Attachment 1

Plant Hatch
Southern Nuclear Operating Company

PRA CONVERSION PROJECT

PRA CONVERSION ACCIDENT SEQUENCE ANALYSIS NOTEBOOK

October 8, 1998
Revision 0

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This report documents the development of the Plant Hatch core damage sequences and their associated event trees. The purpose of the project was to convert the RISKMAN event trees to Windows ETA event trees. This effort is part of a larger project to convert the Hatch RISKMAN model to a CAFTA "linked fault tree" model. This document describes the resultant core damage event trees and sequences. Development of the plant damage model that carries the events out to plant damage states for release category classification is not discussed at this time.

Supporting documentation for this conversion included:

- Plant Hatch Individual Plant Examination (IPE) Report in Response to Generic Letter 88-20 [Reference 3.1]
- Hatch IPE Work Package H60.7 – Event Trees [Reference 3.2]
- Level II Process Plant Hatch, FAI/98-88 [Reference 3.3]

1.1 Event Tree Conversion

As part of the conversion process, Hatch documents prepared during the IPE were reviewed. The document review included the reports identified above as well as fault trees, event trees, and the Hatch IPE submittal. In addition to providing the original event trees, these reports also provided the list of assumptions and success criteria used in the original analysis. Additional insight was provided from the review of the IPE submittal. Since the basic assumptions and success criteria remain true, they will not be reiterated in this report. However, they can be reviewed, if necessary, in the documents referenced above.

During the conversion process, every attempt was made to maintain the fidelity of the IPE model and achieve simplification by combining mitigation systems into similar event tree functions. For each initiator, multiple linked event trees were consolidated into one event tree. In addition, event trees for initiators with similar plant response are grouped and represented by the same converted event trees. The conversion was achieved as follows:

First, all event trees associated with each specific initiator were identified. The frontline system event trees were reviewed and evaluated for similarity in plant response characterized by top events and sequence logic. Initiators with similar plant response and RISKMAN event trees were grouped together for the purpose of developing ETA event trees. For example, all of the transient initiators are grouped under the category of "Transients." This includes RISKMAN initiators LOSUTD, TTRIP, LOMCHV, DCPAN, LODC, MSIVC, SLOCA, BUSC, BUSD, LOBUSE, LOBUSF, LOBUSG, LODWC, SCRAM, LOFW, LOCV, DISCH, INTAKE, and LOPSW. Similarly, all of the RISKMAN ATWS initiators (i.e., ATWSMS, ATWSFW, and ATWSTT) were grouped under the category of ATWS. Initiators ALOCA and LLOCA were grouped under ALLOCA. Separate initiator groups were created for each of the following initiators: IORV, MLOCA, and LOSP.

RISKMAN initiators LOSPAC, LOSPDC, LOSPPS, LOSPVM, LOSPLL, LOSPML, and LOSPSL are not needed since loss of offsite power following each of the corresponding initiators (i.e., LOBUSE, LOBUSF, and LOBUSG for LOSPAC, LODC for LOSPDC, LOPSW for LOSPPS, LOMCHV for LOSPVM, LLOCA for LOSPLL, MLOCA for LOSPML, and SLOCA for LOSPSL) is accounted for in the linked fault tree for the corresponding initiators.

Fire and flood initiators are not included in the scope of this model conversion. They can be added to the CAFTA model in the future. In the Hatch IPE model, these initiators make use of the event tree model for the transient initiators. They can therefore be similarly included in the CAFTA model. Since the break outside containment and V sequence initiators lead to core damage directly, no event trees were developed in this conversion.

It is noted that the ETA event trees encompass only the RISKMAN frontline systems' event trees. The RISKMAN support systems' event trees (ELEC1, MECH1, ELEC2, and MECH2) do not need to be represented in the ETA trees since support systems are linked directly through the fault tree models. Separate support systems event trees are not necessary for a linked fault tree model.

Secondly, top events within the linked RISKMAN event trees for each of the initiator groups were merged or collapsed as appropriate. If separate top events represented different elements of a function, the top events were combined into one ETA event tree heading with multiple inputs. For example, RISKMAN top events CO (condensate initially unavailable for injection), FW (feedwater pumps not available or tripped following transient), FR (feedwater/condensate not recovered before Level 2 reached), and MC (main steam isolation valves (MSIVs) fail to remain open/main condenser not available) could be collapsed into an ETA event tree heading named PCS representing the unavailability of the power conversion system. All of the nodes under this heading in the ETA event tree for "Transient" are represented by a fault tree designated as #PCS. The pound sign serves as an indicator that multiple inputs exist at that node.

In the discussion that follows, each of the event tree groups is described. For each case, the modifications, node headings and sequences are identified and documented.

2.0 EVENT TREES

The following sections provide a detailed description of the accident sequences.

2.1 The Transient Event Tree

This sections contains information regarding the core damage event tree developed for all of the transient initiators, including &LOSUTD, %TTRIP, &LOMCHV, &DCPAN, &LODC, %MSIVC, %SLOCA, &BUSC, &BUSD, &LOBUSE, &LOBUSF, &LOBUSG, &LODWC, %SCRAM, %LOFW, %LOCV, &DISCH, &INTAKE, and &LOPSW. Note that initiators with "&" in the first character of their designators are, in general, support system failure initiating events. Each of these initiators (also called special initiators) is modeled by a system fault tree. The remaining initiators are signified by "%" in the first character of their designators.

This transient event tree covers transient-induced loss of coolant accident (LOCAs) and loss of offsite power (LOSP) following transient initiators. This tree does not include core damage sequences associated with the LOSP initiator and the corresponding station blackout (SBO) scenarios. Core damage sequences induced by anticipated transient without Scram (ATWS) following transient initiators are modeled separately with the ATWS initiators.

EVENT TREE

Figure 2.1-1 displays the transient core damage event tree.

EVENT TREE MODIFICATION

In the IPE, the frontline system core damage sequences for each of the transient initiators were obtained by linking together five RISKMAN frontline systems event trees. For example, event trees TTRIP, INTER1, REC0, RHRCS, and LTC1 were linked together to model the core damage sequences for initiator TTRIP. In IPE for this group of initiators, the first RISKMAN event tree used in the string of linked event trees is TTRIP, MSIVC, SCRAM, LOFW, or LOCV, depending on the initiator. These five RISKMAN event trees have identical tree structure. The only differences between these five event trees are the split fraction assignments for selected top events. These split fraction assignments vary as a function of the initiator considered. With the exception of initiators DISCH, INTAKE, and LOPSW, the remaining four RISKMAN event trees linked together for the quantification of this group of initiators are identical (i.e., INTER1, REC0, RHRCS, and LTC1). Initiators DISCH, INTAKE, and LOPSW use the following set of RISKMAN event trees linked together: TTRIP, INTER1, REC1, RHRCS, and LTC1. The tree structures for RISKMAN event trees REC0 and REC1 are identical. The only differences between these two trees are split fraction assignments.

After reviewing the RISKMAN event trees developed for the previously mentioned group of initiating events, the following key changes were made:

- The initiators were combined into a single transient initiator heading GT (with a node designated by IEGGT).
- Top events modeled in RISKMAN event trees TTRIP/MSIVC/SCRAM/LOFW/LOCV are combined according to the functions provided by the individual systems.
- With the exception of RP, most of the top events in RISKMAN event tree INTER1 are incorporated into lower level fault tree models for LOCA signal, operator restoration following a LOCA signal, automatic/emergency depressurization, main condenser availability, recovery of HPCI/RCIC, etc.
- Recovery top events modeled in REC0 or REC1 are incorporated into the appropriate system fault trees throughout the model.
- Most top events listed in RISKMAN event trees RHRCS and LTC1 are incorporated into the lower level fault trees for ETA headings DE, LO, and QR. RISKMAN top events Z5, DESC2, DESC1, CFF, and IN2 were determined not to be functional requirements for core damage.

The initiators included in the ETA transient initiator heading GT are:

General: %TTRIP, %MSIVC, %SLOCA, %SCRAM, %LOFW, and %LOCV

Special initiators: &LOSUTD, &LOMCHV, &DCPAN, &LODC, &BUSC, &BUSD, &LOBUSE, &LOBUSF, &LOBUSG, &LODWC, &DISCH, &INTAKE, and &LOPSW

For the new ETA event tree GT, nodes under each heading may be represented by one or more fault tree gates. The multiple RISKMAN system models were combined into one fault tree gate with additional compression achieved by combining similar functions into one final fault tree gate with multiple inputs. Listed below are the new top logic gates developed for the ETA event tree nodes and the original inputs associated with each (i.e., RISKMAN event tree top events combined into the gate):

#BVPR	BV, PR
#SORV0/1/2/3	SORV
#PCS	CO, FW, FR, MC, MS
#HP-1	RCIC, HPCI, HI, CW, RD
#ADED	VC, V18, LOCA, L1OP, DWTC, OW
#RP	RP, RPOP
#DEHICO1	DE, HI, CO
#LO	CO, CS, RA, RB, JS, VA, VB, VOP, NS, NSREC, LC
#QRIN1REC/#QRQRA/ #QR/#QT	OL, QC, QS, QT, RA, RB, VA, VB, VOP, HA, HB, QV, IN1, QR

Table 2.1-1 provides a summary of the disposition for each RISKMAN event tree top event.

EVENT TREE HEADINGS & BRANCHES

The following event tree headings and nodes appear on the tree in the approximate chronological order that would be expected during a transient.

GT General Transient Initiating Events. This heading (Branch ID IEGGT) includes all general transient and special initiators.

BVPR Pressure Relief. This heading models the pressure control function performed by the turbine bypass valves and safety relief valves (SRVs) during the initial pressure transient following a plant trip. For transient events with MSIVs open, both the turbine bypass valves and the SRVs may be available. Failure of this event (Branch ID #BVPR) is modeled as resulting in a medium-break LOCA.

SORV SORV Reclosure. This is a multistate heading. It models the reclosure status of SRVs (i.e., the number of stuck open SRVs). The four states applicable to this heading are as follows: all SRVs successfully reclose (Branch ID #SORV0); one SRV fails to reclose (Branch ID #SORV1); two SRVs fail to reclose (Branch ID #SORV2); and three or more SRVs fail to reclose (Branch ID #SORV3).

PCS Power Conversion System. This heading models the availability or unavailability of the power conversion system to provide the core cooling function. Condensate system, feedwater system, and main condenser are included in this heading. One condensate pump and one condensate booster pump are required to support operation of a single feedwater pump when the plant unit is shut down. Only one reactor feed pump is required to provide feedwater flow to the reactor for level control. If the feedwater is initially unavailable following a reactor trip, restoration of feedwater prior to initiation of high-pressure cooling injection (HPCI), or reactor core isolation cooling (RCIC) on Level 2 is also considered in this heading.

Success of this event implies that condensate, feedwater, and main condenser are available for plant response following the reactor trip. For the main condenser to remain available, the MSIVs must remain open, turbine bypass valves must continue to function, and all support for the electrohydraulic control system must be available. Failure of this event (Branch ID #PCS) implies that RCIC/HPCI will be demanded to operate to provide the high-pressure level control function. Due to the rapid vessel depressurization, PCS is not asked in sequences involving three or more stuck-open SRVs (Branch ID #SORV3).

HPI High Pressure Level Control by RCIC/HPCI. This heading models the high-pressure level control function provided by the RCIC and HPCI systems. Both automatic and manual actuations are considered in this heading. Also included in this heading are the operator actions to control HPCI and RCIC to prevent multiple Level 8 trips. For any stuck-open SRVs and medium LOCAs, RCIC is inadequate for vessel level control. For three or more stuck-open SRVs, HPCI is inadequate, and for one or two stuck-open SRVs, HPCI recovery is not credited. This event is only asked in this event tree when PCS is unsuccessful. Success of this event implies that RCIC or HPCI is available to provide the high-pressure level control function. Failure of this event (Branch ID #HP-1) implies that both RCIC and HPCI are unavailable for the vessel level control function and vessel depressurization is required.

ADED Automatic and Emergency Depressurization Conditions. This heading models the automatic and emergency depressurization conditions. The automatic depressurization condition is modeled by generation of the LOCA signal and failure of the operators to inhibit automatic depressurization system (ADS) actuation. LOCA signals include Level 1 and high drywell pressure signals. In addition, it was assumed that loss of main control room (MCR) cooling would result in generation of a LOCA signal. Failure of drywell cooling (RISKMAN Top Event VC) and failure of the operators to vent via the 18 in. vents to prevent a LOCA signal (RISKMAN Top Event V18) were assumed to lead to generation of a high drywell pressure signal.

Emergency vessel depressurization is required by the Plant Hatch procedures if the drywell temperature limit is exceeded. Drywell temperature would increase if drywell cooling fails and the operators fail to initiate drywell spray (RISKMAN Top Event OW), or if the operators fail to restore drywell cooling following a LOCA signal.

Success of this event implies that there are no automatic and emergency depressurization conditions, or the operators successfully inhibit ADS and restore drywell cooling given a LOCA signal. Failure of this event (Branch ID #ADED) implies that ADS would be actuated or the operators are required to initiate emergency vessel depressurization. It is assumed in sequences involving failure of this heading that vessel is depressurized and downstream heading DE is not asked. This heading is not asked if both PCS and HPI fail requiring a vessel depressurization (downstream heading DE).

RP Return to Power Operation. This heading models the success path with the reactor returning to power operation without proceeding to cold shutdown. This heading is only asked if the pressure relief function performed by the turbine bypass valves/SRVs is successful, there is no stuck-open SRV, RCIC/HPCI is successful in controlling vessel level, and there is no automatic/emergency vessel depressurization condition. Success of this event implies that the transient has been terminated and plant returns to power operation. Loss of the main condenser or failure of any support system would cause failure of this event (Branch ID #RP).

DE Depressurization of Vessel Before Core Damage. This heading models the reduction of vessel pressure to permit level recovery. This heading includes the manual emergency depressurization actions required when all high-pressure injection sources are lost. Also included in this heading is the controlled cooldown and pressure reduction to allow the use of condensate and condensate booster pumps. This heading is only asked when both PCS and HPI fail. Success of this event implies that operators successfully depressurize the reactor vessel to allow injection by the low pressure systems. Failure of this event (Branch ID #DEHICO1) implies that reactor vessel remains at high-pressure and core damage would result. #DEHICO1 also accounts for a condensate/condensate booster pump injection at a lower reactor pressure, approximately 500 psig, following vessel pressure reduction using the turbine bypass valves or the SRVs. This is, when available, an alternative way to vessel depressurization followed by low pressure injection. It can be performed without exceeding the cooldown rate. If the operators fail to reduce pressure for condensate injection, it is considered likely that it is because their attention is focused on recovery of other injection systems and restoration of the vessel level, not because they are unaware of the decreasing vessel level. However, the action to emergency depressurize is called for in the EOPs at a specific vessel level. Therefore, the action for controlled cooldown is relatively independent of emergency depressurization.

LO Low Pressure Injection. This heading models the low pressure injection function provided by the condensate, core spray, and low pressure coolant injection (LPCI) systems. Both automatic and manual actions are considered for core spray and LPCI. Success of this event implies that low pressure injection is available. Failure of this event (Branch ID #LO) implies that low pressure injection is unsuccessful.

QR Decay Heat removal. This heading models decay heat removal by shutdown cooling, suppression pool cooling, main condenser, torus vent, etc. A number of different top logic gates have been developed to model the nodes under this heading. They include #QRIN1REC, #QRQRA, #QR, and #QT.

Top logic gate #QRIN1REC models failure of decay heat removal with consideration of recovery of decay heat removal during the period prior to failure of the containment or ECCS. After decay heat removal is lost, the low pressure injection systems would become ineffective due to reactor repressurization. For successful recovery of decay heat removal, HPCI must be available after repressurization of the reactor vessel. The RISKMAN event tree top events associated with the recovery of decay heat removal include IN1 and QR. Top gate #QRIN1REC is used for nodes where high-pressure injection is available, reactor pressure is reduced, there is no stuck-open SRV (or no failure of pressure relief), and low pressure injection is successful. Success implies that decay heat removal is available or is recovered before containment or ECCS is failed. Failure (Branch ID #QRIN1REC) implies that decay heat removal is not recovered, the reactor is repressurized, and the containment fails subsequently.

