrades for first consideration. The upgrades which are to be investigated will consist of the following:

- o Addition of a toxic gas monitoring system (toxic gas hazard is the most important contribution to base case risk)
- o Radiation detection enhancement
- o Redundant train addition
- o Seismic upgrade
- o Tornado capability

2. Toxic Gas Monitoring Analysis (Step 1 Enhancement)

One possible enhancement of the control room HVAC system is to install a toxic gas monitoring system.

The accidental release of a chemically toxic vapor cloud from the railroad, the highway, or fixed installations in the vicinity of the unit could potentially lead to loss of control room habitability.

The Unit 1 control room HVAC system does not have any toxic gas monitoring capability. Possible detection by Unit 2/3 or other site personnel could occur. The hazard associated with toxic gas involves the following steps:

- o Occurrence of the hazard
- o Possible detection
- o Protective action

The nature of the chemical affects the degree of toxicity, and hence, the time available for the operator to respond. In the analysis, the available time is assumed to be short for the more serious toxic gases (chlorine, ammonia, gasoline, etc.).

The analysis of toxic gas hazards is based upon several assumptions. First, the values for release, transport, and interaction are adopted from analyses performed for the Unit 2/3 FSAR and provided to the NRC ~~in SCE's responses~~ to III.D.3.4 for Unit 1 [4]. A number of potential releases were identified and evaluated.

The monitoring system that is evaluated is taken to be 0.99 reliable for the monitored gases. This is a design value assumption and should be achievable with reasonable technology. Monitored gases include:

- o Propane
- o Gasoline
- o Butane
- o Chlorine
- o Ammonia

For these substances the effect of the monitoring is to reduce the risk of control room habitability loss by a factor of 0.01 due to residual failure probability of the monitoring system.

For unmonitored substances, the value from these studies [1] is taken directly with only negligible credit given for notification by Unit 2/3 or the Highway Patrol.

Figure 4 presents the fault tree for toxic gas hazard to the control room. The probability of loss of control room habitability due to toxic gas effects, with the upgrades in place, is estimated to be 2.3×10^{-7}/year.

The estimated frequency of loss of control room habitability in the base case is 6×10^{-6}/year. As a result of the enhanced toxic gas monitoring system, the frequency of loss is reduced to 7.2×10^{-7}/yr. The reduction is estimated to be 5.3×10^{-6}/year. For this study, this change is taken as the risk reduction. This is very conservative as other protective features may reduce the risk of core melt by orders of magnitude lower. For example, for a given loss of control room habitability, a transient must occur which requires shutdown and the operator must fail to successfully shutdown the plant from the remote shutdown panel. This is shown in Figure 5.

The cost associated with this enhancement is approximately $500,000.

3. <u>Radiation Detection and Isolation</u> (Step 2 Enhancement)

The evaluation of radiation hazard assumes that a release from any unit on-site could affect control room habitability. The fault tree for this effect is shown in Figure 6. A radiation hazard is evaluated for Unit 2/3 and Unit 1 separately. The likelihood of a radiation hazard event is assumed to be 1×10^{-5}/year, a typical value for core damage and serious release. No credit is taken for the fission product retention effect of containment resulting in conservatism.

The existing control room has a radiation monitor, but no provision for an automatic isolation. Still, the likelihood of operator action is high as a serious release of radioactivity is almost certainly an identified accident prior to release.

The factor of .03 for Unit 2/3 causing an effect at Unit 1 is a wind direction factor assuming a uniform wind rose. This factor is conservative for the San Onofre site.

The design enhancement consists of automating the isolation of the air intake on high radiation which would enhance the ability to preclude air intake of radioactive material. This reduces the failure of action to be taken by an order of magnitude.

The overall probability of loss of control room habitability due to radiation is estimated to be 2.1×10^{-7}/year, based on a core melt frequency of 1.0×10^{-5}. Incorporation of an enhanced system is estimated to reduce this contribution to 1.0×10^{-9}/year. This is a change of 2.1×10^{-7} and reduces the total frequency from 7.2×10^{-7}/year to 5.1×10^{-7}/year. Thus, a risk reduction of 2.1×10^{-7}/year from the implementation of a radiation detection and isolation HVAC system.

The cost associated with this enhancement is approximately $300,000.

4. Upgraded Redundant HVAC System (Step 3 Enhancement)

To further improve the control room HVAC system performance, a conceptual control room habitability system shown in Figure 7 is considered.

Figure 8 presents the fault trees for the upgraded HVAC system. It is noted that only events during normal operation are significantly affected by the modification.

The probability for normal loss of control room habitability in the base case is estimated to be 1.8×10^{-7}/year. Incorporation of this enhancement is estimated to reduce this contribution to 2.5×10^{-9}/year. This is a change of approximately 1.8×10^{-7}/year. The overall loss of control room habitability is therefore reduced to 3.4×10^{-7}/year.

Since a new building must be constructed to accommodate the redundant equipment, this enhancement represents a large impact. The estimated cost is approximately $1,300,000.

5. Seismic Upgrade (Step 4 Enhancement)

The current control room HVAC is assumed to be able to withstand a .25g earthquake. A possible enhancement of control room HVAC system is to upgrade it so that the system can withstand a 0.67g level earthquake. The significant effect of this upgrade is only on seismic risk; other hazards remain the same.

The SSMRP[2] study is used as the basis for the evaluation of the seismic risk of San Onofre 1 control room HVAC system.

Assuming that the air handling unit dominates the seismic risk, a bounding analysis using the failure probability of the air handling unit for different earthquake levels indicates that the reduction in frequency of loss of control room habitability is negligible for this upgrade.

For this analysis, no credit was taken for the backup TSC HVAC system. It was further assumed that the response variation of the air handling unit is smaller than the fragility variation of the air handling unit. The failure of the control room HVAC is then approximately independent of the failure of outside cooling. The fragility of components that are upgraded to withstand a 0.67g level earthquake is proportionally scaled up according to the ratio of the two design earthquake levels.

Figure 9 presents the fault tree assessment for the seismically upgraded HVAC system. The probability of overall loss of control room habitability due to earthquake is reduced from 9.3×10^{-8}/year in the base case to 1.7×10^{-10}/year. This is a reduction of approximately 9.3×10^{-8}/year and brings the overall loss of habitability to 2.4×10^{-7}/year. The incremental cost for this enhancement is estimated to be approximately $500,000.

6. Tornado Upgrade (Step 5 Enhancement)

A final design enhancement considered is to upgrade the intake to withstand a tornado. San Onofre 1 is located in Tornado Intensity Region II.

In order for a tornado to cause loss of Control Room habitability, it is necessary for the tornado to occur, strike the plant, generate a missile, and destroy the air intake. Other tornado effects are not of concern to this study as only control room HVAC upgrades are being evaluated. The current HVAC air intake is behind walls and is generally "protected" by a labyrinth type of air intake flow leading to a filter wall which is protected. Using the J. R. McDonald report, "Tornado and Straight Wind Hazard Probability for Ten Nuclear Power Reactor Sites," (Reference 3), the frequency of a significant tornado in Region II which generates a hazard to control room habitability is assessed to be less than 1×10^{-7}/year. As discussed previously, this assessment only addresses the design basis tornado, not wind storms with wind speeds less than the design basis tornado.

The risk reduction is estimated to be 1×10^{-8}/year for the analysis. The cost associated with this enhancement is approximately $1,300,000.

IV. SUMMARY OF ANALYSIS AND INCREMENTAL VALUE IMPACT ASSESSMENT

Table 1A summarizes the risk contributors to loss of control room habitability for various stepwise enhancements of the HVAC system.

The results shown in Table 1A indicate that toxic gas is the most significant contributor to the loss of control room habitability. Each stepwise enhancement changes only one risk contributor significantly. If all of the identified design alternatives were implemented, the frequency of loss of control room habitability would be reduced from 6.0×10^{-6}/year to 2.3×10^{-7}/year.

It is also possible to evaluate the corresponding risk for each enhancement in terms of the core damage frequency. There is, however, a great deal of uncertainty associated with such an evaluation. Furthermore, it is expected that different conditional core melt probabilities (given loss of control room habitability) are associated with different hazardous events. For example, it is more likely to have a core melt when loss of control room habitability is due to an earthquake than when control room habitability loss is due to toxic gas. Since large uncertainty is associated with the evaluation of the core melt frequency, it is prudent to focus on the risk results in terms of loss of control room habitability.

The cost associated with each enhancement is summarized in Table 5. The cost estimates listed, together with the risk reduction, indicate the incremental effectiveness of each enhancement.

Another way to evaluate cost effectiveness is to evaluate both value and impact in terms of dollars and compare using incremental assessment. A variety of algorithms have been postulated for converting from risk reduction to dollars. The NRC safety goal guideline suggests a value of \$20,000 per 1.0×10^{-5}/year reduction in core melt frequency [5]. It is noted that the core melt frequency is generally much lower than the frequency of control room habitability loss. Nevertheless, this value of \$20,000 is applied herein to loss of habitability which may be one or more orders of magnitude conservative. For this analysis, conservative estimates based on the above value yield the following results:

Plant Configuration	Reduction In Frequency of Control Room Habitability Loss	Maximum \$ Value (No Credit for Backups)	Impact
Base Case	-0-	-0-	-0-
Toxic Gas Monitor	5.3×10^{-6}	\$10.6K	\$ 500K
Radiation Protection	2.1×10^{-7}	\$ 0.4K	\$ 300K
Redundancy	1.7×10^{-7}	\$ 0.3K	\$1,300K
Seismic Upgrade	1.0×10^{-8}	\$ .2K	\$ 500K
Tornado Protection	1×10^{-8}	\$ .02K	\$1,300K

V. CONCLUSION

The existing San Onofre 1 HVAC system is a single train system and was designed when the current NRC design requirements were not in existence. A number of upgrades have been identified. These include the addition of toxic gas monitoring, enhancement of radiation monitoring, provision of redundant components to meet single failure criterion, and upgrade of ability to withstand earthquakes. Risk associated with both the current system and its possible enhancement were evaluated using a probabilistic approach and the results assessed in terms of value-impact framework. The risk associated with the control room HVAC system is low. The value-impact assessment indicates that toxic gas monitoring seems to be most cost-effective.

The cost associated with providing a redundant train of HVAC is tremendous, while the value (i.e., risk reduction) is not significant. This suggests that implementing a redundant train of HVAC is not cost-effective.

Based upon these analyses, none of the identifed modifications has a positive value-impact ratio.

References

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6. Memorandum from William J. Dircks, U.S. NRC Executive Director for Operations, to NRC Commissioners. "Action Plan for Implementing the Commission's Proposed Safety Goals," July 6, 1982.

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TABLE 1

CAPABILITY TO WITHSTAND HAZARD AND ALTERNATIVE DESIGNS

CAPABILITY	PRESENT FEATURES	POSSIBLE ENHANCEMENT
Reliable air to Control Room	o 1 train normal HVAC o 1 train backup TSC HVAC plus ouside air o remote shutdown	Add normal redundant fans, filters HVAC unit and dampers, etc.
Toxic gas	o None-rely on-site alert from Unit 2 and 3	Add sensor and alarm or Sensor with Automatic Isolation
Earthquake	o 0.25g design level	Upgrade to 0.67g design level
Tornado	o Primary HVAC within concrete walls - TSC alternate 60' away, light structure o Door opening possible	Add redundant missile proof shields on doors
Radiation	o Local monitor and alarm with manual isolation	Add sensor and alarm in intake duct with automatic isolation

TAB[illegible]A

CONTRIBUTORS TO LOSS OF CONTROL ROOM HABITABILITY

DESIGN CAPABILITY	SAFETY LEVEL	NORMAL OPERATION CONTRIBUTION	TOXIC GAS	RADIATION	EARTHQUAKE	TORNADO
Base Case	6.0×10^{-6}/yr*	1.8×10^{-7}/yr	5.5×10^{-6}/yr	2.1×10^{-7}/yr	9.3×10^{-8}/yr	1.0×10^{-8}/yr
Base Case w/NRC Core Melt Probability	6.0×10^{-6}/yr	1.8×10^{-7}/yr	5.5×10^{-6}/yr	2.6×10^{-7}/yr	9.3×10^{-8}/yr	1.0×10^{-8}/yr
Toxic Gas Monitoring	7.2×10^{-7}/yr	1.8×10^{-7}/yr	2.3×10^{-7}/yr	2.1×10^{-7}/yr	9.3×10^{-8}/yr	1.0×10^{-8}/yr
Radiation Detection	5.1×10^{-7}/yr	1.8×10^{-7}/yr	2.3×10^{-7}/yr	1.0×10^{-9}/yr	9.3×10^{-8}/yr	1.0×10^{-8}/yr
Upgraded HVAC System	3.4×10^{-7}/yr	2.5×10^{-9}/yr	2.3×10^{-7}/yr	1.0×10^{-9}/yr	9.3×10^{-8}/yr	1.0×10^{-8}/yr
Seismic Upgrade	2.4×10^{-7}/yr	2.5×10^{-9}/yr	2.3×10^{-7}/yr	1.0×10^{-9}/yr	1.7×10^{-10}/yr	1.0×10^{-8}/yr
Tornado Upgrade	2.3×10^{-7}/yr	2.5×10^{-9}/yr	2.3×10^{-7}/yr	1.0×10^{-9}/yr	1.7×10^{-10}/yr	ϵ

* All numbers are "per reactor year"

Table 1B

Dependency of Control Room HVAC on Other Systems

Support System	Support Function
Operator Action	1. Manual remote-operation of the fresh air intake dampers and emergency pressurization fan 2. Additional cooling can be provided by operator's opening the door to the TSC and installing portable ventilating fans and duct.
Control & Instrumentation Power	1. AC power required
Auxiliary Cooling Water	1. None required. HVAC chiller is cooled by the air.
Electric Power	1. The 4KV Bus from which the control room HVAC heat pump is fed is a safety-related bus and can be supplied from a diesel generator if offsite power is lost. However, manual loading to the bus is required.

