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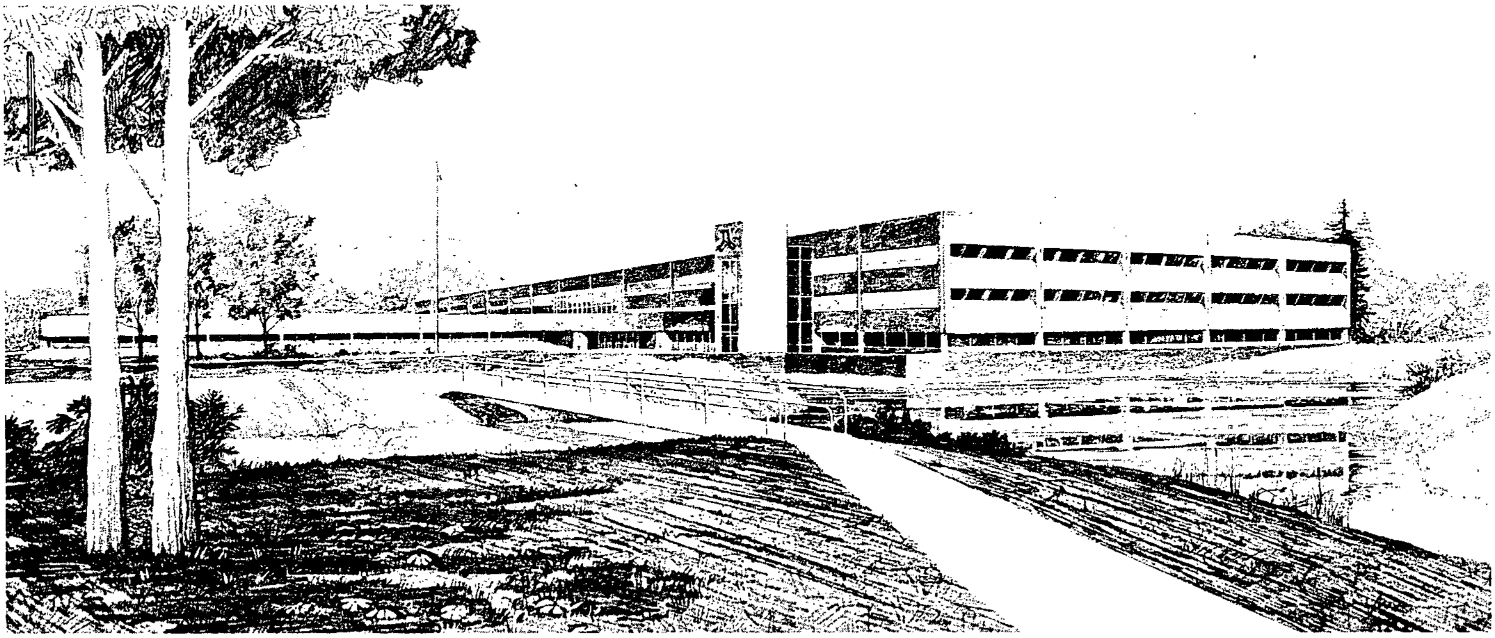

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Methods for Review and Evaluation of Emergency Procedure Guidelines Volume II: Applications to Westinghouse Plants

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METHODS FOR REVIEW AND EVALUATION OF EMERGENCY PROCEDURE GUIDELINES VOLUME II: APPLICATIONS TO WESTINGHOUSE PLANTS

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ABSTRACT

Systematic methods for finalizing, reviewing, or developing improved emergency procedure guidelines are applied to a Westinghouse PWR plant. The methods are based on the use of operator action event trees (OAETS) which document the key operator actions and plant symptoms associated with the various stages of risk significant multiple failure accident sequences. The application of the methodology utilizes OAETS developed for the Zion 1 PWR and the Westinghouse *Owners Group's Emergency Response Guidelines. Since the details of the* Westinghouse Function Restoration Guidelines (FRGs) were not yet complete, this examination did not take the form of an evaluation of the correctness or completeness of the final guidelines. Rather, the product of this examination was a delineation of the necessary characteristics which each FRG must possess when it is developed in complete detail. In addition to methodology demonstration, goals of the project included the identification of those aspects of Westinghouse plant design, operation, or response to multiple failure accident sequences which could result in incomplete, ambiguous, or incorrect guidance to the operator if not carefully addressed in the guideline development or utilization process.

SUMMARY

In previous projects performed under the Nuclear Regulatory Commission's Plant Status Monitoring Program (Refs 1,2), it has been demonstrated that Operator Action Event Trees (OAETs) can provide a systematic tabulation of the key operator actions and plant symptoms associated with the various stages of risk significant multiple failure accident sequences. Volume 1 of this report presented methodologies by which the information documented in these OAETs can be used to systematically review and evaluate functional emergency procedure guidelines and ensure that they provide unambiguous guidance under all important accident conditions. The OAET-based methods can be applied in three basic ways:

1) Preliminary or incomplete guidelines can be fine-tuned and finalized using input gained from a systematic OAET-based investigation of the incomplete guidelines.

2) Complete guidelines can be systematically reviewed and any inadequacies corrected.

3) Guidelines can be produced directly from the OAETs.

In this volume, the ability of these OAET-based methodologies to review, evaluate and produce effective guidelines applicable to a Westinghouse PWR plant design is investigated. This investigation took the form of a review and evaluation of the Function Restoration Guidelines (FRG) portion of the Westinghouse Owners Group's Emergency Response Guidelines. Since the details of many of the FRGs were not yet complete, this examination did not take the form of an evaluation of the correctness or completeness of each guideline. Rather, the primary purpose and product of this examination was a delineation of the necessary characteristics which each FRG must possess when it is developed in complete detail. An additional product of this methodology application was the identification of those aspects of Westinghouse plant design, operation, or response to multiple failure accident sequences which could result in incomplete, ambiguous, or incorrect guidance to the operator if not carefully addressed in the guideline development or utilization process.

This application of the methodologies developed and presented in Volume 1 of this report utilizes OAETs developed for the Zion 1 Westinghouse PWR

(Ref. 2). Best estimate analyses provided by the NRC's Severe Accident Sequence Analysis (SASA) Program were used as the primary source of information related to the physical plant response to multiple failure accident sequences.

The results of this investigation demonstrate that the OAET-based methodologies developed in Volume 1 can provide a very effective tool to the regulatory process associated with the development, review, and ultimate implementation of functional emergency procedure guidelines applicable to Westinghouse PWRs. The OAET based methodology and information base discussed and applied in this volume can be used in the following ways:

1) It could be used as a systematic demonstration that a set of guidelines provides unambiguous guidance under all important accident conditions (both high risk and high frequency accident scenarios); alternatively, it can be used by NRC to independently review submitted guidelines.

2) It can be cited by a specific utility as an integral part of their program to customize the Owners Group's generic guidelines to their specific plant.

3) It can be used as the technical foundation for guideline and procedure development by utilities which do not plan to use the Owners Group's generic guidelines.

The OAET-based methodology demonstrated in this volume for Westinghouse plants could be especially valuable as a integral part of the regulatory process because:

- From the regulatory side, it provides an easily audited process which also provides very high assurance that the guidelines submitted by the Westinghouse Owner's Group and implementation plans submitted by the individual utilities operating Westinghouse PWRs will result in unambiguous operator guidance for both high frequency events and high risk multiple failure accident scenarios.

- From the industry side, it provides a well defined process by which regulatory concerns over the technical content of guidelines and procedures applicable to Westinghouse plants can be systematically satisfied.

While it was not the purpose of this analysis to pass judgement on the guidelines developed by the Westinghouse Owners Group, it is appropriate to note that the results of the application of the guideline review methodology suggest that the WOG guidelines, with a few easily implemented modifications, can provide efficient unambiguous guidance under the wide spectrum of high frequency and high risk accident conditions examined.

CONTENTS

LIST OF ACRONYMS

ADV	Atmospheric Dump Valve
AFW(S)	Auxiliary Feedwater (System)
CSF	Critical Safety Functions
CST	Condensate Storage Tank
ERG	Emergency Response Guidelines
FRG	Function Restoration Guideline
FW	Feedwater
HPIS	High Pressue Injection System
HPRS	High Pressure Recirculation System
LOCA	Loss of Coolant Accident
LOSP	Loss of Offsite Power
LPIS	Low Pressure Injection System
LPRS	Low Pressure Recirculation System
MFW(S)	Main Feedwater (System)
NRC	Nuclear Regulatory Commission
NPSH	Net Positive Suction Head
OAET	Operator Action Event Tree
ORG	Optimal Recovery Guidelines
PORV	Power Operated Relief Valve
PRT	Pressurizer Relief Tank
PSM	Plant Status Monitoring (Program)
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHRS	Residual Heat Removal System
RWST	Refueling Water Storage Tank
SASA	Severe Accident Sequence Analysis (Program)
SG	Steam Generator
SGTR	Steam Generator Tube Rupture
SI	Safety Injection
TMI	Three Mile Island
WOG	Westinghouse Owners Group

Section 1
INTRODUCTION AND BACKGROUND

In Volume 1 of this report, a review of the post-TMI industry directions in the development of emergency procedures was presented. A discussion of the approaches currently being taken by groups representing each of the four major U.S. vendors in the development of improved procedures was provided. Each of these groups has recognized inherent deficiencies in the pre-TMI procedures which required operator diagnosis of specific events. These groups have all turned to function- or symptom - oriented approaches which focus on only a few key symptoms of critical safety functions as the bases for operator guidance under emergency conditions.

In that volume, it was concluded that these functional or symptom based approaches are effective in avoiding many of the problems inherent to the pre-TMI event specific procedures. However, it was also pointed out that the complex interactions of realistic plant response to multiple failure accident sequences often result in many different accident conditions looking the same to the operator, especially if his attention is focused on a relatively limited set of symptoms. This situation could give rise to ambiguous guidance, operator confusion, and aggravation of the upset condition. It was this concern that led to the conclusion that there is a need to 1) identify those accident conditions where this potential ambiguity exists and 2) develop and review emergency procedures in such a way that such potential problems are systematically addressed.

Volume 1 presents a methodology to systematically identify those diverse accident conditions which, because they exhibit common or similar symptoms, may result in ambiguous operator diagnosis and ineffective response. Methodologies are presented to review and evaluate function based emergency procedures guidelines and ensure that they provide unambiguous guidance under all important accident conditions. Related methods were presented to directly produce such guidelines if adaption of existing guidelines is not possible or desired.

These methods are based on the use of Operator Action Event Trees (OAETS) which systematically delineate the required operator actions and key plant symptoms throughout the progression of important accident sequences. These techniques are applicable to any accident scenario whether high risk or high frequency. (see Reference 1 for a basic description of OAETs).

These OAETs can be used to ensure that emergency procedure guidelines possess the following four characteristics necessary to provide unambiguous guidance:

1) The guidelines must be complete. That is, there must be no risk significant states requiring operator action which are not addressed in the guidelines.

2) The instructions in the guidelines must always be correct. That is, if the guidelines instruct the operator to "take action set P when you observe symptom set A", then action set P must be appropriate for every condition that can produce symptom set A.

3) The actions delineated in the guidelines must be complete. There must be no important actions which should be carried out at a particular state which are not included in the guideline action sets indicated at that state.

4) The instructions in the guidelines must always be unambiguous. There must be no plant states which produce symptoms sets which the operator might confuse with guideline symptom sets linked to inappropriate action sets

In the conclusions to Volume 1, it was stated that the OAET-based methodologies to systematically finalize, review, or develop functional emergency procedure guidelines appear to provide a very useful tool to the regulatory process. This methodology could provide a systematic, well-defined, and easily audited demonstration of the technical validity of guidelines. Also, if presented as an integral part of a specific utility's program plan to produce plant-specific procedures from the generic guidelines, it would provide a high degree of assurance to the NRC that the program will achieve its goals.

In this volume, the actual ability of the OAET-based methods to review and develop emergency procedure guidelines appropriate for a Westinghouse Pressurized Water Reactor is tested. There are three general objectives to this analysis:

1) Demonstrate that the OAET-based methodology to systematically review and improve existing procedure guidelines, or to finalize guidelines in the development stage, is feasible when applied to guidelines of the type and style of the Westinghouse Owners Group (WOG) Emergency Recovery Guidelines.

2) Demonstrate that the OAET-based methodology to develop unambiguous diagnostic/action algorithms (which can form the technical framework upon which emergency procedure guidelines can be constructed) is a feasible one, and to ensure that the physical response of Westinghouse PWRs does not produce conditions which cannot be easily addressed with this methodology.

3) To identify and highlight some important aspects of Westinghouse PWR plant response to multiple failure accident sequences which must be carefully addressed in the development or review of emergency procedure guidelines applicable to these plants.

The Operator Action Event Trees which will be used to achieve the above goals were developed for the Zion I Pressurized Water Reactor using best-estimate computer analyses generated under the Nuclear Regulatory Commission's Severe Accident Sequence Analysis (SASA) Program. The specific OAETs used for this demonstration of the methodology are those accident sequences initiated by a loss of offsite power, a small LOCA, and a steam generator tube rupture. These OAETs are presented and discussed in detail in "Operator Action Event Trees for the Zion I Pressurized Water Reactor", [Ref. 2]. Much of the information provided in these OAETs is summarized in Section 3 and the three major Zion OAETS used in this analysis are provided in Appendix I to this volume.

The version of the WOG Emergency Recovery Guidelines utilized in this assessment was that submitted to the NRC in late 1981. [Ref. 3]. Much of the information provided in these guidelines is summarized in Section 3 and 4. Additional information concerning these guidelines is provided in Appendix II to this volume. Many of the specific guidelines had not been completed in detail at that time. Accordingly, detailed reviews of portions of the guidelines are not performed. The OAET-based methodology was used, therefore, not to review, but to provide guidance to the completion of these guidelines by pointing out aspects of the incomplete guidelines which may be susceptible to ambiguity. For an incomplete guideline, the OAET method obviously cannot say if all instructions are correct or unambiguous; however, it can describe the required characteristics which the completed guideline must possess. For example, the actions in the guideline might have to be compatible with those in another guideline, the guideline should perhaps include action X or caution Y, etc. In fact, the use of the OAET-based review methodology in this way to address guidelines in the development stage and to provide guidance to the final stages of development may well be the most productive use of the methodology.

It should be re-iterated that the goals of the analysis are as stated above and are not to pass judgment on the guidelines developed by the Westinghouse Owners Group. The OAETS used, while providing a representative set of risk significant accident conditions, do not necessarily address all risk significant accident conditions at Zion 1 or any Westinghouse PWR. Furthermore, the Westinghouse Owners Group guidelines are not a complete detailed set. Therefore, the analyses reported here are not designed to support such judgments and none are implied or should be inferred.

In the following section, the methodologies to systematically review existing emergency procedure guidelines and to independently develop guidelines are summarized and presented in terms of the Westinghouse PWR design and the Westinghouse Owners Group Emergency Response Guidelines.

In Sections 3 and 4, the OAET-based guideline review methodology is applied to the Westinghouse Owners Group Emergency Response Guidelines.

In Section 5, a summary discussion is provided of the important aspects of Westinghouse PWR physical response to multiple failure accident sequences which were identified by the OAET method as possible areas of ambiguity and confusion and, as such, must be carefully addressed in the production or review of emergency operating procedures applicable to these plants.

In Section 6, the OAET-based guideline development methodology is applied to the Westinghouse PWR design as exemplified by Zion.

In Section 7, the conclusions concerning the ability of the OAET-based methods to review or develop emergency guidelines applicable to Westinghouse PWRs will be summarized.

Section 2

SUMMARY OF METHODOLOGY

Volume 1 of this report presented systematic methodologies to review or develop emergency procedure guidelines using Operator Action Event Trees. In this section, these methodologies will be briefly summarized and presented in terms of the Westinghouse Owners Group Emergency Response Guidelines and Westinghouse PWR design. Volume 1 should be referenced for more detailed discussion of these methodologies.

2.1 GUIDELINE REVIEW METHODOLOGY

Emergency procedure guidelines can be viewed as a collection of instructions, each of which relates a "symptom set" to an "action set". For example, one instruction might be in the form:

> "when you observe Symptom Set A (comprised of symptoms a_1, a_2, a_3), take Action Set P (comprised of actions p_1, p_2, p_3)."

In the Westinghouse Owners Group Emergency Recovery Guidelines (ERGs), these instructions are provided in the form of Critical Safety Function (CSF) Status Trees and the associated Functional Restoration Guidelines (FRGs) (see Appendix II). Each CSF Status Tree directs the operator to one or more FRGs based on the observance of key symptoms indicative of the failure to perform that critical safety function. The FRGs delineate the operator action necessary to restore that particular function. Section 3 presents and discusses in more detail the Westinghouse Owners Group ERGs.

The review process entails asking four basic questions regarding these instructions:

1) Is the Guidelines' collection of symptom sets complete? That is, are there risk significant states requiring operator action which could occur but for which no branch of a CSF tree applies?

2) Are the instructions in the ERGs always right? That is, if the ERG says "when you see symptom set A go to FRG X", are the actions associated with FRG X always appropriate for every situation that can produce symptom set A?

3) Are the ERG action sets always complete? That is, are there important actions which should be carried out at a particular state which are not included in the FRGs indicated at that state?

4) Are the instructions in the ERGs always unambiguous? Are there plant states which produce symptoms sets which the operator might confuse with ERG symptom sets that guide the operator to inappropriate actions?

These four questions can be answered by performing the systematic OAET-based symptoms comparison outlined in Figure 2.1.

As depicted in Figure 2.1, the input information is a description, for each key plant state identified in the Zion OAETs, of the symptoms exhibited by the plant at that state and the necessary operator actions associated with that state. These plant states address both the relatively high frequency initiating events and the much less probable (but higher risk) multiple failure accidents.

In Step #1, attention is focused on the Westinghouse Owners Group's Guidelines and the goal is to translate these Guidelines into a collection of instructions, each of which relates a well defined symptom set to an action set. This can be accomplished by performing three tasks:

1) Generate a complete listing of the specific symptoms which are used in the WOG Guidelines. These correspond to the symptoms which are used to define the branch points of the Critical Safety Function Status Trees.

2) Make these specific symptoms (e.g., hot leg temperature rising above X°) into general symptoms (e.g. hot leg temperature rising), and produce a list of "generalized symptoms". This is done to facilitate comparison between the WOG Guideline symptoms and the OAET symptoms. If this comparison points out potential ambiguities involving the "generalized symptoms", then these few cases can be re-examined using the specific CSF Status Tree symptoms.

3) Translate the WOG Guidelines into instruction sets using the generalized symptom sets and action sets. In the WOG Guidelines, the symptom sets are defined by the CSF trees and the action sets are defined by Function Restoration Guidelines (FRGs). These tabulated instruction sets will be used as input to the systematic comparison steps discussed later.

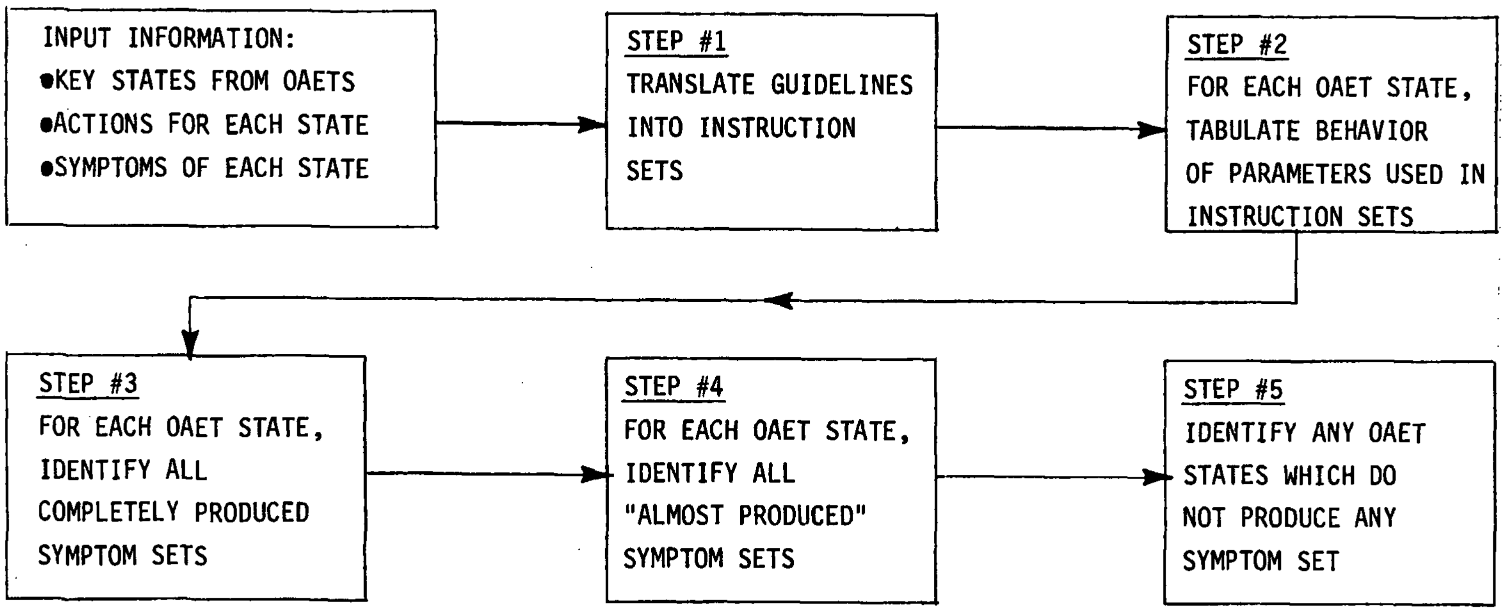

Figure 2.1. Emergency Procedure Review Flowchart for PSM Approach

In Step #2, attention is focused on the Zion OAETs. For each OAET state, the behavior of each of the generalized parameters listed in Step #1 should be tabulated. For some of these states, the behavior of some of the parameters may be uncertain. In these cases, several different symptoms (e.g. pressure rising, pressure stable) may be assigned to the same state. If any of these symptoms is later found to result in potential ambiguities, that particular state and symptom can be looked at more closely. These tabulated symptoms will be used as input to the systematic comparison steps discussed below.

In Step #3, the comparison process begins. The first task is to identify, for each OAET state, any and all WOG Guidelines symptom sets listed in Step #1 which are completely produced. The WOG Guideline action sets (FRGs) associated with these symptom sets should also be identified.

In Step #4, the task is to identify, for each OAET state, any and all WOG Guideline symptom sets listed in Step #1 which are almost produced. For example, if an OAET state exhibits all but one of the symptoms in a Guideline symptom set, this state should be noted here.

In Step #5, any OAET states which do not completely produce any Guideline symptoms set are identified.

The information generated in the above five steps can be used to systematically address the four basic questions listed above.

The first question - Is the collection of WOG Guideline symptom sets complete? - can be directly addressed using the results of Step #5 which identifies any OAET state which does not produce any symptom set in the collection.

The second question - Are the WOG Guidelines instructions always right? - can be addressed using the results of Step #3. For each OAET state, there will be one or more FRGs identified in Step #3. The indicated FRG action sets must be compatible with each other and they must be compatible with the actions associated with that OAET state.

The third question - Are the FRG action sets always complete? - can also be addressed using the results of Step #3. There may be important actions which must take place which are indicated in the OAET but are not included in the indicated FRG action set. It should be recognized here that functional guidelines are not necessarily intended to provide all the detailed steps required to bring the plant to a safe shutdown condition, but, rather, are focused on those actions which will restore the critical safety function. Accordingly, this third question should also focus on actions related to restoration of critical safety functions.

The fourth question - Are the WOG Guidelines always unambiguous? - can be addressed using the results of Step #4. Each OAET state will have associated with it an "almost indicated" Guideline symptom set and the associated FRG action set. First, the FRG action set should be compared with the appropriate action set for that OAET state to see if they are compatible. If they are not compatible, then the question arises whether the operator might confuse the two symptom sets (the actual symptom set exhibited by the plant and the almost indicated guideline symptom set leading to inappropriate actions). The "missing" symptoms should be examined and a judgment made whether the operator will be able to clearly and unambiguously notice their absence and not take the wrong action.

2.2 GUIDELINE DEVELOPMENT METHODOLOGY

The result of the OAET documentation process is a package of information which represents the basic input to the emergency procedure development task. As discussed previously, this package consists of the following:

1) A listing of all key plant states identified in the OAETS.
2) A description of the necessary operator actions associated with each state.
3) A description of the symptoms exhibited by the plant at each state.

Figure 2.2 presents a flow diagram of the methodology used to translate the information contained in the documented operator action event trees into unambiguous decision algorithms which can form the technical framework for emergency procedure guidelines. This methodology is described in detail in Volume 1 of this report and is briefly described in this section.