For sequences in which RCIC or HPCI is successful, there is no stuck-open SRV (or no failure of pressure relief), return to power has failed, and low pressure injection is unavailable, decay heat removal can be achieved by suppression pool cooling (modeled by top logic gate #QT). Success implies that, with suppression pool cooling, the long term operation of RCIC or HPCI can be successful. The reactor would remain at pressure long enough to support HPCI or RCIC injection allowing adequate time to recover low pressure injection. Failure (Branch ID #QT) implies that high-pressure injection would also be lost due to loss of heat removal.

Top logic gate #QR is used in sequences in which there is no stuck-open SRV (no failure of pressure relief) and high-pressure injection is unavailable. Success implies that the decay heat removal function is successful. Failure (Branch ID #QR) implies that no decay heat removal is available.

For sequences in which a stuck-open SRV is present or the initial pressure relief has failed, top logic gate #QRQRA is used. Recovery of decay heat removal during the period prior to containment or ECCS failure is considered.

SEQUENCES

The following descriptions refer to the core damage sequences presented in figure 2.1-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path.

GT_3: IEGGT /#BVPR #SORV0 /#PCS #ADED /#LO #QRIN1REC

A transient event occurs (IEGGT). After the reactor trip, the initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). Condensate, feedwater, and main condenser operate successfully following the plant trip (/#PCS). Since the power conversion system is successful, high-pressure injection by RCIC or HPCI is not necessary. Reactor vessel depressurizes due to automatic depressurization conditions or emergency depressurization requirements (#ADED). The hardware response for vessel depressurization (modeled in #DE) is assumed successful. Due to vessel depressurization, return to power operation is not asked in this sequence. Low pressure injection is successful (/#LO). The decay heat removal function is unavailable (#QRIN1REC) resulting in eventual core damage.

GT_4: IEGGT /#BVPR #SORV0 /#PCS #ADED #LO

Similar to Sequence GT_3 except that low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence.

GT_7: IEGGT /#BVPR #SORV0 #PCS /#HP-1 /#ADED #RP /#LO #QRIN1REC

A transient event occurs (IEGGT). After reactor trip, the initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). The power conversion system (condensate, feedwater, and main condenser) fails to operate following the plant trip (#PCS). High pressure injection by RCIC or HPCI is successful (/#HP-1). There are no automatic depressurization conditions or emergency depressurization requirements to cause vessel depressurization (/#ADED). Therefore, hardware response for the vessel depressurization is not asked in this sequence. Return to power operation has been unsuccessful (#RP). Vessel pressure is reduced due to the cooldown operation provided by RCIC/HPCI. Low pressure injection is successful (/#LO). The decay heat removal function is unavailable (#QRIN1REC) resulting in eventual core damage.

GT_9: IEGGT /#BVPR #SORV0 #PCS /#HP-1 /#ADED #RP #LO #QT

Similar to Sequence GT_7 except that low pressure injection is unsuccessful (#LO). Core cooling can only be achieved by high-pressure injection provided by RCIC/HPCI (/#HP-1). To permit long term RCIC/HPCI operation, suppression pool cooling must be successful. However, in this sequence, suppression pool cooling is unavailable (#QT) resulting in eventual core damage.

GT_11: IEGGT /#BVPR #SORV0 #PCS /#HP-1 #ADED /#LO #QRIN1REC

Same as Sequence GT_3 except that the power conversion system is unavailable (#PCS). High pressure injection is provided by RCIC or HPCI (/#HP-1). Compared to Sequence GT_3, this sequence is not minimal since it involves the additional failure of the power conversion system (#PCS).

GT_12: IEGGT /#BVPR #SORV0 #PCS /#HP-1 #ADED #LO

Same as Sequence GT_4 except that the power conversion system is unavailable (#PCS). High pressure injection is provided by RCIC or HPCI (/#HP-1). Compared to Sequence GT_4, this sequence is not minimal since it involves the additional failure of the power conversion system (#PCS).

GT_14: IEGGT /#BVPR #SORV0 #PCS #HP-1 /#DEHICO1 /#LO #QR

A transient event occurs (IEGGT). After reactor trip, the initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). The power conversion system (condensate, feedwater, and main condenser) fails to operate following the plant trip (#PCS). High pressure injection by RCIC or HPCI is also unavailable (#HP-1). Vessel pressure is successfully reduced by the use of either condensate booster pumps or SRVs/turbine bypass valves (/#DEHICO1). Low pressure injection is successful (/#LO). However, decay heat removal has failed resulting in eventual core damage.

GT_15: IEGGT /#BVPR #SORV0 #PCS #HP-1 /#DEHICO1 #LO

Similar to Sequence GT_14 except that low pressure injection is unsuccessful (#LO) leading to eventual core damage.

GT_16: IEGGT /#BVPR #SORV0 #PCS #HP-1 #DEHICO1

Similar to Sequence GT_14 except that vessel pressure reduction is unsuccessful (#DEHICO1) resulting in eventual core damage.

GT_18: IEGGT /#BVPR #SORV1 /#PCS #QRQRA

A transient event occurs (IEGGT). After reactor trip, the initial pressure relief is successful (/#BVPR). However, one SRV fails to reclose (#SORV1). The power conversion system (condensate, feedwater, and main condenser) operates successfully following the plant trip (#PCS). Due to the stuck-open SRV, vessel pressure will continue to decrease after the initial pressure response. As the vessel pressure reduces, feedwater and condensate booster pumps can be gradually turned off. In this sequence, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage.

GT_20: IEGGT /#BVPR #SORV1 #PCS /#HP-1 /#LO #QRQRA

Similar to Sequence GT_18 except that the power conversion system is unavailable (#PCS) and high-pressure injection is provided by RCIC or HPCI (/#HP-1). Due to the stuck-open SRV, vessel pressure will continue to decrease to the low pressure system shutoff head. Low pressure injection is successful (/#LO). Decay heat removal is unavailable (#QRQRA) resulting in eventual core damage. Compared to Sequence GT_18, this sequence is non-minimal.

GT_21: IEGGT /#BVPR #SORV1 #PCS /#HP-1 #LO

Similar to Sequence GT_20 except that low pressure injection is unavailable (#LO) resulting in eventual core damage.

GT_23: IEGGT /#BVPR #SORV1 #PCS #HP-1 /#DEHICO1 /#LO #QRQRA

Similar to Sequence GT_20 except that high-pressure injection by RCIC/HPCI is unavailable (#HP-1) and vessel pressure reduction by the use of SRVs/turbine bypass valves is successful (/#DEHICO1). Compared to Sequence GT_18, this sequence is non-minimal.

GT_24: IEGGT /#BVPR #SORV1 #PCS #HP-1 /#DEHICO1 #LO

Similar to Sequence GT_21 except that high-pressure injection by RCIC/HPCI is unavailable (#HP-1) and vessel pressure reduction by the use of SRVs/turbine bypass valves is successful (/#DEHICO1). Compared to Sequence GT_21, this sequence is non-minimal.

GT_25: IEGGT /#BVPR #SORV1 #PCS #HP-1 #DEHICO1

Similar to Sequence GT_24 except that vessel pressure reduction has failed (#DEHICO1) resulting in eventual core damage.

GT_27: IEGGT /#BVPR #SORV2 /#PCS #QRQRA

Same as Sequence GT_18 except that two SRVs stick open (#SORV2).

GT_29: IEGGT /#BVPR #SORV2 #PCS /#HP-1 /#LO #QRQRA

Similar to Sequence GT_20 except that two SRVs stick open (#SORV2). Compared to Sequence GT_27, this sequence is non-minimal.

GT_30: IEGGT /#BVPR #SORV2 #PCS /#HP-1 #LO

Similar to Sequence GT_21 except that two SRVs stick open (#SORV2).

GT_32: IEGGT /#BVPR #SORV2 #PCS #HP-1 /#DEHICO1 /#LO #QRQRA

Similar to Sequence GT_23 except that two SRVs stick open (#SORV2). Compared to Sequence GT_27, this sequence is non-minimal.

GT_33: IEGGT /#BVPR #SORV2 #PCS #HP-1 /#DEHICO1 #LO

Similar to Sequence GT_24 except that two SRVs stick open (#SORV2). Compared to Sequence GT_30, this sequence is non-minimal.

GT_34: IEGGT /#BVPR #SORV2 #PCS #HP-1 #DEHICO1

Similar to Sequence GT_25 except that two SRVs stick open (#SORV2).

GT_36: IEGGT /#BVPR #SORV3 /#LO #QRQRA

A transient event occurs (IEGGT). After reactor trip, the initial pressure relief is successful (/#BVPR). However, three or more SRVs fail to reclose (#SORV3). All high-pressure injection sources are lost due to vessel depressurization caused by the stuck-open SRVs. Following vessel depressurization, low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable resulting in eventual core damage (#QRQRA).

GT_37: IEGGT /#BVPR #SORV3 #LO

Similar to Sequence GT_36 except that low pressure injection is unavailable (#LO) resulting in eventual core damage.

GT_39: IEGGT #BVPR /#PCS #QRQRA

Similar to Sequence GT_27 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged.

GT_41: IEGGT #BVPR #PCS /#HP-1 /#LO #QRQRA

Similar to Sequence GT_29 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged. Compared to Sequence GT_39, this sequence is non-minimal.

GT_42: IEGGT #BVPR #PCS /#HP-1 #LO

Similar to Sequence GT_30 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged.

GT_44: IEGGT #BVPR #PCS #HP-1 /#DEHICO1 /#LO #QRQRA

Similar to Sequence GT_32 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged. Compared to Sequence GT_39, this sequence is non-minimal.

GT_45: IEGGT #BVPR #PCS #HP-1 /#DEHICO1 #LO

Similar to Sequence GT_33 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged. Compared to Sequence GT_42, this sequence is non-minimal.

GT_46: IEGGT #BVPR #PCS #HP-1 #DEHICO1

Similar to Sequence GT_34 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged.

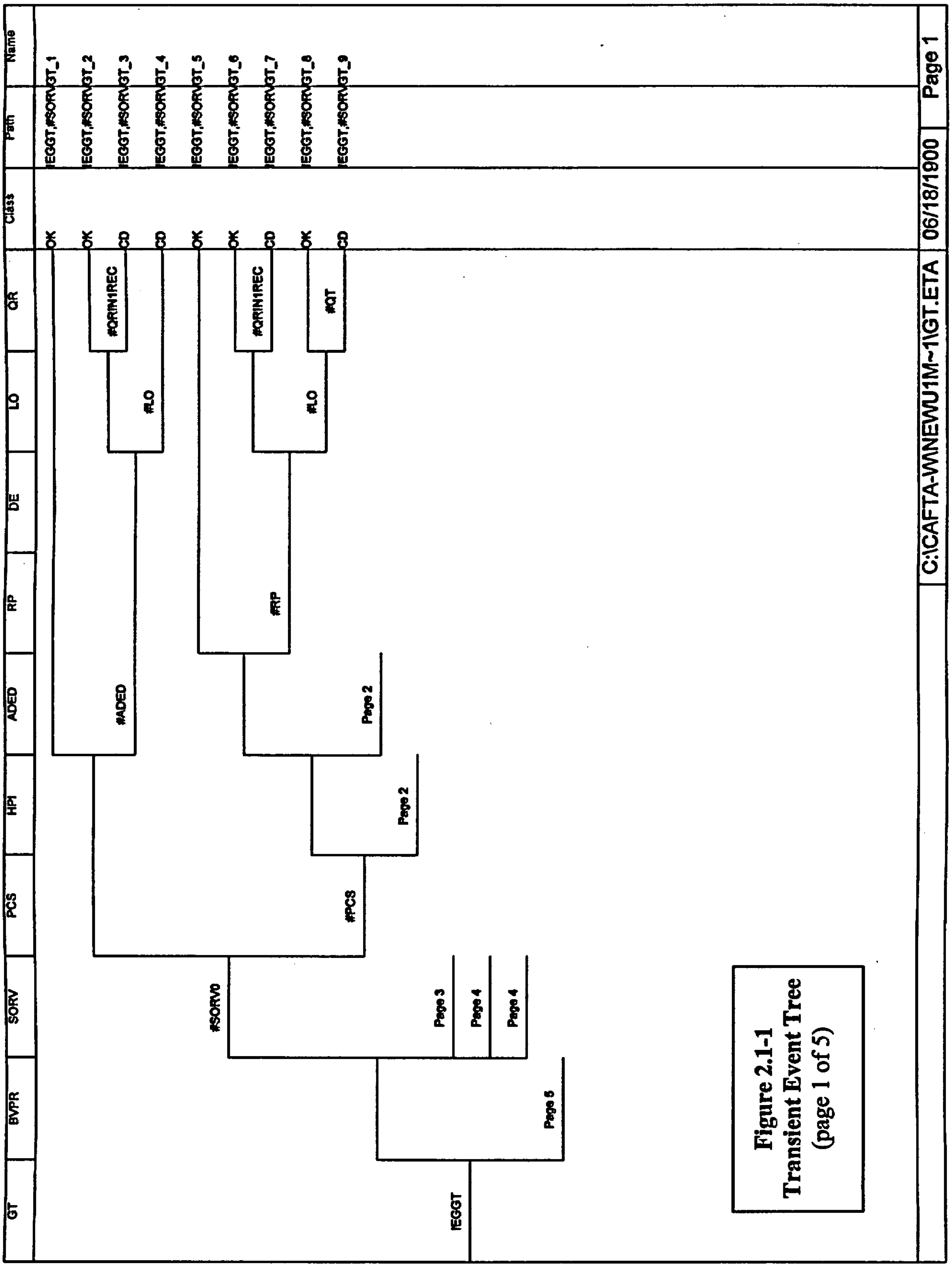
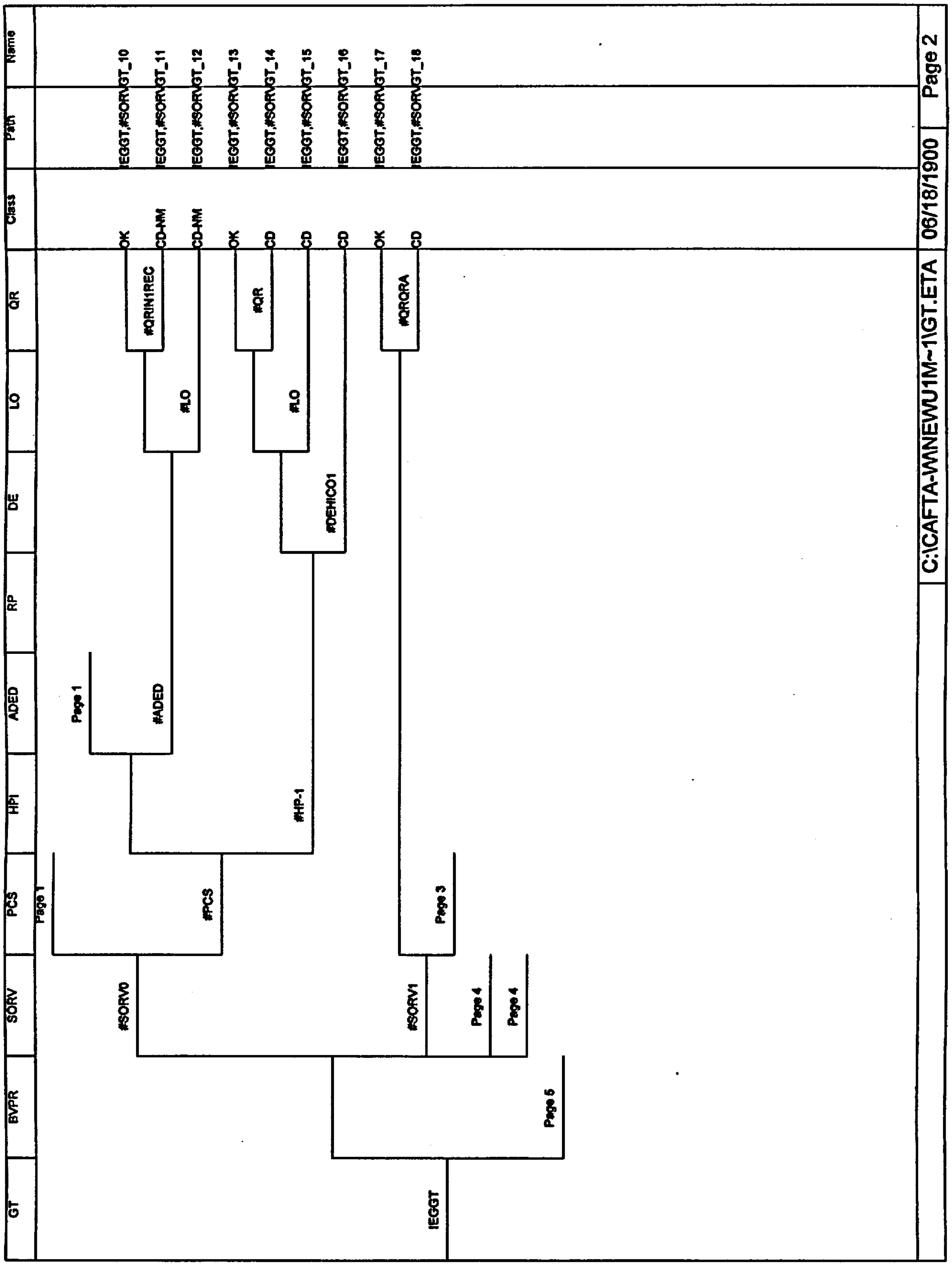