Table 1C

Accident Initiators Leading to the Loss of Control Room Habitability

Initiating Event	Description
1. Loss of offsite power	o Primary power supply to control room HVAC is lost o Diesel generator may be started to provide power to the control room HVAC. o Control room temperature rises to approximately 93 ^{o}F in 10 minutes and then increases slowly to 109 ^{o}F in eight hours without any forced ventilation o Other plant systems dominate the risk to the plant
2. Random failure of the HVAC under hot weather conditions	o Control room temperature rises to approximately 93 ^{o}F in 10 minutes and then increases slowly to 109 ^{o}F in eight hours without any forced ventilation o Options for forced ventilation include access to TSC cooling and access to outside air through temporary ducting

Table 1C (Continued)

Initiating Event	Description
3. Presence of Toxic Gas	o Hazardous cargo traffic accidents on Highway I-5 may potentially release toxic gas to the control room air intake. o A simultaneous occurrence of a transient would be required to have a potential significant risk to the plant.
4. Presence of Radiation	o Significant radiation sources result from core melt from Unit 1, Unit 2, or Unit 3. o Airborne radiation enters control room HVAC intake. o Sources of radiation from accidents less than core melt do not result in control room doses in excess of NRC limits.

Table 1C (Continued)

Initiating Event	Description
	o For radiation sources resulting from core melt of Units 2 or 3, only the fraction that may impact the control room air intake is significant.
5. Earthquakes	o Earthquake causes structural failure of control room HVAC equipment support or blockage of flow path from falling objects. o Earthquakes represent a common cause initiator for the control room HVAC system and other plant safety systems.

Table 1C (Continued)

Initiating Event	Description
6. Tornadoes	o Missile impact and tornado wind loadings may potentially impact the loss of control room habitability by damaging HVAC equipment or blocking air flow. o Like earthquakes, tornadoes represent a common cause initiator and can affect both the control room habitability and other plant safety systems. However, the probability of tornadoes with such a large magnitude (expressed in terms of windspeed) is even smaller than corresponding earthquakes. o Current on-going tornado design review should resolve risk significance of the tornado smaller than the design basis size.

Table 1C (Continued)

Initiating Event	Description
7. Fires	o Fires in the mechanical equipment room may destroy the major components of the control room HVAC. However, the fires in the region are not likely to introduce plant transient since little plant control and power cabling is routed through the area. Fire dampers in ducts prevent the spread of the fire into the control room from the HVAC equipment room. o Portable ventilation equipment would be required to vent the control room of smoke. Operators would don air packs.

Table 2

Data Used for Loss of Control Room Habitability
Due to Excessive Temperature

Component	Failure Rate	Mean Time to Repair	Mission Time
Ventilation Chiller	9.44×10^{-5}/yr.	21 hours	8 hours
Damper	2.67×10^{-7}/hr.	Not Used	8 hours
Fan A-51	7.89×10^{-6}/hr.	Not Used	8 hours
Outdoor Fan	4.84×10^{-4}/demand 7.89×10^{-6}/hr.	Not used	8 hours

* Source: Seabrook Probabilistic Safety Study Table 6.2.1

Table 3

Data Used for Loss of Control Room Habitability
Due to Toxic Gas Release

Event	Probability
Monitored toxic gas occurrence frequency	6.0×10^{-6}/yr. [Ref. 1]
Unavailability of monitoring system	0.01 [Conservative value judged on the basis of Limerick PRA study]
Unmonitored toxic gas occurrence frequency	1.9×10^{-7}/yr. [Ref. 1]
Probability of no warning	0.9 (judgement)
Probability of no manual actuation	0.01 (judgement)

Table 4A

Data Used for Seismic Hazard Evaluation

Earthquake Classification	Earthquake Level	Equipment Response
EQ1	0.15-0.3g	0.39g
EQ2	0.3-0.45g	0.65g
EQ3	0.45-0.6g	0.91g
EQ4	0.6-0.75g	1.16
EQ5	0.75-0.9g	1.43
EQ6	0.9g+	1.90

Fragility of Various Components of the HVAC System for Design to Withstand Earthquake up to 0.25g[1]

	Fragility		
Component	Median	B_R	B_U
Air Handling Units	2.24	0.27	0.31
Duct Work	3.97	0.29	0.46
Fan	2.24	0.27	0.31

[1] Taken from Zion data for SSMRP (.17g basis)

Table 4B

Significant Duration of Accident Sequences for Each Initiating Event

Initiating Event	Duration
1. Loss of offsite and onsite Power	o Battery depletion in several hours o Recovery of offsite power and D.G must occur in approximately 6 hours or less o Control room habitability not controlling
2. Random failure of the Control Room HVAC under Hot Weather Conditions	o Hot weather conditions that yield highest control room heat load persist for less than 8 hours.
3. Presence of Toxic Gas	o Diffusion and dilution depends on the quantity and the nature of the toxic gas.
4. Presence of Radiation	o Most critical period occurs within the first few hours

Table 4B (Continued)

Initiating Event	Duration
5. Earthquakes	o Failure dominated by structural effects on HVAC equipment
6. Tornadoes	o Duration of tornadoes is less than a half an hour
7. Fires	o Most fires are extinguished in 1 hour. Brown's Ferry fires were extinguished after approximately 7 hours.

TABLE 5

VALUE-IMPACT RESULTS FOR VARIOUS ENHANCEMENTS: LOSS OF CONTROL ROOM HABITABILITY

PLANT CONFIGURATION	OVERALL SAFETY	INCREMENTAL COST	INCREMENTAL RISK REDUCTION
Base Case	6.0×10^{-6}/yr	-0-	-0-
Toxic Gas Monitoring	7.2×10^{-7}/yr	$ 500K	5.3×10^{-6}/yr
Radiation Enhancement	5.1×10^{-7}/yr	$ 300K	2.1×10^{-7}/yr
Redundant Train	3.4×10^{-7}/yr	$1,300K	1.7×10^{-7}/yr
Seismic Upgrade	2.4×10^{-7}/yr	$ 500K	1.0×10^{-7}/yr
Tornado Upgrade	2.3×10^{-7}/yr	$1,300K	1.0×10^{-8}/yr