As shown in Figure 2.2, the first step involves explicitly linking the OAET information to the performance of the critical safety functions upon which the original event tree analysis was performed. This step entails the following tasks:

- Categorize the OAET states by the critical safety function most threatened at that state
- Identify parameters whose behavior provides the most direct indication of the status of each critical function
- Describe the behavior of each of these parameters at each state

The results of step #1 are a preliminary set of accident categories with each state in each category described in terms of key parameters.

The second step depicted in Figure 2.2 involves the comparison of the actions associated with each state in each category. The tasks involved in this step are to:

- Assess the mutual compatibility of actions associated with states within the same category
- Move states with incompatible actions into other categories or produce new categories
- Identify and compare different but compatible actions within each category.

The results of Step #2 will be comprised of a final set of categories, each of which is comprised only of states with compatible actions. In addition, a tabulation of the various actions associated with the different states in each category will be provided.

The third step shown on Figure 2.2 entails the production of accident and state "signatures". These signatures are the minimum sets of symptoms by which the operator can identify any accident category or state within that category. The specific tasks associated with this step are:

- Define general symptoms indicative of all states within a category in terms of key parameters.
- Compare these symptoms with the symptoms of all other states in all other categories.
- Add symptoms, if necessary, until the set of symptoms associated with each category is unique.
- Compare symptoms of states within each category to define a minimum set of symptoms by which each state can be uniquely defined.

The fourth, and final, step of the process depicted in Figure 2.2 is *the translation of these documented OAETs and accident signatures into diagnostic/action algorithms*, which allow the operator to efficiently translate the observed symptoms into required responses and can thereby form the technical framework upon which unambiguous emergency procedure guidelines can be constructed. The fundamental task is to select and logically order the specific symptoms at which the operator should look to unambiguously and efficiently determine and carry out the required response. The form and content of the documented OAETS and signatures allow this task to be carried out in a straightforward manner. The accident and state signatures have been explicitly developed to remove the ambiguity; the only remaining task is to optimize the procedures, or diagnostic algorithm, by ordering the symptom monitoring process to produce the most efficient diagnosis of the required action.

All of these steps are discussed in much greater detail in Volume 1 of this report.

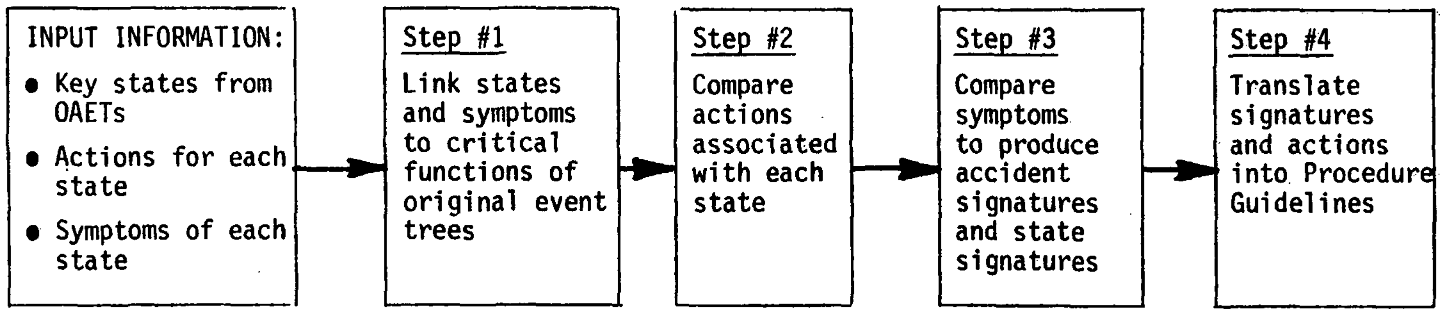

Figure 2.2. Emergency Procedure Development Flowchart

Section 3
COMPARATIVE SYMPTOMS ANALYSIS

In Section 2, a methodology by which completed or partially completed emergency procedure guidelines could be reviewed and/or finalized was presented. That methodology, based upon the use of Operator Action Event Trees, entails asking four basic questions related to the completeness and ambiguity of the guidelines. As discussed in Section 2.1, these questions can be answered by performing a five step systematic symptoms comparison using the documented OAETs and the emergency procedure guidelines. In this section, that symptoms comparison is performed using the Westinghouse Owners Group Emergency Response Guidelines and a set of OAETs developed for the Zion 1 PWR.

3.1 ZION OAETS

The Zion Operator Action Event Trees were based on best estimate computer analyses performed at the Idaho National Engineering Laboratory and Los Alamos National Laboratory for the NRC's Severe Accident Sequence Analysis (SASA) Program.

These trees logically display the role of the operator throughout the progression of risk significant accident sequences. An illustrative example of an OAET is provided in Figure 3.1. As input to this symptoms comparison task, the OAETs provide:

1) A listing of the key plant states associated with risk significant accident sequences

2) A description of the required operator actions for each of these states

3) A delineation of the symptoms exhibited by the plant at each of these states

The Zion OAETs are presented and discussed in Reference 2. The specific OAETs used for purposes of this analysis were those initiated by a loss of offsite power, a small LOCA, and a steam generator tube rupture. These OAETs are provided in Appendix I. Reference 2 should be examined for a detailed discussion of these trees.

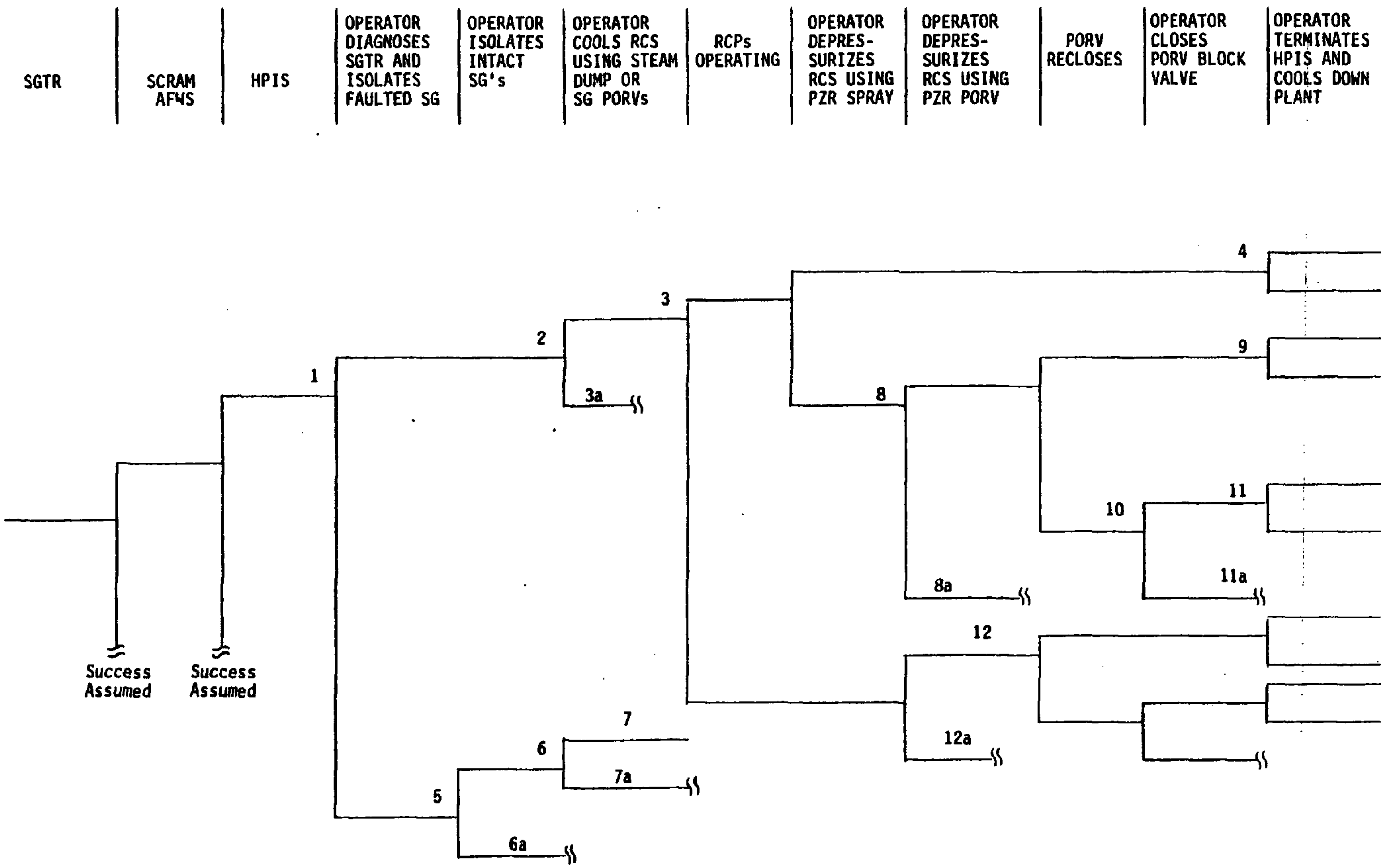

Figure 3.1. Illustrative Example of an Operator Action Event Tree

3.2 WOG EMERGENCY RESPONSE GUIDELINES

The WOG Emergency Response Guidelines (ERGs) are composed of two major parts: 1) The Optimal Recovery Guidelines (ORGs) and Emergency Contingencies, and 2) The Critical Safety Function (CSF) Status Trees and Function Restoration Guidelines (FRGs). The ORGs and Emergency Contingencies provide event specific guidance. If the operator is unable to immediately diagnose an abnormal condition, or if the ORGs do not restore the condition to normal, the operator should monitor the critical safety functions and restore them to normal using the CSF trees and the FRGs. The FRGs are expected to be applicable only in those situations in which, as a result of multiple or sequential failures, the plant has evolved to a condition where the ORGs and Emergency Contingencies may not be reliable or direct operator control of plant systems may be required to maintain critical safety functions.

The CSF trees are developed to monitor six critical safety functions: subcriticality, reactor coolant system integrity, core cooling, reactor coolant inventory, heat sink, and containment integrity. The operator is instructed to satisfy each critical safety function in the order listed above (subcriticality first, containment integrity last). The trees are structured in such a way that each pathway through the tree corresponds to a particular combination of symptoms. Within each tree, priorities are assigned for actions depending upon the symptoms which exist at the time. A pathway in a tree with a "Red" priority must be addressed immediately before proceeding to the next tree; an "Orange" priority indicates that the critical safety function is under severe challenge and prompt operator actions is necessary, but only after all "Red" conditions have been satisfied. "Yellow" indicates a critical safety function which is not fully satisfied and may eventually require operator actions. "Green" indicates that the critical safety function is satisfied and no operator action is required.

Figure 3.2 presents an illustrative example of a CSF tree. This particular tree addresses reactor coolant system integrity. The solid line on this tree corresponds to a "Red" priority, while the dashed line is "Orange". Dots correspond to "Yellow", and the light line is "Green". By determining the

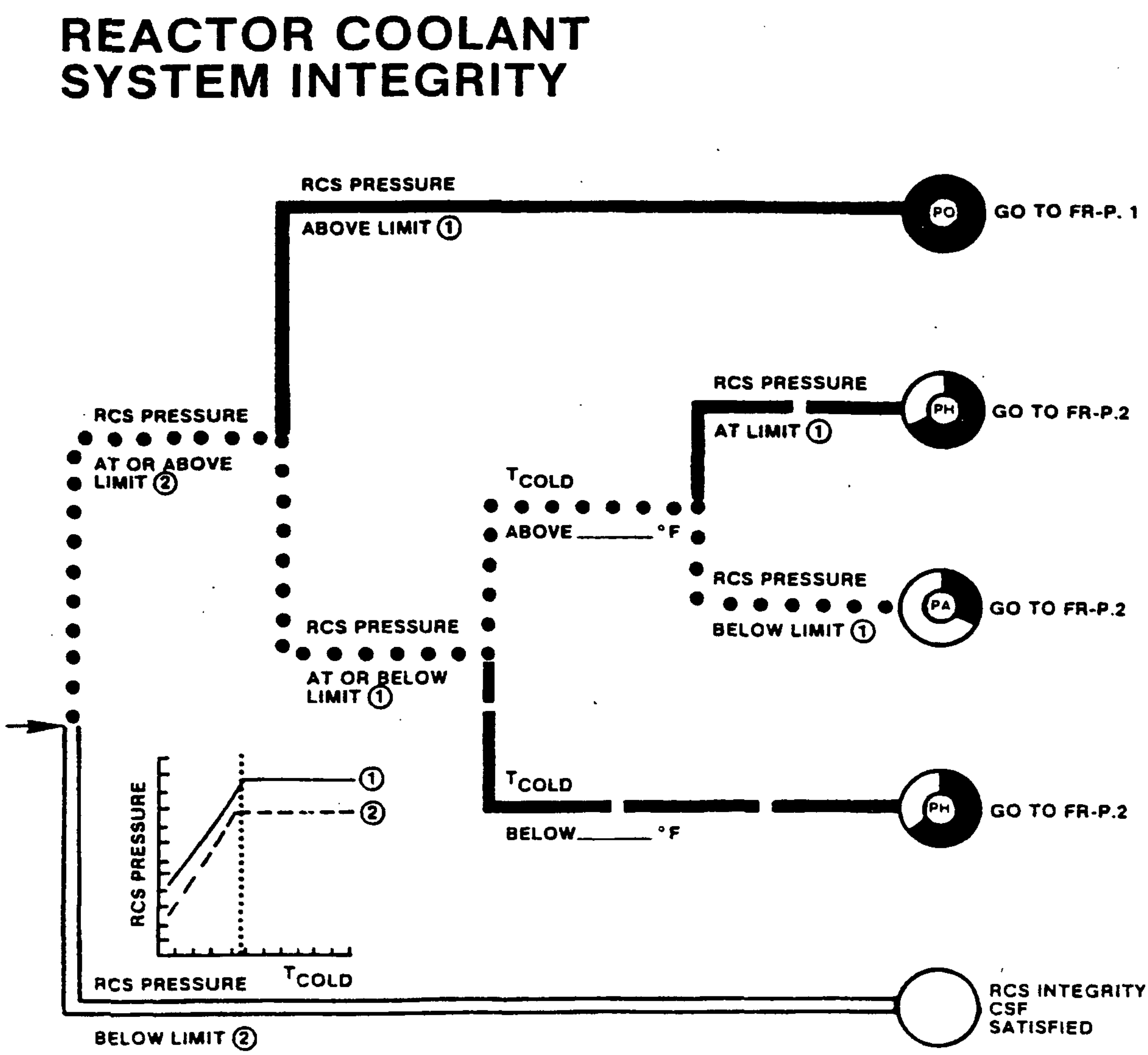

Figure 3.2. Illustrative Example of a Critical Safety Function Status Tree

symptoms which exist at the plant state in question, the operator is directed to the appropriate FRG (in this case, P.1 or P.2). If an entire set of symptoms cannot be found, or if the critical safety function is satisfied, the operator would proceed on to the next CSF tree in order. Using Figure 3.2 as an example, if the RCS pressure is above limit 2 and limit 1 (both limits being plant specific values based upon the PORV setpoint), the operator should proceed to FRG P.1 immediately ("Red" priority). If the RCS pressure is between these two limits, and T_{cold} is below some plant specific value, he should go to P.2, but only after checking the other trees for any "red" conditions. After satisfying himself that the critical safety function of reactor coolant system integrity is satisfied, the operator would proceed to the CSF tree which addresses "core cooling".

Thus, the CSF tree and associated FRGs provide as input to this symptoms comparison a set of instructions, each of which relates a "symptom set" (defined by the branches in the CSF trees) to an "action set" (defined by the specific FRG). Each of the six CSF trees are presented in Appendix II to this volume.

It should be noted that the three Zion OAET used in this comparison (which addressed sequences initiated by a small LOCA, a steam generator tube rupture, or a loss of off-site power) did not address any plant states where plant subcriticality was threatened. Therefore the CSF tree associated with subcriticality was not used in the investigation reported here.

3.3. DEFINITION OF KEY SYMPTOMS

Table 3.1 provides a listing of all of the symptoms included in the WOG Critical Safety Function Trees. As can be seen in Table 3.1, some of these symptoms involve plant specific set point and operating values. In order to facilitate the comparison between the symptom sets defined by the CSF trees and those listed in the OAETs, the CSF tree symptoms were "generalized" to address the trend rather than a specific value of a parameter. For example, the symptom "Cold Leg Temperature rises to above a°F" is generalized to "Cold Leg Temperature Rises". Table 3.2 presents the list of generalized symptoms used to perform the symptoms comparison. As can be seen in Table 3.2, some of the generalized symptoms involved more than merely describing the trend of a parameter (rising, falling, stable). These few exceptions involved changes in parameters beyond a value which produces well defined effects on system response. For example, a rising RCS pressure should be distinguished from an RCS pressure which has risen to the PORV setpoint because the opening of this valve has significant implications to the performance of the critical safety functions. Thus, in Table 3.2, Symptom 1a is "RCS Pressure Rising (but below PORV setpoint)" while symptom 1d is "RCS pressure at PORV setpoint".

As noted, the use of the generalized symptoms in Table 3.2 facilitated the comparison. If potential ambiguities are identified which involve a generalized symptom, then the specific symptom used in the CSF trees can be examined for these few cases. The effects of this symptoms generalization on the symptoms comparison process are discussed further in Section 7.

3.4 SYMPTOM SETS

As previously discussed, each branch on the CSF trees relates a set of symptoms to a set of actions. In addition, each state in the OAETs defines a set of symptoms and an associated set of operator actions. Both the CSF tree symptom sets and the OAET symptom sets can now be defined in terms of a consistent set of generalized symptoms.

Table 3.3 presents the symptoms sets defined by each branch of the CSF trees along with the indicated FRG which should be carried out when that symptom set is observed. The number and letter used to define each symptom are those presented in Table 3.2. (for example, Symptom 2a is "Cold Leg Temperature Rising"). Thus, Table 3.3 represents a translation of the CSF trees into a set of instructions, each of which associates a symptom set with an action set. For example, when the operator observes Symptom 1a (RCS Pressure Rising, but still below PORV setpoint) and Symptom 2a (Cold Leg Temperature Rising), he is instructed to take the actions delineated in FRG P.2.

The symptoms exhibited by the plant at each of the OAET states are summarized in Table 3.4. Again, the parameter number and the letter which describes the behavior of that parameter are defined in Table 3.2. In some cases, multiple symptoms involving the same parameter are indicated. For example, in Table 3.4, the symptoms associated with State S-4 indicate that the

RCS pressure (parameter #1) could be either rising (a) or remaining stable (b). These multiple (and sometimes contradictory) symptoms are due to either:

1) a state where the parameter is going through a transition from one trend to another; in these cases the operator may actually observe either or both symptoms.

2) a state where the physical plant response (e.g. voiding in the core) may affect the symptoms observed by the operator (e.g. pressurizer level); in these cases indications of these symptoms may be highly unreliable.

3) a state where the behavior of a certain parameter is simply unknown or highly uncertain.

If potential ambiguities are identified involving OAET states with such multiple symptoms, these few cases can be examined individually in more detail. The effects of the use of such multiple symptoms in Table 3.4 on the symptoms comparison process are discussed further in Section 7.

3.5 SYMPTOMS COMPARISON

The CSF tree symptom sets identified in Table 3.3 can now be compared with the OAET symptom sets delineated in Table 3.4. As discussed in Section 2, the first comparison task is to identify any and all OAET states which will completely produce any of the CSF tree symptom sets. This is accomplished by systematically working through each OAET state on Table 3.4 searching for the presence of the symptom sets listed in Table 3.3. For example, OAET state S-1 exhibits symptoms 7c and 8a (a falling pressurizer level with the reactor vessel upper head level indicated "full"). As seen in Table 3.3, these symptoms comprise a complete CSF tree symptom set. Should the operator observe both of these symptoms, he is directed by the WOG guidelines to perform FRG I.2.

Table 3.5 lists, for each OAET state, all of the CSF tree symptom sets which are completely indicated. Also provided are the FRGs associated with the completely produced symptom sets. For those OAET states which completely produce more than one CSF tree symptom set, the symptom sets and associated FRGs are listed in order of the priority assigned by the WOG guidelines.

Table 3.6 identifies, for each OAET state, all of the CSF tree symptom sets which are "almost" produced. That is, every OAET state which exhibits all but one of the symptoms associated with an FRG is identified in Table 6. For example, as seen in Table 3.3, one symptom set associated with FRG H.2 is comprised of symptoms 9b, 10a, 11a, 12a, but not 13c. Therefore, in Table 6, OAET state S-1 is indicated as "almost" producing a symptom set associated with FRG H.2.

Table 3.7 lists all those OAET states which do not completely produce any of the CSF tree symptom sets listed in Table 3.3.

As discussed in Section 2, the symptoms comparison results tabulated in Tables 5, 6, and 7 will be used to systematically address questions related to the completeness, accuracy, and ambiguity of the WOG guidelines. Each of the entries in these three tables is discussed in this regard in Section 4.

Table 3.1

SYMPTOMS INCLUDED IN WESTINGHOUSE TREES

1. RCS Pressure ≥ X psi, where, at lower temperatures, 'X' is a plant specific value related to a NDT limit, and at higher temperatures is a pressure slightly above the pressurizer safety valve setpoint

2. RCS pressure <X psi

3. RCS Pressure >Y psi, where 'Y' is, at lower temperatures, sufficiently below 'X' *such that the pressure is not expected to* rise from below 'X' to above 'Y" during successive sweeps through the status trees. At higher temperatures, 'Y' is the setpoint for opening the pressurizer PORV

4. RCS pressure at Y psi

5. RCS pressure ≤Y psi

6. RCS pressure <Y psi

7. T_{COLD} > a°F, where 'a' is a plant specific value left undefined *in the CSF trees*

8. T_{COLD} < a°F

9. Reactor Coolant indicated > b°F subcooled, where 'b' is the magnitude of the uncertainty associated with the subcooling meter indications at the specific plant

10. Reactor Coolant indicated < b°F subcooled

11. Core Exit Thermocouples >1200°F

12. Core Exit Thermocouples <1200°F

13. Core Exit Thermocouples indicating > 700°F

14. All Core Exit Thermocouples indicating < 700°F

15. At least one Reactor Coolant Pump operating

16. All Reactor Coolant Pumps stopped

17. Wide range reactor vessel level indicated ≥ 100%

18. Wide range reactor vessel level indicated below 100%

19. Narrow range reactor vessel level indicated above 3½ feet

20. Narrow range reactor vessel level indicated below 3½ feet

Table 3.1 (Continued)

SYMPTOMS INCLUDED IN W TREES

21. Pressurizer level indicated above i%, where 'i' is the high pressurizer level reactor trip setpoint for the specific plant

22. Pressurizer level indicated between i% and j%, where 'j' is the letdown isolation setpoint for the plant

23. Pressurizer level indicated below j%

24. Reactor vessel upper head level indicated full

25. Reactor vessel upper head level indicated less than full

26. RHRS not in service

27. RHRS in service

28. Core Exit Thermocouples indicating above c°F, where 'c' is the maximum RHRS cut in temperature for the plant

29. Core Exit Thermocouples indicating below c°F

30. No steam generators available for use

31. At least one steam generator available for use

32. Feedwater flow is not available

33. Feedwater flow is available for use as required

34. Both the atmospheric dumps and the condenser are not available

35. The atmospheric dump and/or the condenser is available for use as required

36. Steamline pressure above d psia, where 'd' is slightly above the highest setpoint of the steamline safety valves for the plant

37. Steamline pressure below d psia

38. Steam generator level indicated above e%, where 'e' indicates the plant specific level above which the steam generator U-tubes should be completely covered

39. Steam generator level indicated below e%

40. T_{HOT} is above g°F, where 'g' is a plant specific value left undefined in the CSF trees

41. T_{HOT} is below g°F

42. Containment pressure above design pressure for the plant

Table 3.1 (Continued)

SYMPTOMS INCLUDED IN W TREES

43. Containment pressure below design presure

44. Containment pressure above the H-1 setpoint, where H-1 is a plant specific value left undefined by the CSF trees

45. Containment pressure below the H-1 setpoint

46. Containment radiation level above xx, where 'xx' is, for non-subatmospheric containments, the containment ventilation isolation setpoint. For plants with subatmospheric containments, it is high enough above local background to clearly indicate an abnormal condition

47. Containment hydrogen concentration above yy, where 'yy' is the concentration at which uncontrolled hydrogen ignition and burning occurs