Figure 2.1-1
Transient Event Tree
(page 1 of 5)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Page 4
Page 4
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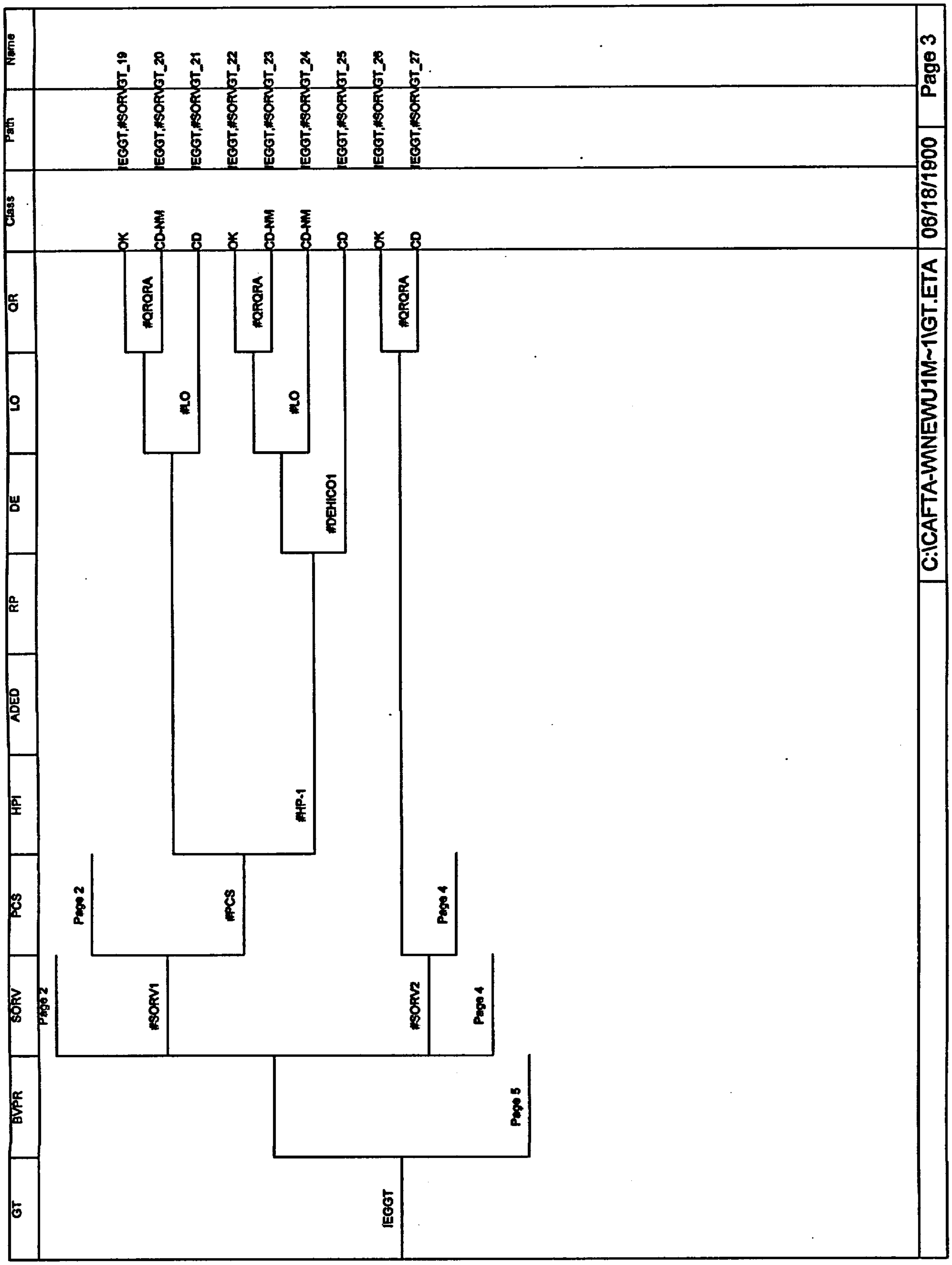
Page 2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Page 2
Page 4
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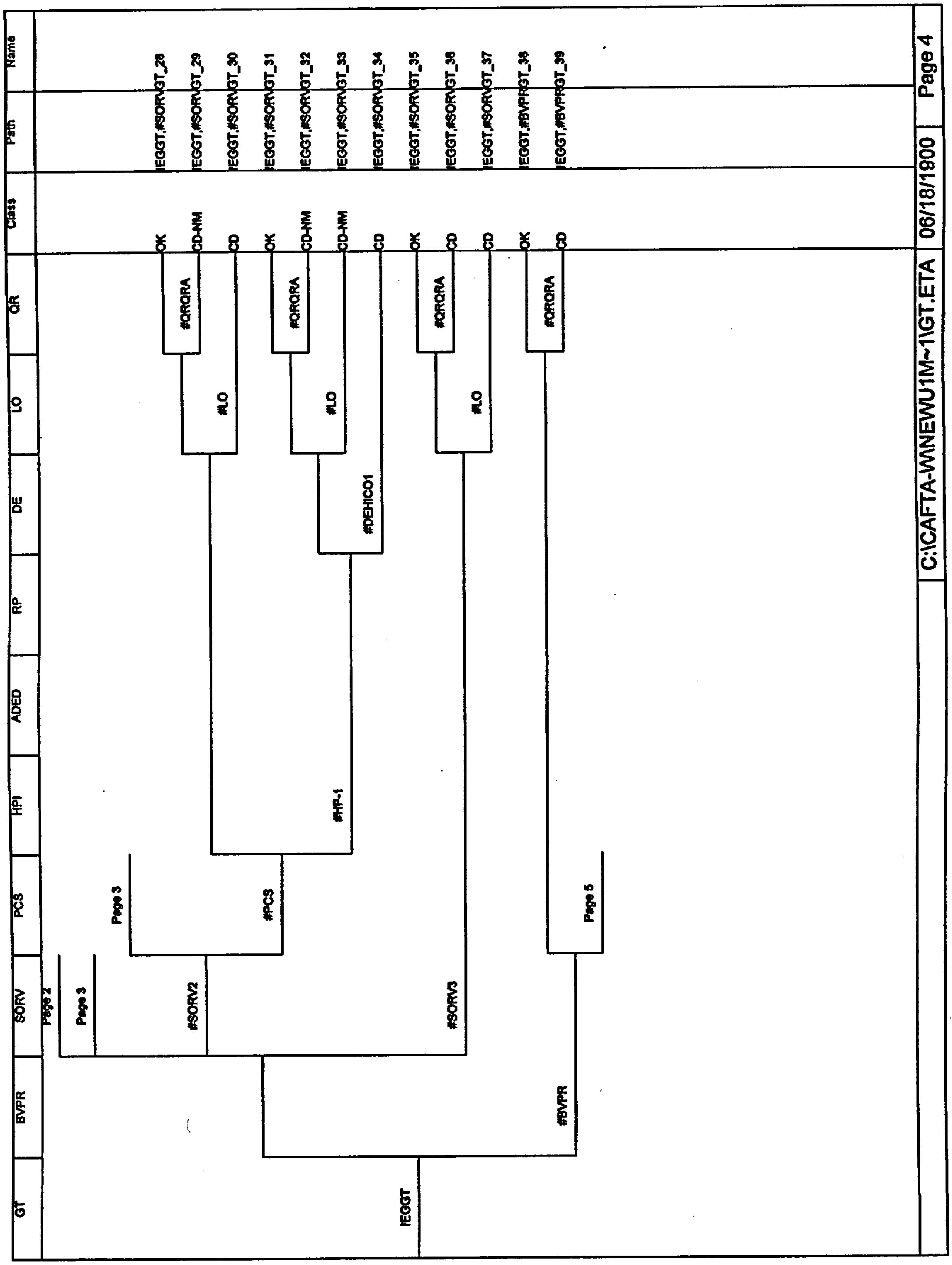
Page 3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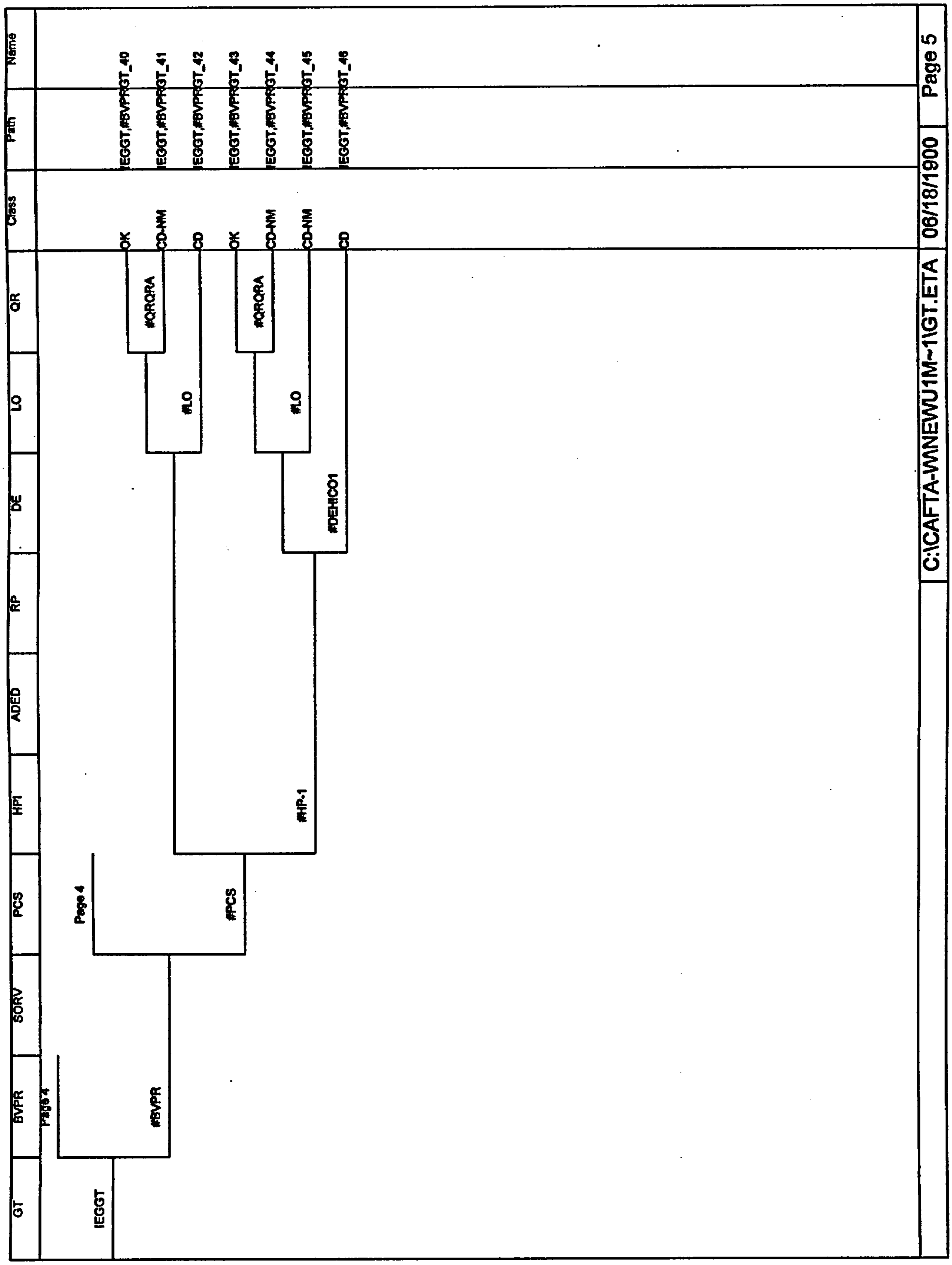
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Page 5

TABLE 2.1-1
TRANSIENT EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
TTRIP/MSIVC/SCRAM /LOFW/LOCV IE	Transient Initiator	Incorporated in core damage event tree model under gate IEGGT.
TTRIP/MSIVC/SCRAM /LOFW/LOCV BV	Bypass valves fail to open for pressure control	Incorporated in core damage event tree model under gate #BVPR (system fault tree model gate BVPR-016).
TTRIP/MSIVC/SCRAM /LOFW/LOCV PR	Pressure relief inadequate	Incorporated in core damage event tree model under gate #BVPR (system fault tree model gates BVPR-SIGFAIL, BVPR-010, BVPR-017).
TTRIP/MSIVC/SCRAM /LOFW/LOCV SORV	SRV reclosure status	Incorporated in core damage event tree model as gates #SORV0, #SORV1, #SORV2, and #SORV3.
TTRIP/MSIVC/SCRAM /LOFW/LOCV CO	Condensate system for injection	Incorporated in core damage event tree model under gates #LO, #PCS, #PCS-1, and #DEHICO1 (system fault tree model gates CO and CO-1).
TTRIP/MSIVC/SCRAM /LOFW/LOCV FW	Feedwater not available after transient	Incorporated in core damage event tree model under gates #PCS and #PCS-1(system fault tree model gate FW).
TTRIP/MSIVC/SCRAM /LOFW/LOCV FR	Feedwater/Condensate not recovered before Level 2 reached	Incorporated in core damage event tree model under gates #PCS and #PCS-1(system fault tree model gate FR).
TTRIP/MSIVC/SCRAM /LOFW/LOCV MC	MSIVs fail to remain open/main condenser not available	Incorporated in core damage event tree model under gate #PCS (system fault tree model gate MC-1).
TTRIP/MSIVC/SCRAM /LOFW/LOCV RCIC	RCIC fails	Incorporated in core damage event tree model under gates #HP-1, #HP-3, and #HP-B.
TTRIP/MSIVC/SCRAM /LOFW/LOCV HPCI	HPCI fails	Incorporated in core damage event tree model under gates #HP-1, #HP-3, #HP-B, HPCI-1, and #QRIN1REC (system fault tree model gate HPCI-2).
INTER1 VC	Drywell cooling inadequate to prevent LOCA signal	Incorporated in core damage event tree model under top logic gates #ADED and #DEHICO1 (system fault tree model gate VC).
INTER1 V18	Operators fail to vent via 18" vents to prevent LOCA signal on loss of cooling	Incorporated in core damage event tree model under gate #ADED (system fault tree model gate V18).
INTER1 LOCA	LOCA signal (Level 1 or high drywell pressure) generated	Incorporated in core damage event tree model under gate #ADED (system fault tree model gates LOCASIG, LOCASIGVC, and LOCASIGWS).
INTER1 MS	MSIVs fail to isolate reactor	Incorporated in core damage event tree model under gates #PCS and #PCS-1 (system fault tree mode gate MS-1 under system model MC-1).