FIGURE 1

CONTROL ROOM HVAC SYSTEM SCHEMATIC DIAGRAM

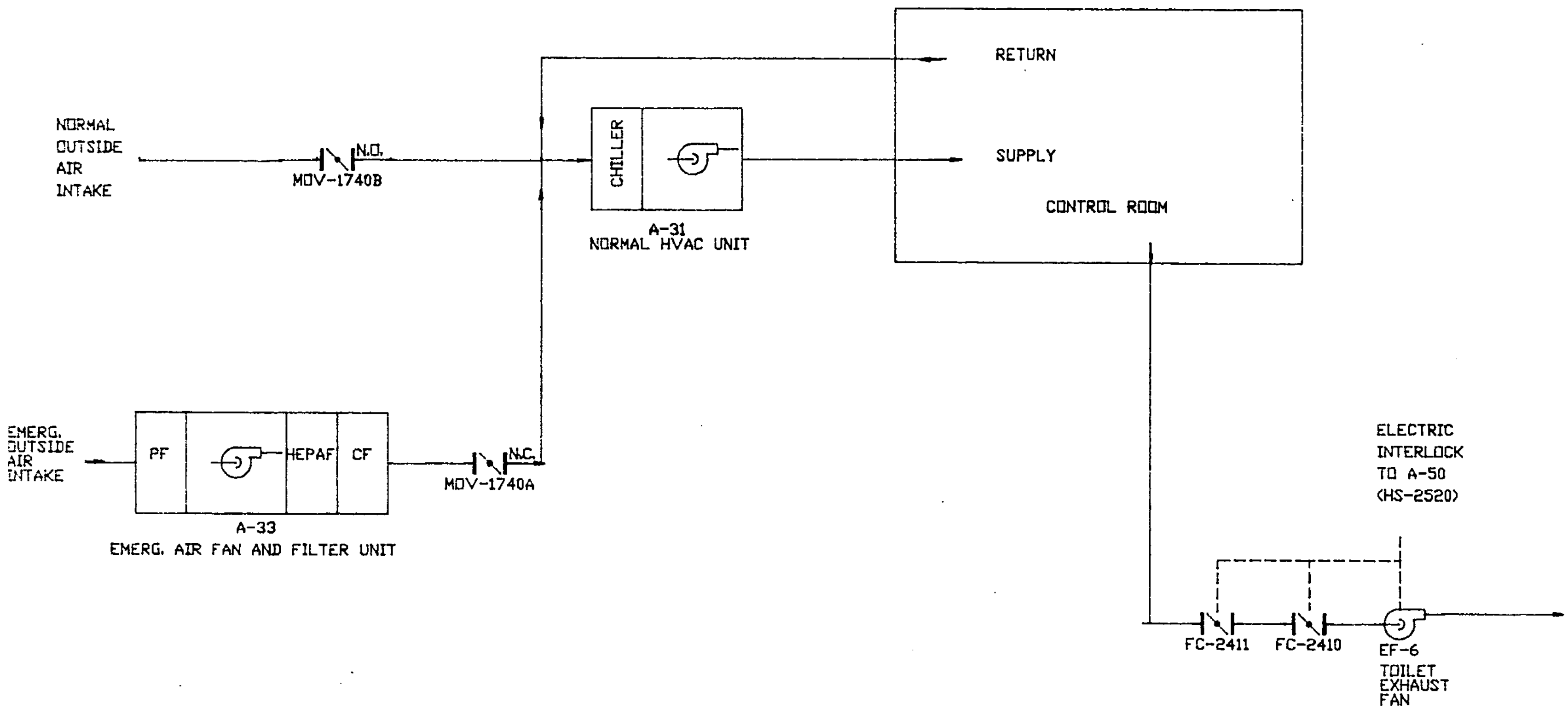


FIGURE 2

TECHNICAL SUPPORT CENTER HVAC SCHEMATIC DIAGRAM

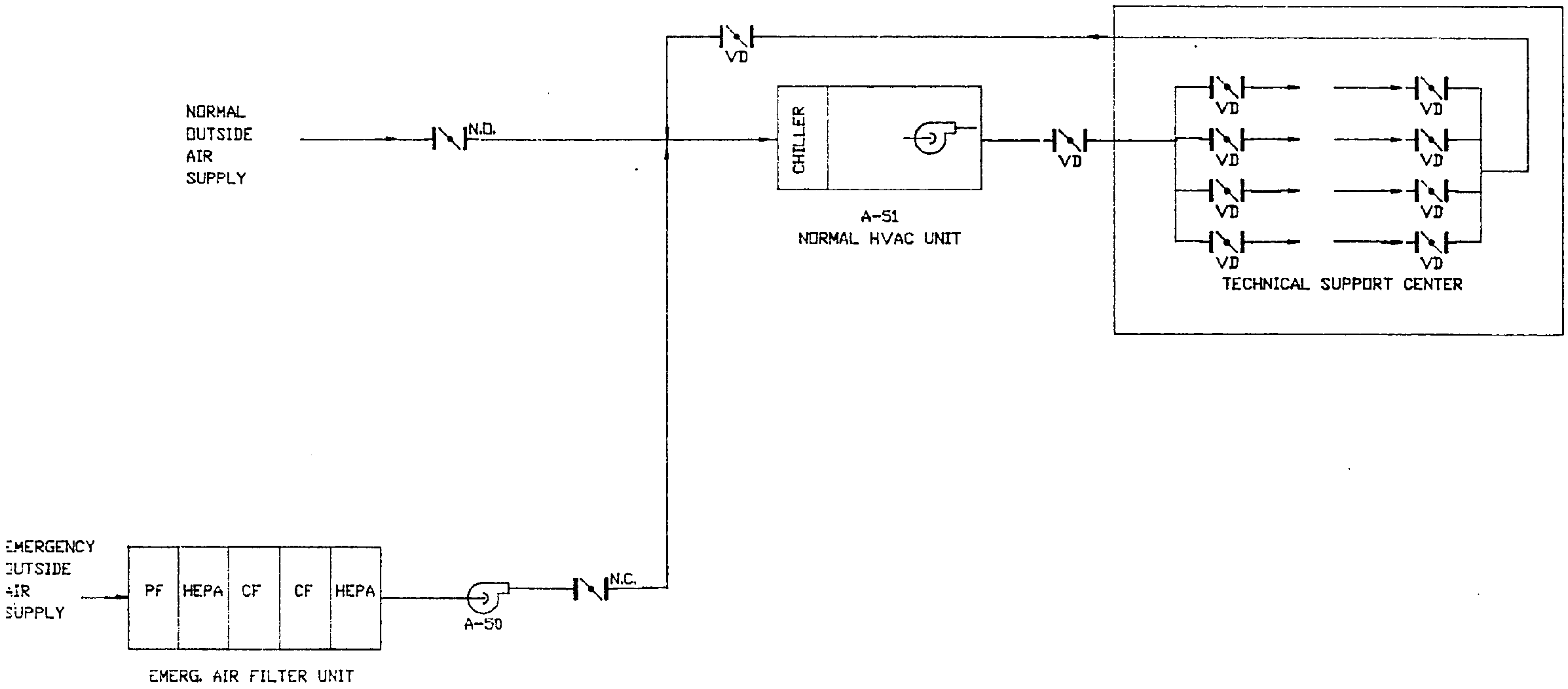


FIGURE 3, SHEET 1

FAULT TREE FOR LOSS OF CONTROL ROOM HABITABILITY - BASE CASE

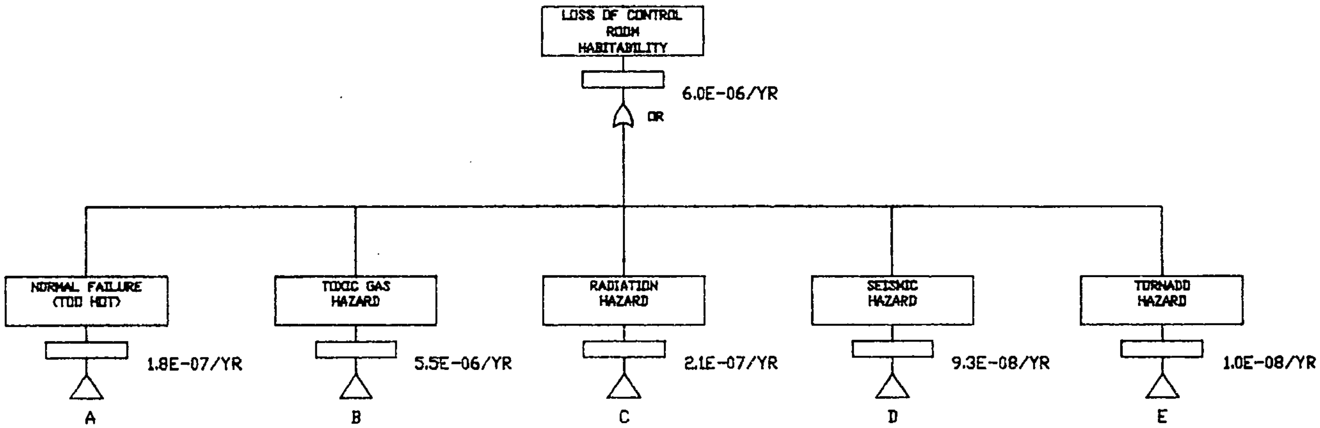


FIGURE 3, SHEET 2

'TOO HOT' CASE

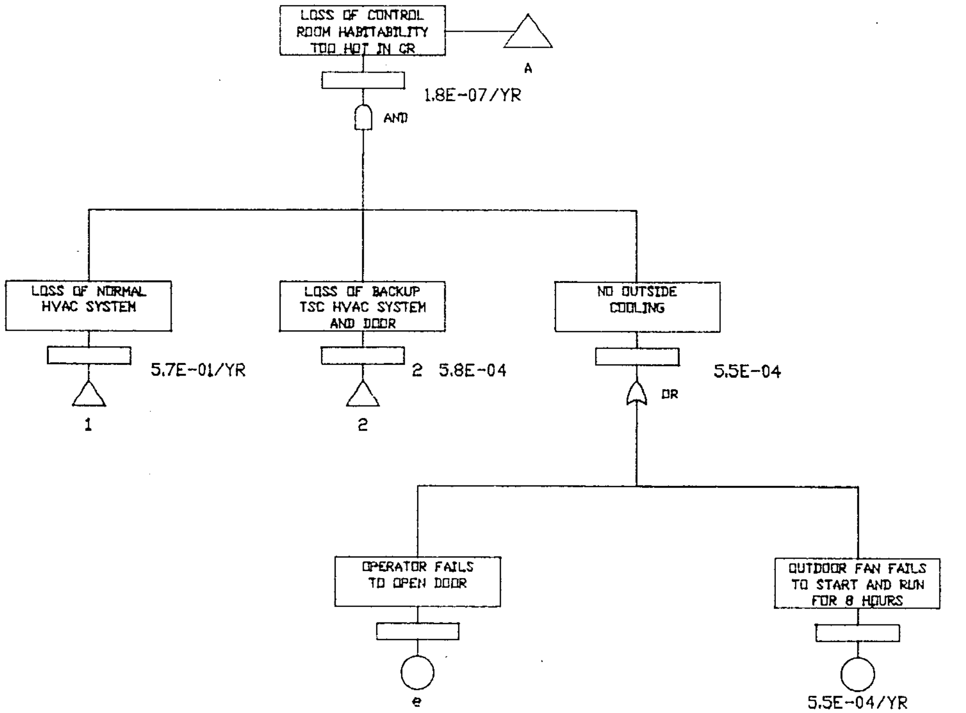


FIGURE 3, SHEET 3

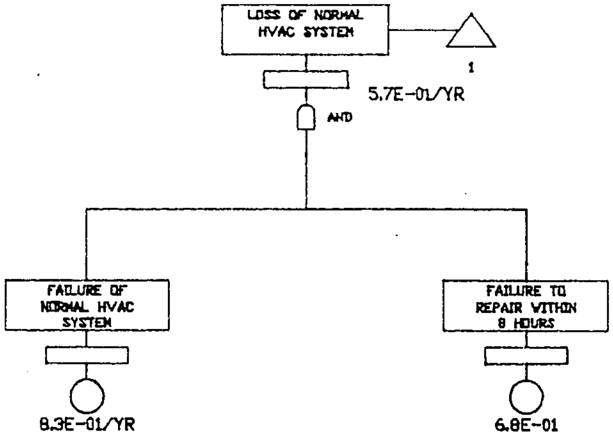


FIGURE 3, SHEET 4

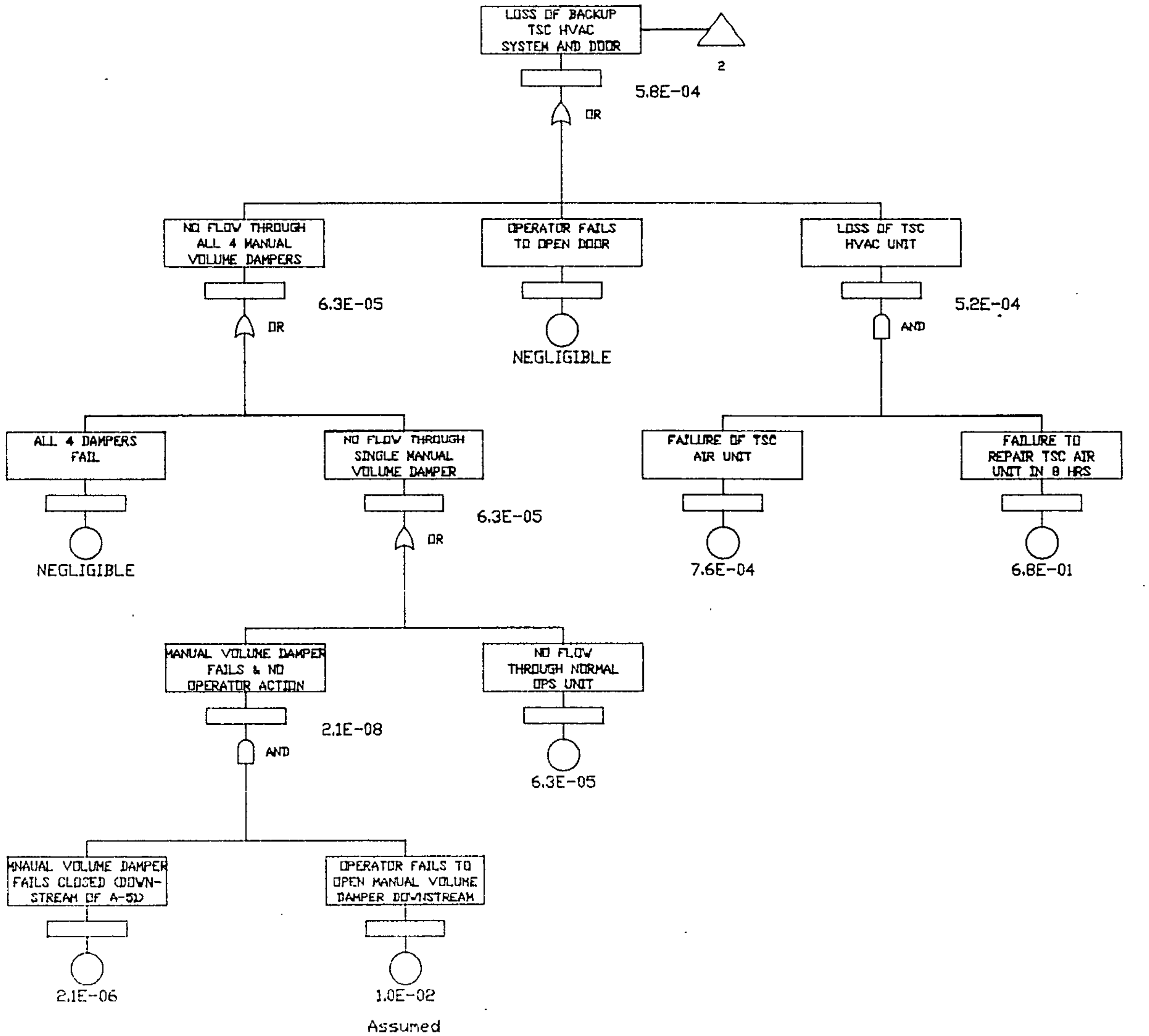


FIGURE 3, SHEET 5

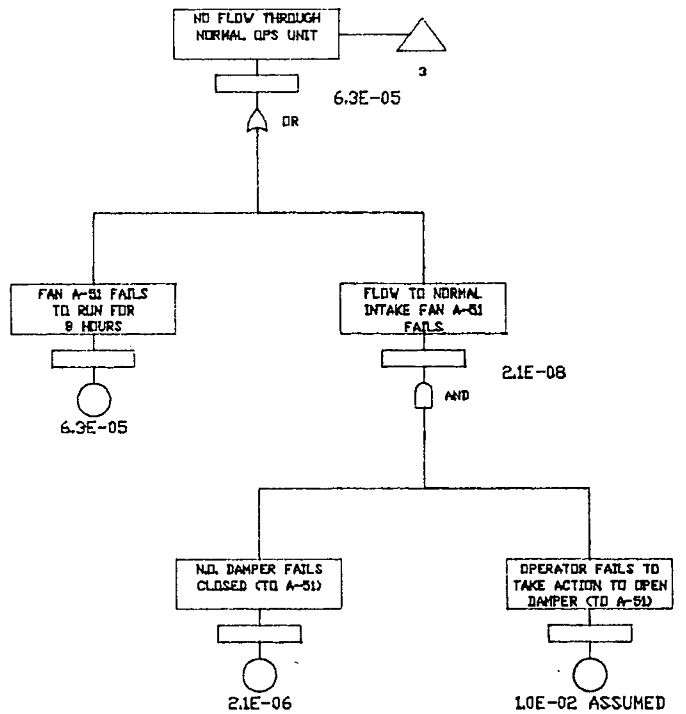
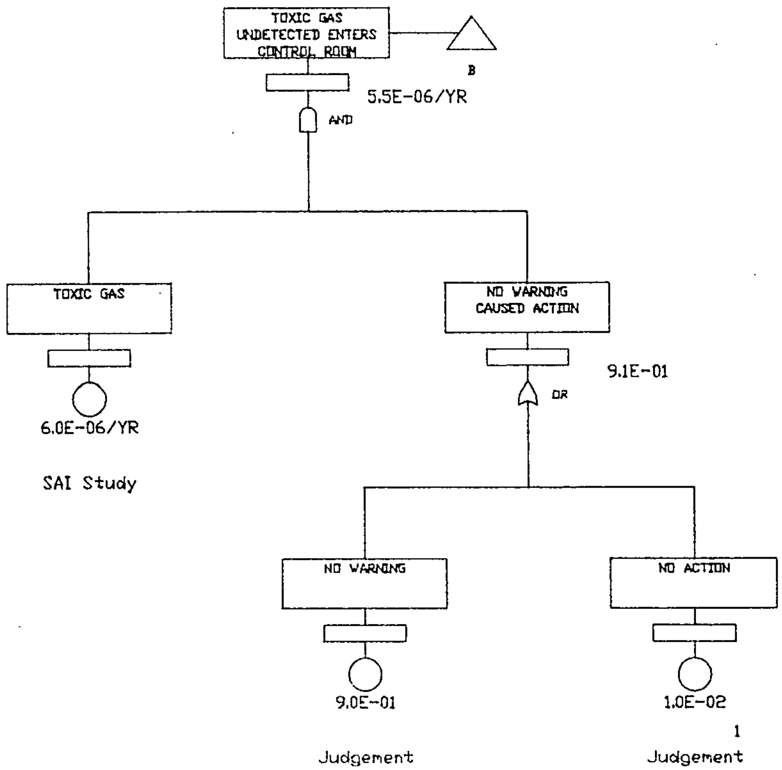
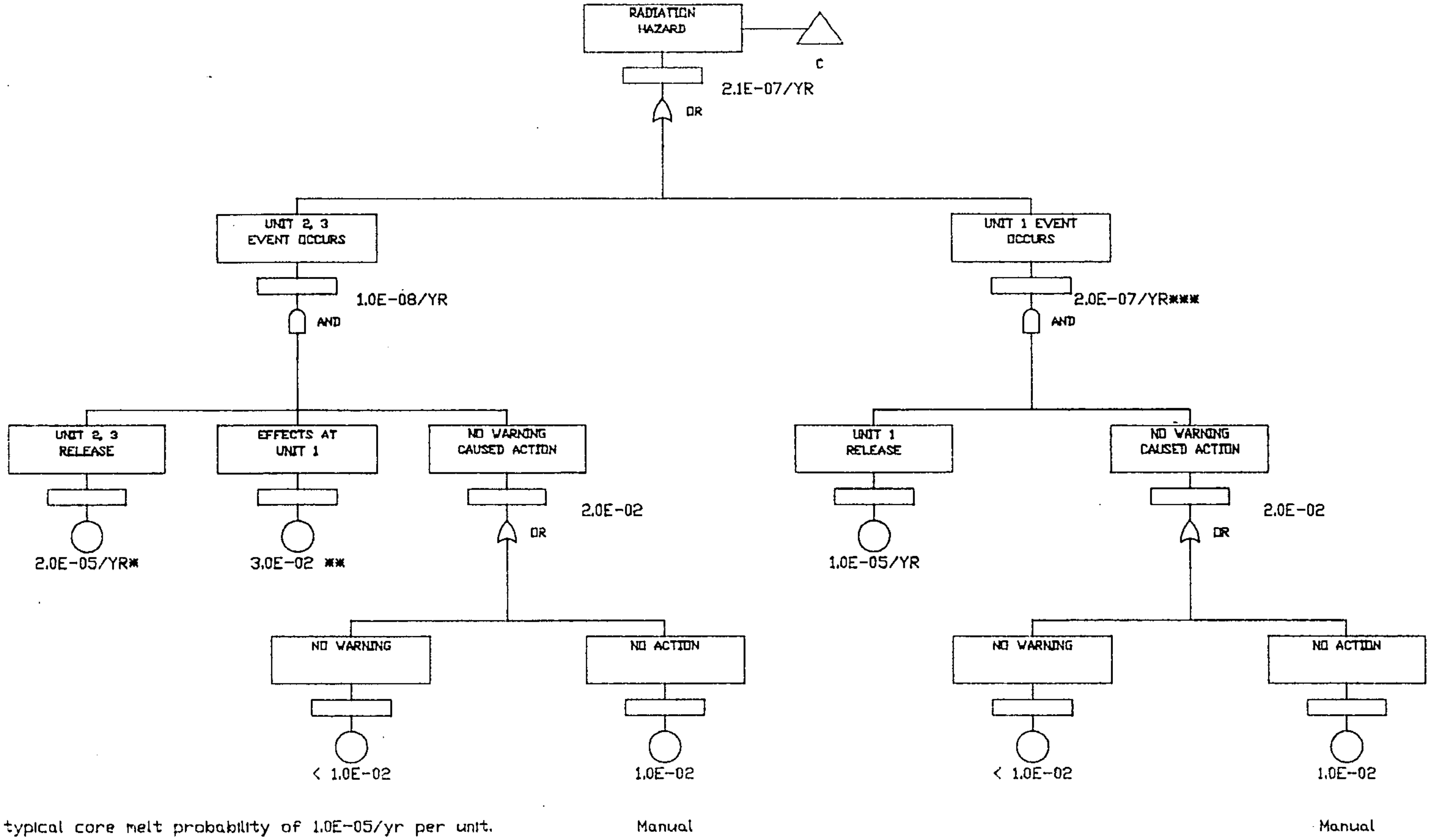


FIGURE 3, SHEET 6



[1] This is believed to be conservative.