48. Containment hydrogen concentration below yy

49. Containment sump level above sump flood level at the plant

50. Containment sump level below flood level at the plant

Table 3.2

"GENERALIZED" SYMPTOM IDENTIFIERS USED FOR FUNCTION-RESTORATION GUIDELINE IDENTIFICATION

Parameter Number	Parameter	Symptom Label	Symptom
1	RCS Pressure	a	Rising (but below PORV setpoint)
		b	Stable (below PORV setpoint)
		c	Falling (below PORV setpoint)
		d	At PORV setpoint
		e	Above PORV setpoint
2	Cold Leg Temperature (T_{COLD})	a	Rising
		b	Stable
		c	Falling
3	Subcooling margin	a	Adequate
		b	Inadequate
4	Core Exit Temperature	a	Rising
		b	Stable
		c	Falling
5	Reactor Coolant Pumps (RCPs)	a	At lease one in operation
		b	All stopped
6	Reactor Vessel Level	a	Rising
		b	Stable
		c	Falling
7	Pressurizer level	a	Rising
		b	Stable (between high and low level trip setpoints)
		c	Falling
8	Reactor Vessel Upper Head Level	a	Full
		b	Not Full
9	RHRS	a	In service
		b	Not In Service
10	Steam Generators	a	Available
		b	Unavailable
11	Feedwater Flow (main or auxiliary)	a	Present
		b	Not Present
12	Condenser and/or ADVs	a	At least one available
		b	Neither available

Table 3.2 (Continued)

Parameter Number	Parameter	Symptom Label	Symptom
13	Steam Generator Level	a	Rising
		b	Stable
		c	Falling
14	Containment Pressure	a	Rising Above Design Pressure
		b	Rising (But Below Design Pressure)
		c	Stable
		d	Falling
15	Containment Radiation Level	a	Rising
		b	Stable
		c	Falling
16	Containment Hydrogen Level	a	Rising
		b	Stable/Falling
17	Containment Sump Level	a	Rising
		b	Stable
		c	Falling
18	Secondary Pressure	a	Rising (But Below Safety Valve Setpoint)
		b	Stable/Falling
		c	At or Above Safety Valve Setpoint
19	Hot Leg Temperature (T_{HOT})	a	Rising
		b	Stable/Falling

Table 3.3

SYMPTOM SETS INDICATING FUNCTION RESTORATION GUIDELINE IS REQUIRED

Function Restoration Guideline	Critical Safety Function Addressed	Symptom Set(s)* Indicating Action	Guideline Priority
P.1	Coolant System Integrity	1e	Red
P.2	Coolant System Integrity	1a,2a	Orange
		1a,2c	Yellow
		1d,2a	Orange
C.1	Core Cooling	3b,4a	Red
		3b,4a,5a,6c	Red
		3b,4a,5b,6c	Red
C.2	Core Cooling	3b,4a,5b,6a	Orange
		3b,4b,5b,6c	Orange
C.3	Core Cooling	3b,4a,5a,6a	Yellow
		3b,4b,5b,6a	Yellow
I.1	Reactor Coolant Inventory	7a,8a	Orange
I.2	Reactor Coolant Inventory	7c,8a	Yellow
		7c,8b	Orange
I.3	Reactor Coolant Inventory	7a,8b	Orange
		7b,8b	Orange
H.1	Heat Sink	9b,10b	Red
		9b,10a,11b	Red
		9b,10a,11a,12b,18c	Red
		4a,9a,10b	Red
		4a,9a,10a,11b	Red
		4a,9a,10a,11a,12b,18c	Red
H.2	Heat Sink	9b,10a,11a,12b,13c,18a	Yellow
		9b,10a,11a,12a,13c	Yellow
		4a,9a,10a,11a,12b, 13c,18a	Yellow
		4a,9a,10a,11a,12a,13c	Yellow

*(Using "Generalized" Symptoms; See Table 3.2)

Table 3.3 (continued)

SYMPTOM SETS INDICATING FUNCTION RESTORATION GUIDELINE IS REQUIRED

Function Restoration Guideline	Critical Safety Function Addressed	Symptom Set(s) Indicating Action	Guideline Priority
H.3	Heat Sink	9b,10a,11a,12b,13a 18a,19a	Yellow
		4a,9a,10a,11a,12b 13a,18a,19a	Yellow
Z.1	Containment	14a	Red
Z.2	Containment	14b	Orange
Z.3	Containment	14c,15a	Orange
Z.4	Containment	14c,15b,16a	Orange
Z.5	Containment	14c,15b,16b,17a	Orange

Table 3.4

SYMPTOMS EXHIBITED BY OAET PLANT STATES FOR THE SMALL BREAK LOCA INITIATOR

State Number	State Numbers of Other Similar States	Parameter Number (see Table 3.2) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
S-1	-	c	b	a	b	b	c	c	a	b	a	a	a	b	b	a	b	a	b	b
S-2	S-15	a	b	a	b	b	a	b	a	b	a	a	a	b	d	b	b	a	b	b
S-3	S-16	c	b	a	c	b	b	b	a	a	a	a	a	b	d	b	b	a	b	b
S-4	S-17	(a,b)	b	a	a	b	b	b	a	b	a	a	a	b	d	b	b	a	b	b
S-5	-	(a,b, c)		b	a	b	b	a	a	a	b	a	a	a	b	(c,d)	(a,b)	b	a	b
S-6	S-10	c	b	a	c	b	b	b	a	a	a	a	a	b	d	(a,b)	b	b	(b,c)	b
S-7	S-11,20,24	b	b	a	c	b	b	b	a	a	a	a	a	b	d	(a,b)	b	b	b	b
S-8	S-12	(a,b)	b	a	a	b	b	b	a	b	a	a	a	b	c	a	b	b	b	a
S-9	-	c	a	a	a	b	c	c	a	b	a	a	a	b	d	a	b	a	b	a
S-13	-	c	(a,b)	b	a	b	c	c	b	b	a	a	a	b	c	a	b	a	a	a
S-14	S-18,22	c	b	a	(a,b)	b	c	c	b	b	a	a	a	b	b	a	b	a	c	(a,b)
S-19	-	c	b	a	b	b	a	b	a	b	a	a	a	(b,c)	(c,d)	a	b	a	b	b
S-21	S-25	c	b	a	a	b	(b,c)	(b,c)	a	b	a	(a,b)	a	(b,c)	c	a	b	a	b	a
S-23	-	c	b	a	b	b	a	b	a	b	a	a	a	b	(c,d)	a	b	a	b	b
S-26	-	c	a	b	a	b	c	c	b	b	a	a	a	b	(b,c)	a	(a,b)	a	a	a

Table 3.4 (Continued)

SYMPTOMS EXHIBITED BY OAET PLANT STATES FOR THE LOSP INITIATOR

State Number	State Numbers of Other Similar States	Parameter Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
LOSP-1	LOSP-10	a	b	a	a	b	b	a	a	b	a	b	a	c	c	b	b	b	c	a
LOSP-2	-	c	b	a	(b,c)	b	b	(b,c)	a	b	a	a	a	a	c	c	b	b	c	b
LOSP-3	LOSP-6,19	c	b	a	(b,c)	b	b	(b,c)	a	(a,b)	a	a	a	b	c	c	b	b	b	b
LOSP-4	LOSP-7,8, 9,13,16,17, 18,25,28	d	b	(a,b)	a	b	c	a	a	b	b	b	a	c	b	a	b	a	c	a
LOSP-5	LOSP-14	c	b	a	c	b	b	(b,c)	a	b	a	a	a	a	(c,d)	b	b	a	(b,c)	b
LOSP-11	-	c	b	a	c	b	b	(b,c)	a	b	a	a	a	a	(c,d)	b	b	b	(b,c)	b
LOSP-12	LOSP-15, 19,22	c	b	a	b	b	b	(b,c)	a	b	a	a	a	b	c	b	b	b	b	b
LOSP-20	LOSP-23	c	b	a	b	b	c	c	a	b	a	a	a	(a,b)	c	b	b	b	(a,b)	b
LOSP-21	LOSP-24	c	b	(a,b)	c	b	c	a	a	b	a	a	a	b	b	a	b	a	b	b
LOSP-26	LOSP-29	c	b	a	b	b	c	c	a	b	b	b	a	(a,b)	c	b	b	b	(a,c)	a
LOSP-27	LOSP-30	c	b	b	b	b	c	(a,b,c)	a	b	b	b	a	c	b	a	b	a	(b,c)	a
LOSP-31	-	c	b	(a,b)	c	b	b	c	a	b	a	a	a	(b,c)	c	b	b	b	(b,c)	c

Table 3.4 (Continued)

SYMPTOMS EXHIBITED BY OAET PLANT STATES FOR THE SGTR INITIATOR

State Number	State Numbers of Other Similar States	Parameter Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SGTR-1	-	(a,b,c)	b	(a,b)	(b,c)	(a,b)	b	c	(a,b)	b	a	a	a	(a,b,c)	c	b	b	b	(a,b,c)	b
SGTR-2	SGTR-6	(a,b)	b	(a,b)	(b,c)	(a,b)	b	(a,b,c)	(a,b)	b	a	a	a	(a,b,c)	c	b	b	b	(a,b,c)	b
SGTR-3	SGTR-7	(b,c)	c	(a,b)	(b,c)	(a,b)	b	(a,b,c)	(a,b)	b	a	a	a	(b,c)	c	b	b	b	(b,c)	b
SGTR-4	-	(a,b)	(b,c)	(a,b)	(b,c)	a	b	(a,b,c)	(a,b)	b	a	a	a	b	c	b	b	b	b	b
SGTR-5	-	(a,b)	b	a	b	(a,b)	b	(a,b,c)	(a,b)	b	a	a	a	(a,b,c)	c	b	b	b	(a,b)	b
SGTR-8	SGTR-8a	(b,c)	(b,c)	(a,b)	(a,b,c)	a	b	(a,b,c)	(a,b)	b	a	a	a	b	c	b	b	b	b	b
SGTR-9	SGTR-10, 11	(b,c,	(b,c)	(a,b)	(a,b,c)	a	b	(a,b,c)	(a,b)	b	a	a	a	b	(b,c,d)	(a,b)	b	(a,b)	b	b
SGTR-12	-	(b,c,	(b,c)	(a,b)	(a,b,c)	b	b	(a,b,c)	(a,b)	b	a	a	a	b	(b,c,d)	(a,b)	b	(a,b)	b	b
SGTR-3a	SGTR-7a	(b,c)	b	(a,b)	(a,b,c)	(a,b)	b	(a,b,c)	(a,b)	b	a	a	(a,b)	b	c	b	b	b	(a,b,c)	(a,b)
SGTR-6a	-	(b,c)	b	(a,b)	(b,c)	(a,b)	b	(a,b,c)	(a,b)	b	a	a	a	(a,b,c)	c	b	b	b	(a,b,c)	b
SGTR-11a	-	c	b	(a,b)	(a,b,c)	a	b	(a,b,c)	(a,b)	b	a	a	a	b	(b,c,d)	a	b	a	b	b
SGTR-12a	-	(a,b)	b	(a,b)	(b,c)	b	b	(a,b,c)	(a,b)	b	a	a	a	b	c	b	b	b	b	b

Table 3.5

FRG SYMPTOM/ACTION SETS WHICH ARE COMPLETELY ASSOCIATED WITH OAET STATES

OAET STATE	SYMPTOM SET	FRG	GUIDELINE PRIORITY*
S-1	14b	Z.2	Orange
	7c,8a	I.2	Yellow
S-5	7a,8a	I.1	Orange
	14c,15a	Z.3	Orange
	14c,15b,16b,17a	Z.5	Orange
S-8,12	14c,15a	Z.3	Orange
S-9	7c,8a	I.2	Yellow
S-13	3b,4a 3b,4a,5b,6c	C.1 C.1	Red Red
	7c,8b	I.2	Orange
	14c,15a	Z.3	Orange
S-14,18,22	7c,8b	I.2	Orange
	14b	Z.2	Orange
S-19	14c,15a	Z.3	Orange
	9b,10a,11a,12a,13c	H.2	Yellow
S-21,25	9b,10a,11b	H.1	Red
	14c,15a	Z.3	Orange
	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow
S-23	14c,15a	Z.3	Orange
S-26	3b,4a 3b,4a,5b,6c	C.1 C.1	Red Red
	7c,8b	I.2	Orange
	14b	Z.2	Orange
	14c,15a	Z.3	Orange

*Red is highest priority followed by Orange and then Yellow.

Table 3.5 (Continued)

FRG SYMPTOM/ACTION SETS WHICH ARE COMPLETELY ASSOCIATED WITH OAET STATES

LOSP-1,10	9b,10a,11b	H.1	Red
	7a,8a	I.1	Orange
LOSP-2	7c,8a	I.2	Yellow
LOSP-3,6,19	7c,8a	I.2	Yellow
LOSP-4,7,8,9,13,16, 17,18,25,28	3b,4a 3b,4a,5b,6c	C.1 C.1	Red Red
	9b,10b	H.1	Red
	7a,8a	I.1	Orange
	14b	Z.2	Orange
LOSP-5,14	14c,15b,16b,17a	Z.5	Orange
	7c,8a	I.2	Yellow
LOSP-11	7c,8a	I.2	Yellow
LOSP-12,15,22	7c,8a	I.2	Yellow
LOSP-20,23	7c,8a	I.2	Yellow
LOSP-21,24	7a,8a	I.1	Orange
	14b	Z.2	Orange
LOSP-26,29	9b,10b	H.1	Red
	7c,8a	I.2	Yellow
LOSP-27,30	9b,10b	H.1	Red
	3b,4b,5b,6c	C.2	Orange
	7a,8a	I.1	Orange
	14b	Z.2	Orange
	7c,8a	I.2	Yellow
LOSP-31	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow

Table 3.5 (Continued)

FRG SYMPTOM/ACTION SETS WHICH ARE COMPLETELY ASSOCIATED WITH OAET STATES

SGTR-1	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow
SGTR-2,6	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow
SGTR-3,7	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow
SGTR-4	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	1a,2c	P.2	Yellow
	7c,8a	I.2	Yellow
SGTR-5	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow

Table 3.5 (Continued)

FRG SYMPTOM/ACTION SETS WHICH ARE COMPLETELY ASSOCIAED WITH OAET STATES

SGTR-8,8a	3b,4a	C.1	Red
	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow
SGTR-9,10,11	3b,4a	C.1	Red
	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	14b	Z.2	Orange
	14c,15a	Z.3	Orange
	14c,15b,16b,17a	Z.5	Orange
	7c,8a	I.2	Yellow
SGTR-12	3b,4a	C.1	Red
	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	14b	Z.2	Orange
	14c,15a	Z.3	Orange
	14c,15b,16b,17a	Z.5	Orange
	7c,8a	I.2	Yellow

Table 3.5 (Continued)

FRG SYMPTOM/ACTION SETS WHICH ARE COMPLETELY ASSOCIATED WITH OAET STATES

SGTR-3a,7a	3b,4a	C.1	Red
	9b,10a,11a,12a,18c	H.1	Red
	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow
SGTR-6a	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow
	9b,10a,11a,12a,13c	H.2	Yellow
SGTR-11a	3b,4a	C.1	Red
	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	14b	Z.2	Orange
	14c,15a	Z.3	Orange
	7c,8a	I.2	Yellow
SGTR-12a	7a,8a	I.1	Orange
	7c,8b	I.2	Orange
	7a,8b	I.3	Orange
	7b,8b	I.3	Orange
	7c,8a	I.2	Yellow

Table 3.6

FRGs Almost Indicated at OAET States

OAET STATE \ FRG	P.2	C.1	C.2	C.3	I.1	I.2	I.3	H.1	H.2	H.3	Z.1	Z.2	Z.3	Z.4	Z.5
S-1			X		X			X	X		X		X		
S-2,15	X			X	X	X	X	X	X		X	X			X
S-3,16					X	X	X				X	X			X
S-4,17	X	X			X	X	X	X	X		X	X			X
S-5	X			X		X	X	X	X		X	X	X		
S-6,10					X	X	X				X	X	X		
S-7,11, 20,24					X	X	X				X	X	X		
S-8,12	X	X			X	X	X	X	X		X	X			
S-9	X	X			X			X	X		X	X	X		
S-13	X		X				X		X		X	X			X
S-14,18,22		X	X				X	X	X		X		X		
S-19				X	X	X	X	X			X	X			X
S-21,25		X			X		X				X	X			X
S-23				X	X	X	X	X	X		X	X			X
S-26	X		X				X	X	X		X			X	X

Table 3.6 (continued)

FRGs Almost Indicated at OAET States

OAET STATE \ FRG	P.2	C.1	C.2	C.3	I.1	I.2	I.3	H.1	H.2	H.3	Z.1	Z.2	Z.3	Z.4	Z.5
LOSP-1,10	x	x				x	x		x		x	x	x	x	x
LOSP-2					x		x	x	x		x	x	x		
LOSP-3,6					x		x	x	x		x	x	x		
LOSP-4,7,8, 9,13,16,17, 18,25,28	x		x			x	x				x		x		
LOSP-5,14					x		x	x	x		x	x	x	x	
LOSP-11					x		x	x	x		x	x	x	x	x
LOSP-12,15, 19,22					x		x	x	x		x	x	x	x	x
LOSP-20,23			x		x			x	x		x	x	x	x	x
LOSP-21,24		x	x			x	x	x	x		x		x		
LOSP-26,29			x		x						x	x	x	x	x
LOSP-27,30		x		x			x				x		x		
LOSP-31		x			x			x			x	x	x	x	x

Table 3.6

FRGs Almost Indicated at OAET States

OAET STATE \ FRG	P.2	C.1	C.2	C.3	I.1	I.2	I.3	H.1	H.2	H.3	Z.1	Z.2	Z.3	Z.4	Z.5
SGTR-1	x		x	x	x		x	x			x	x	x	x	x
SGTR-2,6	x		x	x				x			x	x	x	x	x
SGTR-3,7	x	x	x	x				x			x	x	x	x	x
SGTR-4		x						x	x		x	x	x	x	x
SGTR-5	x							x			x	x	x	x	x
SGTR-8,8a	x			x				x	x		x	x	x	x	x
SGTR-9,10, 11				x				x	x		x			x	
SGTR-12			x	x				x	x		x			x	
SGTR-3a,7a									x	x	x	x	x	x	x
SGTR-6a		x	x	x							x	x	x	x	x
SGTR-11a				x				x	x		x				x
SGTR-12a	x	x	x	x				x	x		x	x	x	x	x

Table 3.7

OAET States For Which No FRG Is Indicated

Initiator	Plant State (s)
Small Break LOCA (S)	S-2,15 S-3,16 S-4,17 S-6,10 S-7,11,20,24
Loss of Offsite Power (LOSP)	All States have at least one indicated FRG
Steam Generator Tube Rupture (SGTR)	All states have at least one indicated FRG

Section 4

EXAMINATION OF WESTINGHOUSE GUIDELINES

As discussed in Section 2, a systematic review or examination of function-based emergency procedure guidelines must entail asking four basic questions regarding the completeness and clarity of the guidance. The results of the comparative symptom analyses tabulated in Tables 3.5, 3.6, and 3.7 will allow these four questions to be answered for the Westinghouse Owners Group Emergency Response Guidelines. Reference 2 should be examined for detailed descriptions of the OAET states discussed in this section.

4.1 QUESTION #1: ARE THE SYMPTOM SETS COMPLETE?

This first question is concerned with the completeness of the coverage of the Guidelines. This question addresses the fundamental premise of the function-based guidelines: monitoring a relatively few symptoms indicative of the critical safety functions will allow the operator to determine whether the plant is stable or that operator intervention is necessary. The basic task in addressing this question is to identify any risk significant states requiring operator action for which no guideline applies. Should any such states exist and occur, the operator would be without guidance and (if he strictly follows the guidelines) may erroneously assume no action is required.

Table 3.7 can be used to answer this question for the Westinghouse guidelines. This table delineates all OAET states which would not lead the operator to one of the Function Restoration Guidelines (FRGs). With one possible exception, the OAET states indicated in Table 3.7 are "success" states and require no significant operator action. Therefore, no FRG should be indicated at these states.

The one exception involves State S-4 (or the nearly identical state, S-17). At these states the operator has been successful in isolating the small break. The primary system inventory has been restored by the operation of the HPIS and/or charging pumps. The reactor has been cooling and depressurizing, and is in a state equivalent to that of hot shutdown. At this point, the steam generators are available and the auxiliary feedwater system is maintaining a stable steam generator level. Steam is being dumped either to the condenser or through the ADVs. The operator has attempted to provide long term cooling with the RHRS; however, that system has failed.

The preferred course of action is to maintain the plant in a hot shutdown condition while repairing the failures that resulted in the RHRS unavailability. This requires that the AFWS be available for continued heat removal. If the operator is able to use the steam dump system, the AFWS can be operated essentially indefinitely. If steam is being discharged to the atmosphere, the condensate storage tank inventory will gradually become depleted. If AFWS operation is required for an extended period (more than 5 hours), the operator must make provisions to refill the tank. Demineralized water is preferred, as this would avoid introduction of impurities into the condensate system. However, the quantity of demineralized water is limited. Hence, the plant is designed so that the service water system can be used for this purpose. Operator action is required to align the service water system to refill the condensate tank.

Since the decay heat is being removed through the steam generators to either the condenser or to the atmosphere, no critical safety function is being challenged and no FRG is indicated. However, if steam is being dumped to the atmosphere, the operator should anticipate the need to replenish the feedwater inventory. This anticipating action is especially important if the required tasks entail significant time to perform.

Thus, no state in which a critical safety function was being challenged was found which did not lead the operator to one or more FRGs. However, states may occur which will inevitably lead to the challenge of the critical safety functions unless operator intervention occurs. These states should be incorporated into the guidelines in order to allow timely operator response.

4.2 QUESTIONS #2 & #3: ARE THE INDICATED ACTIONS ALWAYS APPROPRIATE AND COMPLETE?

Once the operator has observed a complete symptom set (as defined by the CSF trees), he will be directed to one or more FRGs. Questions #2 and #3 are concerned with the actions indicated within these FRGs. Table 3.5 can be used to address the two questions for the Westinghouse guidelines. This table lists, for each OAET state, all of the CSF tree symptom sets which are completely produced and the associated FRG(s). The indicated FRG(s) must satisfy three criteria:

(1) If more than one FRG is indicated for a plant state, the actions indicated by those FRGs must be compatible among themselves.

(2) The actions indicated by the FRGs should be compatible with those indicated by the OAETs.

(3) All significant actions in the OAETs should be addressed by the indicated FRGs; in other words, the FRG action sets must be complete.

For each entry in Table 3.5, the indicated FRGs were examined with respect to these three criteria. Since the details of many of the FRGs were not yet complete, this examination did not take the form of an evaluation of the correctness or completeness of each guideline. Rather, the primary purpose and product of this examination was a delineation of the necessary characteristics which each FRG must possess when it is developed in complete detail.

The results of this examination for each OAET state listed in Table 3.5 are presented below:

<u>State S-1</u>

At this state a small LOCA has occurred. The reactor has scrammed, the RCPs have tripped, and the AFWS has begun operation. The HPIS is also in operation, supplying coolant to the vessel.

The operator's basic duties at this point are to ensure HPIS actuation to replace coolant lost out the break, isolate containment, and ensure initiation of containment protection systems (fan coolers or containment spray) if required. Even for small breaks, the containment pressure responds quickly and could rise in State S-1 to where the fan coolers should be actuated.

The two FRGs which may be indicated by the symptoms at State S-1 are I.2 (Response to Low Inventory) and Z.2 (Response to High Containment Pressure). These guidelines are appropriate at State S-1 and it is anticipated that the actions in these two FRGs will be compatible.

It should also be noted that vapor space breaks or stuck open pressurizer relief valves could provide a falsely high pressurizer level and could prevent the operator from going to FRG I.2 Also, there will be some inevitable voiding in the upper head following most small LOCAs. Entry to this guideline should not rely on level measurements which could easily be unreliable due to the effects of this voiding.

State S-5

At State S-5 a small LOCA has occurred but the HPIS has successfully actuated and is in operation providing coolant to the core. The break is not isolated, and water released through the break is causing the sump level to increase.

FRGs I.1, Z.3, and Z.5 may be indicated by the symptoms present at this state. FRG I.1 focuses on reestablishing control of the pressurizer level while providing for adequate RCS subcooling. FRG Z.3 provides guidance to minimize the release of radioactivity from the containment and FRG Z.5 provides guidance in response to containment flooding.

At State S-5, the operator should continue plant cooldown and transfer to recirculation cooling prior to RWST depletion. The operator may have a limited time to perform the transition from injection to recirculation of the sump water, especially for larger breaks where the containment spray pumps are running. One factor which must be considered in transferring to recirculation is the need for adequate NPSH for the low head RHRS pumps. This requires that the containment water level reach a certain elevation before the sump line suction valves open. Hence, the plant must be designed such that when the RWST low level alarm occurs, the minimum containment sump criterion appears to be satisfied for all LOCAs. However, in the case of the stuck-open relief valve, it is uncertain if there will be adequate sump water level at the RWST low level set point. This is because some of the primary coolant released through the stuck-open valve will be contained in the pressurizer relief tank (PRT). This will delay the time required to fill the sump to an adequate height, and consequently reduce the time the operator has available to transfer from injection to recirculation operation. These considerations should be incorporated into the final development of the three FRGs noted above.