TABLE 2.1-1
TRANSIENT EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
INTER1 L1OP	Status of operator actions following LOCA signal	Incorporated in system fault tree model gates NORDWC1 (under core damage event tree gates #DEHICO1 and #ADED), NOINADS1 (under core damage event tree gate #ADED), NOTBISO1 (under system fault tree model gates NOCRD, PSWTB-2, and HI-1), and L1OP. Gate NOCRD is under gate #DE which is under #DEHICO1. HI-1 is under #DEHICO1, HPCI-1, #HP-1, #HP-3, and #HP-B. L1OP is under HI-G008-1 which is under HI-1.
INTER1 CW	RBCCW not available	Incorporated in system fault tree model gates RD (under NOCRD and NOCRD-1), NOCRD (under #DE and thus #DEHICO1), and NOCRD-1 (under HI-1 which is under #DEHICO1, HPCI-1, #HP-1, #HP-3, and #HP-B).
INTER1 RD	CRD pumps are unavailable for injection	Incorporated in system fault tree model gate RD which is under gates NOCRD and NOCRD-1. NOCRD is under #DE and thus #DEHICO1. NOCRD-1 is under HI-1 which is under #DEHICO1, HPCI-1, #HP-1, #HP-3, and #HP-B.
INTER1 RP	Return to power operation not possible or failed	Incorporated in core damage event tree model under gate #RP.
REC0/REC1 DCREC	DC power not restored to deenergized bus	Incorporated in system fault tree model gates DC-1R25S001, NBA-NOXFR, and NBA-NOXFR-1.
REC0/REC1 NBREC	Normal busses remain deenergized	Incorporated in system fault tree model gates NBA-NOXFR, NBA-NOXFR-1, XD-1, and XD-2.
REC0/REC1 SWREC	PSW not restored	Incorporated in system fault tree model for PSW under gates NOSWREC1, NOSWREC2, NOKMCR1, and L-PS-G125.
REC0/REC1 RSREC	Motor cooling for RHRSW pumps not available/not restored	Incorporated in system fault tree model for RHRSW under gate RSREC.
REC0/REC1 KMCR	Main control room cooling not recovered/purge mode not available	Incorporated in system fault tree models for MCR cooling, PSW, etc. under gates NOKMCR1, NOMCRPURGE, VM-G038, and PSWDISCHKMCR1.
REC0/REC1 KRSDP	Transfer of control to remote shutdown panel(s) not accomplished	Incorporated in system fault tree models for LPCI, RCIC, etc. under gate NOKRSDP-1.
RHRCS Z5	Dummy top event – RHR/CS event tree not bypassed	Not a functional requirement for core damage mitigation
RHRCS VA	RHR/CS loop A room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VA.
RHRCS VB	RHR/CS loop B room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VB.

TABLE 2.1-1
TRANSIENT EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
RHRCS VOP	Operators fail to trip unneeded pumps on loss of RHR/CS room cooling	Incorporated in system fault tree models for RHR and core spray under gates CS-VA and CS-VB.
RHRCS NS	LPCI/CS low pressure permissive signal fails	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS NSREC	LPCI/CS low pressure permissive not recovered	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS LC	LPCI/CS initiation signals unavailable	Incorporated in system fault tree models for core spray, LPCI, turbine building PSW isolation, and diesel 1B MCC AC-1R24S026 under gate LC.
RHRCS RA	RHR loop A pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPA, RHRLOOPA-1, and SDCLOOPA.
RHRCS RB	RHR loop B pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPB, RHRLOOPB-1, and SDCLOOPB.
RHRCS JS	LPCI injection paths for both loops unavailable	Incorporated in system fault tree model for RHR under gates LPCI (under core damage event tree gate #LO) and QS (under core damage event tree gates #QR, #QRQRA, #QRIN1REC).
RHRCS CS	Core spray system fails	Incorporated in system fault tree model for core spray under gate CS which is under core damage event tree gate #LO.
RHRCS HA	RHR service water pumps in division I fail	Incorporated in system fault tree model for RHR under gates QT and QS.
RHRCS HB	RHR service water pumps in division II fail	Incorporated in system fault tree model for RHR under gates QT and QS.
LTC1 HI	High pressure core cooling inadequate/not recovered	Incorporated in system fault tree model under gate HI-1. HI-1 is under #DEHICO1, HPCI-1, #HP-1, #HP-3, and #HP-B.
LTC1 DWTC	Drywell temperature control inadequate – sprays required	Incorporated in core damage event tree model under gate #ADED.
LTC1 OW	Operators fail to initiate drywell sprays on increasing drywell temperature	Incorporated in core damage event tree model under gate #ADED (system fault tree model gate OW).
LTC1 DE	Operators fail to depressurize vessel before core damage occurs	Incorporated in core damage event tree model under gates #DEHICO1 and #DE.
LTC1 DESC2	Emergency depressurization occurs	Not a functional requirement for core damage mitigation.
LTC1 RPOP	Normal cooldown initiated	Incorporated in core damage event tree model under gate #RP.

TABLE 2.1-1
TRANSIENT EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LTC1 LO	Low pressure injection and control inadequate	Incorporated in core damage event tree model under gate #LO.
LTC1 OL	Operators fail to provide adequate long term heat removal	Incorporated in core damage event tree model under gates #QR, #QT, #QRQRA, and #QRIN1REC.
LTC1 QS	RHR shutdown cooling path not available	Incorporated in core damage event tree model under gates #QR, #QRQRA, and #QRIN1REC (system fault tree gate QS).
LTC1 QC	Main condenser unavailable	Incorporated in core damage event tree model under gates #QR, #QRQRA, and #QRIN1REC (system fault tree gate QC).
LTC1 QT	Torus cooling not available	Incorporated in core damage event tree model under gates #QR, #QT, #QRQRA, and #QRIN1REC (system fault tree gate QT).
LTC1 QV	Containment vent not available for heat removal	Incorporated in core damage event tree model under gates #QR, #QRQRA, and #QRIN1REC (system fault tree gate QV).
LTC1 DESC1	Containment pressure increases; manual operation of SRVs precluded	Not a functional requirement for core damage mitigation.
LTC1 IN1	Injection fails to remain available when reactor repressurizes	Incorporated in core damage event tree model under gate #QRIN1REC.
LTC1 QR	Heat removal not recovered before ECCS or containment fails	Incorporated in core damage event tree model under gates #QRIN1REC and #QRQRA.
LTC1 CFF	ECCS systems fail before containment fails	Not a functional requirement for core damage mitigation.
LTC1 IN2	Injection fails to remain available after containment failure	Not a functional requirement for core damage mitigation.

2.2 The Anticipated Transient Without Scram (ATWS) Event Tree

This section contains information regarding the ATWS core damage event tree. This event tree models core damage event sequences associated with those "ATWS initiators" included in the RISKMAN IPE model. In principal, ATWS is not an initiator. It is a plant condition following transient initiating events. For modeling convenience, however, event sequences involving failure of the reactor scram function following plant transients are treated as initiators in both IPE and this CAFTA model. Of all the transient events, the most significant initiating events for ATWS mitigation are turbine trip, loss of feedwater, and MSIV closure because of their frequency of occurrence and impact on plant response during the progression of the ATWS events. Therefore, the event tree model described in this section is characterized by three ATWS initiators: turbine trip, loss of feedwater, and MSIV closure. The MSIV closure ATWS initiator, however, really represents event sequences involving failure of the reactor scram function following both the MSIV closure and the loss of condenser vacuum events.

EVENT TREE

Figure 2.2-1 displays the core damage event tree for the ATWS initiator. The following discussion describes the event tree modifications, defines the event tree headings, and describes the sequences presented.

EVENT TREE MODIFICATIONS

In the IPE, the core damage sequences for each of the ATWS initiators were obtained by linking together the following 7 RISKMAN frontline systems event trees: ATWSSUP, ATWS, ATWSBIT, INTER3, REC0, RHRCS, and LTC3. The same set of event trees were linked together for all three initiators in this group. After reviewing the RISKMAN event trees developed for this group of initiating events, the following key changes were made:

- The initiators were combined into a single ATWS initiator heading ATWS (with a node designated by IEGATWS).
- Top events modeled in RISKMAN event trees ATWSSUP, ATWS, and ATWSBIT are combined according to the functions provided by the individual systems.
- With the exception of V18, CW, RD, and RP, top events in RISKMAN event tree INTER3 are incorporated into lower level fault tree models for LOCA signal, operator restoration following a LOCA signal, automatic/emergency depressurization, main condenser availability, etc. RISKMAN Top Events V18, CW, RD, and RP were determined to not be ATWS functional requirements for core damage.
- Recovery top events modeled in REC0 are incorporated into the appropriate system fault trees.
- Most top events listed in RISKMAN event trees RHRCS and LTC3 are incorporated into the lower level fault trees for ETA headings DE, LO, and QR. RISKMAN Top Events Z5, DESC2, DESC1, IN1, QR, CFF, and IN2 were determined to not be ATWS functional requirements for core damage.

The initiators included in the ETA ATWS initiator heading ATWS are: %ATWSTT, %ATWSFW, and %ATWSMS.

For the new ETA event tree ATWS, nodes under each heading may be represented by one or more fault tree gates. The multiple RISKMAN system models were combined into one fault tree gate with additional compression achieved by combining similar functions into one final fault tree gate with multiple inputs. Listed below are the new top logic gates developed for the ETA ATWS event tree nodes and the original inputs associated with each (i.e., RISKMAN event tree top events combined into the gate):

#RSCRAM	HCU, ARIA, ARIB, RPS, ARI, MT
RPT	RPT
#BVPR	BV, PR
#SORV0/1/2/3	SORV
#PCS	CO, FW, FC, MC, MS
HPCI-1	HPCI
#BI	BIIT, SL, OS
#TINJ	TINJ, HO
#HR	TINJ, HR
#ADEDWS/ADWS	VC, LOCA, L1OP, DWTC, OW/VC, LOCA, L1OP
#DEWS/#DE	VC, LOCA, L1OP, DWTC, OW, DE/DE
#LOWS	CO, CS, RA, RB, JS, VA, VB, VOP, NS, NSREC, LC, LO
#QR/#QT	OL, QC, QS, QT, RA, RB, VA, VB, VOP, HA, HB, QV

Table 2.2-1 provides a summary of the disposition for each RISKMAN event tree top event.

<u>EVENT TREE HEADINGS & BRANCHES</u>

The following event tree headings and nodes appear on the tree in the approximate chronological order that would be expected during an ATWS.

ATWS ATWS Initiating Events. The ATWS initiator is defined as a transient (including support system failure) or small LOCA initiating event followed by failure of the automatic and manual reactor trip. Since failure of the reactor trip is modeled under heading RSCRAM, the ATWS heading just includes transient initiators without consideration of the status of reactor scram. For ATWS core damage, the most important and highest frequency transient initiators are turbine trip, loss of feedwater, MSIV closure, and loss of condenser vacuum. MSIV closure and loss of condenser vacuum also present severe impact on ATWS mitigation. The impact of MSIV closure and loss of condenser vacuum are very similar, therefore, these two initiators are combined and represented by the MSIV closure initiator. As such, the top logic gate IEGATWS developed for this heading (Branch ID IEGATWS) includes the following 3 initiators: turbine trip with ATWS (%ATWSTT), loss of feedwater with ATWS (%ATWSFW), and MSIV closure with ATWS (%ATWSMS).

RSCRAM Reactor Shutdown. This heading models the scram function provided by the reactor protection system (RPS), alternate rod insertion (ARI) system, and manual operator scram. The reactor can be brought to a shutdown condition by inserting a sufficient number of control rods. Scram signals from the RPS would deenergize the scram pilot valves causing control rod insertion. An ARI scram signal would open the ARI valves to depressurize the scram air header causing control rod insertion. The scram pilot valves can also be deenergized by the manual RPS scram signal. Success of this event implies that reactivity control is established by inserting the control rods via automatic RPS scram, automatic ARI actuation, or manual operator trip. Failure of this event (Branch ID #RSCRAM) implies that reactivity control function is unsuccessful.

RPT Recirculation Pump Trips (RPT). This heading models the RPT logic required for successful pressure control under ATWS conditions. The ATWS high-pressure and the end-of-cycle trip are modeled. No credit is taken for the ATWS low level trip signal. Successful RPT requires that both recirculation pumps trip automatically given an ATWS event. Success of this event implies that both recirculation pumps are tripped, RCS pressure is decreased, and reactor power is reduced. Failure of this event implies that the RPT and RCS pressure control are unsuccessful. It is conservatively assumed in this ATWS event tree model that failure of RPT would result in core damage.

BVPR Pressure Relief. This heading models the pressure control function performed by the turbine bypass valves and SRVs during the initial pressure transient. For transient events with MSIVs open, both the turbine bypass valves and the SRVs may be available. Failure of this event (Branch ID #BVPR) is conservatively modeled as resulting in core damage.

SORV SORV Reclosure. This is a multistate heading. It models the reclosure status of SRVs (i.e., the number of stuck open SRVs). All open SRVs must close after the vessel pressure falls below the SRV setpoints. The four states applicable to this heading are: all SRVs successfully reclose (Branch ID #SORV0); one SRV fails to reclose (Branch ID #SORV1); two SRVs fail to reclose (Branch ID #SORV2); and three or more SRVs fail to reclose (Branch ID #SORV3). Failure of three or more SRVs to reclose is conservatively modeled as resulting in core damage.

PCS Power Conversion System. This heading models the availability or unavailability of the power conversion system to provide the core cooling function. Condensate system, feedwater system, and main condenser are included in this heading. One condensate pump and one condensate booster pump are required to support operation of a single feedwater pump when the plant unit is shut down. One reactor feed pump is required to provide feedwater flow to the reactor for level control. If feedwater is initially unavailable, no credit for restoration of feedwater is considered in this heading.

Success of this event implies that condensate, feedwater, and main condenser are available for plant response following the transient. For main condenser to remain available, the MSIVs must remain open, turbine bypass valves must continue to function, and all support for the electrohydraulic control system must be available.

Failure of this event (Branch ID #PCS) implies that HPCI will be demanded to operate to provide the high-pressure level control function.

HPI High Pressure Level Control by HPCI. This heading models the high-pressure level control provided by the HPCI system. HPCI must initiate on vessel low water Level 2 and provides makeup to the reactor. Only automatic actuation is considered in this heading. Success of this heading implies that HPCI is available to provide the high-pressure level control function. Failure of this heading (Branch ID HPCI-1) implies that HPCI is unavailable for the vessel level control function and vessel depressurization is required. This event is only asked in this event tree when PCS fails.

BI Boron Injection. This heading models the injection of cold shutdown boron concentration into the reactor by the standby liquid control system (SLCS) during an ATWS event. It includes the conditions under which boron injection must be initiated (i.e., exceeding the boron injection initiation temperature [BIIT]), availability or unavailability of SLCS, and the operator action to initiate the SLCS. Success of this event implies that either the BIIT is not exceeded, or BIIT is exceeded and SLCS is successful. Failure of this event (Branch ID #BI) implies that the BIIT is exceeded and SLCS injection is unsuccessful.