FIGURE 3, SHEET 7



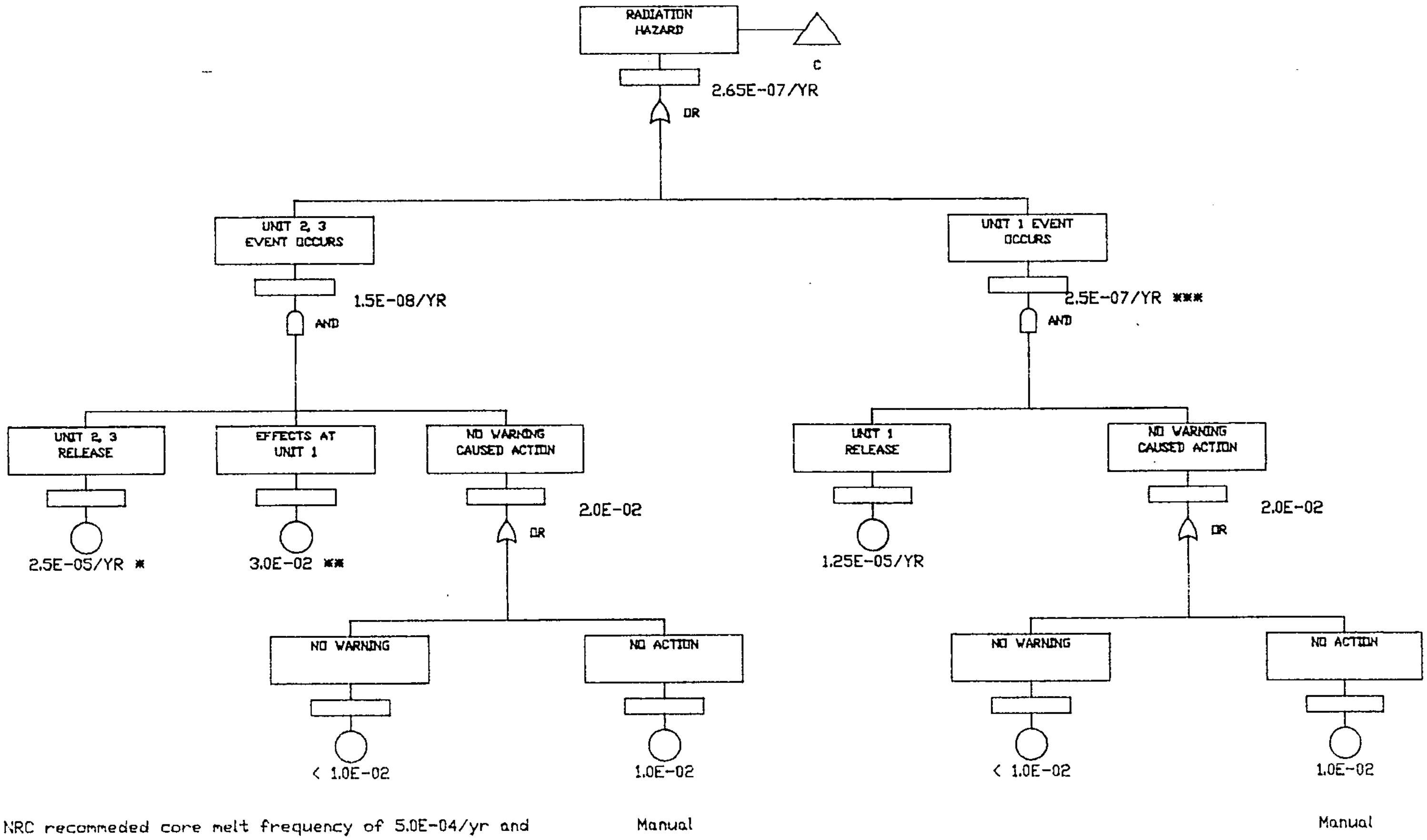
* Assumes typical core melt probability of 1.0E-05/yr per unit.

** Assumes uniform distance to 1 sector (1/16 = 0.06) and arbitrary 50% chance of actual intake effects (0.06 * 50% = 0.03)

*** Assumed to be dominated by severe release near intake. All less severe sources of radiation appear to be piped to the stack.

FIGURE 3, SHEET 7A

SENSITIVITY STUDY



* Assumes NRC recommeded core melt frequency of 5.0E-04/yr and containment probability failure of 2.5E-02 based on Oconee PRA.

** Assumes uniform distance to 1 sector (1/16 = 0.06) and arbitrary 50% chance of actual intake effects (0.06 * 50% = 0.03)

*** Assumed to be dominated by severe release near intake. All less severe sources of radiation appear to be piped to the stack.

FIGURE 3, SHEET 8

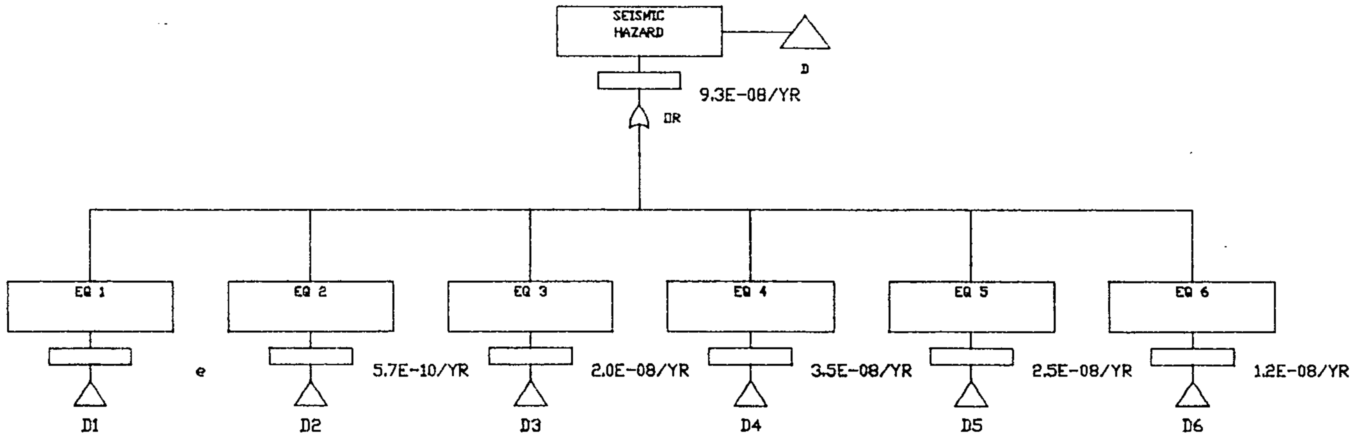
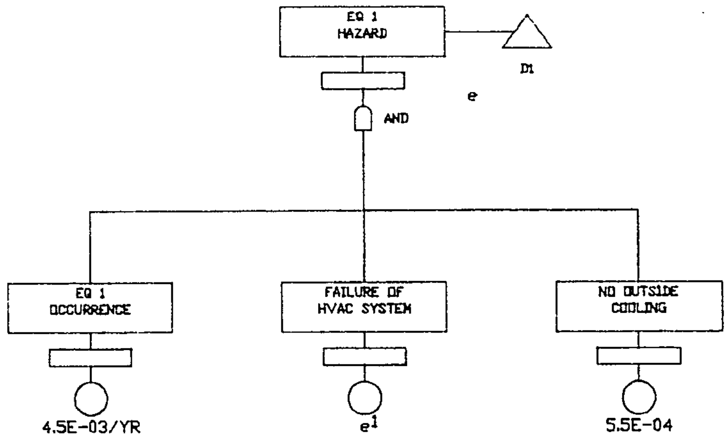
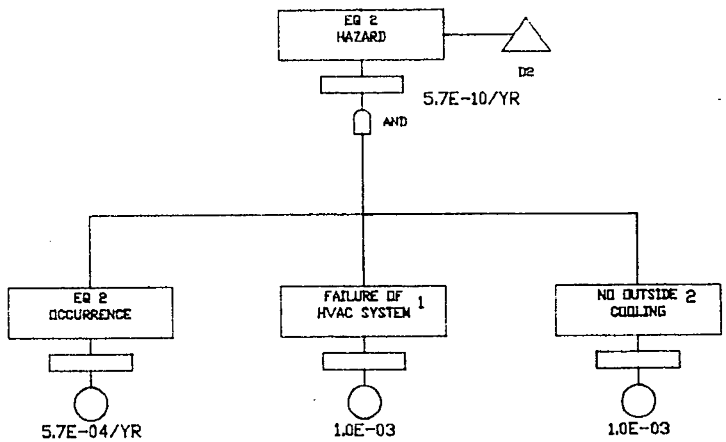


FIGURE 3, SHEET 9



[1]Random failure independent of earthquake treated in 'Too Hot' base case.

FIGURE 3, SHEET 10



[1] No credit assumed for TSC HVAC backup.

[2] Outside fan assumed to be independent of normal HVAC.

FIGURE 3, SHEET 11

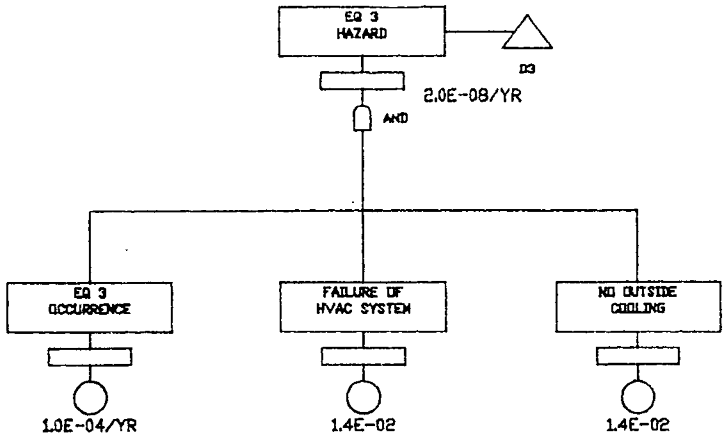
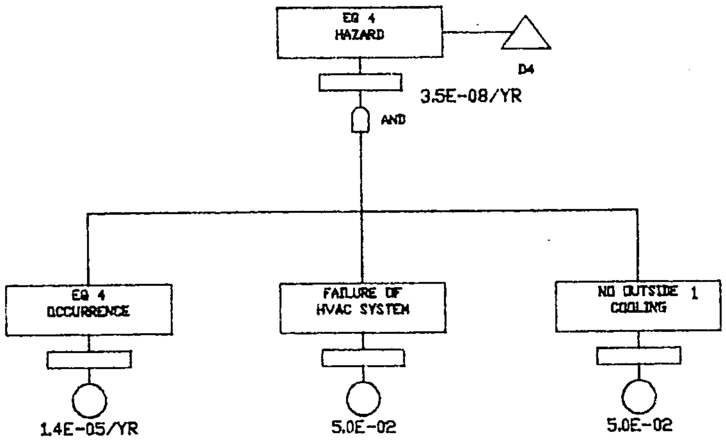


FIGURE 3, SHEET 12



[1] For higher earthquake levels the dependency becomes greater. At this earthquake level, the value of 5E-02 is nearly equal to typical CMF factors (beta) and is assumed to adequately represent the dependency.