States S-8,12

At these states, a small LOCA has occurred. While the operator has not been able to isolate the break, he has been successful in ensuring high pressure injection and subsequent transfer to recirculation. However, attempts to initiate long-term RHR cooling have failed. Decay heat is still being removed via the steam generators with steam being dumped to the condenser or through the ADVs. The only FRG indicated at this state is Z.3 which focuses on the high containment radiation levels which should accompany an unisolated break inside containment.

Since the impacts of the failure to provide long term cooling have not yet been felt, no FRG directed at decay heat removal is indicated at these states. However, the operator should anticipate the requirement to provide a long term heat sink. As previously discussed in Section 4.1 for State S-4, the FRGs directed at decay heat removal should address states such as these where future action is very likely or inevitable.

State S-9

State S-9 is a continuation of State S-5. A small LOCA has occurred and the HPIS inventory has been depleted following successful operation. The break is not isolated, and recirculation of the sump water is necessary. However, the transfer to the recirculation cooling mode (HPRS) has not been accomplished, or the HPRS has been in operation but has subsequently failed. Recirculation with the LPRS, or repair of the HPRS, is necessary before the primary system inventory is depleted.

From Table 3.5 it is noted that FRG I.2 is indicated by the symptoms present at State S-9. This FRG is used to respond to the low system inventory which would occur at this state. This FRG, when developed to completion, must be compatible with the actions required at this state. If repairs to the HPRS cannot be made in a relatively short time, the operator has two options available. One option is to reestablish HPIS flow to buy time to repair the HPRS. This would necessitate providing a source of makeup to the RWST. Recirculation of the sump water would still eventually be necessary before thewater level rises to an unacceptable level. The second option is to depressurize the primary system and use the Low Pressure Recirculation System to provide coolant to the core.

State S-13

At State S-13 the break has not been isolated and HPRS and LPRS operations have failed. The RWST inventory has depleted, and no core coolant is being provided.

Because of the severe nature of events at this state, FRG C.1, I.2, and Z.3 are all indicated by the symptom sets which are fully present. FRG C.1 is a response to inadequate core cooling, I.2 is a response to low system inventory, and Z.3 is a response to high containment radiation. These various guidelines must be mutually compatible.

There is one important aspect of operator action which should be addressed by these guidelines due to the potential for conflicting instructions. In response to an inadequate subcooling margin, the operator may be reluctant to take any action designed to lower the RCS pressure. However, there is the need to provide coolant to the core and remove heat by any means possible at this state. This may require system depressurization (manually opening PORVs).

S-14,18,22

State S-14 involves a small break LOCA with failure of the HPIS. State S-18 is a continuation of State S-14 in which the operator has been unable to isolate the break. At State S-22, the operator has been unable to sufficiently depressurize the primary system using the steam generator ADVs to enable LPIS operation.

The operator's role throughout this progression of states is to restore HPIS, or to depressurize the primary system and use the LPIS to restore and maintain coolant inventory. If high pressure injection cannot be established, the operator response should be directed at opening the relief valves on all of the steam generators. If this is not successful in reducing pressure, then all of the pressurizer PORVs should be manually opened to directly reduce system pressure. However, it is questionable for most small breaks whether opening the PORVs will sufficiently reduce primary pressure to allow low pressure injection. In such cases, the RCPs may be used to circulate the two phase mixture through the core. This would lengthen the time to core damage.

During the depressurization process, care should be taken not to lower the pressure to the point where accumulator nitrogen might be injected into the primary system. After depressurization, it is important to avoid repressurizing the primary system above the low-head SI shutoff head. Auxiliary Feedwater to the steam generators should be ensured to prevent the steam generators from acting as heat sources after the accumulators and LPIS inject coolant into the RCS.

Two FRGs are completely indicated for these states - I.2 and Z.2. FRG I.2 is a response to the low system inventory produced by the break and failure of safety injection. FRG Z.2 is a response to the high containment pressure produced by the unisolated break. These FRGs address the important problems existing at these states. It is possible that conditions could deteriorate to the point where FRG C.1 may be indicated. This is addressed in State S-26.

State S-19

At this state the operator has successfully depressurized the system using the ADVs following HPIS failure. Makeup is being provided to the core with the LPIS. Containment spray operation is continuing as the break remains unisolated. Decay heat is being removed through the steam generators. The FRGs indicated by the symptoms which exist at this state are H.2 and Z.3. FRG H.2 is designed to respond to the low steam generator level caused by opening of the ADVs. After the secondary side has blown down, auxiliary feedwater will restore the level and the need for action under H.2 will be obviated. It should also be noted that rapid steam dump could cause flashing and erratic or falsely high steam generator level readings. FRG Z.3 is a response to the high radiation levels in containment associated with the unisolated break. Actions defined in the guideline should be compatible with the conditions at this state.

States S-21,25

At these states the LPIS had been in operation providing coolant to the core. Long term cooling with the LPRS was then attempted, but the LPRS failed. At this point, the RWST is near depletion and the operator must find a way to maintain coolant inventory either by replenishment of the RWST and continuation of injection, or by removing the recirculation problems. FRG I.2, which is indicated by the symptoms at this state, should address these actions. This FRG should note that there is a limit to the length of time that the injection mode can be continued. Rising water level in containment may produce excessive loads on the containment structure leading to a loss of containment integrity and the release of radioactivity to the outside environment. Also, rising water level may submerge (and fail) critical circuits or components. Containment guidelines (FRG Z.3 is indicated at these states) should address the need to conserve RWST water and avoid unnecessary flooding of containment.

FRGs H.1 or H.2 may also be indicated at these states. These FRGs address the lack of a secondary heat sink supplied by the Auxiliary Feedwater System. These FRGs should take care to differentiate between short term failure of the steam generator heat sink when it is expected to provide the normal heat removal path and long term unavailability of the system when other heat sinks (RHR) are normally used. Operator actions and priorities are certainly different between these two situations.

State S-23

At this state the small break has occurred and the HPIS has failed. The operator has successfully depressurized the primary system using the pressurizer PORVs (although this might be very difficult under most small LOCA conditions), and is providing coolant to the core with the LPIS. The system pressure is reduced and LPIS has restored the primary system inventory. This state is very similar to State S-19, except for the method of primary system depressurization.

The only FRG indicated at this state is FRG Z.3. This FRG will address high radiation levels in containment. Because of the combination of the leak through the break and the release from the PORVs, the radiation level in the containment will be elevated. FRG Z.3 should include actions associated with containment isolation and containment spray operation.

In addition to monitoring the radiation level inside containment, the operator must also monitor the LPIS operation and switch to recirculation when necessary. Because of the successful operation of the LPIS at this time, there is no obvious threat on any other critical safety functions. The FRG which addresses the use of LPIS (I.2) should anticipate the need for a transfer to recirculation.

State S-26

This state is a continuation of States S-14, S-18, and S-22. At this point, a small break has been followed by failure of HPIS. The operator has failed to adequately depressurize the primary system below the shutoff head of the LPIS pumps using the secondary ADVs or the pressurizer PORVs. No coolant is being provided to the vessel, and the core will eventually uncover. Operation of the RCPs may delay core damage by circulating the available steam/water coolant.

Because of the severe nature of the events at this state, several FRGs are indicated. The FRGs indicated by the symptoms present at this time are C.1, I.2, Z.2, and Z.3. These deal with core cooling, reactor system inventory, high containment pressure, and high radiation inside containment, respectively.

The actions associated with the final versions of these guidelines must be mutually compatible and no guidelines should detract from the primary objective of establishing some form of coolant flow to the core.

STATES LOSP-1,10

At these states, a loss of offsite power initiating event has occurred. The reactor has successfully scrammed and the reactor coolant pumps and the main feedwater pumps have tripped. With the secondary steam flow isolated, the steam generator secondary pressure will rapidly increase to the atmospheric dump valve setpoint. The loss of main feedwater will result in a rapid drop of the steam generator secondary level. The pressurizer level will experience an initial rapid rise which is arrested by reactor scram followed by a more significant rise as the pumps coast down. The operator's responsibilities at these states are to verify the automatic responses and ensure that auxiliary feedwater flow is established.

The rising pressurizer level could direct the operator to FRG I.1 which is designed to respond to pressurizer flooding. Since the pressurizer level will peak shortly after RCP trip and then begin a gradual descent, the operator should avoid taking unnecessary actions to remedy a self-correcting situation.

FRG H.1 will also be indicated at these states. The initial actions indicated in H.1 address the need to establish auxiliary feedwater flow and are thus compatible with the situation at States LOSP-1 and 10.

STATE LOSP-2

At state LOSP-2 the plant has experienced a loss of offsite power. The on-site emergency power system is functioning, and automatic actuation of the AFWS has occurred. The primary system inventory is being maintained while heat is removed through the steam generators. The pressurizer level will continue the gradual descent from the elevated level produced by pump coastdown. The existence of the generalized symptom "Pressurizer level falling" caused FRG I.2 to be indicated. However, the level, while falling, should be above the points which will actually indicate FRG I.2. Therefore, the operator should not actually be directed to this guideline at LOSP-2.

This state is therefore analogous to the states listed in Table 3.7. It is essentially a "success" state requiring no significant operator action.

STATES LOSP-3,6,19

At these states, the operator has successfully established a source of makeup to the CST and stable long-term auxiliary feedwater flow is available.

These states are very similar to LOSP-2. The FRG I.2 listed in Table 3.5 will actually not be indicated because the pressurizer level, while falling, should remain above the levels required to initiate FRG I.2. This is a "success" state requiring no significant operator action.

STATES LOSP-4,7,8,9,13,16,17,18,25,28

All of these states involve the failure to establish (or maintain) auxiliary feedwater flow to the steam generators. The primary duties of the operator are to:

(1) attempt to establish AFW, or failing that

(2) blow down one or more steam generators and establish low pressure backup feedwater (condensate pumps) flow if possible, or failing that

(3) initiate "feed and bleed" cooling.

The operator should be aware that option (2) might result in primary depressurization to the SI setpoint. If, in option (3), the operator fails to open two or more PORVs the resultant RCS depressurization will not be sufficient to allow adequate SI. In this case, the operator should start the RCPs and continue efforts to depressurize.

The FRGs which may be indicated by the symptoms present at these states are C.1, I.1, H.1, and Z.2. FRG C.1 provides guidance under inadequate core cooling conditions. FRG I.1 is a response to the high pressurizer level. FRG H.1 is directed at a response to the secondary heat sink caused by the loss of feedwater. FRG Z.2 is a response to high containment pressure. These FRGs must be mutually compatible with respect to the directions provided to the operator.

If the situation has deteriorated to the point where subcooling is threatened, the operator may be reluctant to depressurize the primary system further as a means of cooling. This potential incompatibility between FRG C.1 and H.1 should be addressed and unambiguous guidance provided to the operator concerning the use of "feed and bleed" cooling.

STATES LOSP-5,14

At these states automatic actuation of the AFW system has failed, but the operator has been successful in manually establishing a source of AFW. This "delayed" feedwater is maintaining the inventory in the steam generator. However, the pressurizer PORV has opened to relieve the RCS pressure increase resulting from the temporary loss of the steam generators. The containment sprays have begun operation to counter the pressure rise inside containment.

The FRGs which may be indicated by the symptoms at these states are FRG I.2 and Z.5. These guidelines are designed to respond to the potential effects of the open PORV; I.2 is a response to a low system inventory and Z.5 is a response to a high containment sump level. These guidelines are not expected to produce any incompatibilities and should provide adequate guidance should these states occur.

STATES LOSP-11,12,15,22

At these states the plant has experienced a loss of offsite power. The onsite diesel generator has failed to start, but the turbine driven AFW pump is supplying water to the steam generators. These states are very similar to state LOSP-2, with the primary difference being the absence of AC power.

These states are also "success" states requiring no significant operator action. FRG I.2 should not actually be indicated at these states because the pressurizer level, while falling, will remain above the levels requiring operator response.

STATES LOSP-20,23

At these states the operator has been successful in establishing stable long term feedwater flow to the steam generators. The pressurizer PORV has reseated, but the transient has caused a tube rupture in a steam generator to occur. The primary inventory is decreasing as coolant escapes through the rupture and FRG I.2 is indicated to respond to this loss of inventory.

The effects of the events preceding the tube rupture did not result in combinations of symptoms which falsely lead the operator to guidelines beyond those which a tube rupture alone would indicate. Additionally, no operator actions are required at this state which are not also required in response to a tube rupture initiating event. State SGTR-1 should be referred to for a discussion of the guidance provided in response to a steam generator tube rupture.

STATES LOSP-21,24

At these states the operator has been successful in establishing stable long-term feedwater flow to the steam generators, and the steam generators are intact. However, a pressurizer PORV has failed to reseat, and the primary system is being depressurized through this valve.

Two FRGs are indicated by the symptoms present at these states. FRG I.1 is a response to pressurizer flooding, while FRG Z.2 is a response to a high containment pressure.

The effects of the events preceding the stuck open PORV did not result in combinations of symptoms which falsely lead the operator to guidelines beyond those which a small LOCA (in the vapor space) would indicate. Additionally, no operator actions are required at this state which are not also required in response to a small LOCA initiating event. See State S-1 for a discussion of the guidance provided in response to a stuck open PORV.

STATES LOSP-26,29

At these states the operator has been unable to establish a stable long-term feedwater flow to the steam generators, and they are drying out or have dried out. The effects of these events have resulted in a tube rupture in one of the steam generators.

The FRGs indicated by the symptoms at these states are FRG I.2 and FRG H.1. FRG H.1, a response to a loss of secondary heat sink, takes priority over FRG I.1 (which is a response to a low primary system inventory). FRG H.1 should be compatible with I.2 and should provide effective guidance even with a concurrent steam generator tube rupture. The actions detailed in FRG I.2 in response to the leak of primary inventory through the rupture should be consistent with the conditions existing at these states (e.g., intact steam generators are dried out).

STATES LOSP-27,30

The operator has been unsuccessful in establishing a long-term source of feedwater to the steam generators, and they are drying out. In addition, a PORV on the pressurizer has stuck open, and primary coolant is being released to the containment.

Several FRGs are indicated by the symptoms at this state. FRGs C.2, I.1, I.2, H.1, and Z.2 are all indicated. FRG C.2 is a response to a potential loss of core cooling, FRG I.1 is a response to a flooding pressurizer, FRG I.2 is a response to a low primary system inventory, FRG H.1 is a response to a loss of the secondary heat sink, and FRG Z.2 is a response to a high containment pressure. FRG H.1 has priority in this group, followed by FRGs C.2 and I.1.

These guidelines must be mutually compatible and provide unambiguous guidance under the conditions present at those states. One area of guidance which should be of primary concern is that associated with the PORVs. An appropriate action for the operator to take at these states is to close the block valve on the stuck open PORV and use the other PORV(s) to control the primary pressure in a "feed and bleed" cooling mode. Guidelines directed at responding to a loss of inventory or elevated containment pressure may emphasize the desirability of closing all PORVs. Guidelines directed at providing a heat sink should not ignore the potential effects of a rapid depressurization associated with a stuck open PORV on core cooling.

STATE LOSP-31

This state involves a loss of offsite power and a stuck open or ruptured steam generator secondary relief valve. Following the initiating event and the resultant trip of the main feedwater pumps, the secondary pressure will increase to the secondary relief valve setpoint. At this point, the relief valve is assumed to rupture or to stick full open. This will produce a rapid depressurization of the affected steam generator and a corresponding rapid decrease of the primary pressure and rapid cooldown of the primary system due to the significantly greater cooling ability of the ruptured secondary.

The FRGs indicated by the symptoms at this state are FRG I.2 and FRG H.2. FRG I.2 is a response to the decreasing pressurizer level associated with the rapid cooldown, while H.2 is a response to low steam generator level. These guidelines should be mutually compatible and provide guidance which is consistent with the conditions at this state. FRG I.2 should caution the operator concerning pressurized thermal shock. This sequence will produce a rapid cooldown of the primary system followed by a repressurization with the charging pumps. The operator should be cautioned that the ruptured or stuck open relief valve could result in a falsely high steam generator secondary level reading.

STATE SGTR-1

At this state a tube rupture has occurred in one of the steam generators. Primary inventory is escaping through this rupture at a rate which is greater than the makeup ability of the Chemical And Volume Control System (CVCS). The reactor has successfully scrammed, auxiliary feedwater flow to the steam generators has been initiated and the HPIS has been automatically actuated.

There are two characteristics of the plant response to steam generator tube ruptures that could affect the operator's perception of this state and several subsequent states. The first is that, due to the nature of the event, the conditions in the faulted steam generator may be quite different than those in the intact steam generators. In fact, it is the existence of varied levels and pressures in the different steam generators which provides a key indication to the operator that a tube rupture has occurred. Thus, depending upon which steam generator is monitored, the operator can observe a variety of often conflicting parameter behaviors.

The second characteristic is the fairly high uncertainty concerning the expected behavior of reactor vessel and pressurizer level and primary pressure following a steam generator tube rupture. The effect of the tube rupture on these parameters is a function of break size and the timing of other events. For some spectrum of small sized breaks, the operation of the HPIS may repressurize the system rapidly, causing the pressurizer level to increase. For other breaks, the leakage may be such that the level goes off-scale low very quickly and does not return for some time. HPIS flow and break flow may also equilibrate so that the pressurizer level stabilizes. What the operator sees the level doing depends on when he looks, and how big the break is. Available analysis (and experience) also indicates that voiding in the upper portions of the reactor vessel is possible during almost any stage of the SGTR event. The voids may collapse very quickly, especially with the reactor coolant pumps in operation, or they may take some large amount of time to collapse. Operator guidance should ensure that voids are not produced in the core or in the loops which could inhibit coolant circulation.

Thus, steam generator tube rupture events may exhibit a wide variety of symptoms and care must be taken to provide unambiguous guidance throughout the progression of such incidents.

The FRGs indicated by the symptoms of state SGTR-1 are FRG I.2 and FRG H.2. FRG I.2 is a response to low primary system inventory, while FRG H.2 is a response to low steam generator level. There are no obvious incompatibilities between the two FRGs. The actions of FRG I.2 focus on restoring primary level to normal, while those of FRG H.2 are aimed at restoring secondary level. These two sets of actions do not appear to include the potential for conflicting instructions.

The actions included in the FRGs are also anticipated to be consistent to a major degree with the actions indicated by the OAET for this state. There will be a need for SI operation at this state, and the instructions appropriate to this requirement are assumed to be included as part of FRG I.2. Also, due to the scram, the level in the unaffected steam generators may drop until AFW is supplied. This is addressed by FRG H.2.

Of course, there are may additional actions which the operator should perform in response to a steam generator tube rupture which are not expected to be explicitly included in the indicated guidelines. For example, one of the operator's primary responsibilities is to identify and isolate the affected steam generator, minimizing the release of the contaminated steam outside of the containment. Isolation of the AFW supply to the affected steam generator is necessary while maintaining the levels in the unaffected loops. The steam isolation valve in the affected loop should also be closed to halt steaming to the condenser from the affected loop.

These actions are based on the successful diagnosis of a tube rupture and are addressed in Emergency Instruction E-3 which deals exclusively with steam generator tube ruptures. The guidance provided in the indicated FRGs does address the affected critical safety functions and, consistent with the goals of the functional guidance provided by the CSFTs and FRGs, should allow the operator to effectively restore these functions. However, due to the significance of the operator actions detailed in E-3, consideration should be given to explicitly addressing the diagnosis of and response to steam generator tube ruptures in FRG I.2.

STATES SGTR-2,6

At states SGTR-2 and 6 the operator has identified the affected steam generator and has taken steps to isolate it. In state SGTR-2 he has closed the steam isolation valve in the affected loop and has terminated AFW flow to the affected steam generator. In state SGTR-6 the isolation valve in the affected loop would not close, but the operator has closed all other isolation valves and the turbine bypass and turbine stopvalves, thus isolating the affected steam generator from the condenser and from the other steam generators. Auxiliary feedwater is still being delivered to the unaffected steam generators. The operator's primary responsibility at these states is to ensure adequate coolant inventory is maintained while cooling down and depressurizing the primary system to minimize flow out the break.

Due to the possibility that both pressurizer and upper head level may be affected by the size of the break, timing of other events, and voids (as discussed in state SGTR-1), any of the three FRGs which rely on these level measurements (I.1, I.2, and I.3) could be indicated at these states. FRG I.1 is a response to pressurizer flooding, while FRG I.2 and I.3 are responses to low primary system inventory and a void in the reactor vessel, respectively. The other FRG indicated for states SGTR-2 and 6 is FRG H.2, a response to a low steam generator level. FRG H.2 may not actually be required at this time if the low steam generator level is in the faulted steam generator only. However, a check on all steam generator levels should be performed, and AFW flow restored or maintained in the available non-faulted ones. FRG H.2 is therefore appropriate at this state.

Obviously, the actions of I.1 and I.2 will not be compatible. These guidelines, which involve guidance concerning the operation of the letdown and charging systems, cannot rely on uncertain level measurements to define the appropriate operator response. At these states, the operator could be instructed to increase SI flow or decrease SI flow with equal probability. It is imperative that these guidelines provide unambiguous guidance under these conditions. This would entail definitive methods of diagnosing the possibility of voids before embarking on FRG I.1 or I.2 and unambiguous guidance related to the operation (or termination) of the charging or injection systems once voids have been suspected.

In addition, potential confusion may arise at these states due to the operator's desire to lower primary pressure to below the affected steam generator's secondary pressure in order to stop the flow out of the primary system. This depressurization could be contrary to the guidance provided under voiding conditions. Cautions should be included in the inventory maintenance guidelines concerning the potential conflicts between lowering the pressure to decrease primary outflow (and increasing injection flow) and void formation.

<u>*STATES SGTR-3,7*</u>

At these states, the operator has isolated the faulty steam generator (state SGTR-3) or, failing that, all of the intact steam generators (state SGTR-7), and has cooled the RCS by depressurizing the secondary system using steam dump to the condenser or through the steam generator PORV. The primary system inventory is being maintained with the HPIS.

The indications for pressurizer level and reactor vessel upper head level may be affected by the presence of voids (voiding in the upper head is probably inevitable for these states). Thus, the behavior of these symptoms may not be reliable indications of the true conditions existing at these states.

The operator's primary task at these states is to continue the primary system depressurization to a value less than the pressure in the ruptured steam generator. There are two ways to accomplish this objective. The preferred method is to use the pressurizer sprays. The coolant used for pressurizer spray is taken from the cold leg downstream of the reactor coolant pump (RCP). Pump operation provides the driving force to deliver water to the pressurizer. Hence, RCP operation is required to utilize the pressurizer sprays. The availability of these pumps will depend upon the initial depressurization following the tube rupture. The criteria for automatic RCP trip are activation of HPIS and depressurization below a specific value (a design dependent value lower that the SI setpoint). If the RCPs are unavailable to power the pressurizer sprays, the alternate method for depressurizing the primary system is to manually open the pressurizer PORV.

The indicated FRGs for these states are exactly the same as those indicated at states SGTR-2 and 6. The discussion for these states is again applicable here.

The possibility of void formation at these states due to rapid depressurization results in the unreliability of pressurizer level and upper head level as true indicators of primary system inventory. Accordingly, these parameters should not be relied upon to guide operation of the charging or injection system as they may be in FRGs I.1 and I.2 Additionally, the operator's desire to lower the primary system pressure in order to stop flow out of the primary system may be in conflict with other instructions should voids be present or suspected. The operator must be provided with unambiguous guidance concerning the depressurization process and operation of charging or injection systems which takes into account the likelihood of void formation in the early stages of the incident.

At these states, the operator is also faced with a decision concerning the operation of the RCPs. There may be two strong incentives to keep the RCPs running at these states: 1) the availability of the RCPs would allow the operator to use the pressurizer sprays in depressurizing the RCS and thus avoid the necessity of opening PORVs; 2) the RCPs would provide enhanced mixing and any steam bubbles which may have formed during the initial RCS depressurization following the break should be dissipated in a relatively short time.

However, there may be other reasons (e.g., equipment protection) for turning the pumps off (or keeping them off) during depressurization events such as small LOCAs and steam generator tube ruptures. The operator may be directed to FRG I.2 or I.3 at these states. Both of these guidelines should provide unambiguous guidance concerning RCP operation.