TINJ Termination of High Pressure Injection. This heading models the operator action to terminate all high-pressure injection to lower vessel level as rapidly as possible to near top of active fuel (TAF). This event also includes conditions under which high-pressure injection must be terminated. Conditions which direct the operators to terminate all high-pressure injection are 1) reactor power above 5%, 2) torus temperature exceeding the BIIT, and 3) one or more SRVs discharging to the torus or drywell pressure above 1.85 psig, and level above TAF. Success of this event implies that either termination of high-pressure injection is not required or the operators have successfully terminated all high-pressure injection when required. Failure of this event (Branch ID #TINJ) implies that there is a need to terminate high-pressure injection and the operators have failed in terminating high-pressure injection.

HR **Failure of HPCI to Restart following Termination of Injection to Lower Water Level. This heading (Branch ID #HR) models the restart of HPCI following termination of high-pressure injection for ATWS scenarios.**

ADED Automatic and Emergency Depressurization Conditions. This heading models the automatic and emergency depressurization conditions. The automatic depressurization condition is modeled by generation of the LOCA signal and failure of the operators to inhibit the ADS actuation. LOCA signals include Level 1 and high drywell pressure signals. In addition to a loss of all high-pressure injection, it was assumed that a Level 1 signal would be generated if there is a requirement for termination of all high-pressure injection. Furthermore, failure of the operators to control feedwater, RCIC, and HPCI to lower and control vessel level and thus to reduce reactor power was assumed to cause generation of a Level 1 signal. Failure of drywell cooling (RISKMAN Top Event VC) was assumed to lead to generation of a high drywell pressure signal.

Emergency vessel depressurization is required by the Plant Hatch procedures if the drywell temperature limit is exceeded. Drywell temperature would increase if drywell cooling fails and the operators fail to initiate drywell spray (RISKMAN Top Event OW). Drywell cooling would also be lost if the operators fail to restore drywell cooling following a LOCA signal.

Success of this event implies that there are no automatic and emergency depressurization conditions, or the operators successfully inhibit ADS and restore drywell cooling given a LOCA signal. Failure of this event (Branch IDs #ADEDWS) implies that ADS would be actuated (gate ADWS is true) or the operators are required to initiate emergency vessel depressurization (gate EDWS is true). If gate ADWS is true, the downstream heading DE will also be true since gate ADWS is also included under top logic gate #DEWS. This implies that, if ADS would be actuated (i.e., ADS condition exists and the operators fail to inhibit), the reactor vessel is assumed to successfully depressurize (i.e., no failure in depressurization). Top logic gate ADWS is used in sequences in which a Level 1 condition has occurred (i.e., failure of #BI, #TINJ, #HR, or #PCS and HPCI-1). Failure of top gate ADWS in these sequences (Brach ID ADWS) implies that the operators have failed to inhibit ADS. It is therefore assumed in sequences involving failure of top gate ADWS that vessel is depressurized and downstream heading DE is not asked.

DE Depressurization of Vessel Before Core Damage. This heading models the reduction of vessel pressure to allow low pressure injection. Two top logic gates (#DE and #DEWS) are used under this heading. Top gate #DE includes the manual emergency depressurization actions required when all high-pressure injection sources are lost or power reduction by all other methods is unsuccessful. This top logic gate is only asked in sequences in which top gate ADWS is successful (i.e., no ADS actuation) or #ADEDWS is successful. Success of this event implies that the operators successfully depressurize the reactor vessel to allow injection by the low pressure systems. Failure of this event (Branch ID #DE) implies that reactor vessel remains at high pressure.

In addition to those modeled for #DE, also included in top gate ID #DEWS for sequences involving failure of top logic gate #ADEDWS (i.e., ADS would be actuated or emergency depressurization is required) are logic gates ADWS (i.e., ADS would be actuated) and EDWS (i.e., emergency depressurization is required). Top logic gate #DEWS is only asked when gate #ADEDWS is used and fails. Under top gate #DEWS, gate EDWS is "anded" with gate #DE. Therefore, if gate ADWS under top gate #ADEDWS is true, this event (#DEWS) is also true. It is assumed that the reactor vessel would be successfully depressurized if the ADS actuation has occurred. In other words, automatic vessel depressurization is assumed to occur when both gates ADWS (under #ADEDWS) and #DEWS fail. Success of this event implies that there is no automatic vessel depressurization and the operators have successfully depressurized the vessel given a requirement for emergency depressurization. Failure of this event (Branch ID #DEWS) implies that either an automatic vessel depressurization has occurred, or emergency depressurization is required and the operators fail to manually depressurize.

LO Low Pressure Injection. This heading models the low pressure injection function provided by the condensate, core spray, and low pressure coolant injection (LPCI) systems. Manual control of low pressure injection following vessel depressurization (i.e., control the rate of cold water injection and thus reactivity increase) is also considered in this heading. Success of this event implies that low pressure injection is successful. Failure of this event (Branch ID #LOWS) implies that low pressure injection is unsuccessful.

QR Decay Heat removal. This heading models decay heat removal by shutdown cooling, suppression pool cooling, main condenser, or torus vent. Two different top logic gates were used to model the nodes under this heading. They include #QR and #QT.

In general, top gate #QR is used for decay heat removal which considers main condenser, suppression pool cooling, shutdown cooling, and torus vent. Success implies that the decay heat removal function is successful. Failure (Branch ID #QR) implies that no decay heat removal is available.

For sequences in which HPCI is successful, there is no stuck-open SRV (or no failure of pressure relief), and low pressure injection is unavailable, decay heat removal can be achieved by suppression pool cooling (modeled by top logic gate #QT). Success implies that, with suppression pool cooling, the long term operation of HPCI can be successful. The reactor vessel would remain at high pressure. Failure (Branch ID #QT) implies that high-pressure injection would also be lost due to loss of heat removal.

SEQUENCES

The following descriptions refer to the core damage sequences presented in figure 2.2-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path.

ATWS_3: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 /#PCS /#ADEDWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is successful in providing core cooling (/#PCS). No ADS actuation occurs and no emergency depressurization is required

(/#ADEDWS). Reactor vessel remains at high pressure. However, heat removal function is unsuccessful (#QR) resulting in eventual core damage. Note that #QR is conservatively assumed to be required for long term cooling even though heat removal via main condenser as part of the PCS is successful

ATWS_5: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 /#PCS #ADEDWS /#DEWS /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (#BVPR). All SRVs that open have reclosed successfully (#SORV). Core cooling is initially provided by the power conversion system (/#PCS). The reactor is successfully depressurized due to an emergency depressurization requirement (#ADEDWS, /#DEW). The low pressure injection system successfully provides vessel level control function following vessel depressurization, but heat removal function is unavailable resulting in eventual core damage. Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_6: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 /#PCS #ADEDWS /#DEWS #LOWS

Similar to Sequence ATWS_5 except that low pressure injection is unsuccessful (#LOWS) resulting in eventual core damage.

ATWS_7: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 /#PCS #ADEDWS #DEWS

Similar to Sequence ATWS_5 except that automatic vessel depressurization has occurred or vessel depressurization has failed given an emergency depressurization requirement (#ADEDWS and #DEWS). Core damage is conservatively assumed in this sequence due to the uncontrolled injection of cold water following vessel depressurization or due to failure to depressurize when required.

ATWS_9: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ /#HR /#ADEDWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI is successful in providing high-pressure vessel water level control (/HPCI-1). BIIT is exceeded (due to loss of the PCS and possible discharging through the SRVs) and SLCS injection is successful (/#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection (since SRVs may be discharging) and lowered water level to top of active fuel (/#TINJ). HPCI is successfully restarted (/#HR). However, heat removal function is unsuccessful (#QR) resulting in eventual core damage. Without the heat removal function, eventual depressurization will be required due to Heat Capacity Temperature Limit. Despite successful depressurization (/#DE) and low pressure injection, low pressure injection will be lost due to an overheated or failed suppression pool.

In this sequence, vessel depressurization to allow low pressure injection is not initially needed since HPCI is available. However, failure of suppression pool cooling would cause vessel depressurization due to HCTL concerns as well as failure of the long term HPCI operation. But, vessel depressurization and low pressure injection would be successful (/#DE and /#LOWS). Note that successful lowering of level and subsequently power will put the heat load within bypass capacity thus relieving the load on the torus, if the power conversion system is available.

Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_10B: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ /#HR /#ADEDWS /#DE #LOWS #QT

Similar to Sequence ATWS_9 except that low pressure injection would be unavailable if needed (#LOWS). For HPCI to continue to operate and provide long term core cooling, suppression pool cooling must be available. However, suppression pool cooling is unavailable in this sequence (#QT) resulting in eventual core damage.

ATWS_12: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ /#HR /#ADEDWS #DE #QT

Similar to Sequence ATWS_9 except that vessel depressurization would be unavailable if needed (#DE). For HPCI to continue to operate and provide long term core cooling, suppression pool cooling must be available. However, suppression pool cooling is unavailable in this sequence (#QT) resulting in eventual core damage.

ATWS_14: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ /#HR #ADEDWS /#DEWS /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI is successful in providing high-pressure vessel water level control (/HPCI-1). BIIT is exceeded (due to loss of the PCS and possible discharging through the SRVs) and SLCS injection is successful (/#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection (since SRVs may be discharging) and lowered water level to top of active fuel (/#TINJ). HPCI is successfully restarted (/#HR). However, an emergency vessel depressurization is required and has been successfully achieved. The low pressure systems are successful in providing controlled injection of cold water for vessel inventory makeup. However, the heat removal function is unsuccessful (#QR) resulting in eventual core damage. Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_15: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ /#HR #ADEDWS /#DEWS #LOWS

Similar to Sequence ATWS_14 except that controlled low pressure injection is unsuccessful (#LOWS) resulting in eventual core damage. Compared to Sequence ATWS_6, this is a non-minimal sequence.

ATWS_16: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ /#HR #ADEDWS #DEWS

Similar to Sequence ATWS_14 except that an ADS actuation has occurred or vessel depressurization has failed given an emergency depressurization requirement (#ADEDWS, #DEWS). Core damage is assumed. Compared to Sequence ATWS_7, this is a non-minimal sequence.

ATWS_18: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ #HR /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI is successful in providing high-pressure vessel water level control (/HPCI-1). BIIT is exceeded (due to loss of the PCS and possible discharging through the SRVs) and SLCS injection is successful (/#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection (since SRVs may be discharging) and lowered water level to top of active fuel (/#TINJ). However, HPCI restart is unsuccessful (#HR). Manual depressurization is therefore required to permit low pressure injection for vessel level control. Vessel depressurization (required due to unavailability of all high-pressure injection sources) and low pressure injection are successful (/#DE, /LOWS). Heat removal function is unsuccessful (#QR) resulting in eventual core damage. Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_19: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ #HR /ADWS /#DE #LOWS

Similar to Sequence ATWS_18 except that controlled low pressure injection is unsuccessful (#LOWS) resulting in eventual core damage.

ATWS_20: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ #HR /ADWS #DE

Similar to Sequence ATWS_18 except that vessel depressurization has failed resulting in eventual core damage.

ATWS_21: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI /#TINJ #HR ADWS

Similar to Sequence ATWS_18 except that automatic vessel depressurization has occurred. Core damage is assumed due to the uncontrolled cold water injection from the low pressure injection systems.

ATWS_23: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI #TINJ /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI is successful in providing high-pressure vessel water level control (/HPCI-1). BIIT is exceeded (due to loss of the PCS and possible discharging through the SRVs) and SLCS injection is successful (/#BI). The operators fail to terminate high-pressure injection (since SRVs may be discharging) and lower water level to top of active fuel (#TINJ). High pressure injection from HPCI is not sufficient to maintain operating water level for a full power ATWS. As such, reactor water level will decrease to a point where power matches flowrate: around 20% for HPCI. This is getting close to the Top of Active Fuel (TAF). Based on the torus approaching the HCTL, manual depressurization is conservatively assumed to be required in this sequence to prevent containment and core damage. Vessel depressurization and controlled low pressure injection are successful (/#DE, /LOWS). Heat removal function is unsuccessful (#QR) resulting in eventual core damage due to loss of suction source for low pressure injection. Note that reactor power at lowered water level should be within bypass capacity which would serve to remove the heat load from containment, if available.

Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_24: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI #TINJ /ADWS /#DE #LOWS

Similar to Sequence ATWS_23 except that controlled low pressure injection is unsuccessful (#LOWS) resulting in eventual core damage.

ATWS_25: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI #TINJ /ADWS #DE

Similar to Sequence ATWS_23 except that vessel depressurization has failed (#DE), following failure to reduce power by lowering vessel level to TAF when needed. Core damage therefore conservatively results from fuel being uncovered from lack of low pressure injection.

ATWS_26: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 /#BI #TINJ ADWS

Similar to Sequence ATWS_23 except that automatic vessel depressurization has occurred (ADWS). Core damage is assumed due to the uncontrolled cold water injection from the low pressure injection systems.

ATWS_28: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ /#HR /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI is successful in providing high-pressure vessel water level control (/HPCI-1). BIIT is exceeded (due to loss of the PCS and possible discharging through the SRVs) and SLCS injection is unsuccessful (#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection (since SRVs may be discharging) and lowered water level to top of active fuel (/#TINJ). Manual depressurization is performed to further reduce reactivity. Vessel depressurization and controlled low pressure injection are successful (/#DE, /LOWS). However, the heat removal function is unsuccessful (#QR). Operation of HPCI will lead to the need for depressurization due to HCTL being approached. Without long term cooling, the torus will be lost as a suction source to low pressure systems. Without low pressure injection, the core will become uncovered and damage will occur. Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_29: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ /#HR /ADWS /#DE #LOWS

Similar to Sequence ATWS_28 except that controlled low pressure injection is unsuccessful resulting in eventual core damage.

ATWS_31: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ /#HR /ADWS #DE #QT

Similar to Sequence ATWS_28 except that vessel depressurization is not performed and suppression pool fails resulting in eventual core damage. In this sequence, HPCI is the only source for vessel water level control. Long term operation of HPCI requires successful suppression pool cooling. Compared to Sequence ATWS_12, this is a non-minimal sequence.

ATWS_32: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ /#HR ADWS

Similar to Sequence ATWS_28 except that automatic vessel depressurization has occurred. Core damage is assumed due to the uncontrolled injection of cold water from the low pressure systems..

ATWS_34: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ #HR /ADWS /#DE /#LOWS #QR

Similar to Sequence ATWS_18 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_35: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ #HR /ADWS /#DE #LOWS

Similar to Sequence ATWS_19 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_19, this is a non-minimal sequence.

ATWS_36: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ #HR /ADWS #DE

Similar to Sequence ATWS_20 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_20, this is a non-minimal sequence.

ATWS_37: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI /#TINJ #HR ADWS

Similar to Sequence ATWS_21 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_21, this is a non-minimal sequence.

ATWS_39: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI #TINJ /ADWS /#DE /#LOWS #QR

Similar to Sequence ATWS_23 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_40: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI #TINJ /ADWS /#DE #LOWS

Similar to Sequence ATWS_24 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_24, this is a non-minimal sequence.

ATWS_41: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI #TINJ /ADWS #DE

Similar to Sequence ATWS_25 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_25, this is a non-minimal sequence.

ATWS_42: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS /HPCI-1 #BI #TINJ ADWS

Similar to Sequence ATWS_26 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_26, this is a non-minimal sequence.

ATWS_44: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS HPCI-1 /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). All SRVs that open have reclosed successfully (#SORV0). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI is unavailable in providing high-pressure vessel water level control (/HPCI-1). Manual depressurization is required to allow vessel inventory control by the low pressure injection systems. Vessel depressurization and controlled low pressure injection are successful (/ADWS, /#DE, /LOWS). However, the heat removal function is unsuccessful (#QR) resulting in eventual core damage. Note that, at this point, the power level is within bypass valve capacity. If the power conversion system is available, it can limit the energy being dumped to the suppression pool.

Compared to Sequence ATWS_3, this is a non-minimal sequence.