FIGURE 3, SHEET 13

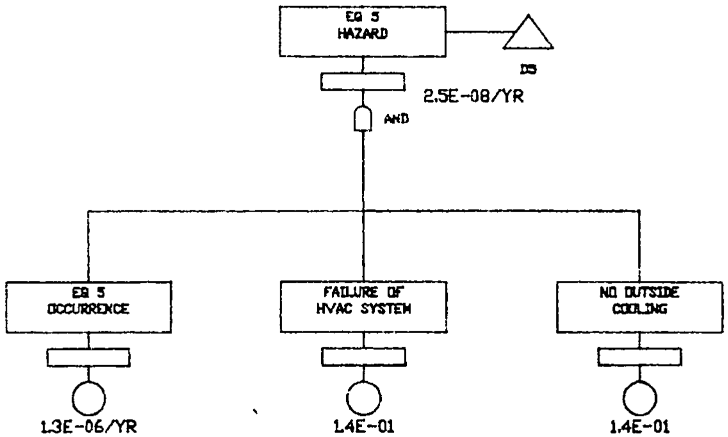


FIGURE 3, SHEET 14

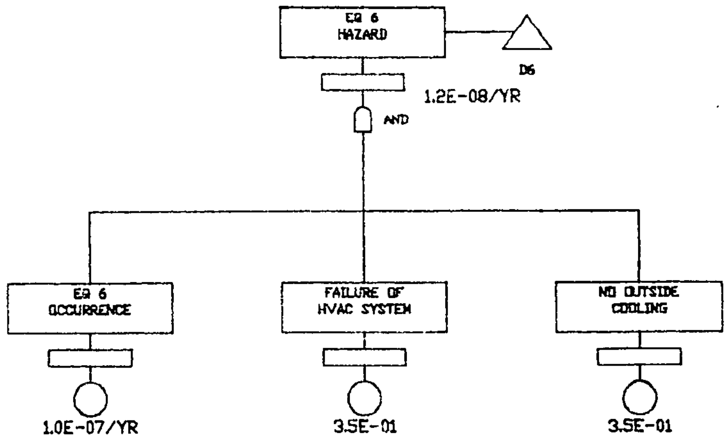


FIGURE 3, SHEET 15

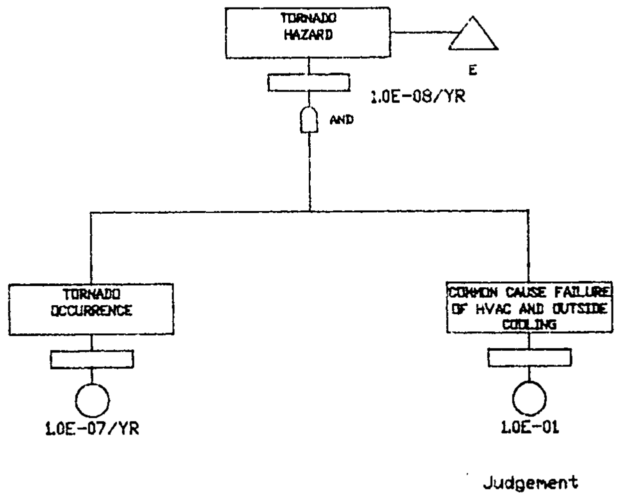


FIGURE 4, SHEET 1

FAULT TREES FOR TOXIC GAS HAZARD - UPGRADED CASE

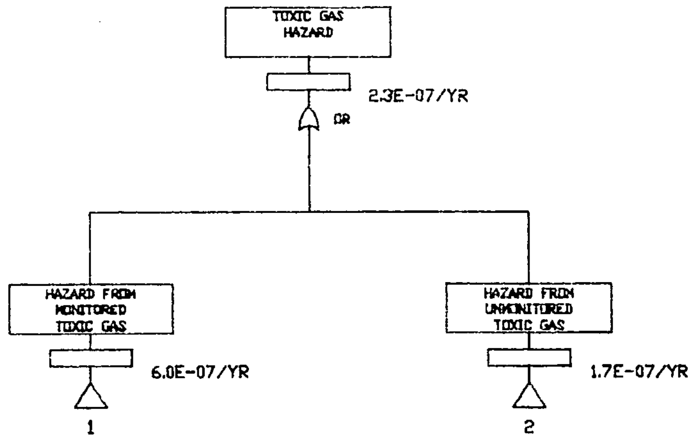


FIGURE 4, SHEET 2

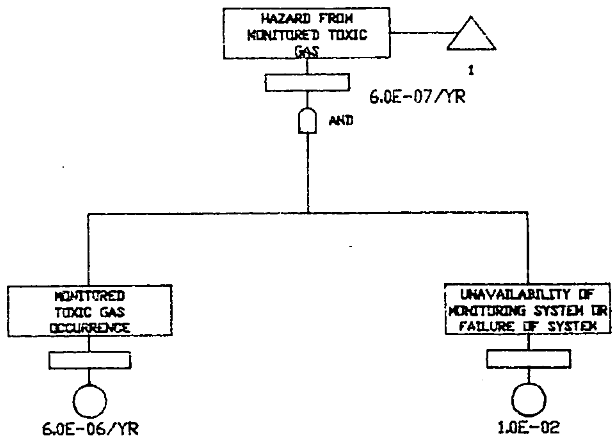


FIGURE 4, SHEET 3

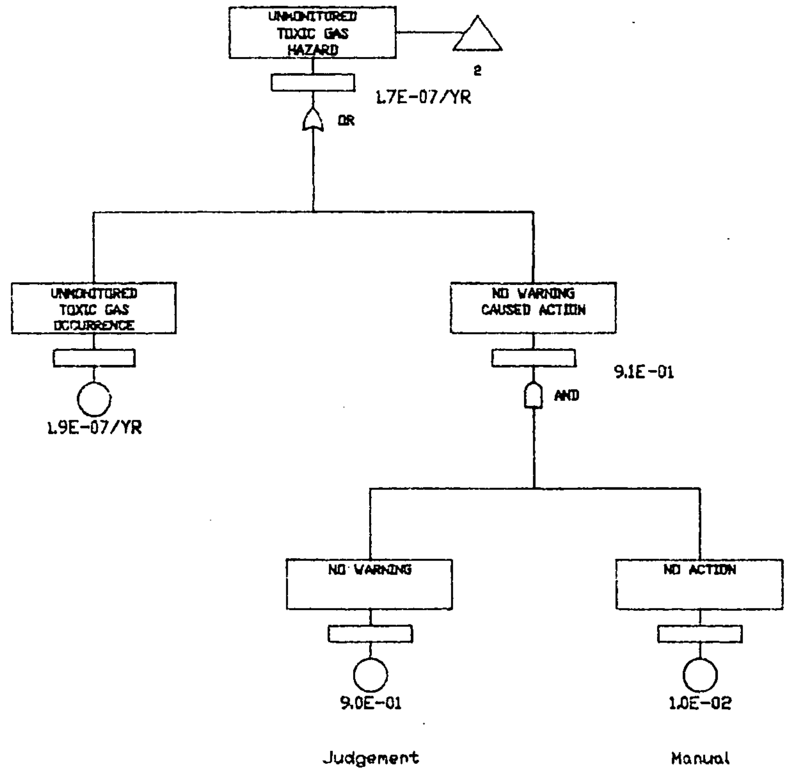


FIGURE 5, SHEET 1

CORE MELT FREQUENCY DUE TO LOSS OF CONTROL ROOM HABITABILITY - UPGRADED CASE

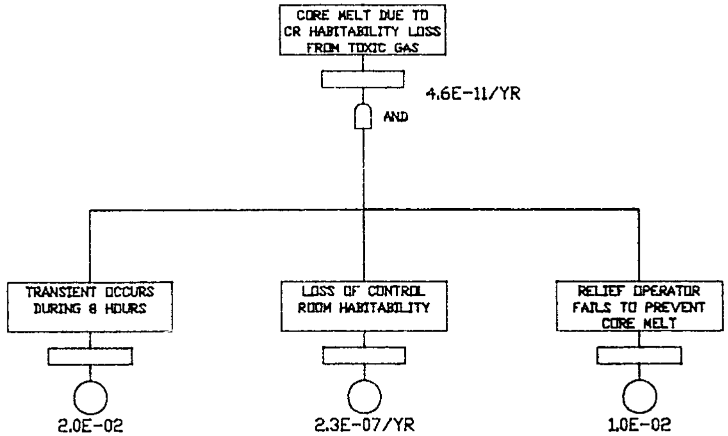
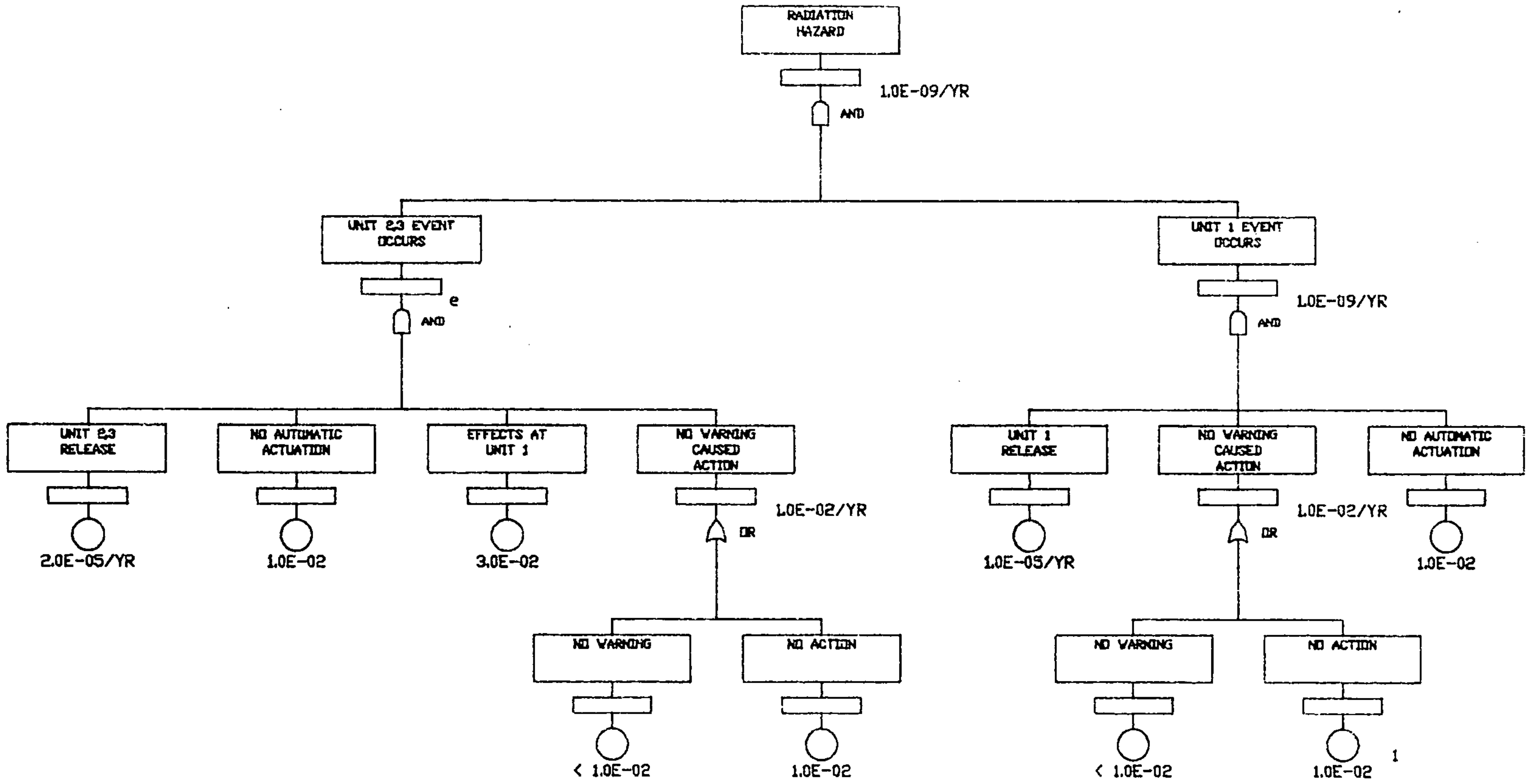


FIGURE 6

FAULT TREES FOR RADIATION HAZARD - UPGRADED CASE



[1] This value is believed to be conservative for this sensitivity study.