STATE SGTR-4

At this state the operator has isolated the faulted steam generator and cooled the RCS by using steam dump or the steam generator PORVs. The reactor coolant pumps (RCPs) are still in operation at this state, allowing the operator to use the pressurizer spray to depressurize the RCS. The RCS pressure has been lowered to a value below the ruptured steam generator secondary pressure and flow out of the primary system has ceased. The operator will begin to become concerned about the HPIS repressurizing the primary system to a point which would reestablish flow out the break.

The pressurizer level and upper head level may still be unreliable indicators of the actual primary inventory and the operator could be directed to FRGs I.1, I.2, or I.3. FRG P.2 (Response to High RCS Pressure) may also be indicated; however, this would require a high RCS pressure well above the secondary pressure where break flow would be reestablished. This could occur, but the operator will probably have been alerted to a rising RCS pressure long before it reached the values required for FRG P.2, and at this stage it is unlikely that FRGs I.2 or I.3 would also be indicated. Thus, only P.2 and I.1 need to be compatible.

In any case, the operator requires unambiguous guidance concerning the termination of HPIS under these conditions. Termination criteria should not rely only on level measurements such as those used to indicate FRG I.1, but should be consistent with those described in Emergency Instruction E-3, namely:

1) RCS pressure is increasing: This verifies that inventory is increasing and that there are no other major leakage paths. This also insures that any voids formed during the depressurization phase are collapsed.

2) Pressurizer level has been re-established: In conjunction with increasing pressure, this confirms that RCS inventory is sufficient.

3) Adequate subcooling margin exists in RCS: margin should provide for any temperature differences between core and instrument location. If available, a comparison of pressurizer temperature and reactor vessel water temperature can provide quick check of subcooling.

The combination of these three symptoms should provide assurance to the operator that HPIS can be safely terminated. A confirmation of available heat sinks will add to the confidence that subcooling will remain without HPIS repressurization.

STATE SGTR-5

At this state the SGTR event has occurred and the HPIS is in operation. However, the operator has not been able to isolate the faulted steam generator.

The FRGs which may be indicated by the symptoms present at this state are FRGs I.1, I.2, I.3 and H.2. These FRGs are the same as indicated for states SGTR-2,3,6, and 7, and those states should be referenced for more details.

As discussed for states SGTR-2 and 6, FRG H.2 may not actually be required at this time if the low steam generator level is in the faulted steam generator only. However, a check on all steam generator levels should be performed, and AFW flow restored or maintained in the available non-faulted ones. FRG H.2 is therefore appropriate at this state.

STATES SGTR-8,8a

At these states the operator has failed to or been unable to depressurize the primary system with the pressurizer spray or the PORVs. Because of the elevated pressure in the primary system relative to that in the faulted steam generator, coolant continues to flow through the break. HPIS makeup is thus required for an extensive period of time.

As in the previous states, the operator may be directed to FRGs I.1, I.2, or I.3. The same comments provided above for states SGTR 2,3,6, and 7 apply here.

Table 3.6 also indicates that FRG C.1 may be indicated at this state. However, while the possibility exists that the core exit temperature may be slightly rising at this point (especially if the intact steam generators have egun to act as heat sources), the temperature will not reach the specific values required to indicate FRG C.1.

STATE SGTR-9

At these states the operator has successfully depressurized the RCS by opening the pressurizer PORVs. HPIS flow is continuing to enter the vessel while the flow through the break is declining as the primary pressure drops to or below the secondary pressure. At this time, the plant condition is similar to State SGTR-4. The main difference is that additional primary coolant has been lost as a result of discharge through the PORV. Hence, the additional SI flow will be required to restore inventory. Furthermore, release to the PRT may have exceeded its capacity resulting in a release of primary coolant to the containment.

Any of the three guidelines directed at coolant inventory - FRGs I.1, I.2, or I.3 - may be indicated at this state. The same comments discussed above for State SGTR-4 also apply here. In addition, due to the opening of the PORVs, the containment guidelines Z.2, Z.3, and Z.5 may be indicated.

Z.2 is a response to high containment pressure, Z.3 is a response to a high radiation level inside containment, and Z.5 is a response to a high sump level. These guidelines will not actually be indicated until the PORVS have been kept open for a long time. The guidelines should be consistent with the depressurization actions required at this state. FRGs P.2 and C.1 are also listed in Table 3.6 for this state. However, while the primary pressure and core exit temperature may be rising shortly in later stages of this state, they will not reach the specific values required for FRG P.2 and C.1.

STATE SGTR-10

At this state, the pressurizer PORV has stuck open during the depressurization process. This will result in a faster depressurization rate and more rapidly climbing containment parameters such as radiation level, pressure, and sump level (if the pressurizer relief tank capacity is exceeded). The guidelines which will be indicated here are the same as those at SGTR-9. The containment guidelines should allow the possibility of blocking one PORV while using the others to continue the depressurization process if necessary.

STATE SGTR-11

This state is analogous to SGTR-9 after the stuck open PORV has been blocked. Refer to the discussion provided for that state.

STATE SGTR-12

State SGTR-12 is analogous to State SGTR-9 except that the RCPs are not operating. Because the pressurizer sprays were therefore unavailable, the operator was forced to use the pressurizer PORVs for depressurization of the RCS.

The FRGs and associated discussions for this state are the same as for state SGTR-9. Also, as discussed previously, the operator may perceive benefits to be gained from starting the RCPs at this state. Unambiguous guidance should be provided within the indicated FRGs (I.1, I.2, or I.3) concerning restart of the RCPs.

States SGTR-3a,7a

At these states the operator has successfully isolated the faulted steam generator (State SGTR-3a) or the intact steam generators (state SGTR-7a). However, he has not depressurized the secondary side. Heat removal would still be taking place through the intact steam generators. The steam may be passed to the condenser or through cycling steam generator PORVs.

The guidelines which may be indicated at these states include FRG I.1, I.2 or I.3. The same comments provided in states SGTR-3 and 7 concerning these guidelines apply here.

STATE SGTR-6a

At this state the operator has been unable to isolate any of the steam generators and contaminated steam continues to flow to the condenser. Inventory from the RCS is continuing to leak through the break.

The FRGs indicated for this state are the same as for state SGTR-5, and the discussion for that state is also applicable here.

STATE SGTR-11a

This state involves a steam generator tube rupture compounded by a stuck open PORV. The block valve has not been closed and coolant is flowing out of the rupture and the open relief valve. HPIS continues to replace lost inventory.

As in previous states, SGTR-2,3,6,7,9,10,11,12, any of the three coolant inventory guidelines may be indicated here. Previous comments concerning these guidelines also apply here. The stuck open relief valve may also result in the indication of FRGs Z.2 and Z.3 which address high containment pressure and radiation, respectively. No incompatibilities are anticipated for these guidelines. Table 3.6 also lists FRG C.1 as being indicated at this state. However, while the core exit temperature may begin to rise, it will not reach the specific levels required to indicate FRG C.1.

STATE SGTR-12a

This state is essentially identical to SGTR-8a. The unavailability of the RCPs has prevented the use of the pressurizer sprays in this state. The discussion of the indicated guidelines for State SGTR-8a also applies here.

4.3 QUESTION # 4: ARE THE GUIDELINES UNAMBIGUOUS?

An examination of Table 3.4, which lists the symptoms exhibited by the plant at key states of risk significant sequences, shows that many diverse accident conditions can exhibit quite a few common symptoms. This leads to the concern that the operator might confuse one accident condition with another, especially if his attention is focused on only a few symptoms. This concern is often translated into a basic question regarding functional guidelines:

> Can such guidelines, which utilize a relatively limited set of symptoms indicative of critical safety functions, provide unambiguous guidance under all important accident conditions (including severe multiple failure sequences)?

In this section, this concern will be systematically addressed for the WOG ERGs by examining all instances where an OAET state exhibits all but one of the symptoms associated with an FRG. These "almost indicated" FRGs are delineated in Table 3.6. For each entry in this table, two specific questions have been asked. The first was whether it is possible that the operator may "see" the missing symptom and attempt to carry out the indicated guideline. That is, are the prevailing conditions similar enough to the required symptoms that the operator might undertake the indicated actions? If the answer to this first question was "yes", then the additional question was asked whether the indicated actions were appropriate at that state.

As expected, for the vast majority of the entries in Table 3.7, this "missing symptom" was found to be so dissimilar from expected conditions that no operator confusion would exist or the indicated actions would not be inconsistent with the required actions at that state. However, there were a few cases where the possibility of ambiguous guidance and operator confusion exists. These specific situations are presented and discussed below for each initiating event.

Two comments concerning the results of this part of the investigation should be noted here. First, FRG Z.1 has only one indicating symptom (containment pressure above design pressure) as does FRG P.1 (RCS pressure above PORV setpoint). Since the operator is not expected to misdiagnose either of these symptoms, these two FRGs are not discussed below. Secondly, the question of ambiguous guidance has already been addressed to a significant degree in Section 4.2 by assigning more than one possible behavior to a single parameter at a particular state. By including these multiple symptoms in Table 3.4, most of the situations where the operator could perceive that an FRG has been indicated have been included in Table 3.5 and therefore included in Section 4.2 where the appropriateness of the indicated action was discussed. Thus, the investigation of "almost indicated" FRGs can be viewed as a check on the investigation presented in the previous section on "completely indicated" FRGs. Should an error have been made in a symptom behavior in Table 3.4 resulting in the omission of a fully indicated FRG from Table 3.5, then this investigation will find that FRG and ask the same questions raised in Section 4.2 concerning the appropriateness of the indicated actions at that state. Thus, a valuable by-product of this section is the second chance to pick up any states which "slipped through" the previous section. In addition, the investigation of "almost indicated" FRGs represents an evaluation of the potential impact of faulty instrument readings on the efficacy of the emergency procedures. In effect, this investigation represents a "single failure analysis" of the guidelines with respect to faulty instrument readings.

Small Break LOCA States

At State S-1, a small LOCA has occurred followed by successful actuation of the HPIS. If the break occurs in the vapor space of the pressurizer or is due to a stuck-open relief valve, a falsely high pressurizer level indication could exist and FRG I.1 (Response to Pressurizer Flooding) might be indicated. The intent of this guideline would be inappropriate at this state and the cautions concerning the need to ensure adequate RCS subcooling and establishment of a secondary heat sink prior to termination of HPIS (which are noted in the objective of this guideline) should be carefully incorporated into the final version. Further, the falsely high pressurizer level might prevent the operator from going to FRG I.2 (Response to Low Inventory) which requires a low pressurizer level.

At states S-4 and S-17, the break has been isolated but long term cooling with the HPRS or LPRS has been unsuccessful. Without a heat sink, the RCS pressure and temperatures will begin to rise and could reach levels sufficient to indicate FRG P.2. This situation is analogous to LOSP states where heat removal through the steam generators is unavailable and "feed and bleed" cooling is required. The P.2 guidelines should allow the operator to clearly differentiate between overpressurizations caused by HPIS and those caused by lack of cooling. In the first case, HPIS termination is indicated; in the second case (such as S-4 or S-17), restart of HPIS may be required.

States S-14, 18, and 22 represent a sequence where a small break has occurred followed by a failure of HPIS. The break was not or could not be isolated and the primary system was not sufficiently depressurized using the steam generator ADVs to allow LPIS performance. At such states, the operator should try to depressurize the primary system using the pressurizer PORVs in order to allow accumulators and LPIS to maintain coolant inventory. It is possible that the initial depressurization following the break could either produce steam bubbles or lead the operator to suspect that inadequate subcooling exists. If this occurs, the operator may be reluctant to depressurize the system further especially if he believes that opening the PORVs will perhaps not be sufficient to lower the pressure to the point where LPIS is able to provide adequate flow. FRGs C.1, C.2, and C.3 should provide unambiguous guidance under these conditions where voids may have occurred but depressurization is still required to allow coolant injection to the core.

Loss of Offsite Power States

At states LOSP-1 and LOSP-10, the initiating event has just occurred followed by the automatic plant responses to this event into scram, RCP trip, and MFW trip. Best estimate analyses of the early stages of these events indicate that the primary pressure and coolant temperature can both rise very quickly to fairly high levels during the pump coastdown before peaking and subsequently declining. These initial pressure and temperature rises could reach levels required for FRG P.2. If the operator responds to this initial rise, which might last 200-400 seconds, he could take unnecessary actions under FRG P.2 and aggravate what would have been a self correcting situation.

At states LOSP-4,7,8,9,13,16,17,18,25, and 28, all feedwater is unavailable and the steam generators are drying out or have dried out. The RCS pressure and coolant temperatures will rise rapidly without an available heat sink. Feed and bleed cooling may be required if a heat removal path through the steam generators cannot be established. In this case, manually opening the PORVs and actuation of HPIS will be required. The RCS pressure and coolant temperature may rise to the point where the symptoms required for FRG P.2 could be observed. As discussed above for states S-4 and S-17, the P.2 guideline should allow for differentiation between overpressurizations caused by HPIS and those caused by a lack of heat removal.

In states such as these (and also in LOSP-26,27,29, and 30), the situation may have deteriorated to the point where the operator suspects that subcooling has been lost. As previously discussed, FRGs C.1, C.2, and C.3 should provide unambiguous guidance under conditions where depressurization is required to provide a viable heat sink or desired to decrease break flow.

Steam Generator Tube Rupture States

The possibility of void formation exists during the depressurization associated with steam generator tube ruptures. This situation exists in virtually all of the SGTR states. These voids could cause the operator to see a falsely high pressurizer level. The operator could also become convinced that he has lost adequate subcooling. These symptoms could lead the operator to FRG I.1 and FRGs C.2 or C.3. FRG I.1 is directed at pressurizer flooding and FRGs C.2 and C.3 are a response to inadequate core cooling. The actions appropriate at most SGTR states include ensuring HPIS operation and depressurizing the primary system. These actions could be perceived to be in conflict with the primary goals of FRGs I.1, C.2, and C.3. In order to ensure unambiguous guidance to the operator under such conditions, this I.1 guideline should caution the operator about falsely high pressurizer levels and the C.2 and C.3 guidelines should recognize and explicitly address the operator's desire to further depressurize the primary system.

Section 5

RESULTS OF EXAMINATION OF WESTINGHOUSE FUNCTION RESTORATION GUIDELINES

In the immediately preceding section, operator action event trees (OAETs) developed for the Zion plant have been used to systematically examine the functional guidance provided in a recent version of the Westinghouse Owners Group's Emergency Response Guidelines. Four basic questions directed at the completeness and clarity of this guidance were addressed for each OAET state. In this section, the results of this examination are collected, summarized, and presented below for each Function Restoration Guideline.

It should be reiterated that the primary purpose of this examination was not to pass judgment on the WOG guidelines, but to systematically identify and discuss those aspects of Westinghouse plant design, operation, or response to accident conditions which should be carefully considered when these guidelines are finalized and reviewed. However, it is appropriate to note that the results summarized below suggest that WOG guidelines, with a few easily implemented modifications, will be able to provide efficient unambiguous guidance under the wide spectrum of multiple failure accident conditions examined here.

FRG P.1 - Response to RCS Overpressurization

The objective of the instructions included in this guideline is to reduce RCS pressure below the code safety valve setpoint. The operator is instructed to perform the actions of this FRG when the RCS pressure exceeds the safety valve setpoint. There were no plant states included in the three OAETs utilized in this study in which the safety valves did not prevent the pressure from reaching such levels. Thus, no specific comments regarding this FRG were generated. However, the comments presented below for FRG P.2 should be referred to due to the similarity of these guidelines.

FRG P.2 - Response to High RCS Pressure

The objective of this guideline is to prevent the RCS from overpressurizing. This guideline may be indicated when a depressurization event (e.g., a small LOCA or SGTR) has been followed by a successful repressurization using the HPIS. FRG P.2 will provide guidance to terminate HPIS under these conditions. Since a rising pressurizer level may also accompany this recovery, FRG P.2 should be compatible with FRG I.1. These guidelines should ensure that the

HPIS termination criteria are clearly delineated and include a confirmation of adequate inventory together with adequate subcooling, establishment of a viable heat sink, and high RCS pressure.

A high RCS pressure can also be caused by a lack of core cooling. The absence of an adequate heat sink in many of the OAET states produced symptoms which could indicate FRG P.2. This guideline must allow the operator to clearly differentiate between overpressurizations due to successful safety injection and those caused by a primary system heat-up. FRG P.2 should provide unambiguous guidance to initiate "feed and bleed" cooling when high RCS pressure is caused by the inability to establish heat removal through the steam generators.

Because this guideline will contain instructions to terminate HPIS as well as instructions to initiate HPIS, the corresponding symptoms should be clearly detailed in order to ensure unambiguous guidance.

<u>FRG C.1 - Response to Inadequate Core Cooling</u>

This guideline is directed at those conditions where inadequate heat removal from the primary system has caused subcooling to be lost and the core exit temperature to be high. This guideline could be indicated when the steam generators have failed to provide an adequate heat sink. In such cases, FRG H.1 may also be indicated and these guidelines must be compatible. It may also be indicated when a small break has been followed by failure of HPIS to inject coolant. In these cases, FRG I.2 may also be indicated and these guidelines must be compatible.

FRG C.1 must provide unambiguous guidance to the operator concerning depressurization of the primary system. Under conditions where subcooling has been lost (or the operator suspects some voiding has occurred), the operator may be reluctant to lower the primary pressure. However, in many deteriorating states, the only cooling option available is to manually lower the primary pressure in order to establish a "feed and bleed" cooling mode, or to inject coolant using low pressure systems. Unambiguous guidance should be provided under this condition concerning:

1) Recovery of subcooling margin
2) Establishment of a heat sink (FRG H.1).
3) Recovery of system inventory (FRG I.2)

FRG C.2 - Response to a Potential Loss of Core Cooling

This guideline is very similar in intent and content to FRG C.1 and the comments noted above for C.1 also apply here.

Because the elevated temperatures (above 1200°F) for FRG C.1 are not required for FRG C.2, this guideline may be indicated following depressurization events such as SGTRs which cause voiding or lead the operator to suspect a loss of subcooling. In these situations, the operator may also see a falsely high pressurizer level due to the voiding. If this occurs, the operator could be directed to FRG I.1 which addresses pressurizer flooding. The priorities of these two guidelines and the contents of both should ensure that the HPIS is maintained under such conditions and not terminated until a reliable indication of true inventory has been obtained (see FRG I.1, below). The operator should also be provided with unambiguous guidance concerning operation of the RCPs under these conditions. The RCPs might be circulating a 2-phase mixture which is just covering the core. Tripping of the pumps under such conditions could result in phase separation and immediate uncovery of the core.

FRG C.3 - Response to Saturated Core Conditions

This guideline should be very similar to FRGs C.1 and C.2; the comments presented above for these guidelines also apply here.

FRG I.1 - Response to Pressurizer Flooding

The objective of this guideline is to reestablish control of the pressurizer level within the normal range. Increased letdown and reduced charging flow would normally be used to control level.

This guideline may be indicated when a break of the primary system (e.g., small LOCA or SGTR) has been followed by successful operation of the safety injection system which replenishes lost inventory and begins to overfill the pressurizer. In this situation, FRG P.2 may also be indicated, and these two guidelines should be compatible under these recovery condition. In addition, FRG I.1 should provide guidance to anticipate the need for switchover to recirculation flow when that requirement inevitably follows from the actions already included in this guideline.

A pressurizer level indication sufficiently high to direct the operator to FRG I.1 may also be produced due to breaks in the pressurizer vapor space or due to voiding in the primary system. In these situations, the guideline must allow the operator to clearly detect false indications of primary inventory and must ensure that safety injection is not terminated until inventory is truly recovered.

A high pressurizer level can also be caused by a system expansion associated with a loss of secondary heat sink (e.g., LOSP-4). Under these conditions FRG H.1 and, perhaps, C.1 will also be indicated. These guidelines must all be mutually compatible when no heat sink is available and "feed and bleed" cooling is required. With respect to FRG I.1, the guideline should include the establishment of a secondary heat sink in its criterion for safety system termination.

It should also be noted that the pressurizer level may initially increase to levels indicative of FRG I.1 immediately after some transient initiators before peaking and subsequently declining (see, for example, State LOSP 1 or 10). This guideline should caution the operator about taking unnecessary actions in response to a self-correcting condition.

FRG I.2 - Response to Low System Inventory

The objective of this guideline is to reestablish normal system inventory. Increased charging or safety injection flow and reduced letdown would normally be used.

The symptoms which are required by FRG I.2 (below normal pressurizer level together with high vessel level) would be expected during LOCA and SGTR sequences in which primary system inventory is being depleted. They could also occur during loss of heat sink sequences when the RCS pressure has increased to the PORV setpoint and mass is being lost out of the cycling valve. The actions under these conditions are straightforward: establish and maintain coolant injection until inventory has recovered with the break isolated or recirculation is necessary. The priority of these actions with respect to other concerns such as lack of subcooling (see FRG C.1 or C.2 above) should be clearly stated. During LOCA or cycling PORV conditions, guidelines directed at high containment radiation and pressure (Z.2 and Z.3) may also be indicated. FRG I.2 should be compatible with these guidelines. Also, no unnecessary draws on SI water supply should be allowed if recirculation is not available.

The operator should be provided with guidance for the timely termination of SI or the switchover to recirculation. If this guidance is provided on this guideline, the operator would not need to enter another guideline (such as FRG I.1 or P.2) to take these inevitable actions. Cautions concerning timely SI termination to minimize pressurized thermal shock concerns after a rapid cooldown event, or to prevent repressurization of the primary system past the secondary pressure after a steam generator tube rupture event should be included wherever SI termination guidance is provided. The operator should also be cautioned that a falsely high pressurizer reading can result from breaks in the vapor space, stuck open relief valves, or void formations in the vessel or loops. The guidance under loss of coolant events must be carefully defined and must not rely on often unreliable level measurements as currently in FRG I.2.

FRG I.3 - Response to Void in Reactor Vessel

The operator is directed to this guideline when in-vessel level measurements indicate less than full. As the title implies, depressurization events which result in voiding conditions can produce the symptoms indicative of FRG I.3. Steam generator tube ruptures and small break LOCAS are examples of events which could produce the voids in the upper head region. These types of events may often also produce the symptoms required for FRG C.1, C.2, and C.3. The actions included in FRG I.3 should therefore be compatible with these three guidelines.

If the cause of the voiding was depressurization associated with a steam generator tube rupture (SGTR), the operator may perceive incentives to lower the primary pressure or to restart an RCP. A lowering of the primary pressure in response to an SGTR would seemingly be incompatible with the immediate goals of this guideline. Restarting of an RCP may provide enhanced mixing and ~~help~~ collapse ~~voids. The I.3 guidelines should recognize that the operator~~ may also suspect that a steam generator tube rupture has occurred and should provide unambiguous guidance concerning the priorities of void collapse, RCP operation, and controlled primary depressurization (with HPIS in operation).

<u>FRG H.1 - Response to Loss of Secondary Heat Sink</u>

This guideline is directed at restoring heat removal capability when the steam generators are not able to remove sufficient heat from the primary system (due, for example, to a loss of all feedwater). In such circumstances, the operator should try to 1)establish AFW flow, or 2) depressurize the steam generator and use a low pressure backup feedwater source such as condensate pumps, or 3) initiate "feed and bleed" cooling.

This guideline could be indicated coincidentally with guidelines in response to inadequate core cooling (FRG C.1). Should such severe conditions exists, the operator may be reluctant to take actions which would depressurize the primary system such as options (2) and (3) above. This FRG should provide unambiguous guidance concerning establishment of a viable heat sink under conditions where the operator suspects that saturated conditions may exist.

Additionally, a long term failure of RHR could produce the symptoms necessary to indicate FRG H.1. This guideline should allow differentiation between conditions immediately after shutdown where the steam generators are expected to be the normal heat removal path and those associated with loss of RHR cooling after a successful cooldown has occurred.

<u>FRG H.2- Response to Low Steam Generator Level</u>

The objective of this guideline is to restore steam generator level to the narrow range when auxiliary feedwater is available. The symptom sets indicative of this FRG require the steam generator level to be such that the U-tubes are completely covered. When rapid steam dump has occurred (for example, operator opens ADVs to depressurize) flashing could cause falsely high readings and the operator may not realize that low level exists.

FRG H.3 - Response to Loss of Normal Steam Dump Capability

The objective of this guideline is to reestablish capability to dump steam to either the condenser or to the atmosphere. No significant comments were generated concerning this guideline.

FRG Z.1 - Response to Containment Overpressure

The objective of this guideline is to reduce containment pressure below design pressure using the containment spray system and fan coolers. There were no plant states included in the three OAETS utilized in this study in which the containment pressure was expected to exceed design pressure. Thus, no specific comments regarding the FRG were generated. However, the comments presented below for FRG Z.2 should be referred to due to the similarity of these guidelines.