ATWS_45: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS HPCI-1 /ADWS /#DE #LOWS

Similar to Sequence ATWS_44 except that controlled low pressure injection is unsuccessful resulting in eventual core damage.

ATWS_46: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS HPCI-1 /ADWS #DE

Similar to Sequence ATWS_44 except that vessel depressurization has failed resulting in eventual core damage.

ATWS_47: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS HPCI-1 ADWS

Similar to Sequence ATWS_44 except that an ADS actuation has occurred. Core damage is assumed due to the uncontrolled injection of cold water by the low pressure systems.

ATWS_49: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ /#HR /#ADEDWS /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). One SRV sticks open after opening (#SORV1). The power conversion system is successful in providing core cooling (/#PCS). BIIT is exceeded (due to the stuck-open SRV) and SLCS injection is successful (/#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection and lowered water level to top of active fuel (/#TINJ). HPCI is successfully started (/#HR). There are no ADS actuation and emergency depressurization requirement. Due to the stuck-open SRV, reactor vessel is eventually depressurized and low pressure injection is successful. The heat removal function is unsuccessful (#QR) resulting in eventual core damage. Similar to Sequence ATWS_3, this is a conservative assumption since main condenser as part of the power conversion system is available.

ATWS_50: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ /#HR /#ADEDWS #LOWS

Similar to Sequence ATWS_49 except that low pressure injection is unsuccessful (#LOWS) resulting in eventual core damage.

ATWS_52: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ /#HR #ADEDWS /#DEWS /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). One SRV sticks open after opening (#SORV1). The power conversion system is successful in providing core cooling (/#PCS). BIIT is exceeded (due to the stuck-open SRV) and SLCS injection is successful (/#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection and lowered water level to top of active fuel (/#TINJ). HPCI is successfully started (/#HR). An emergency depressurization is required and manual operator depressurization is successful. Low pressure injection is successful following vessel depressurization. The heat removal function is unsuccessful (#QR) resulting in eventual core damage. Without torus cooling, a part of #QR, the low pressure injection systems would lose their suction source. The loss of low pressure injection would cause core damage due to core uncovery. Similar to Sequence ATWS_49, this is a conservative assumption since main condenser as part of the power conversion system is available. Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_53: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ /#HR #ADEDWS /#DEWS #LOWS

Similar to Sequence ATWS_52 except that low pressure injection is unavailable. Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_54: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ /#HR #ADEDWS #DEWS

Similar to Sequence ATWS_52 except that an ADS actuation has occurred or emergency depressurization is required and the operators fail to depressurize. Core damage is assumed for this sequence.

ATWS_56: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ #HR /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). One SRV sticks open (#SORV1). The power conversion system is successful in providing core cooling (/#PCS). BIIT is exceeded (due to the stuck-open SRV) and SLCS injection is successful (/#BI). To reduce reactor power, the operators have successfully terminated all high-pressure injection and lowered water level to top of active fuel (/#TINJ). HPCI start is unsuccessful (#HR). Vessel depressurization and low pressure injection are successful (/#DE, /LOWS). Heat removal function is unsuccessful (#QR) resulting in eventual core damage. Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_57: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ #HR

/ADWS /#DE #LOWS

Similar to Sequence ATWS_56 except that low pressure injection is unavailable (#LOWS) resulting in eventual core damage. Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_58: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ #HR /ADWS #DE

Similar to Sequence ATWS_56 except that vessel depressurization has failed resulting in eventual core damage due to core uncovery.

ATWS_59: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ #HR ADWS

Similar to Sequence ATWS_56 except that automatic vessel depressurization has occurred. Core damage is assumed due to the uncontrolled cold water injection.

ATWS_61: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI #TINJ /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). One SRV sticks open (#SORV1). The power conversion system is successful in providing core cooling (/#PCS). BIIT is exceeded (due to the stuck-open SRV) and SLCS injection is successful (/#BI). The operators fail to terminate high-pressure injection and lower water level to top of active fuel (#TINJ). Manual depressurization is assumed to be required to reduce reactivity. Manual vessel depressurization and low pressure injection are successful (/#DE, /LOWS). Heat removal function is unsuccessful (#QR) resulting in eventual core damage. Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_62: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI #TINJ /ADWS /#DE #LOWS

Similar to Sequence ATWS_61 except that low pressure injection is unsuccessful (#LOWS) resulting in eventual core damage. Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_63: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI #TINJ /ADWS #DE

Similar to Sequence ATWS_61 except that manual vessel depressurization has failed (#DE) resulting in eventual core damage.

ATWS_64: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI #TINJ ADWS

Similar to Sequence ATWS_61 except that automatic vessel depressurization has occurred (ADWS). Core damage is assumed due to uncontrolled injection.

ATWS_66: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ /#HR /#ADEDWS /#LOWS #QR

Similar to Sequence ATWS_49 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_67: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ /#HR /#ADEDWS #LOWS

Similar to Sequence ATWS_50 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_69: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ /#HR #ADEDWS /#DEWS /#LOWS #QR

Similar to Sequence ATWS_52 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_70: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ /#HR #ADEDWS /#DEWS #LOWS

Similar to Sequence ATWS_53 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_71: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ /#HR #ADEDWS #DEWS

Similar to Sequence ATWS_54 except that boron injection is unsuccessful (#BI). Compared to Sequence ATWS_54, this is a non-minimal sequence.

ATWS_73: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ #HR /ADWS /#DE /#LOWS #QR

Similar to Sequence ATWS_56 except that boron injection has failed (#BI). Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_74: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ #HR /ADWS /#DE #LOWS

Similar to Sequence ATWS_57 except that boron injection has failed (#BI). Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_75: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ #HR /ADWS #DE

Similar to Sequence ATWS_58 except that boron injection has failed (#BI). Compared to Sequence ATWS_58, this is a non-minimal sequence.

ATWS_76: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI /#TINJ #HR ADWS

Similar to Sequence ATWS_59 except that boron injection has failed (#BI). Compared to Sequence ATWS_59, this is a non-minimal sequence.

ATWS_78: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI #TINJ /ADWS /#DE /#LOWS #QR

Similar to Sequence ATWS_61 except that boron injection has failed (#BI). Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_79: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS #BI #TINJ /ADWS /#DE #LOWS

Similar to Sequence ATWS_62 except that boron injection has failed (#BI). Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_80: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI #TINJ /ADWS #DE

Similar to Sequence ATWS_63 except that boron injection has failed (#BI). Compared to Sequence ATWS_63, this is a non-minimal sequence.

ATWS_81: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI #TINJ ADWS

Similar to Sequence ATWS_64 except that boron injection has failed (#BI). Compared to Sequence ATWS_64, this is a non-minimal sequence.

ATWS_83: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ /#HR /#ADEDWS /#LOWS #QR

Similar to Sequence ATWS_49 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_84: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 /#PCS /#BI /#TINJ /#HR /#ADEDWS #LOWS

Similar to Sequence ATWS_50 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_50 this is a non-minimal sequence.

ATWS_86: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ /#HR #ADEDWS /#DEWS /#LOWS #QR

Similar to Sequence ATWS_52 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_52 this is a non-minimal sequence.

ATWS_87: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ /#HR #ADEDWS /#DEWS #LOWS

Similar to Sequence ATWS_53 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_53 this is a non-minimal sequence.

ATWS_88: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ /#HR #ADEDWS #DEWS

Similar to Sequence ATWS_54 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_54 this is a non-minimal sequence.

ATWS_90: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ #HR /ADWS /#DE /#LOWS #QR

Similar to Sequence ATWS_56 except that power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_49 this is a non-minimal sequence.

ATWS_91: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ #HR /ADWS /#DE #LOWS

Similar to Sequence ATWS_57 except that power conversion system is unavailable and HPCI is successful in providing core cooling initially following the transient. Compared to Sequence ATWS_50 this is a non-minimal sequence.

ATWS_92: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ #HR /ADWS #DE

Similar to Sequence ATWS_58 except that power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_58 this is a non-minimal sequence.

ATWS_93: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI /#TINJ #HR ADWS

Similar to Sequence ATWS_59 except that power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_59 this is a non-minimal sequence.

ATWS_95: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI #TINJ /ADWS /#DE /#LOWS #QR

Similar to Sequence ATWS_61 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_49 this is a non-minimal sequence.

ATWS_96: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI #TINJ /ADWS /#DE #LOWS

Similar to Sequence ATWS_62 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_50 this is a non-minimal sequence.

ATWS_97: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI #TINJ /ADWS #DE

Similar to Sequence ATWS_63 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_63 this is a non-minimal sequence.

ATWS_98: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 /#BI #TINJ ADWS

Similar to Sequence ATWS_64 except that the power conversion system is unavailable (#PCS) and HPCI is successful in providing core cooling initially following the transient (/HPCI-1). Compared to Sequence ATWS_64 this is a non-minimal sequence.

ATWS_100: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 #BI /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). One SRV sticks open (#SORV1). The power conversion system is unsuccessful in providing core cooling (#PCS). HPCI-1 is successful in providing core cooling during the initial period following the transient (/HPCI-1). BIIT is exceeded (due to the stuck-open SRV) and SLCS injection is unsuccessful (#BI). No ADS actuation has occurred. Manual vessel depressurization and low pressure injection are successful (/#DE, /LOWS). Heat removal function is unsuccessful (#QR) resulting in eventual core damage. Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_101: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 #BI /ADWS /#DE #LOWS

Similar to Sequence ATWS_100 except that low pressure injection is unavailable (#LOWS) resulting in eventual core damage. Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_102: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 #BI /ADWS #DE

Similar to Sequence ATWS_100 except that manual vessel depressurization has failed resulting in eventual core damage.

ATWS_103: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS /HPCI-1 #BI ADWS

Similar to Sequence ATWS_100 except that automatic vessel depressurization has occurred. Core damage is assumed due to the uncontrolled injection of cold water from low pressure systems.

ATWS_105: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS HPCI-1 /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). One SRV sticks open (#SORV1). Both the power conversion system and HPCI are unsuccessful in providing core cooling (#PCS, HPCI-1). Manual vessel depressurization is required to allow low pressure injection for core cooling. No ADS actuation has occurred. Vessel depressurization and low pressure injection are successful (/#DE, /LOWS). The heat removal function is unsuccessful (#QR) resulting in eventual core damage. Compared to Sequence ATWS_49, this is a non-minimal sequence.

ATWS_106: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS HPCI-1 /ADWS /#DE #LOWS

Similar to Sequence ATWS_105 except that low pressure injection is unavailable resulting in eventual core damage. Compared to Sequence ATWS_50, this is a non-minimal sequence.

ATWS_107: IEGATWS #RSCRAM /RPT /#BVPR #SORV1 #PCS HPCI-1 /ADWS #DE

Similar to Sequence ATWS_105 except that manual vessel depressurization is unsuccessful resulting in eventual core damage due to lack of low pressure injection.

ATWS_108: IEGATWS #RSCRAM /RPT /#BVPR #SORV0 #PCS HPCI-1 ADWS

Similar to Sequence ATWS_105 except that ADS actuation has occurred. Core damage is assumed due to the uncontrolled injection of cold water from low pressure systems.

ATWS_110: IEGATWS #RSCRAM /RPT /#BVPR #SORV2 /ADWS /#DE /#LOWS #QR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). Two SRVs stick open (#SORV2). Both the power conversion system and HPCI will eventually become ineffective due to the vessel pressure decrease through the stuck-open SRVs. Manual vessel depressurization (conservatively assumed to be required) and low-pressure injection are successful (/ADWS, #DE, #LOWS). However, the heat removal function is unavailable (#QR) resulting in eventual core damage.

ATWS_111 IEGATWS #RSCRAM /RPT /#BVPR #SORV2 /ADWS /#DE #LOWS

Similar to Sequence ATWS_110 except that low pressure injection is unavailable (#LOWS) resulting in eventual core damage.

ATWS_112 IEGATWS #RSCRAM /RPT /#BVPR #SORV2 /ADWS #DE

Similar to Sequence ATWS_110 except that manual depressurization (#DE) is unsuccessful resulting in eventual core damage.

ATWS_113 IEGATWS #RSCRAM /RPT /#BVPR #SORV2 ADWS

Similar to Sequence ATWS_110 except that automatic vessel depressurization has occurred. Core damage is assumed due to the uncontrolled injection of cold water by the low pressure systems.

ATWS_114 IEGATWS #RSCRAM /RPT /#BVPR #SORV3

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief is provided by the turbine bypass valves and SRVs (/#BVPR). Three or more SRVs stick open (#SORV3). Rapid vessel depressurization occurs. It is assumed that core damage results due to uncontrolled injection.

ATWS_115 IEGATWS #RSCRAM /RPT #BVPR

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Both recirculation pumps trip (/RPT). Initial vessel pressure relief by the turbine bypass valves and SRVs is unsuccessful (#BVPR). Core damage is assumed.

ATWS_116 IEGATWS #RSCRAM RPT

Following the occurrence of a transient, reactor shutdown by the RPS, ARI, and manual operator action is unsuccessful (#RSCRAM). Recirculation pump trip fails (RPT). Core damage is assumed.