FIGURE 7

CONCEPTUAL UPGRADED CONTROL ROOM HVAC SYSTEM

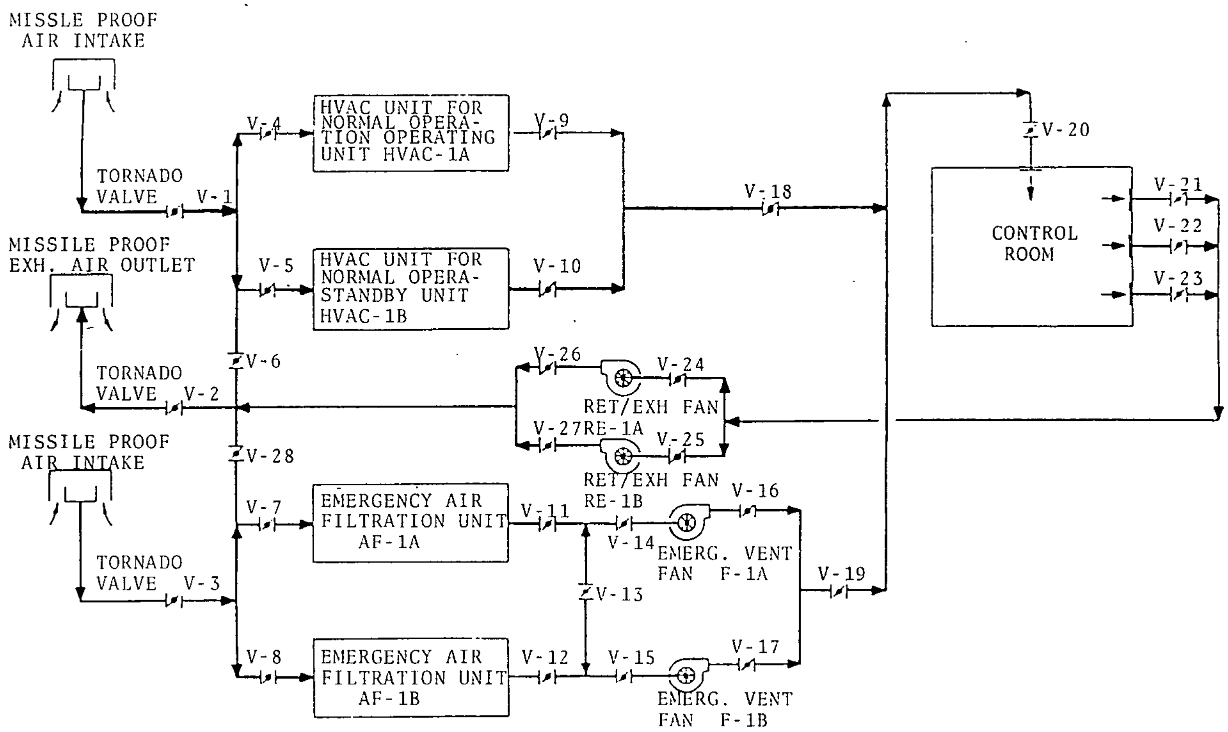


FIGURE 8, SHEET 1

FAULT TREES FOR CONTROL ROOM HVAC SYSTEM - UPGRADED CASE

"TOO HOT" CASE

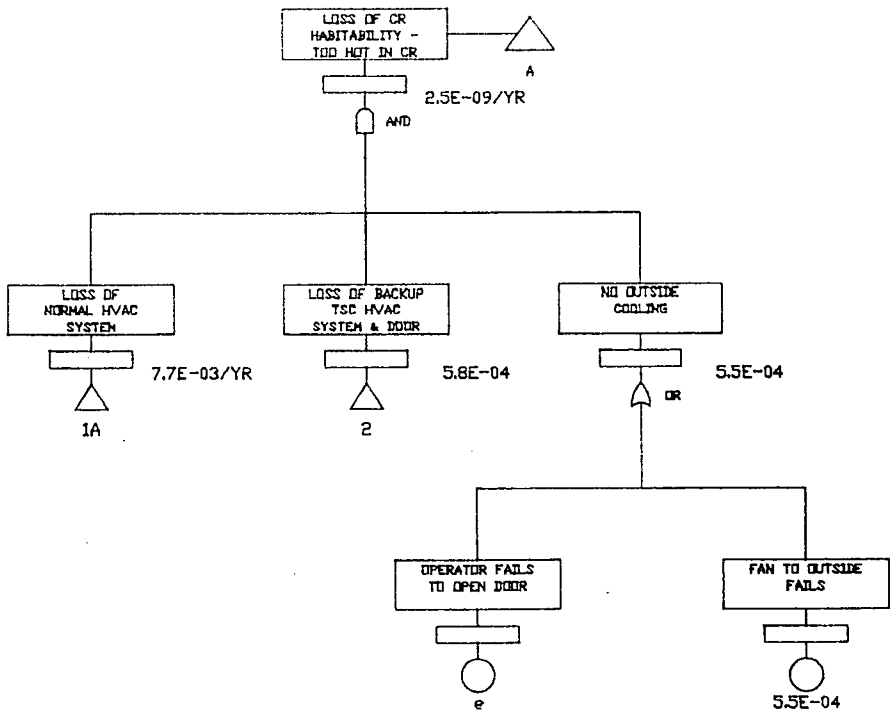


FIGURE 8, SHEET 2

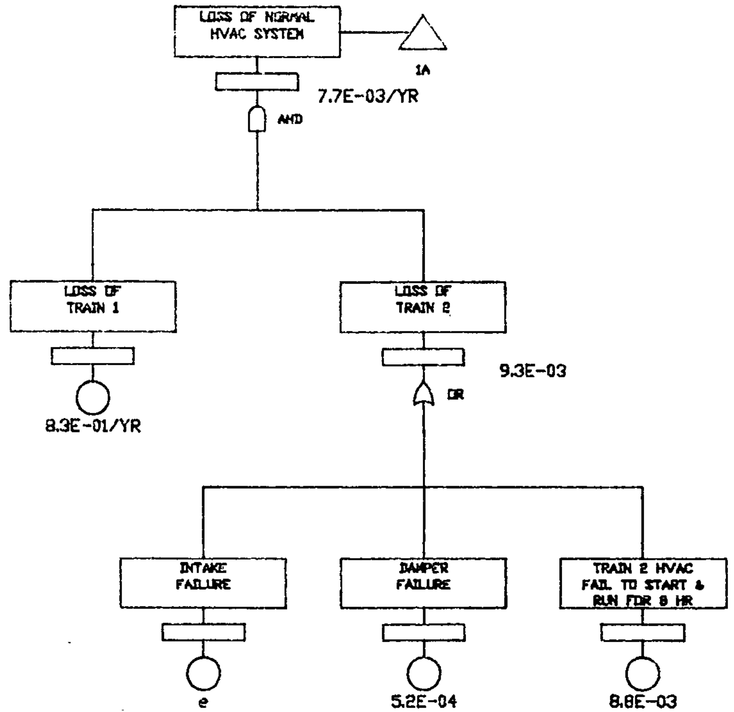


FIGURE 8, SHEET 3

'TOO HOT' CASE

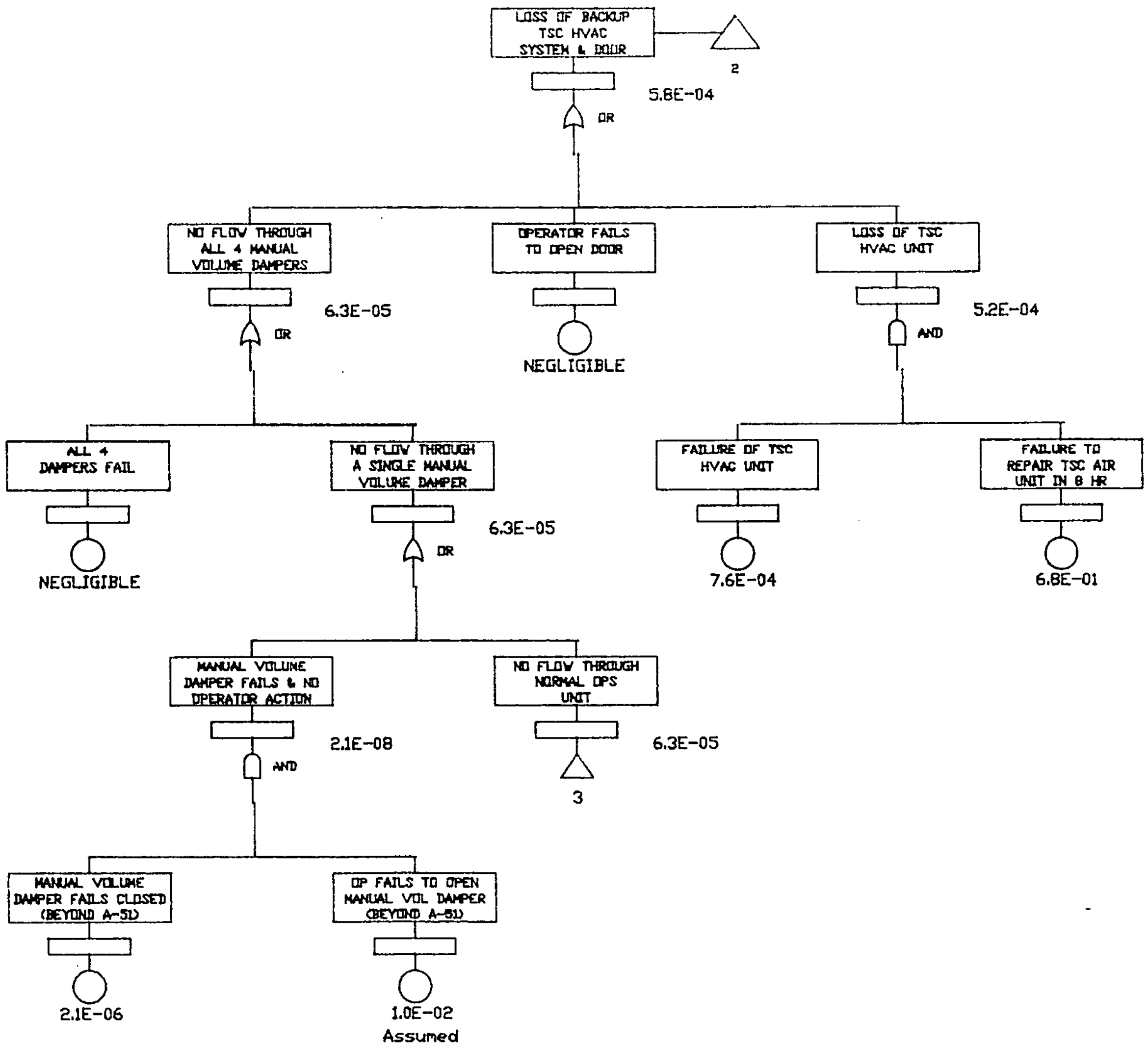


FIGURE 8, SHEET 4

'TOO HOT' CASE

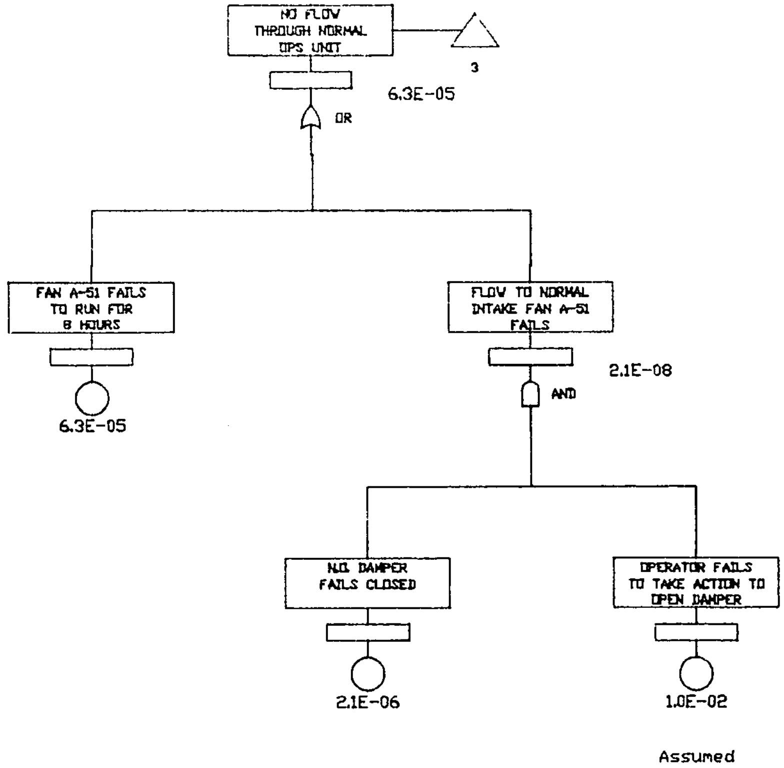


FIGURE 9, SHEET 1

FAULT TREES FOR SEISMIC HAZARD - UPGRADED CASE

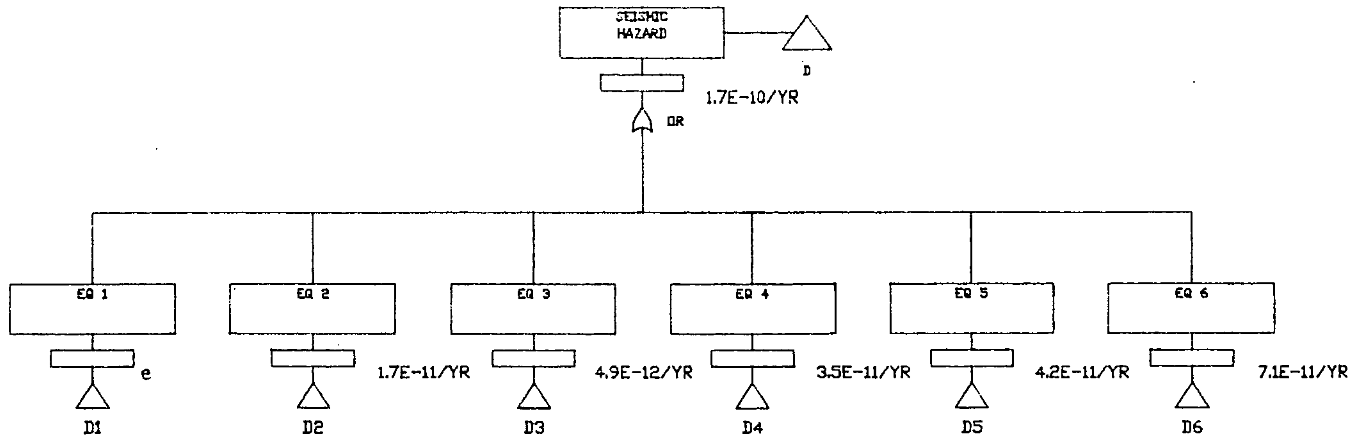
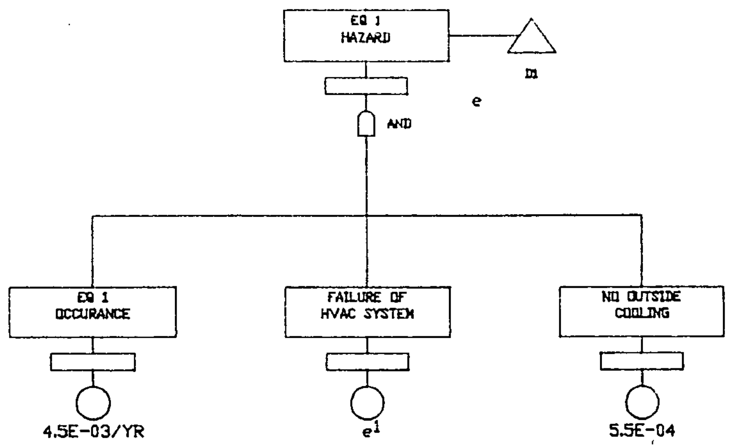
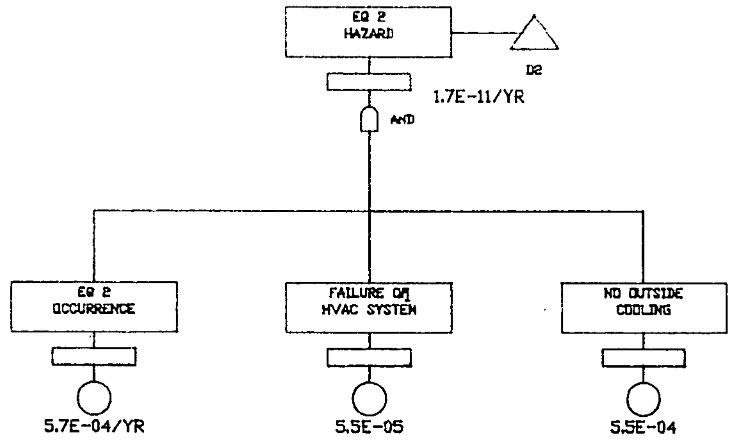


FIGURE 9, SHEET 2



[1]Random failure independent of earthquake treated in 'Too Hot' base case.

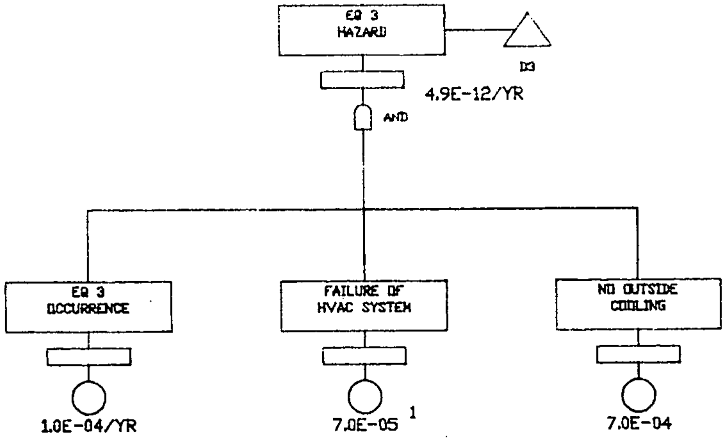
FIGURE 9, SHEET 3



1

Common cause failure probability of 0.1 between the redundant HVAC system is assumed.