FRG Z.2 - Response to High Containment Pressure

The operator will be directed to this guideline when a high containment pressure is observed. This could be caused by releases into containment associated with LOCAs or open PORVS. The operator is provided guidance concerning the use of containment fan coolers and the containment spray. Under some conditions, the water available for SI must be conserved and containment spray should be terminated. This guideline should clearly state priorities of core cooling and containment cooling and indicate when unnecessary draws or the RWST should be isolated.

FRG Z.3 - Response to High Containment Radiation levels

The objective of this guideline is to minimize the release of radioactive material from the containment. The symptoms indicative of this guideline could be produced by primary coolant releases into containment due to LOCAs or open PORVs. Accordingly, this guideline may be indicated coincidentally with guidelines designed to respond to these releases such as C.1, I.1, I.2, I.3, or H.1. Containment isolation actions included in FRG Z.3 should not be incompatible with the performance of tasks called for in these guidelines.

FRG Z.4 - Response to High Hydrogen Concentration in Containment

The objective of this guideline is to prevent possible hydrogen ignition. No comments regarding this guideline were generated.

FRG Z.5 - Response to Containment Flooding

This guideline will be indicated when the containment sump level exceeds flood level. This could occur due to an accumulation of primary coolant release and containment spray. No significant comments regarding this guideline were generated.

Section 6

DEVELOPMENT OF EMERGENCY PROCEDURE GUIDELINES

In Volume 1 of this report, a methodology was presented by which self-validating functional emergency procedure guidelines could be developed. This methodology, which systematically applies the information documented in operator action event trees (OAETs), is summarized in Section 2 of this volume.

In this section, the results of a "small scale" application of that methodology using the Zion OAETS is presented. The goal of this application was not to produce detailed procedures - that would require human factors and other relevant inputs well beyond the scope or purpose of this project - but to test whether the procedure development methodology could adequately accommodate the particular accident response characteristics of a Westinghouse PWR. The application was, therefore, to produce, using the methods of Section 2, a fairly simple diagnostic/action algorithm from the Zion OAETs which could form the technical foundation upon which detailed unambiguous emergency procedures could be constructed.

As described in Section 2, the emergency procedure (or diagnostic algorithm) development methodology can be viewed as a systematic iterative process of plant state categorization, comparison of symptoms and actions associated with the states in each category, and recategorization. This process is continued until an unambiguous guideline (or decision algorithm) is produced which associates unique symptom sets with required action sets. Described in the subsections below are the key features of the small scale demonstration of this process. Conclusions derived from this application concerning the relative capabilities and benefits of the guideline development methodology are presented in Section 7.

6.1 INITIAL CATEGORIZATION

The first step was to select a set of critical safety functions and to initially categorize all OAET states according to the function most seriously threatened at that state.

In order to demonstrate that this initial categorization can be fairly general in nature and still result in effective guidelines, only two critical safety functions were defined for this initial categorization:

1) Maintenance of Coolant Inventory
2) Removal of Decay Heat

All OAET states were put into one of these two categories and described in terms of the behavior of parameters selected to be indicative of the performance of these two critical functions. Pressurizer level was selected to be the parameter most directly indicative of coolant inventory and the behavior of the hot leg temperature was selected to be indicative of the decay heat removal capability. In addition, the basic operator actions required at each OAET were summarized.

Thus, this initial step provided two separate lists of OAET states - one comprised of states where coolant inventory is being lost and the other where insufficient heat removal is available. Each state in each list was also described in terms of two parameters - pressurizer level and hot leg temperature - and the required operator actions. This initial categorization is presented in Tables 6.1 and 6.2.

Table 6.1

STATES INVOLVING INSUFFICIENT HEAT REMOVAL

OAET States(s)	General Behavior of Hot Leg Temperature
S-4,17	Rising from low levels (350°)
S-8,12	Rising from low levels
S-21,25	Rising from low levels
LOSP-1,10	Initial drop followed by rapid rise above normal level and then slow decline
LOSP-4,7,8 9,13,16,17, 18,25,28	Slow decline until steam generator dryout, followed by rapid rise
LOSP-26,29	Slow decline until steam generator dryout, followed by rapid rise
LOSP-27,30	Rapid rise followed by slow decline as ECC restores subcooling
LOSP-31	Rapid drop below normal level followed by slow rise as faulted steam generator dries out

Table 6.2

STATES INVOLVING LOSS OF COOLANT INVENTORY

OAET States(s)	General Behavior Pressurizer Level
S-1	Steady decline below normal levels; vapor space break could indicate rising level
S-5	Steady rise back to normal range
S-6,10	Stabilized in normal range
S-9	Slow decline below normal level
S-13	Continued decline to empty
S-14,18,22	Steady decline below normal range
S-19	Steady rise back to normal range
S-23	Steady rise back to normal range after transient effects of opening PORVS
S-26	Continued decline to empty
LOSP-20,23	Steady decline; void formations could indicate false levels
LOSP-21,24	Steady decline followed by recovery as ECCs initiates; stuck open PORV may produce false high readings

OAET States	General Behavior Pressurizer Level
SGTR-1	Steady decline
SGTR-2,6	Continued decline followed by recovery to normal levels; void formation could produce false high readings
SGTR-3,7	Steady rise to normal after HPIS flow exceeds break flow
SGTR-4	Steady rise to normal level
SGTR-5,6a	Decline followed by recovery to normal levels; void formation could produce false readings
SGTR-8,8a	Steady rise to normal range after HPIS flow exceeds break flow
SGTR-9,10, 11,12	Steam release through PORV plus SGTR plus HPIS produces transient level readings ultimately stabilizing in normal range
SGTR-3a,7a	Recovery to normal level followed by decline
SGTR-11a	Dependent upon break size; void formation likely to produce unreliable readings

6.2 SYMPTOMS/ACTIONS COMPARISON

The systematic symptoms/action comparison described in Section 2 was then performed using the initial categorization. This comparison was performed to identify states in the same category with incompatible actions, or states in the same category which exhibit diverse symptoms. When incompatible action sets were identified, different categories were established. "Accident signatures" were identified for each resulting category by selecting additional symptoms which the operator can use to uniquely and unambiguously diagnose the existence of any category.

Key features of this action/symptoms comparison and recategorization process included the following:

- Table 6.2 demonstrates that pressurizer level can be an unreliable indication of true coolant inventory when a vapor space break (or open PORV) occurs or when the depressurization process associated with the loss of inventory produces voids in the primary system. For example, in State SGTR-2 the pressurizer level could possibly be increasing, remaining stable, or decreasing. RCS pressure is a more consistently reliable initial indicator of events leading to a loss of inventory and was used as the primary symptom in accident signatures of such states.

- For loss of feedwater events, the coolant temperature can be slowly declining until the steam generators dry out. Direct indicators of heat removal through the steam generators such as secondary pressure, steam generator secondary level, or AFW flow were used to diagnose loss of heat removal states before core temperature increases significantly.

- Loss of heat removal states which have progressed to where loss of subcooling is suspected or has occurred were differentiated from less severe states. Core exit thermocouples should be used as a more direct indication of core temperature.

- Loss of heat removal sequences can lead to loss of inventory sequences if the RCS pressurizes to the PORV setpoint; however, in these cases a high RCS pressure rather than a drop in RCS pressure will be associated with a loss of coolant state (unless the PORV sticks open or is manually kept open in a "feed and bleed" cooling mode).

- A high RCS pressure can also be indicative of a successful recovery from loss of inventory using HPIS. However, it should not be used alone to terminate HPIS.

- The signature for true recovery states where HPIS termination is required is comprised of 1) Recovering RCS pressure 2) Pressurizer level within normal range 3) Adequate subcooling 4) established heat sink through steam generators or RHR.

- Overcooling transients can also produce lower pressure and were differentiated from loss of inventory states by containment conditions and secondary pressure.

- Loss of subcooling conditions can be indicated at states where the operator may desire to depressurize the primary system to establish a heat sink or inject coolant. These states were differentiated from those where depressurization is not beneficial.

6.3 FINAL CATEGORIZATION AND ALGORITHM DEVELOPMENT

The above symptom/action comparison process was continued until categories with compatible "action sets" were identified and unique "symptom sets" could be associated with these categories. These final categories and their associated signatures were then translated into a basic operator diagnostic algorithm which can form the foundation for emergency procedure development. This diagnostic algorithm is presented in Figures 6.1 and 6.2. The ten distinct action sets indicated by this diagnostic algorithm are summarized in Table 6.3. The key features of this algorithm can be summarized as follows:

- Two basic types of accidents are addressed: "failure to remove heat" and "failure to maintain coolant inventory"

- Separate instructions are provided when loss of subcooling has occurred.

- Response to loss of subcooling takes into account whether RCS pressure has remained high or increased as the coolant temperature has risen above T_{sat} or whether the loss of subcooling was primarily due to a depressurization event

- The operator is directed to guidelines associated with restoring containment conditions from the action sets associated with core heat removal and coolant inventory rather than independently.

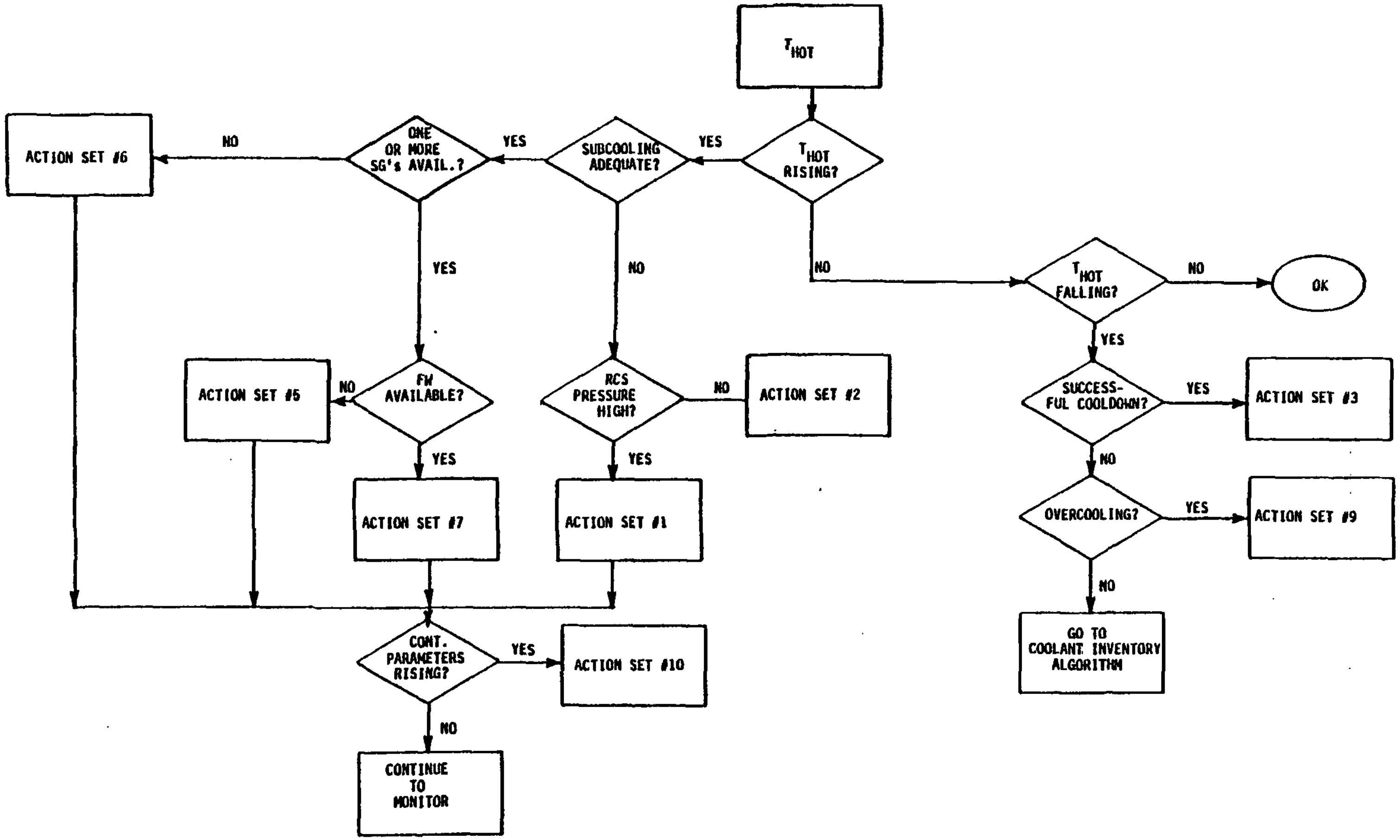

Figure 6.1. Heat Removal Diagnostic Algorithm

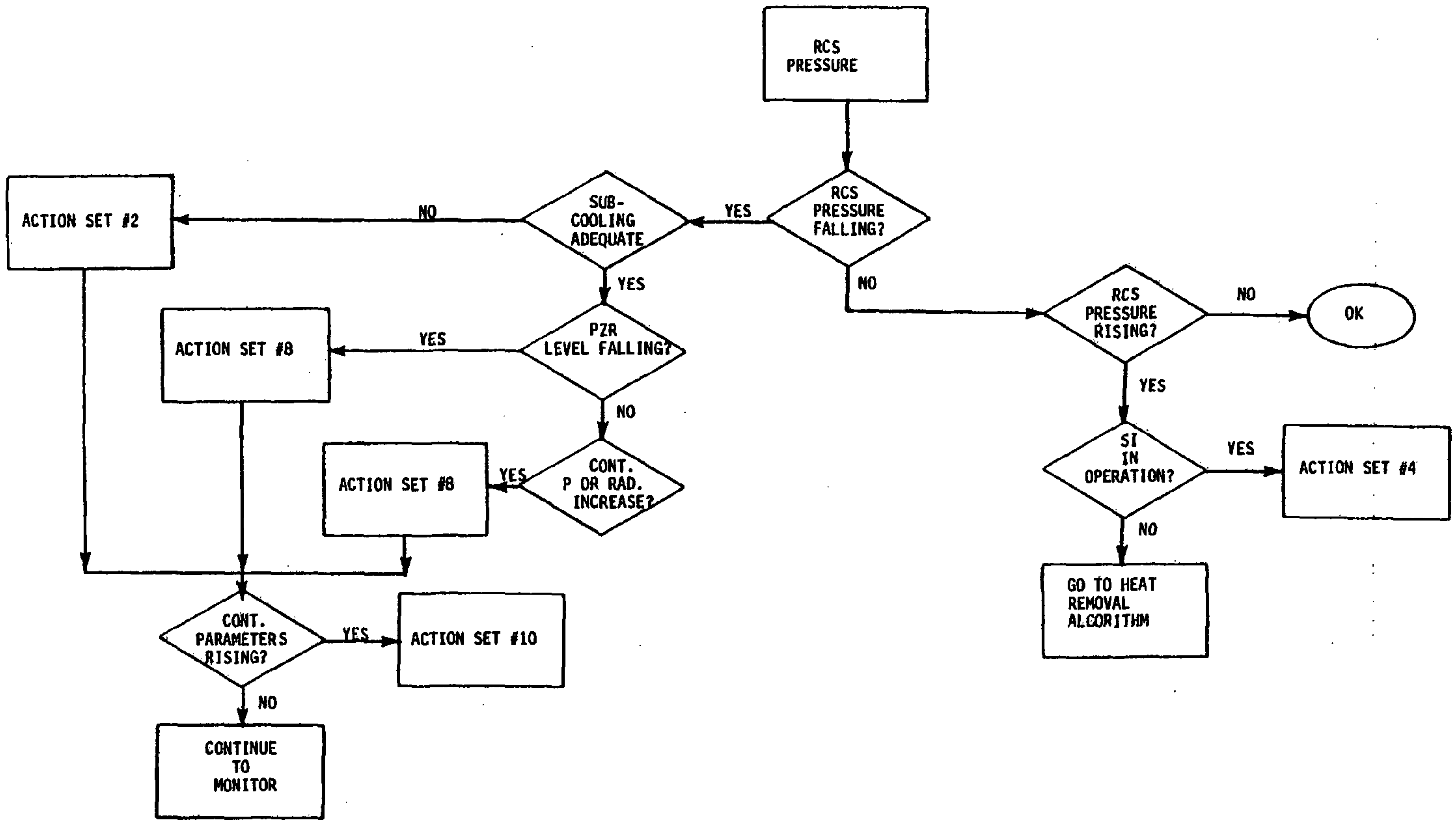

Figure 6.2. Coolant Inventory Algorithm

Table 6.3

ACTION SETS AND ASSOCIATED SIGNATURES

Action Set	General Description of Required Operator Action	Signature
#1	These actions should restore adequate subcooling under the conditions of an elevated T_{HOT} and RCS pressures. These actions are directed at providing a heat sink to reduce primary coolant temperature to below saturation conditions at PORV set point. These actions are identical to those described in Action Set #5 except for consideration of voiding which may have been produced in the primary system. Under these conditions, restarting of an RCP should be considered to enhance mixing, and depressurizations of the secondary and primary to enhance core cooling must be performed with extreme care in order to avoid additional voiding.	o Coolant Temperature Rising o Subcooling Margin Inadequate o RCS Pressure Rising (above normal values)
#2	These actions should restore adequate subcooling under the conditions of a reduced RCS pressure. These actions are directed at elevating RCS pressure while maintaining available heat sinks. Primary modes are use of the PRZ heaters, increased charging, and SI if necessary.	o Coolant Temperature Rising o Subcooling Margin Inadequate o RCS Pressure Dropping (below normal values)
#3	These actions will continue the cooldown process and throttle feedwater if necessary. Switchdown to RHR cooling will be made at a predetermined temperature and pressure.	o Coolant Temperature Falling o Heat Sink Available o Pressure Dropping
#4	These actions will terminate SI flow after successful recovery. In addition to the rising RCS pressure, termination criteria should include a recovered PZR level, an adequate subcooling margin, and the availability of a viable heat sink.	o RCS Pressure Rising o SI in operation o Recovered RZR Level o Adequate Subcooling o Heat Sink Available

Table 6.3 (Continued)

Action Set	General Description of Required Operator Action	Signature
#5	The intent of these actions is to establish a heat sink when insufficient heat is being removed through the steam generators due to lack of feedwater. If AFW flow cannot be established the steam generators should be depressurized and the condensate pumps used to supply feedwater. If successful, the cooldown process should be continued using Action Set #3. If not successful, recovery attempts should continue with Action Set #6.	o Coolant Temperature Rising o Subcooling Adequate o One or More Steam Generators Available o FW Not Available (or low SG level)
#6	These actions are designed to establish feed and bleed cooling when heat removal through the steam generators is not possible. This will involve manually opening PZR PORVs and controlling SI flow. Subcooling margin should be continuously monitored and the pressure throughout the cooldown process.	o Coolant Temperature Rising o Subcooling Adequate o Steam Generators Not Available as Heat Sink
#7	These actions are designed to enhance cooling through the steam generators when feedewater is available by dumping steam from the secondary using steam generator PORVs if necessary or increasing feedwater flow. Secondary pressure and level should be monitored to determine optimum cooldown strategy.	o Coolant Temperature Rising o Subcooling Margin Adequate o One or More Steam Generators Available o FW Available
#8	These actions are designed to respond to a diminishing primary coolant inventory by actuating or increasing charging or SI flow. If high pressure injection is not available, the operator must depressurize the primary system and use low pressure injection. Sub-cooling margin should be continuously monitored during this depressurization process. The operator should also look for signs of a steam generator tube rupture (steam level radiation, increasing secondary level in one SG) and if appropriate, carry out actions in response to SGTR. These would include HPIS actuation, isolation of affected SG, lowering pressure in primary system, cooldown, etc.	o RCS Pressure Falling o Subcooling Adequate o PZR Falling Below Normal or o Containment Pressure or Radiation Increasing

Table 6.3 (Continued)

Action Set	General Description of Required Operator Action	Signature
#9	These actions are designed to respond to overcooling transients by throttling FW flow or by isolating secondary break.	o Coolant Temperature Falling o RCS Pressure Falling o Low SG Pressure o High SG Level
#10	These actions, taken as a group, are designed to keep containment pressure, radiation level, sump level, and hydrogen concentration within acceptable limits. Containment spray and fan coolers can be used to reduce pressure. The containment should be isolated if high radiation is detected. ECCS recirculation should be established before containment becomes flooded. The operator should also terminate unnecessary containment spray and isolate any leaks into containment on high sump level. Hydrogen concentration can be reduced by use of recombiners and igniters.	o Containment Pressure Rising o Containment & Radiation Level Rising o Containment & Sump Level High o Containment Hydrogen Concentration high

Section 7

CONCLUSIONS AND RECOMMENDATIONS

As discussed and demonstrated in References 1 and 2, Operator Action Event Trees provide a systematic tabulation of the key operator actions and plant symptoms associated with the various stages of risk significant multiple failure accident sequences. Volume 1 of this report presented methodologies by which the information documented in these OAETs can be used to systematically review and evaluate functional emergency procedure guidelines and ensure that they provide unambiguous guidance under all important accident conditions. The OAET-based methods can be applied in three basic ways:

1) Preliminary or incomplete guidelines can be fine-tuned and finalized using input gained from a systematic OAET-based investigation of the incomplete guidelines.

2) Complete guidelines can be systematically reviewed and any inadequacies corrected.

3) Guidelines can be produced directly from the OAETs.

The primary goal of the work reported in this volume was twofold:

1) To ascertain whether the OAET methodology could, in actuality, be used to finalize or review guidelines of the format and content of the Westinghouse Owners Group's Emergency Response Guidelines, and

2) To identify and discuss any aspects of Westinghouse plant design, operation, or response to multiple failure accident sequences which could result in incomplete, ambiguous, or incorrect guidance to the operator if not carefully addressed in the guideline development process.

In addition, a small scale demonstration of the ability of an OAET-based methodology to directly produce unambiguous functional guidelines was presented. Operator Action Event Trees developed for the Zion Westinghouse PWR were used to achieve the goals.

The results of the investigation reported in Sections 3 and 4 demonstrate that the OAET methodology can, in fact, be effectively used to review and finalize incomplete guidelines produced by independent means such as those produced by WOG. Further, if complete guidelines are available, the same methodology can provide an effective technical review of these guidelines.

In addition, although it was not the purpose of this analysis to pass judgement on the WOG guidelines, the results of the application of the review methodology suggest that the WOG guidelines, with a few easily implemented modifications, will be able to provide efficient guidance under the wide spectrum of multiple failure accident conditions examined here.

The methodology also proved effective in identifying the key implications of Westinghouse plant design and physical accident response to the development of guidelines of the form used by WOG. These implications are summarized in Section 5 and should be addressed in the final development process of the WOG guidelines. It should be noted here that Westinghouse is aware of many of the concerns raised in Section 5 and these and other concerns are intended to be explicitly addressed in subsequent versions of the guidelines. Emphasis should be placed on incorporation of the concerns cited in Section 5. Human factors expertise should be applied to subsequent versions of the guidelines to ensure that these particular potential areas of ambiguity are effectively addressed.

The methodology can also be used to directly develop guidelines from the OAETs. However, there are obviously many diverse aspects of emergency guideline development which are not addressed by this process. For example, the optimum decision algorithm defined by the accident signatures is not necessarily an effective guideline from a human factors standpoint for operators who have been trained for many years on alternate formats. For this reason, if reasonable guidelines have been developed by independent means (as they certainly have for Westinghouse plants), the OAET-based methodologies are far better utilized as a tool to finalize or review than as a means to develop an alternate set of guidelines. If an individual plant decides not to use the generic Westinghouse guidelines, the OAET based methods could be used to develop alternate guidelines, or (perhaps more effectively) to adapt the generic guidelines to the individual plant.

In addition to this major conclusion concerning the validity of the OAET based methodology, a few more specific conclusions regarding the methodology can be made:

- The use of "generalized" symptoms is an effective way of facilitating the symptoms comparison tasks. The few cases where use of these generalized symptoms led to inaccuracies were easily identified and corrected.

- If the behavior of a parameter at any particular state is in transition, fluctuating, or uncertain for any reason, multiple behaviors should be assigned to that state rather than choosing a "best guess" behavior. The few cases where uncertain parameters lead to concerns over ambiguous or incorrect guidance can be investigated in more detail. In this way, resources are expended only when necessary and are focused on specific concerns.

- The investigation of "almost indicated" states is an essential part of the methodology because it provides a systematic investigation of similar looking states, as well as a second chance to identify overlooked fully indicated states.

These results and conclusions demonstrate that the OAET-based methodologies developed in Volume 1 can provide a very effective tool to the regulatory process associated with the development, review, and ultimate implementation of functional emergency procedure guidelines applicable to Westinghouse PWRs. The methodology can be used in the following ways:

1) It could be used as a systematic demonstration that a set of guidelines provides unambiguous guidance under all important accident conditions; alternatively, it can be used by NRC to independently review submitted guidelines.

2) It can be cited by a specific utility as an integral part of their program to customize the Owners Group's generic guidelines to their specific plant.