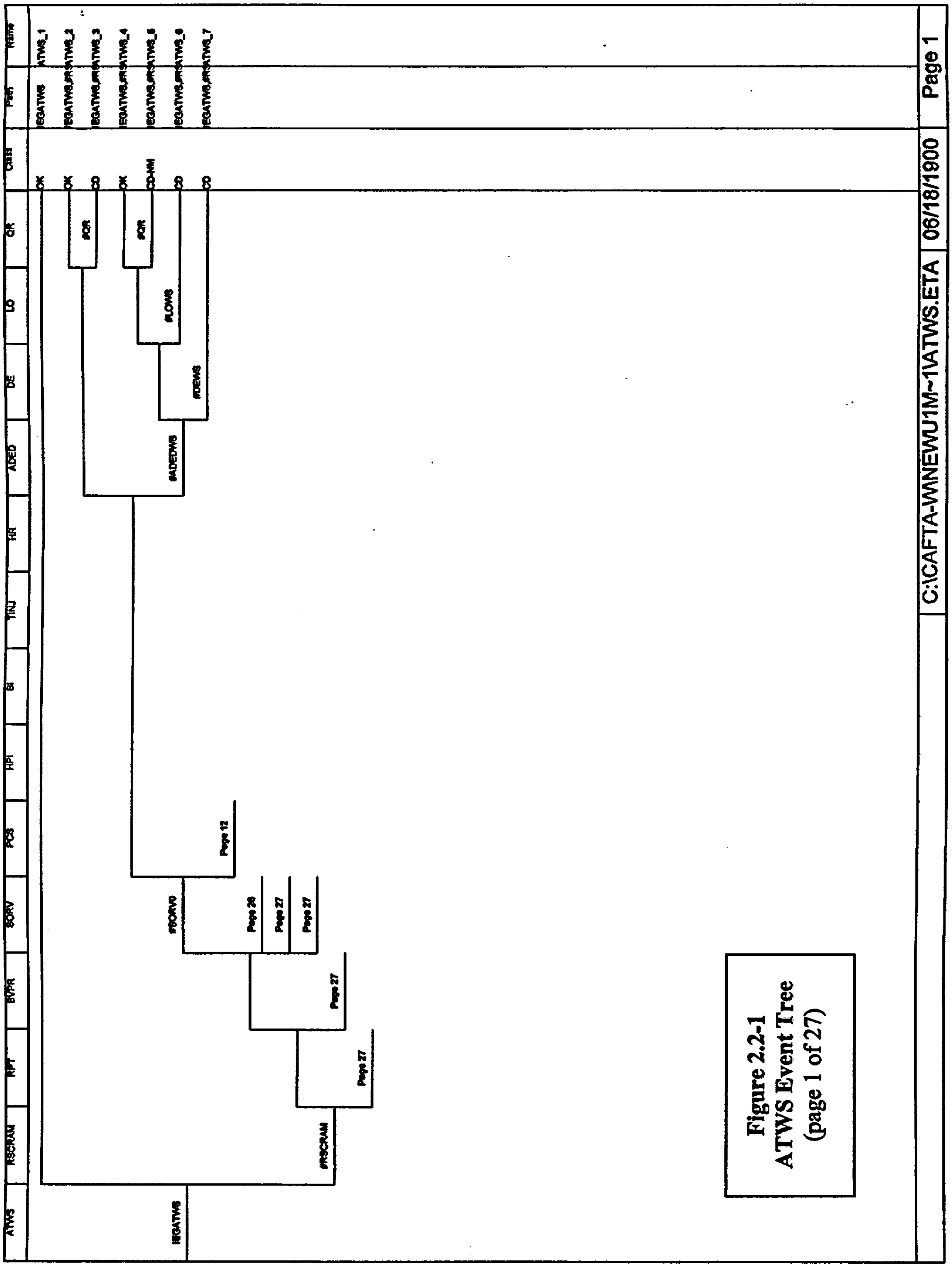

Figure 2.2-1
ATWS Event Tree
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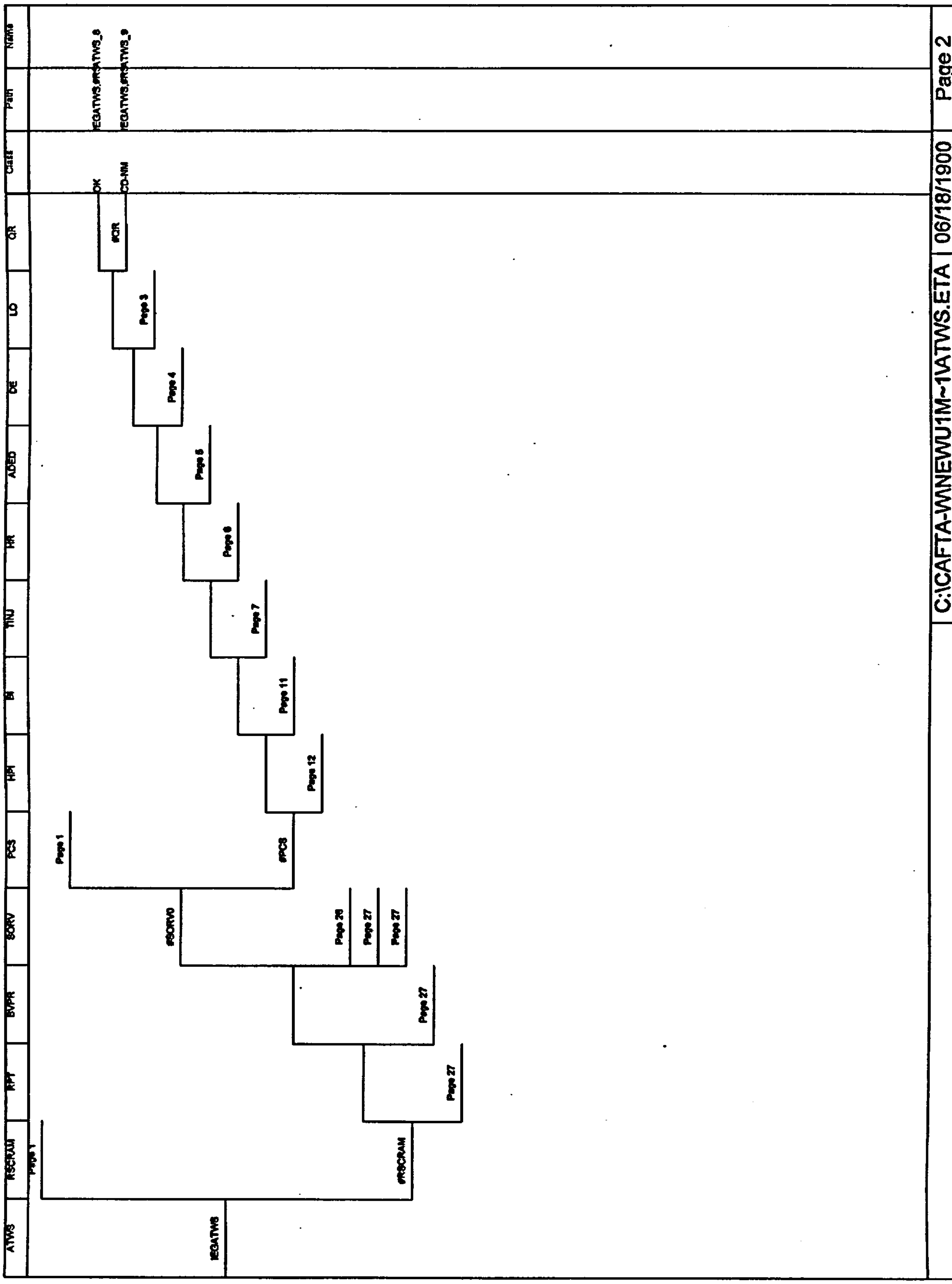
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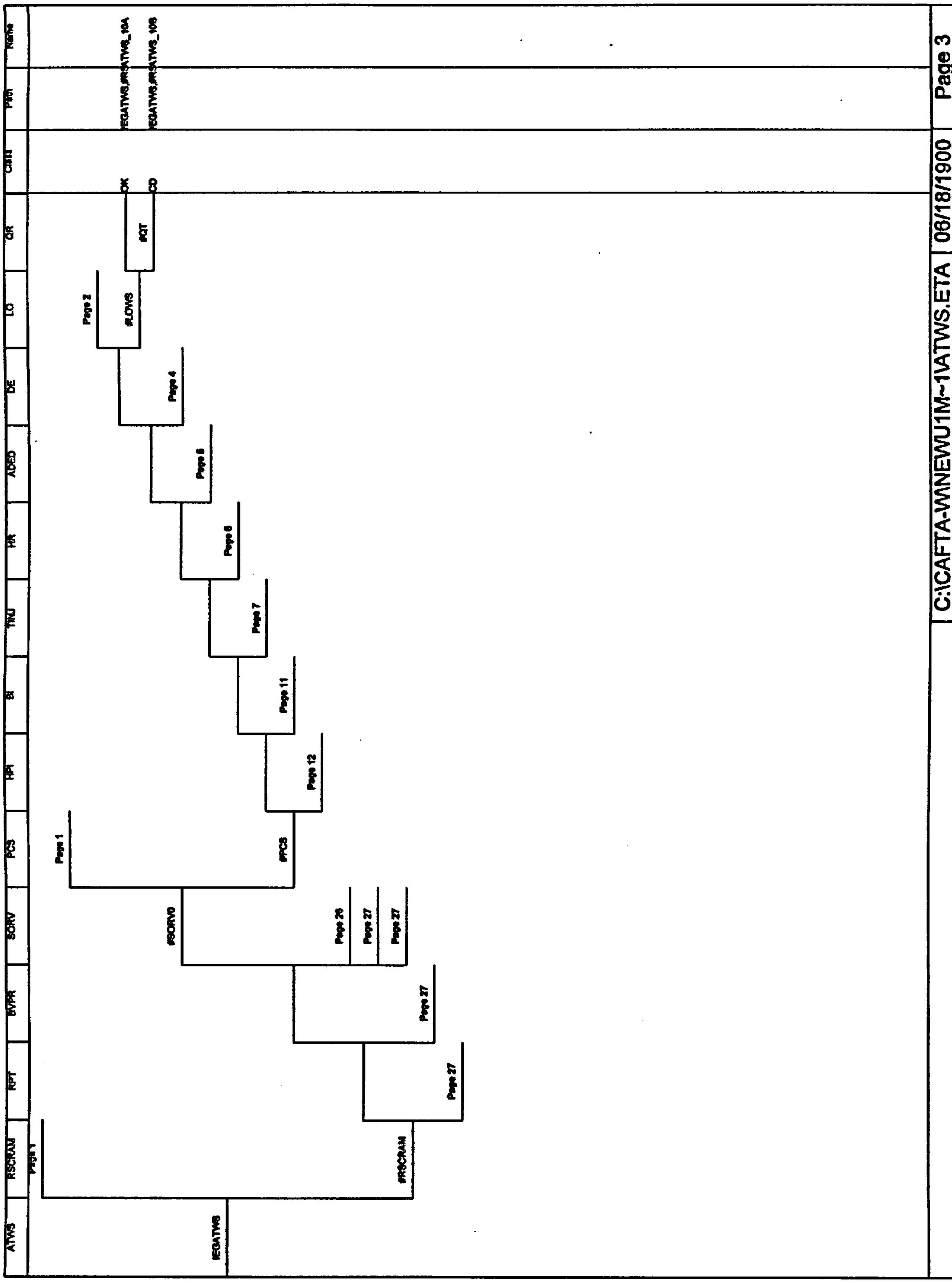
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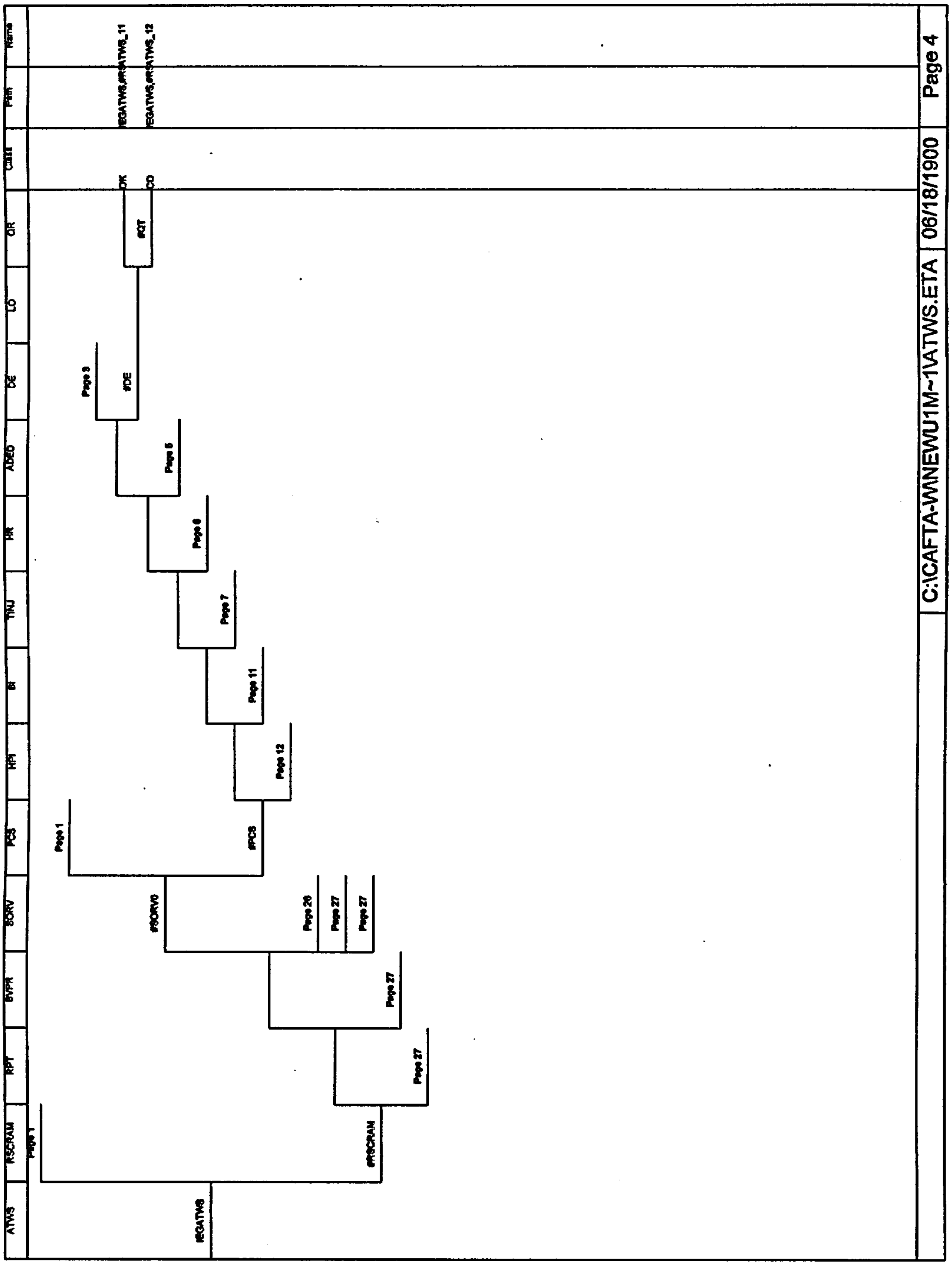
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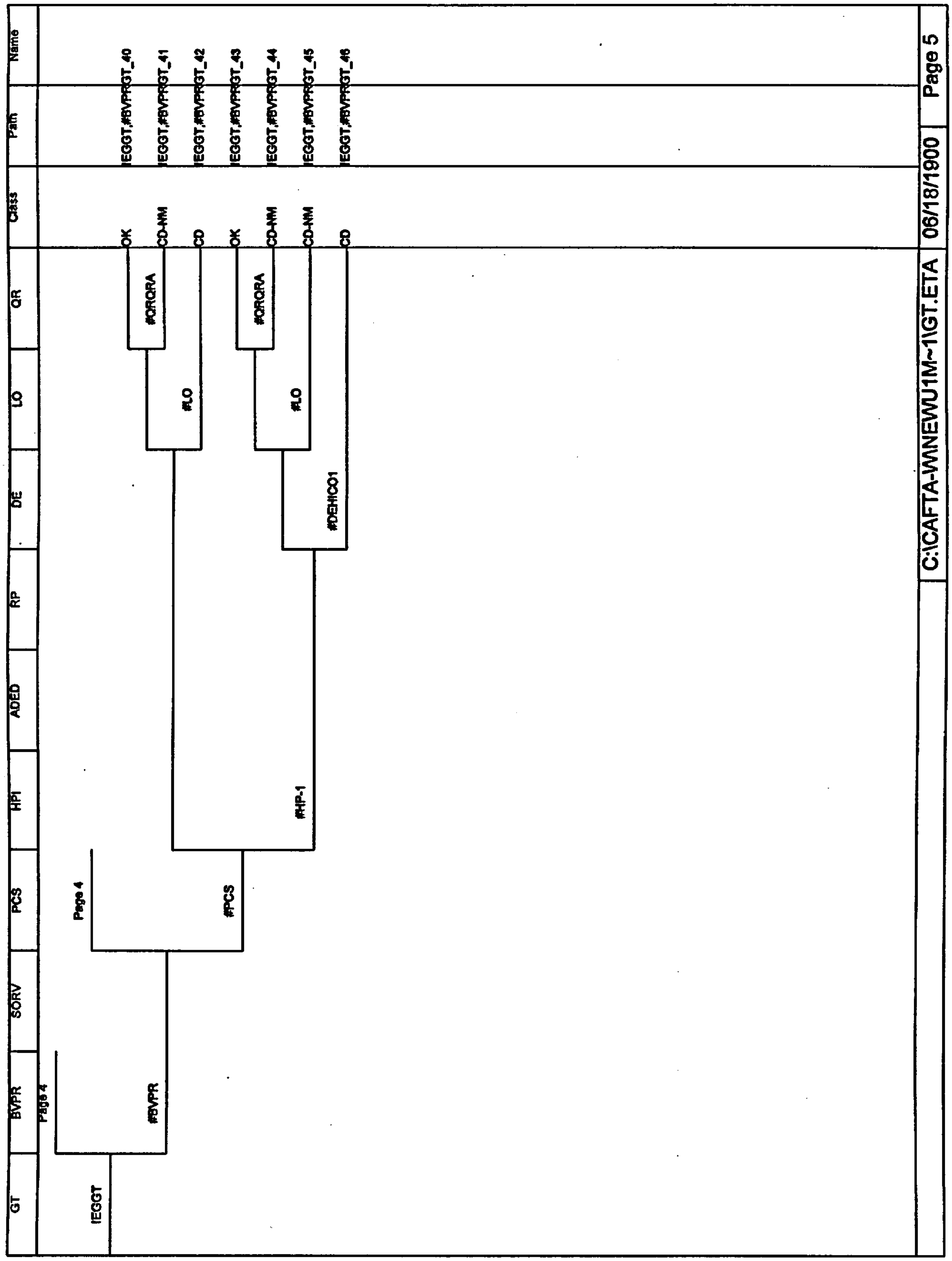