FIGURE 9, SHEET 4



[1] Common cause failure probability of 0.1 between the redundant HVAC systems is assumed.

FIGURE 9, SHEET 5

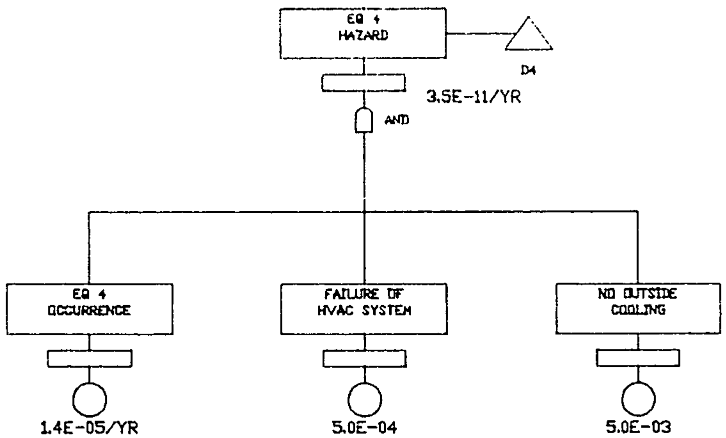


FIGURE 9, SHEET 6

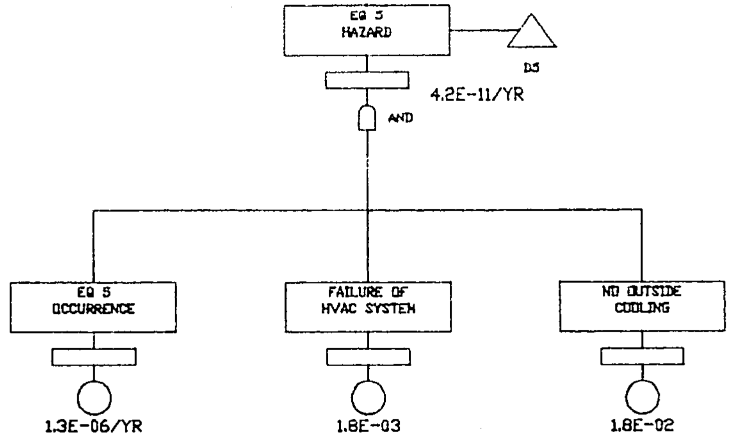
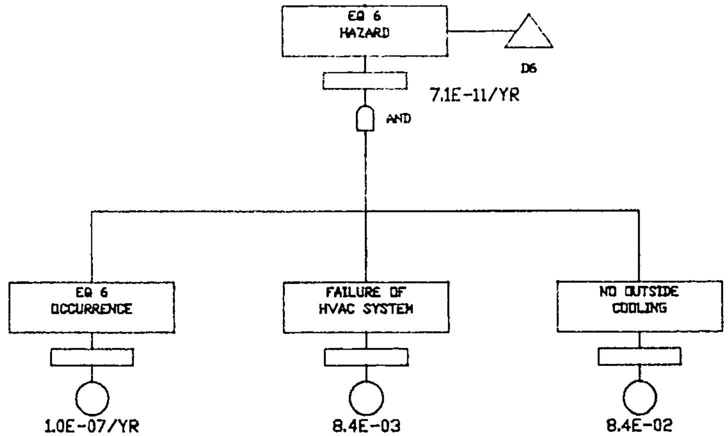


FIGURE 9, SHEET 7



APPENDIX A

DOSE ASSESSMENT

The following is a radiological dose assessment of the Unit 1 control room following a design basis loss-of-coolant accident with the control room HVAC in its present design. The analysis is based on assumptions and methodologies identified in Standard Review Plan Section 6.4 and its associated references. Any deviations from the NRC assumptions and methods are indicated in the analysis.

The dose calculation methodology is based on standard differential equations modeling the generation, release to environment, transport to the control room intake, buildup in the control room, removal by containment spray or charcoal filters, and decay of radioactive fission products from a loss-of-coolant accident.

The assumptions utilized in the calculations are summarized in Table A1. The solutions to the differential equations describing each portion of the model are listed on Table A2. An IBM-PC basic code was written to solve the solutions to the differential equations over timesteps where the inputs remain constant. Time varying inputs include: the atmospheric dispersion factor, the containment leak rate, the operation of containment spray, the control room intake flow, the occupancy factor of the control room, wind direction factors, and wind speed factors. The dose calculation is performed for a period of 30 days following the accident.

X/Q values for radiological releases from the containment were calculated based on an analysis presented in Reference 1. These releases were assumed to be from a diffuse source (i.e., activity leaking from many points on the surface of the containment) with a point receptor (a single intake). X/Q values were calculated for time periods of 0-8 hours, 8-24 hours, 1-4 days, and 4-30 days.

For the 0-8 hour calculation, results of recent analysis of diffusion tests near buildings were utilized[1]. The results of these tests showed that for most meteorological combinations of atmospheric stability and wind speed, the model and methodology provided in Reference 6 to Standard Review Plan Section 6.4 overestimates even the maximum measured concentration, usually by one to two orders of magnitude.

Because of this large overestimation of the NRC model, the 0-8 hour X/Q was calculated based on the recommendations of Reference 2 in Reference 1. The studies provided in the reference were conducted at two dissimlar sites with containment areas differing by nearly a factor of two. Consistency between the two sets of measured concentrations was obtained by scaling the plume path length by the square root of the minimum cross sectional area of the containment. Utilizing this approach a one hour X/Q for San Onofre Unit 1 was calculated. This one hour value was conservatively assumed to apply for 0-8 hours and also reflects an upper bound envelope of measured concentrations.

The dose calculation was performed for four different cases:

- o Case 1 - Existing control room HVAC design without a single failure
- o Case 2 - Existing control room HVAC design with a single failure

The single failure impacting the control room dose the greatest is the failure of the normal fresh air damper to close upon operation of the remote manual switch in the control room. This failure results in the introduction of a maximum of 1100 cfm of unfiltered air into the control room, in addition to the 1100 cfm taken in by the emergency supply fan and filtered through the emergency filter unit.

The results of the calculations are presented below:

Case	Whole Body gamma dose (rem)	Whole Body NRC limit (rem)	Beta Skin dose (rem)	Beta skin dose NRC limit (rem)
1	6.5	5	11.2	30
2	6.6	5	12.9	30

The whole body gamma dose slightly exceeds the NRC criteria for all cases. The beta skin is less than the NRC limit for all cases.

*Note: The portion of the whole body gamma dose to the operators from sources outside the control room is equal to 6.2 rem[5].

References

1. Control Room Habitability Evaluation San Onofre Nuclear Generating Station Unit 1, NUS 3704, Rev. 1, January 30, 1981.

2. San Onofre Unit 1 Final Safety Analysis Report

3. San Onofre Unit 1 Technical Specifications

4. San Onofre Unit 1 Calculation No. 324 "Analysis of Dose Consequences in the Control Room from LOCA" February 13, 1978.

5. Letter from J.E. Dempsey of Bechtel Power Corporation to J.G. Haynes of Southern California Edison, File No. 1304 944, October 11, 1977.

6. "CRDOSEB4 - An IBM PC Based Control Room Dose Calculational Model." Nucon Inc., August 1985.

Table A1

Dose Calculation Assumptions

Parameter	Value
Power level for 1000 days prior to LOCA	1,347 MWth[2]
Containment volume	34,230 m^3[2]
Volume of containment unsprayed	4,780 m^3[1]
Volume of containment sprayed	29,450 m^3[1]
Mixing flow rate between sprayed and unsprayed region	0.472 m^3/sec[1]
Containment leak rate	0.12%/day for 0-24 hours[3] 0.064%/day for > 24 hours[3]
X/Q at control room intake	1.5×10^{-3} sec/m^3[1] 1.0×10^{-3} sec/m^3[1] 3.8×10^{-4} sec/m^3[1] 1.1×10^{-4} sec/m^3[1]

Table A1 (Continued)

Parameter	Value
Isotopes considered	
o Krypton	5 [1]
o Xenon	6 [1]
Fraction of total released activity released to sprayed volume	
o Noble gases	1.0 [1]
Fraction of total released activity released to unsprayed volume	
o Noble gases	0.0 [1]
Control room emergency fresh air intake flow	0.519 m^3/sec (1100 cfm) [1]
Control room volume	779.3 m^3 [1]
Fraction of core isotopes available for release	
o Kryton	1.0 [1]
o Xenon	1.0 [1]
Fraction of released isotopes which remain airborne available for release	
o Noble gases	1.0 [1]

Table A1 (Continued)

Parameter	Value
Time periods	
o 1	2 hours
o 2	2-8 hours
o 3	8-24 hours
o 4	24 hours-4 days
o 5	4 days-30 days
Radius of control room as hemisphere	7.2 meters
Breathing rate of control room personnel	0.000347 m^3/sec [1]
Nuclide decay constants and fission yields	[1]
Average beta and gamma energies	[1]
Isotopic gamma energies and decay fractions	[1]
Absorption coefficients for air	[1]
Leak rate from RCS water outside containment	625 cc/hr [1]

Table A1 (Continued)

Parameter	Value
Infiltration of unfiltered air into the control room in existing design	11 cfm[4]
Single failure evaluated in existing system	Normal fresh air damper fails to close
Whole body gamma dose to the operators from sources outside the control room	6.2 rem[1]

Table A2

EQUATIONS USED IN DOSE CALCULATION

Initial primary system activity for isotopes of concern:

$$A_o = 8.65 \times 10^5 \; P_o G_i F_i F_r \; (1-e^{-LrTo}) \text{ (curies)}$$

where:

A_o = Initial activity of isotope i (curies)
P_o = Power level for past 1000 days (MWth)
G_i = Fission yield (fraction)
F_i = Fraction of isotope i released which remains airborne
F_r = Fraction of isotope i released from the fuel
L_r = Radioactive decay constant for isotope i (sec-1)
T_o = Time at full power (sec)

Primary containment integrated activity:

$$A_{ci} = c_2 e^{-m2t} - c_1 e^{-m1t}$$

$$c_2 = A_{10} (L_1 - m_1) + A_{20} (L_2 - m_1)/(m_2 - m_1)$$

$$c_1 = A_{10} (L_1 - m_1) + A_{20} (L_2 - m_2)/(m_2 - m_1)$$

$$m_1 = 1/2 \; (L_1 + L_2 + Q/V_1 + Q/V_2) + 1/2 \; ((L_1 + L_2 + Q/V_1 + Q/V_2)2 - 4 \; (Q/V_2 \times L_1 + Q/V_1 \times L_1 + L_1 \times L_2))1/2$$

$$m_2 = 1/2 \; (L_1 + L_2 + Q/V_1 + Q/V_2) - 1/2 \; ((L_1 + L_2 + Q/V_1 + Q/V_2)1/2 \; 4 \; (Q/V_2 \times L_1 + Q/V_1 \times L_1 + L_1 \times L_2))1/2$$

Table A2 (Continued)

$$L_1 = L + L_r + L_p + L_{sp}$$

$$L_2 = L + L_r + L_p$$

$$A_{10} = A_0 \times F$$

$$A_{20} = A_0 \times (1-F)$$

where:

A_{ci} = Primary containment integrated activity for isotope i (curies)

A_{10i} = Initial containment activity of each isotope which is in the sprayed volume for each period (curies)

A_{20i} = Initial containment activity of each isotope which is in the unsprayed volume for each period (curies)

L = Primary containment leak rate (sec^{-1})

L_r = Radiological decay constant for isotope i (sec^{-1})

L_p = Cleanup rate in the primary containment (0 for this model) (sec-1)

L_{sp} = Containment spray removal rate of isotope i (sec^{-1})

F = Fraction of activity released to sprayed volume

Q = Volumetric flow rate between containment volumes (m^3/sec)

V_1 = Volume of sprayed region of containment (m^3)

V_2 = Volume of unsprayed region of containment (m3)

t = Length of time period (seconds)

Table A2 (Continued)

Integrated release rate from the containment:

$$R_i = c_6/m_2 x (1 - e^{-m2t}) - c_7/m_1 x (1 - e^{-m1t})$$

$$c_6 = L_1 \text{ x } c_1$$

$$c_7 = L_1 c_2$$

Control room activity:

$$A_{ci} = c_9 \text{ x } c_6/(L_7 - m_2) \text{ x } e^{-m2t} - C_9 \text{ x } C_7/(L_7 - m_1) \text{ x } e^{-m1t} + c_{10} e^{-L7t}$$

$$c_9 = F_2 \text{ x } Q_{cc} \text{ x } (X/Q)_{cc}$$

$$L_7 = L_R + Q_{cc}/V_{cc}$$

$$c_{10} = A_{co} - c_9 \text{ x } c_6/(L_7 - m_2) + c_9 \text{ x } c_7/(L_7 - m_1)$$

where:

A_{ci} = Control room activity of isotope i (curies)
A_{co} = Initial control room activity for each period (curies)
F_2 = filter non-removal fraction for control room intake filter for isotope i
Q_{cc} = Control room intake flow rate (m^3/sec)
V_{cc} = Volume of control room (m3)

X/Q_{cc} = Atmospheric dispersion factor for each time period (sec/m3)

Table A2 (Continued)

Integrated control room activity:

$$R_{Ci} = c_9 \times c_6/((L_7 - m_2) \times m_2) \times (1 - e^{-m2t}) -$$
$$c_9 \times c_7/((L_7 - m_1) \times m_1 \times (1 - e\text{-}m1t +$$
$$c_{10}/L_7 \times (1 - e\text{-}L7t)$$

where:

R_{Ci} = Integrated control room activity for isotope i (curies)

Integrated beta dose:

$$D_B = 0.23/V_{cc} \times {}_{i} R_{ci} \times E_{Bi}$$

where:

D_B = Integrated beta dose (rems)
E_{BI} = Average beta energy (MeV/dis)

Integrated gamma dose:

$$D_G = 0.25/V_{cc} \times {}_{i} R_{ci} {}_{j} E_{Gij} F_{ij}$$
$$(1\text{-}e \text{ -muxRx } (1 + (mu_j - mu_{aj}) \times R))$$

Table A2 (Continued)

where:

D_G = Integrate gamma dose (rem)

E_{Gij} = Energy of jth gamma from ith isotope (MeV)

F_{ij} = Fraction of jth gamma released from ith isotope per disinigration

R = Equivalent radius of control room if hemisphere (meters)

mu_j = Total Energy absorption coefficient for air for gamma of energy E (m-1)

mu_{aj} = Energy absorpion coefficient for air for gamma of energy E (m-1)

APPENDIX B

RESPONSE TO NRC QUESTIONS

1. Question:

   In general, a revised submittal should include the delineation of accident sequences involving loss of control room habitability, and their quantification.