3) It can be used as the technical foundation for guideline and procedure development by utilities which do not plan to use the Owners Group's generic guidelines.

The OAET-based methodology demonstrated in this volume for Westinghouse plants could be especially valuable as a integral part of the regulatory process because:

- From the regulatory side, it provides an easily audited process which also provides very high assurance that the guidelines submitted by the Westinghouse Owners Group and implementation plans submitted by the individual utilities operating Westinghouse PWRs will result in unambiguous operator guidance under all important accident conditions.

- From the industry side, it provides a well defined process by which regulatory concerns over the technical content of guidelines and procedures applicable to Westinghouse plants can be systematically satisfied.

REFERENCES

1. J. vonHerrmann, R. Brown, A. Tome, "Light Water Reactor Status Monitoring During Accident Conditions." NUREG/CR-1440, EGG-EA 5153, June 1980.

2. R. G. Brown, J. F. Quilliam, J. L. vonHerrmann, "Operator Action Event Trees for the Zion 1 Pressurized Water Reactor." NUREG/CR-2888, September 1982.

3. "Summary of Westinghouse Owners Group Program to Address NUREG-0737, Item I.C.1." Letter from Robert W. Jurgenson (WOG) to Stephen H. Hanauer (NRC) November 30, 1981.

Appendix I

The three Zion operator action event trees which are used in the investigation reported in this volume are presented in this Appendix. These operator action event trees are presented and discussed in much more detail in "Operator Action Event Trees for the Zion 1 Pressurized Water Reactor", NUREG/CR-2888. In that report each state in each operator action event tree is discussed and the following information is documented:

1) The sequence of events which have produced that state

2) The required operator actions at that state

3) The key symptoms exhibited by the plant at that state

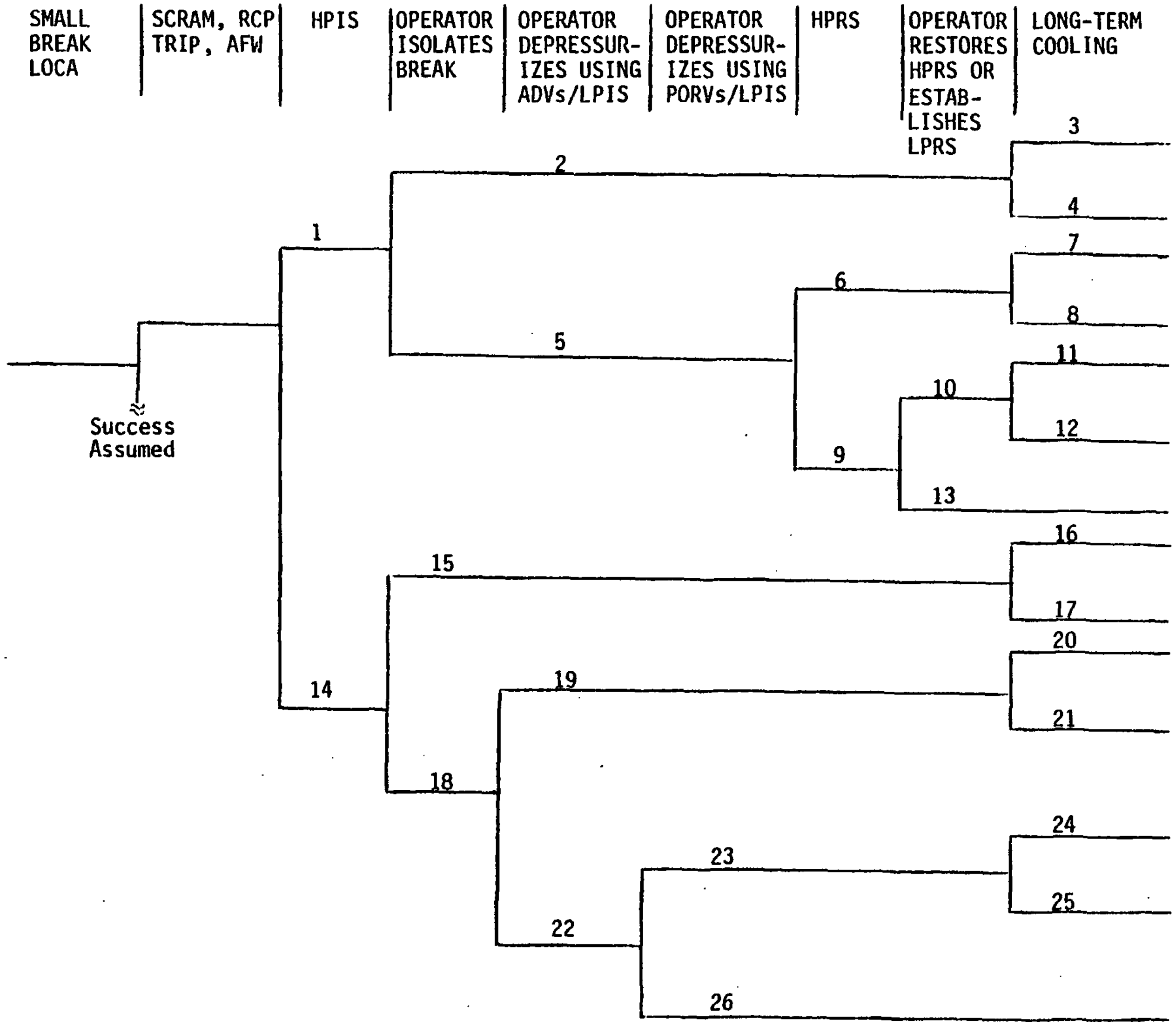

Figure A.I.1. Operator Action Event Tree for Small Break LOCA Sequences

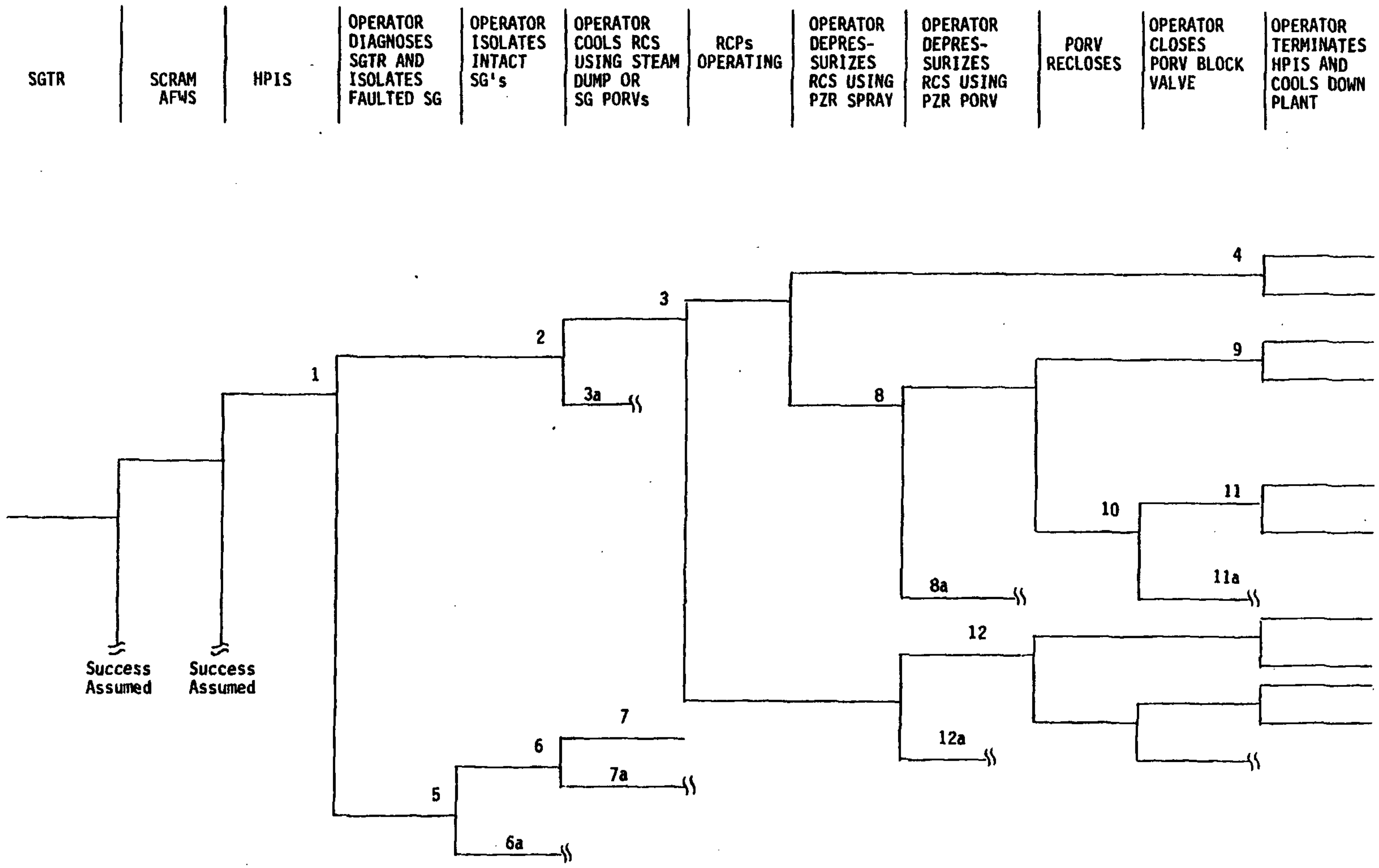

Figure A.I.2. Operator Action Event Tree for Steam Generator Tube Rupture Sequences

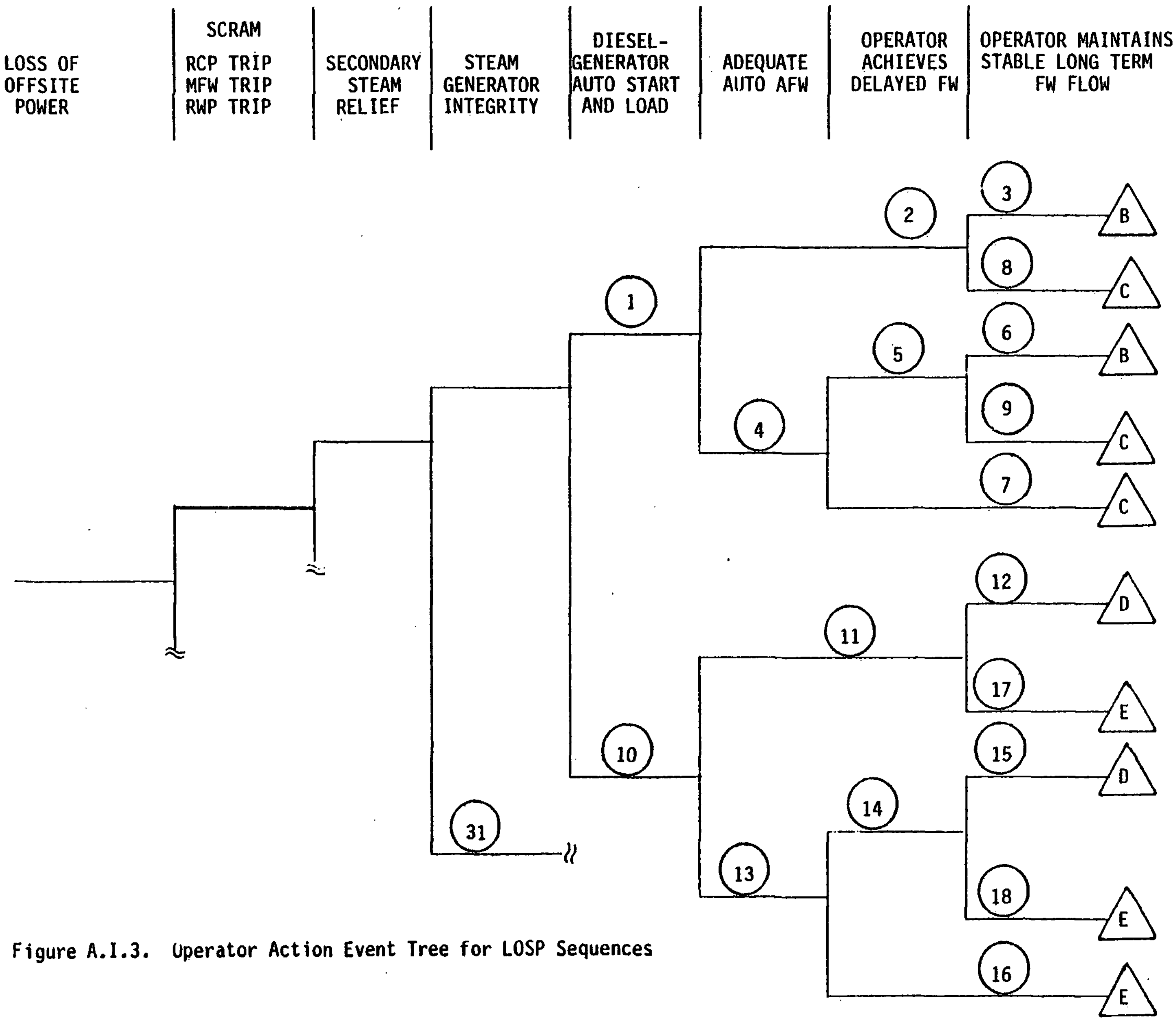

Figure A.I.3. Operator Action Event Tree for LOSP Sequences

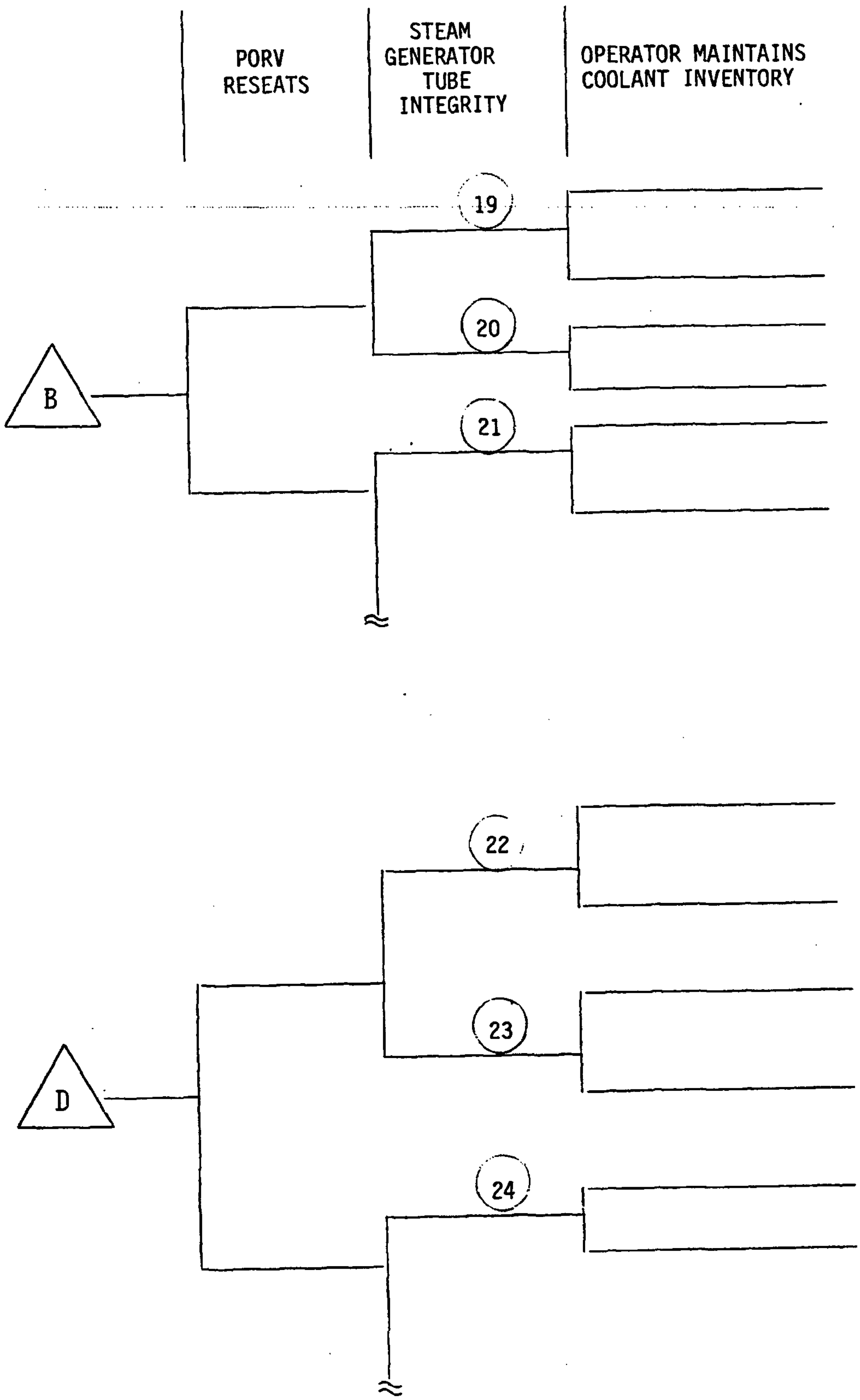

Figure A.I.3. (Continued)

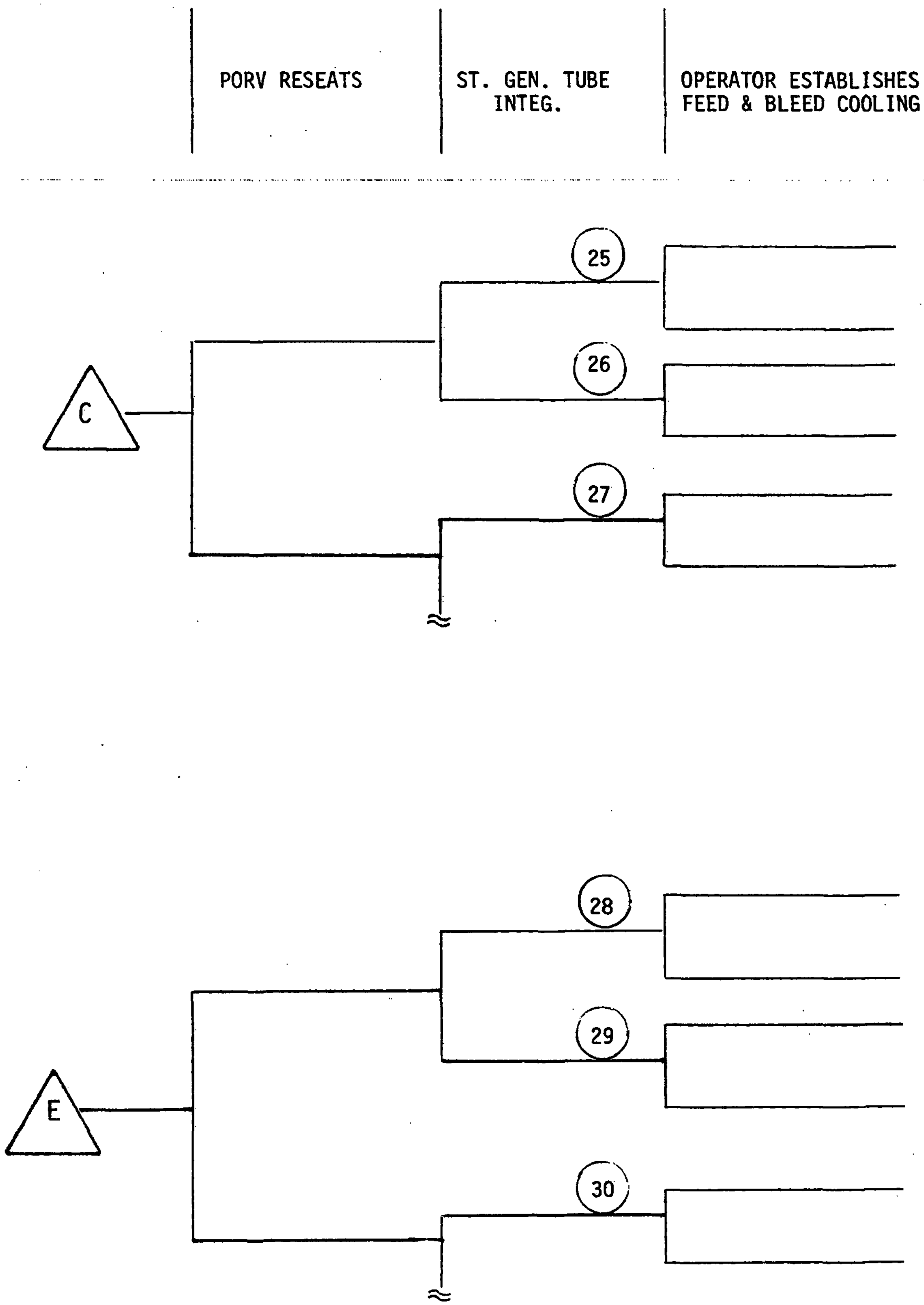

Figure A.I.3. (Continued)

Appendix II

The functional guidance provided in the Westinghouse Owners Group's Emergency Response Guidelines is embodied in Critical Safety Function (CSF) Status Trees and the associated Function Restoration Guidelines (FRGs). The CSF trees, which were used in the investigation reported in this volume, are presented in this Appendix. Also, a brief description of each of the FRGs is also provided.

There were six CSF status trees, each associated with a distinct critical safety function:

1) Subcriticality
2) Reactor Coolant System Integrity
3) Core Cooling
4) Reactor Coolant Inventory
5) Heat Sink
6) Containment

These six trees are presented in Figures A.II-1 through A.II-6.

The six Critical Safety Function Status Trees direct the operator to one or more of eighteen Function Restoration Guidelines. The basic objective of each of these guidelines is summarized in Table A.II-1.