   Response:

   A revised submittal has been prepared which identifies the accident sequences for each of the scenarios leading to the loss of control room habitability. The accident sequences are described in the revised submittal and summarized in Table 1C.

2. Question:

   When possible, bounding analysis can be used to eliminate sequences from consideration. It is possible, for example, that tornadoes could be eliminated on the basis of a bounding analysis. If the only tornado problem involves tornado missile impact on HVAC components (including the air intake) then it is possible that the initiating event frequency is so low that this hazard can be eliminiated from consideration. The tornado analysis should include, however, an estimate of the site tornado hazard probability for tornadoes of sufficiently high wind speed to generate missiles which could fail the control room HVAC, and also the probability that such a missile would hit the HVAC. The present analysis is apparently based on the fact that a design basis tornado (wind speed between 172 mph and 272 mph) has an estimated frequency of hitting the site of 10^{-7}/yr. However, possibly tornadoes (or other wind storms) of lower wind speeds (and higher frequencies of occurrence) could also generate missiles which could fail the HVAC. But the probability that a missile once generated would hit the HVAC intake structure should also be included.

Response:

The tornado analysis is included in the value impact assessment to show that the low probability of design basis tornado occurrence at the San Onofre Unit 1 site results in a comparatively low value of potential upgrades to the control room HVAC system to prevent the loss of system operability due to the effects of such a tornado. The analysis also indicates that the existing design provides significant protection against tornado missiles since: (1) the system and intake duct are located inside a Class I building, and (2) the path outside air must take to reach the intake duct requires passage around several 90 degree bends of structural walls and floors.

The probability of occurrence of wind storms with wind speeds less than the design basis tornado, which could possibly impair the operability of the control room HVAC system, is not addressed in this analysis. A separate integrated study is underway to assess the potential impact of tornadoes on Unit 1 equipment. The integrated study will include a review of the control room HVAC system. The results of the study will be evaluated when completed, and the value impact of any recommended changes to the control room HVAC system will be addressed in a later submittal.

3. Question:

In addition, the toxic gas hazard could also likely be treated by a bounding analysis. Even if toxic gas were to disable the control room operators, core melt would not necessarily ensue. A reactor trip may not occur until after the toxic gas is dissipated and a replacement crew has arrived. The probability that operator action is not required until a replacement crew arrives should be included. The present analysis seems to implicitly assume that the only toxic gas hazard at the site comes from transportation accidents. If there are other possible sources of toxic gases, these should be treated. If not, then this should be stated, with supporting evidence given.

Response:

A bounding analysis is used to treat the loss of control room habitability due to the toxic gas release. Results from PRA studies are used to provide estimates of the probability of core melt given the loss of control room habitability due to toxic gas release.

The revised analysis also takes into account possible offsite sources of toxic gases. A review of surveys and analyses of onsite toxic chemical storage at Unit 1 is being conducted to determine if any chemicals potentially affect Unit 1 control room habitability. The results of the review will be incorporated into the value impact analysis and transmitted to the NRC when the review is completed. Toxic chemicals stored on the Unit 2 and 3 site are not considered since the Unit 2 and 3 FSAR control room habitability analysis bounds the impact of the chemicals on Unit 1 control room habitability.

4. Question:

The most serious of the accidents involving loss of control room habitability would appear to be those involving a reactor trip with simultaneous loss of HVAC. Certain fires which result in smoke getting into the control room may be in this category. Seismic events which cause a radioactive release (e.g., from a steam generator tube rupture or core melt at any of the units with containment leakage, bypass, or rupture) and also fail both the control room HVAC and the technical support center HVAC also fall in this category. Seismic events could also, e.g., cause a fire offsite which results in noxious fumes entering the control room.

Response:

From the risk standpoint, an event involving a reactor trip with simultaneous loss of HVAC represents a low probability occurrence and is thus not very significant.

Fires as an initiating event are evaluated separately based on a bounding analysis as presented in the response to question 2. Seismically induced fires which tend to have a higher impact on the control room HVAC systems than on other plant safety systems are less likely and are not analyzed further. An analysis of the impact of offsite fires on Unit 2 and 3 control room habitability concludes that the maximum range of concentrations onsite from postulated offsite fires are well below acceptable toxicity limits. This analysis is applicable to Unit 1 due to the proximity of Unit 1 to Units 2 and 3.

5. Question:

Greater detail is needed in the seismic analysis. It is not at all clear what the seismic hazard assumed for the site is. Figure 9 of Reference 1 (San Onofre submittal) assigned frequencies for the occurrence of different levels of peak ground acceleration (EQ1, EQ2, etc.). However, there is no hint as to what the acceleration ranges associated with EQ1, EQ2, etc., are. The seismic hazard function, with its basis, must be presented. The fragility parameters for the HVAC system are not given, let alone the basis for the fragility parameters. In the simplified SSMRP methodology, it is also necessary to determine the best-estimate structural response at the location of the component, and the variations of the response. These parameters and their bases were not given.

Response:

The detailed data used in seismic analysis is provided in the revised submittal. The seismic hazard used was plant specific for SONGS 1. The six levels of the earthquakes used in the analysis are:

Level	Peak Ground Acceleration	SONGS 1 Frequency (#/yr)
EQ1	0.15-0.3g	4.5×10^{-3}
EQ2	0.3-0.45g	5.7×10^{-4}
EQ3	0.45-0.6g	1.0×10^{-4}
EQ4	0.6-0.75g	1.4×10^{-5}
EQ5	0.75-0.9g	1.25×10^{-6}
EQ6	0.9g+	1.0×10^{-7}

In addition, the equipment response for each earthquake level is conservatively chosen based on a plant specific assessment performed by Bechtel.

We believe this approach gives a reasonable estimate of the risk profile due to the loss of control room HVAC as a result of seismic events.

6. Question:

The analysis should include a more careful treatment of dependencies. Electric power dependencies have not been treated carefully; other dependencies between different means of ventilating the control room (e.g., operator action, control and instrumentation power, auxiliary cooling water) seem not to be treated at all. Loss of offsite power will impact the control room HVAC, so this initiator should be explicitly treated. Can fumes from the diesel generators enter the control room? (According to one EPRI study, EPRI-NP-309, this was the case at one nuclear power plant.)

Response:

We agree that electric power dependencies should be treated as well as the dependencies between various means of ventilating the control room. Loss of offsite power as an initiating event is discussed in the response to NRC question 1. The effect of operator action is included in our fault tree analysis. The failure rate of control and instrumentation power is considered negligible compared with that of other components of the HVAC systems such as the ventilation chiller and dampers. The cooling of the chiller is by outside air. No auxiliary cooling water is required. Fumes from the diesel generators are not expected to be capable of reaching the control room HVAC intake since the distance between diesel generator exhaust and control room air intake is greater than 225 feet.

7. Question:

What is the reliability of the emergency supply fan and emergency air filter unit components of the HVAC? How frequently are these components tested? How effective are the tests in revealing deficiencies?

Response:

Generic data on the reliability of the emergency supply fan and emergency air filter unit were used in the original submittal. It is believed that given the significantly small risk contribution of the loss of control room habitability, the variation of component reliability would not change the results of our analysis.

Maintenance records for the control room HVAC emergency supply fan and emergency air filter unit indicate that the components are very reliable, with no reported failures. The maintenance records reviewed include only those generated since the Unit 1 restart in the year 1984. The components are surveilled every 720 operating hours or yearly, whichever comes first per Technical Specification 4.11. The tests regularly identify the need for any preventative maintenance (i.e. replacement of worn fan belts), adjustment of air flow, and replacement of the charcoal absorber and/or HEPA filter. Surveillance testing has not found the emergency supply fan inoperable or the filter unit failed, other than normal expected depletion of the charcoal absorber or accumulation of dust on the HEPA filter.

8. Question:

In computing the frequency of radiation hazard challenges to control room habitability, the licensee's analysis assumes a frequency of core melt at a unit as 10^{-5}/yr. This seems low. Some PRAs have estimated 10^{-3}/yr (e.g., Big Rock Point and Indian Point-2 before PRA-inspired fixes) for core melt frequency. Without a PRA for a unit, our best estimate of core melt frequency would be about 5×10^{-4}/yr. Core melt does not necessarily imply a radiation hazard in the control room; one would have to consider the probability of containment failure or bypass.

Response:

We recognize that the core melt frequency can range from 10^{-3}/yr to less than 10^{-5}/yr. However, we do not agree with the NRC assessed value of 5×10^{-4}/yr for core melt, especially for Units 2 and 3 which are newer plants and expected to be highly reliable plant designs. A sensitivity study was conducted based on the NRC assessed value of 5×10^{-4}/yr core melt frequency as shown in figure 3, sheet 7b. Results indicate that the loss of control room habitability due to radiation does not change significantly from the value calculated in the original submittal (2.65×10^{-7}/yr vs 2.1×10^{-7}/yr).

Dose calculations indicate that the design basis loss-of-coolant accident results in whole body gamma doses from sources inside the control room well below the NRC limit of 5 rem. When the dose from sources outside the control room, 6.2 rem, is combined with the dose from sources inside the control room, 0.4 rem, the total exceeds the limit by approximately 1.6 rem. The total beta skin doses calculated are well below the NRC limit of 30 rem. Releases from accidents with a greater probability of occurrence, such as steam generator tube rupture or waste gas decay tank release, do not represent a threat to control room habitability due to the significantly lower level of radiation release. Accident types with a radiation release level between a loss-of-coolant accident and core melt are not postulated. Therefore, core melt is the only accident considered to represent a threat to control room habitability.

9. Question:

The ACRS Subcommitee on Reactor Radiological Effects had some comments on the control room habitability issue which are summarized in a letter from Ebersole to Dircks, dated May 17, 1983. The ACRS subcommittee report notes, in discussing the question of the operators abandoning the control room, and using the remote shutdown panel to shut down the reactor and maintain safe shutdown, that "the shutdown of a nuclear power plant on an emergency basis is a serious matter, and we believe the preferred option is to increase the habitability of the main control room to permit the operators to remain at their normal posts. To this extent we believe that improvements in control room habitability are justified for safety reasons."

From a risk assessment point of view, credit should be given for use of the remote shutdown panel, when it is usable (and when the operators are not disabled). However, operator error in shutting down the reactor from the remote shutdown panel must be treated.

The same letter from the ACRS noted that "some of the models used by the licensees (e.g., those for estimating the rate of temperature rise in a control room following the loss of the air cooling system) appear to be supported by insufficient experimental data." The situation is worse for the licensee's submittal; no justification is given for the rate of temperature rise assumed in the analysis. No justification is given for the 8-hour time period available for recovery.

Response:

We agree with the comments on control room habitability made by the ACRS Subcommittee on Reactor Radiological Effects. The intent of the control room HVAC value impact assessment is to analyze and quantify the value of upgrading the system to current regulatory standards.

The submittal does not take credit for use of the remote shutdown panel in bringing the reactor to a safe shutdown condition in the event of loss of the control room habitability. This is believed to be conservative. The degree of conservatism would depend on the particular scenario and the actual ability of using the remote shutdown panel to control the plant safety systems. The probability of operator error associated with shutting down the reactor from the remote shutdown panel would be a necessary consideration if numerical credit were taken for the shutdown panel. We have chosen to treat loss of habitability as a conservative indication of a serious plant condition. It is equated with core damage only for the purpose of conservative value impact screening review. A high value would clearly necessitate review of this approach and inclusion of remote shutdown capability. The low values calculated are further supported by the conservative method used.

The choice of 8 hours for the time period available for recovery is based upon a combination of operational experience, experimental data, and calculational models. Operational experience has demonstrated that the loss of the control room HVAC system does not normally lead to the loss of control room habitability. Since the existing control room HVAC is a single train system, its loss has been experienced over the operating history of the unit. The loss of the system is typically due to the chiller and recirculation fan wear. Normally inactive components, such as the intake dampers, emergency supply fan, and emergency air filter do not measurably contribute to system inoperability. Upon the loss of the system, alternate ventilation has been set up using portable fans and ducting to bring outside air into the control room until the system is repaired and returned to service. The temperature rise experienced using the alternate ventilation has been described as moderately uncomfortable, but not intolerable.

Documented tests have been conducted to verify the heat loads and cooling capacities of the control room and TSC HVAC systems. The tests indicated that the design heat loads and cooling capacities are conservative. The tests also provided information such as the actual temperatures of the exterior roof of the control room when exposed to the sun for use in a calculational thermodynamic model of the control room. The calculational model includes heat inputs from control room equipment, personnel, fresh air intake, the roof and exposed walls, and cooling from the control room HVAC system, the floor and interior walls, and the TSC HVAC system. The model involves the solution of the steady state heat balance equations over incrementally small time periods to account for heatup of the control room and TSC air, the walls, and the floor.

In the worst and least probable case, including a station blackout event, the model indicates that on the design basis day of 85 ^{o}F, occuring less than 1 percent of the time, with the loss of the control room and TSC HVAC systems, the operators have approximately 10 minutes to establish alternate ventilation before the control room reaches the temperature of 97 ^{o}F, and 40 minutes before the reaching the temperature of 104 ^{o}F. The calculated temperature at the end of eight hours without the establishment of alternate ventilation is 109 ^{o}F. The introduction of 2000 cfm of 85 ^{o}F outside air into the control room within 25 minutes of the loss of all cooling will maintain the control room temperature below 104^{o}F for an indefinite period of time. The likelihood of an 85^{o}F design day extending into nightime hours is extremely small due to the location of the unit on the coast. Thus, the 8-hour time period available for recovery is conservative for all scenarios, except fire, where 1 hour was used.