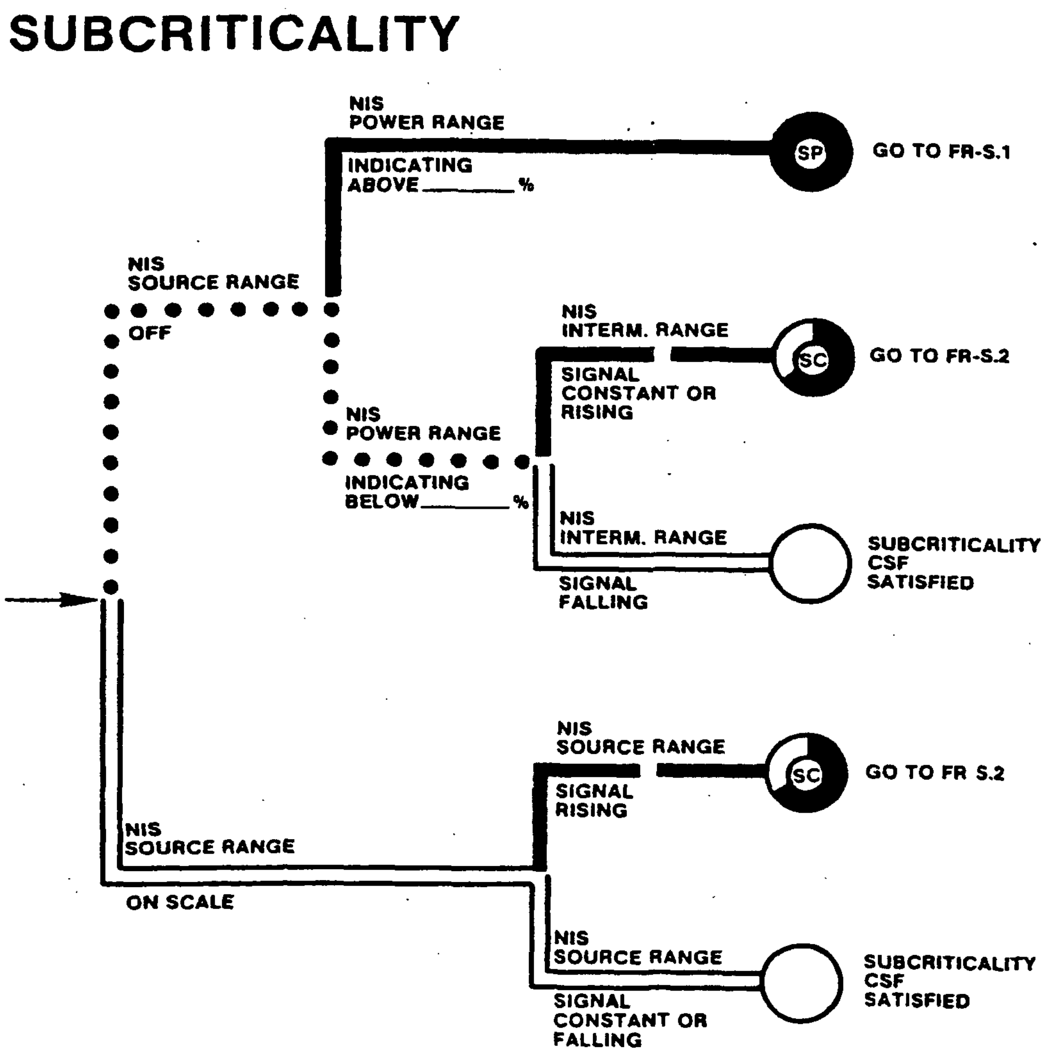

Figure A.II.1. WOG Critical Safety Function Status Tree

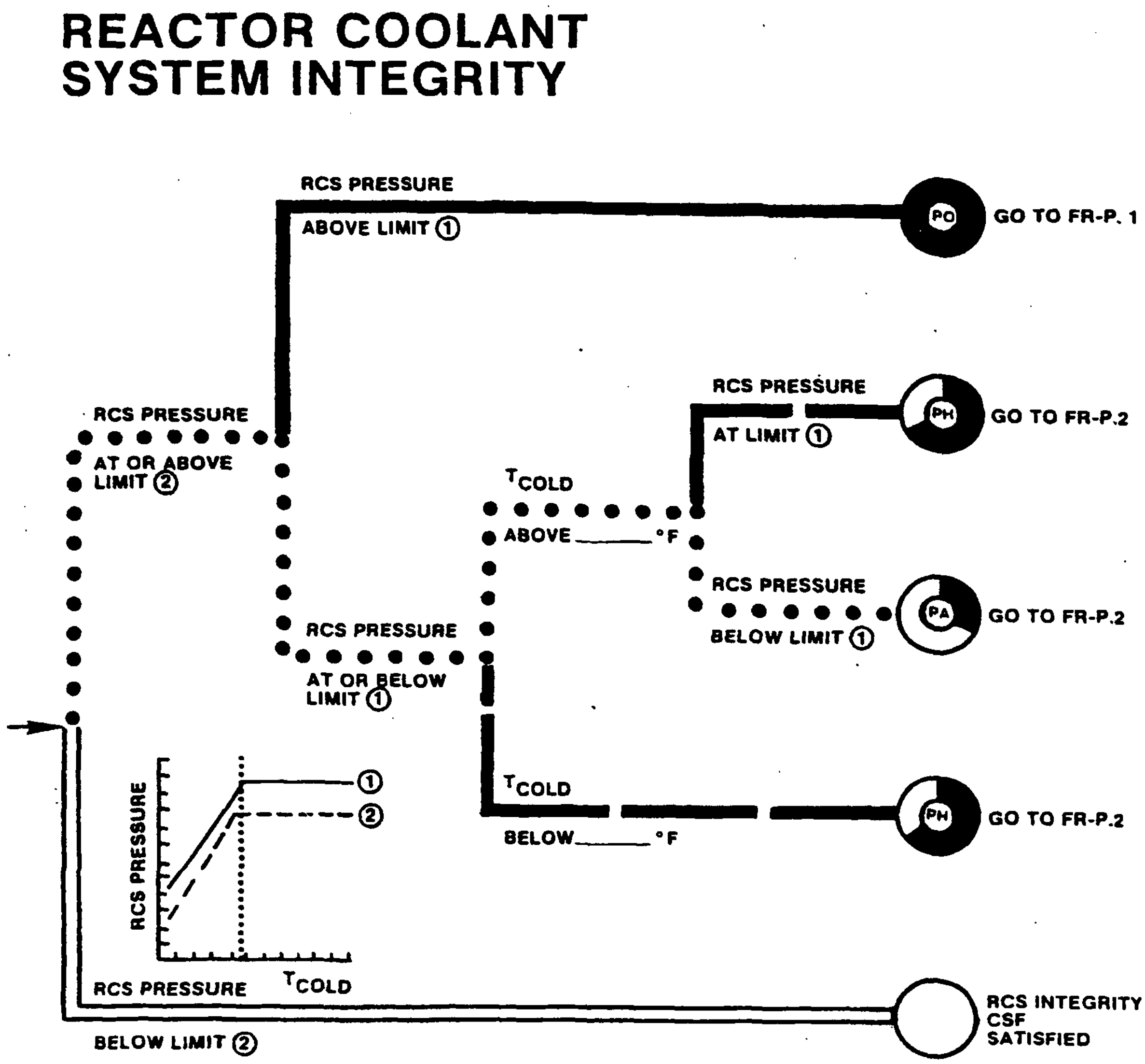

Figure A.II.2. WOG Critical Safety Function Status Tree

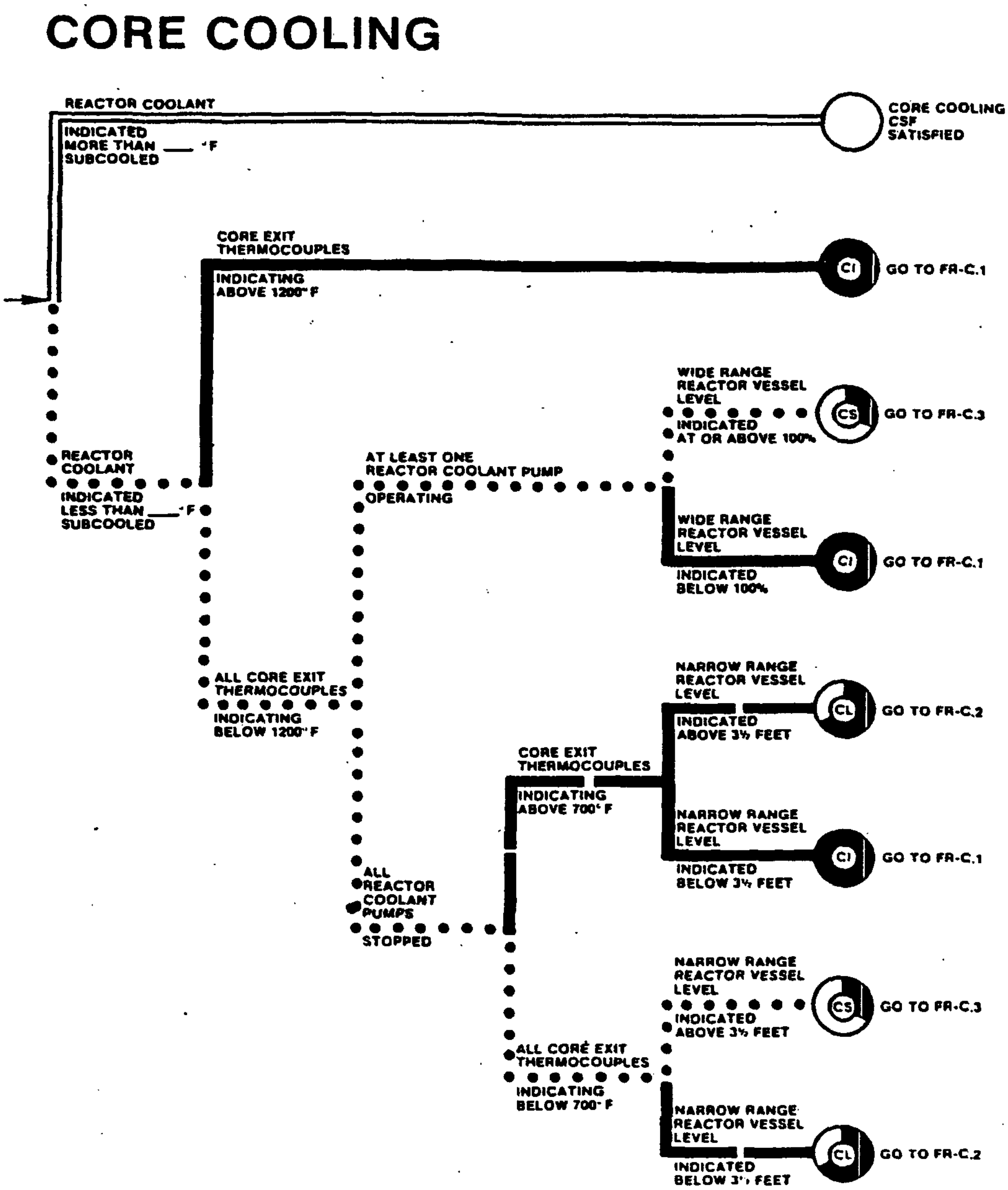

Figure A.II.3. WOG Critical Safety Function Status Tree

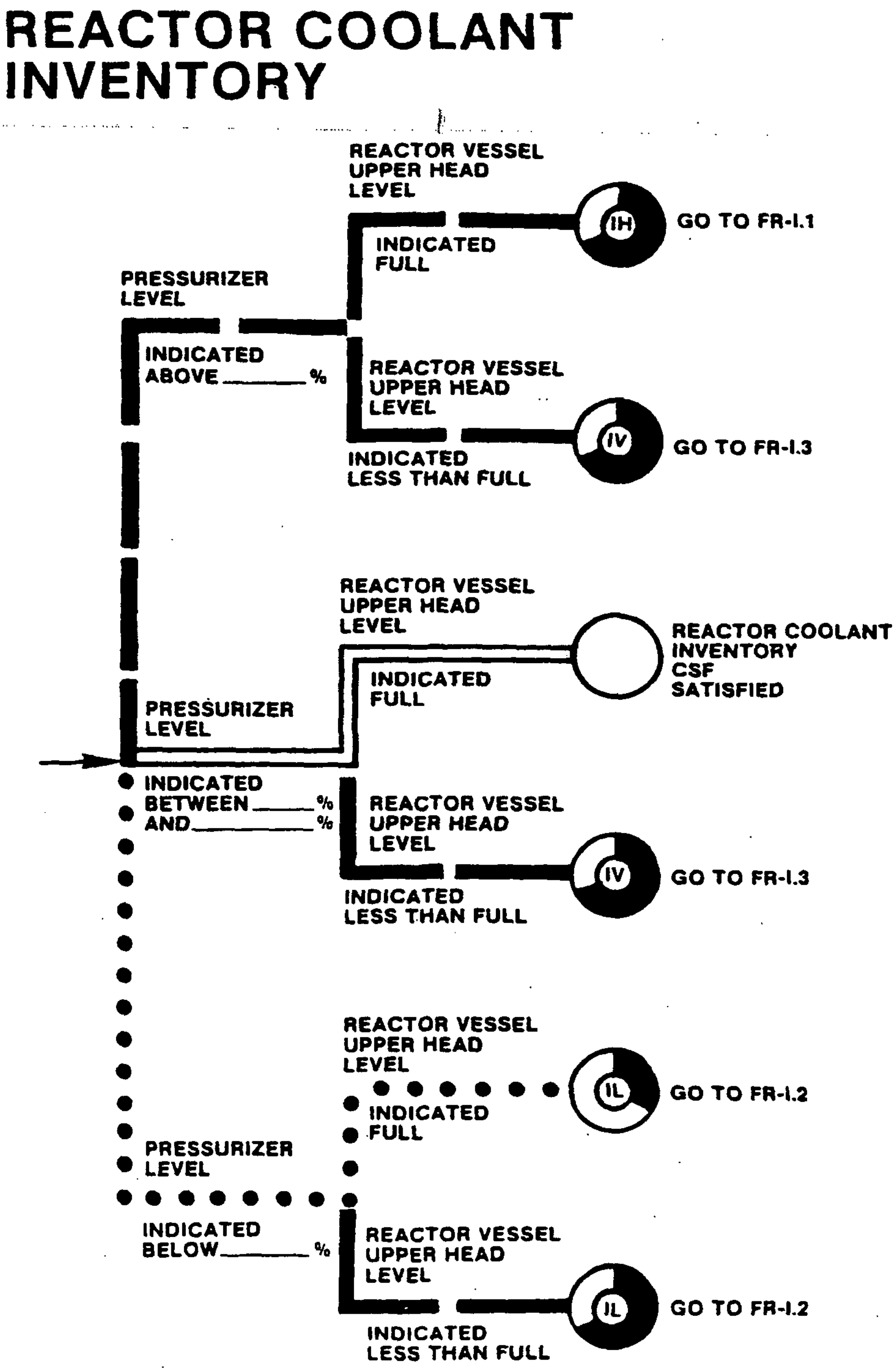

Figure A.II.4. WOG Critical Safety Function Status Tree

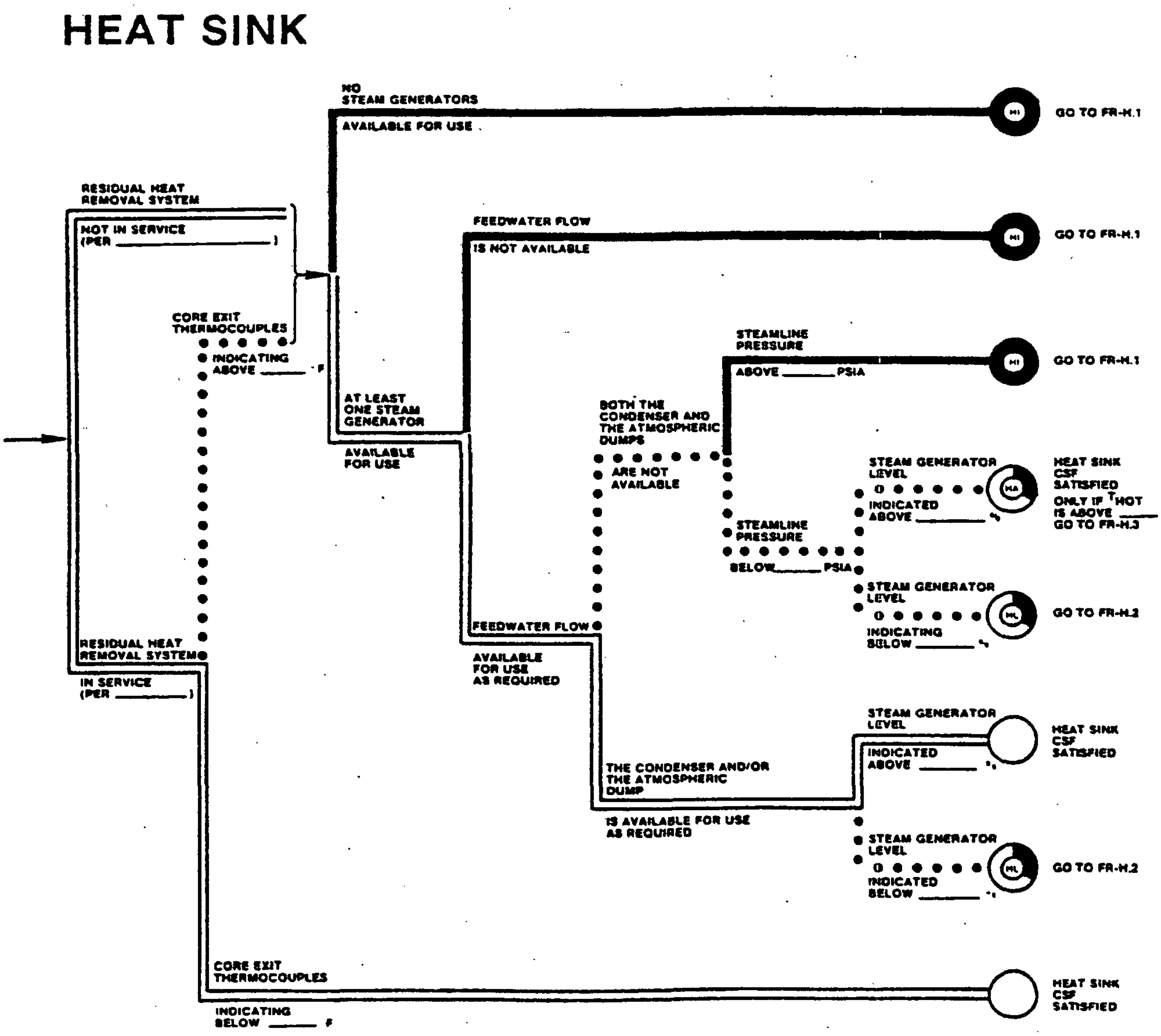

Figure A.II.5. WOG Critical Safety Function Status Tree

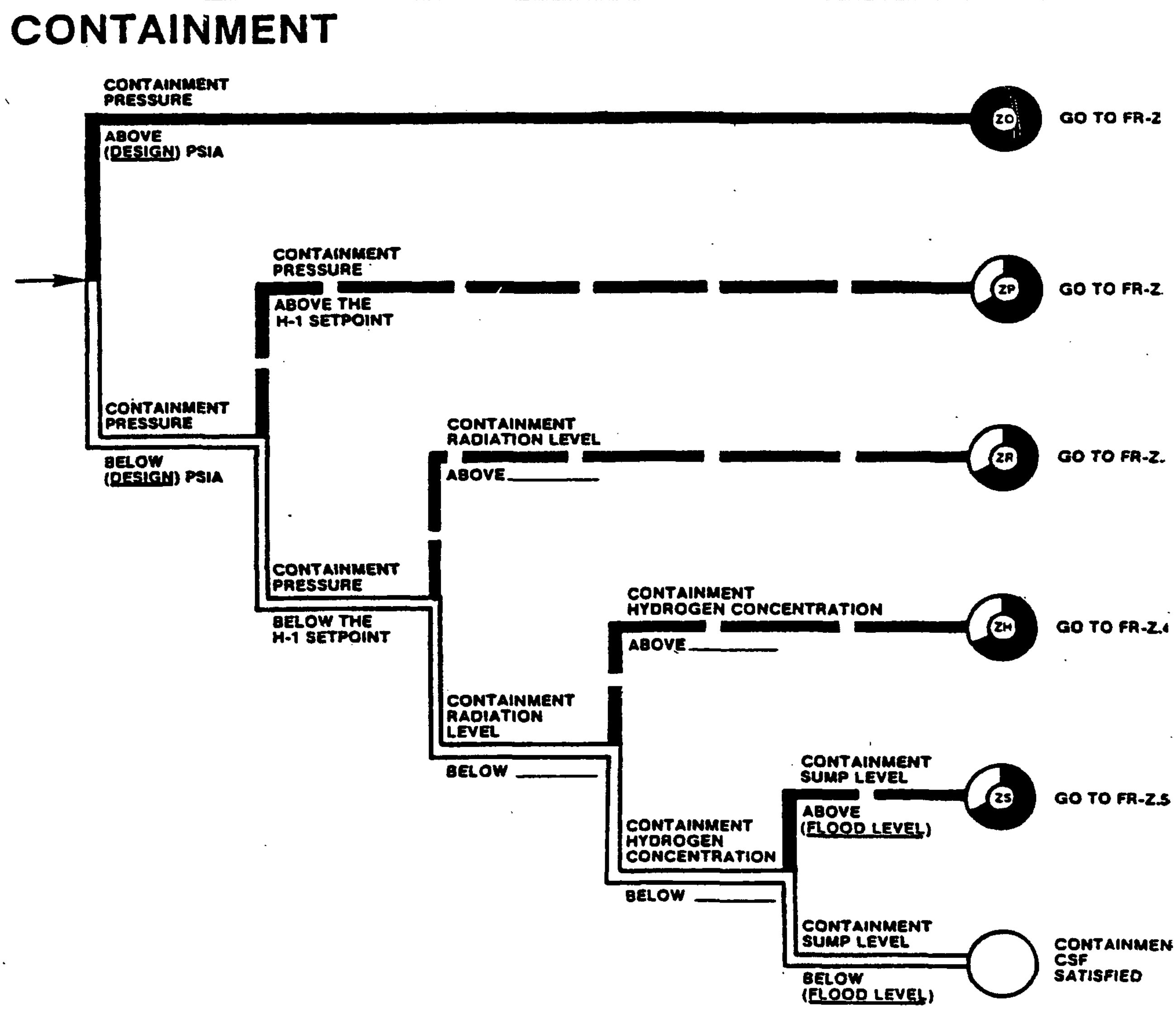

Figure A.II.6. WOG Critical Safety Function Status Tree

Table A.II-1

SUMMARY OF WOG FUNCTION RESTORATION GUIDELINES

FRG	Title	Basic Objective
S.1	Response to Nuclear Power Generation	The objective of this guideline is to return the reactor to subcriticality by tripping rods, boration, or any other means.
S.2	Response to Loss of Core Shutdown	The objective of this guideline is to return the reactor to subcriticality by tripping rods, boration, or any other means.
P.1	Response to RCS Overpressurization	The objective of this guideline is to reduce RCS pressure below the code safety valve setpoint by reducing RCS pressure. If safety injection is the cause of the overpressurization, adequate inventory, heat sink and subcooling must be assured taking into account potential instrument errors due to any adverse containment environmental conditions prior to terminating safety injection.
P.2	Response to High RCS Pressure	The objective of this guideline is to prevent RCS from overpressurizing and reestablishing RCS pressure control. If safety injection is the cause of the high pressure condition, adequate inventory, heat sink, and subcooling must be assured taking into account potential instrument errors due to any adverse containment environmental conditions prior to terminating safety injection.
C.1	Response to Inadequate Core Cooling	The purpose of this guideline is to restore adequate core cooling and to minimize possible core damage. First, an attempt is made to provide high head safety injection. If this is successful, the operator is instructed to return to the emergency operating guidelines. If some source of high pressure water cannot be made available, the operator is instructed to reduce the primary system pressure by depressurizing the secondary. Initially, this will provide accumulator water for core recovery and later, low-head SI will be initiated, to provide long term core cooling.

Table A.II-1 (continued)

C.2	Response to Potential Loss of Core Cooling	The objective of this guideline is to maintain core cooling. Safety injection should remain in service until core cooling is reestablished, and also until adequate pressurizer inventory, secondary heat sink, and RCS subcooling are reestablished. Potential instrument errors due to any adverse containment environmental condition must be taken into account prior to terminating safety injection.
C.3	Response to Saturated Core Conditions	The objective of this guideline is to reestablish RCS subcooling. Safety injection should remain in service until adequate pressurizer inventory, secondary heat sink, and RCS subcooling are reestablished. Potential instrument errors due to any adverse containment environmental condition must be taken into account prior to terminating safety injection.
I.1	Response to Pressurizer Flooding	The objective of this guideline is to reestablish control of pressurizer level within normal range. Increased let down and reduced charging would normally be used to control level. If safety injection is in service, it should remain in service until adequate RCS subcooling and secondary heat sink are reestablished. Potential instrument errors due to any adverse containment environmental condition must be taken into account. RCS subcooling should be maintained at all times.
I.2	Response to Low System Inventory	The objective of this guideline is to reestablish normal system inventory. Increased charging and reduced letdown would normally be used. If inventory cannot be restored, safety injection should be used.
I.3	Response to Void in in Reactor Vessel	The objective of this guideline is to remove voids in the reactor vessel after a stable, subcooled RCS exists. An initial attempt is made to condense the void. If, however, the void is gaseous (noncondensable), a head vent operation must be performed (if possible)to remove the void.

Table A.II-1 (continued)

H.1	Response to Loss of Secondary Heat Sink	The objective of this guideline is to cool the core subsequent to loss of both main feedwater and auxiliary feedwater. If a secondary heat sink cannot be restored, safety injection and manual opening of PORVs are used to establish a heat removal path.
H.2	Response to Low Steam Generator Level	The objective of this guideline is to restore steam generator level to the narrow range. Auxiliary feedwater should be in service and not throttled until narrow range level is restored.
H.3	Response to Loss of Normal Steam Dump Capability	The objective of this guideline is to reestablish capability to dump steam to either the condenser or to the atmosphere. The steam generator PORV isolation valve should be checked open and control air pressure reestablished if lost. If this cannot be done, attempts should be made to establish condenser steam dump. If necessary, valves should be operated locally.
Z.1	Response to Containment Above Design Pressure	The objective of this guideline is to reduce containment pressure below design pressure. The containment spray system and fan coolers should be placed in service to reduce containment pressure. Containment hydrogen concentration should also be checked and reduced if necessary by use of recombiners or igniters.
Z.2	Response to High Containment Pressure	The objective of this guideline is to reduce containment pressure to below the Hi-1 setpoint. Containment isolation should be maintained. Containment fan coolers should be in service. Containment spray may also be necessary. Containment hydrogen concentration should also be checked and reduced if necessary by use of recombiners or igniters.
Z.3	Response to High Containment Radiation Levels	The objective of this guideline is to minimize the release of radioactive material from the containment. Containment isolation Phase A valve position requirements should be verified. Usage of other lines should be evaluated considering the need for the system and potential releases from the line. Containment hydrogen concentration should also be checked and reduced if necessary by use of the recombiners or igniters.

Table A.II-1 (continued)

Z.4	Response to High Hydrogen Concentration in Containment	The objective of this guideline is to prevent a possible hydrogen ignition. Hydrogen concentration should be reduced by use of the recombiners or igniters
Z.5	Response to Containment Flooding	The objective of this guideline is to determine the cause of the containment flooding and determine operability of essential equipment. A survey of potential leakage paths into containment should be made and all non-essential lines isolated. An evaluation of operability of any necessary equipment which may be submerged should also be made.

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