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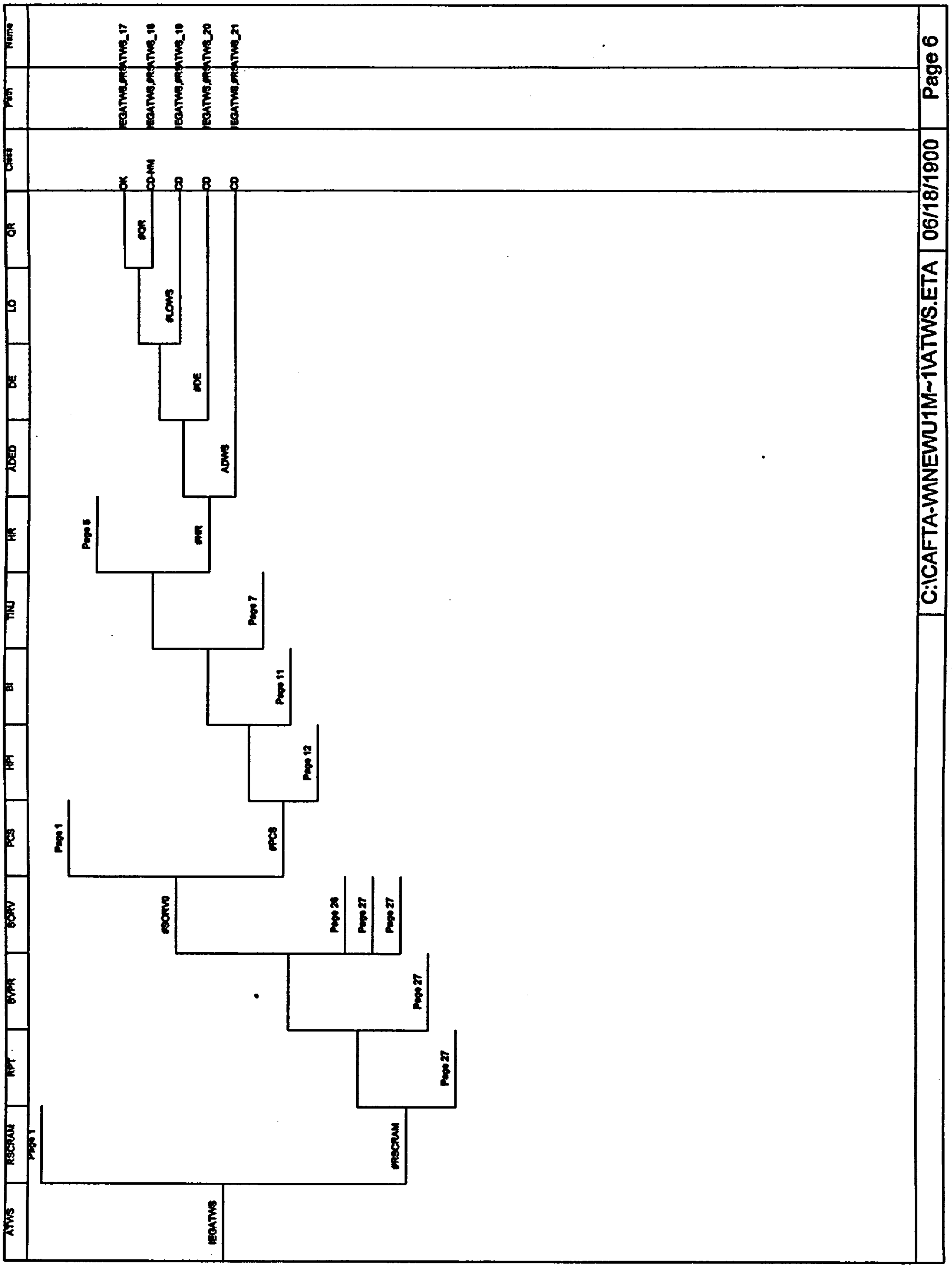
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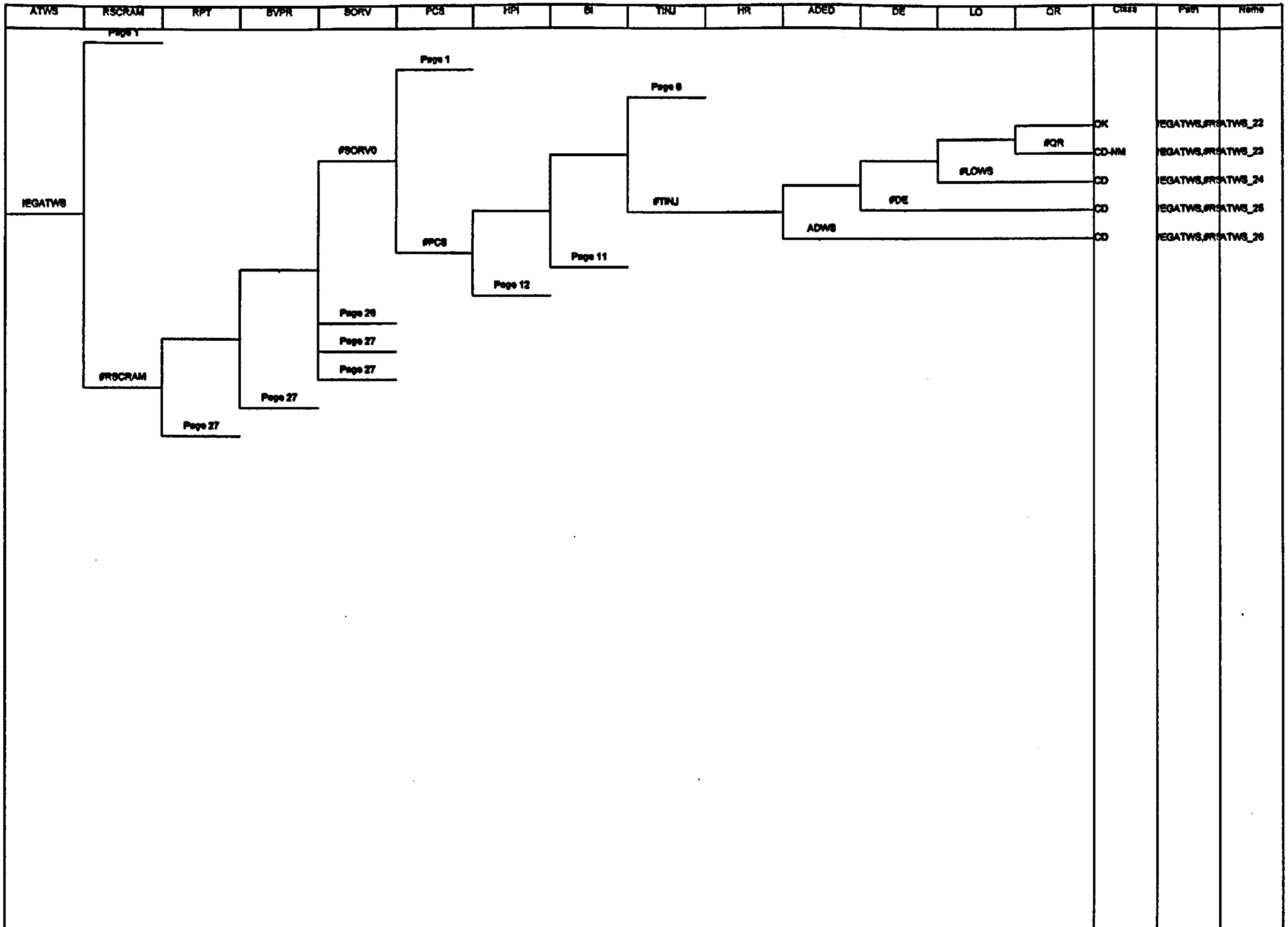
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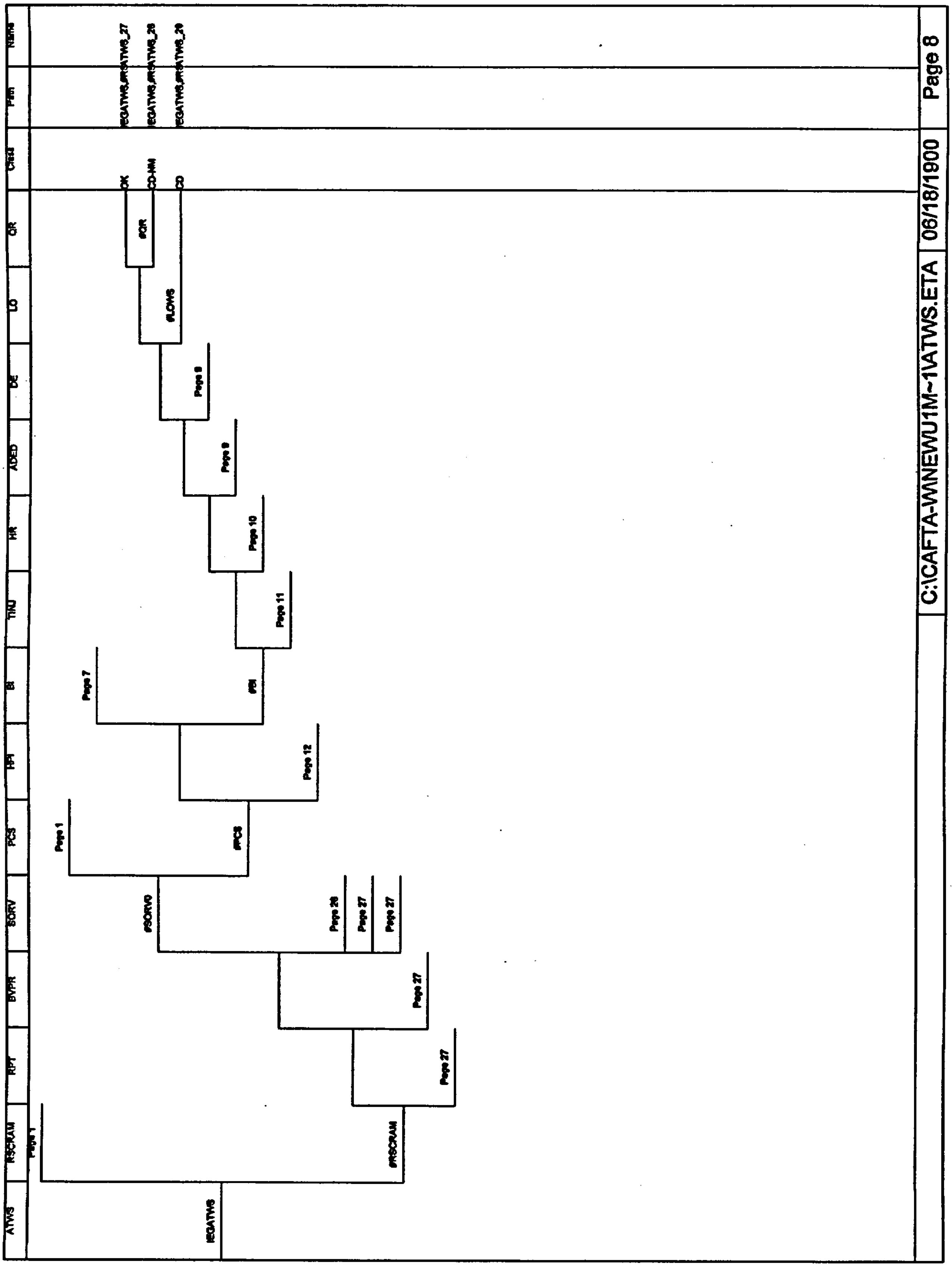
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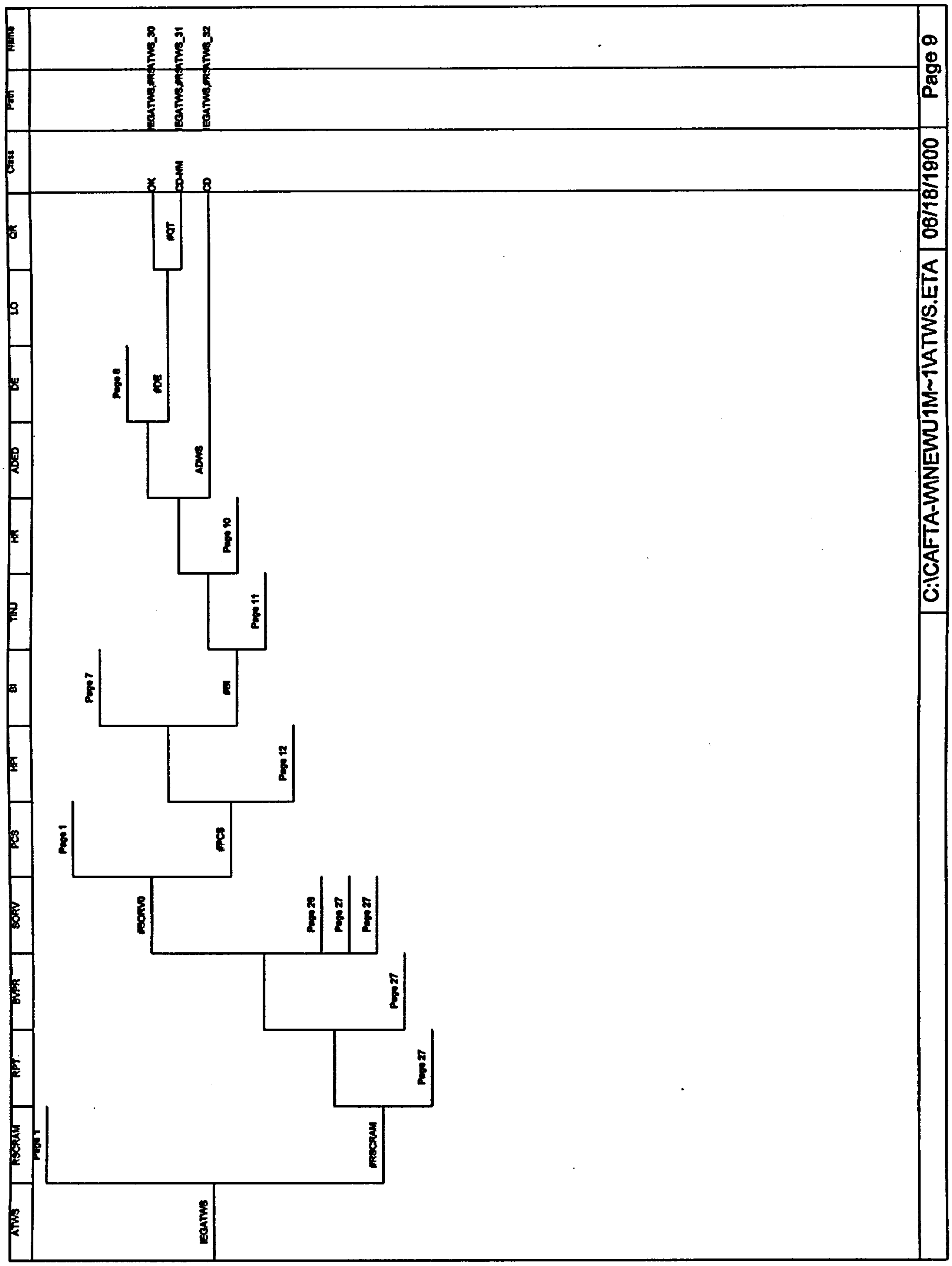
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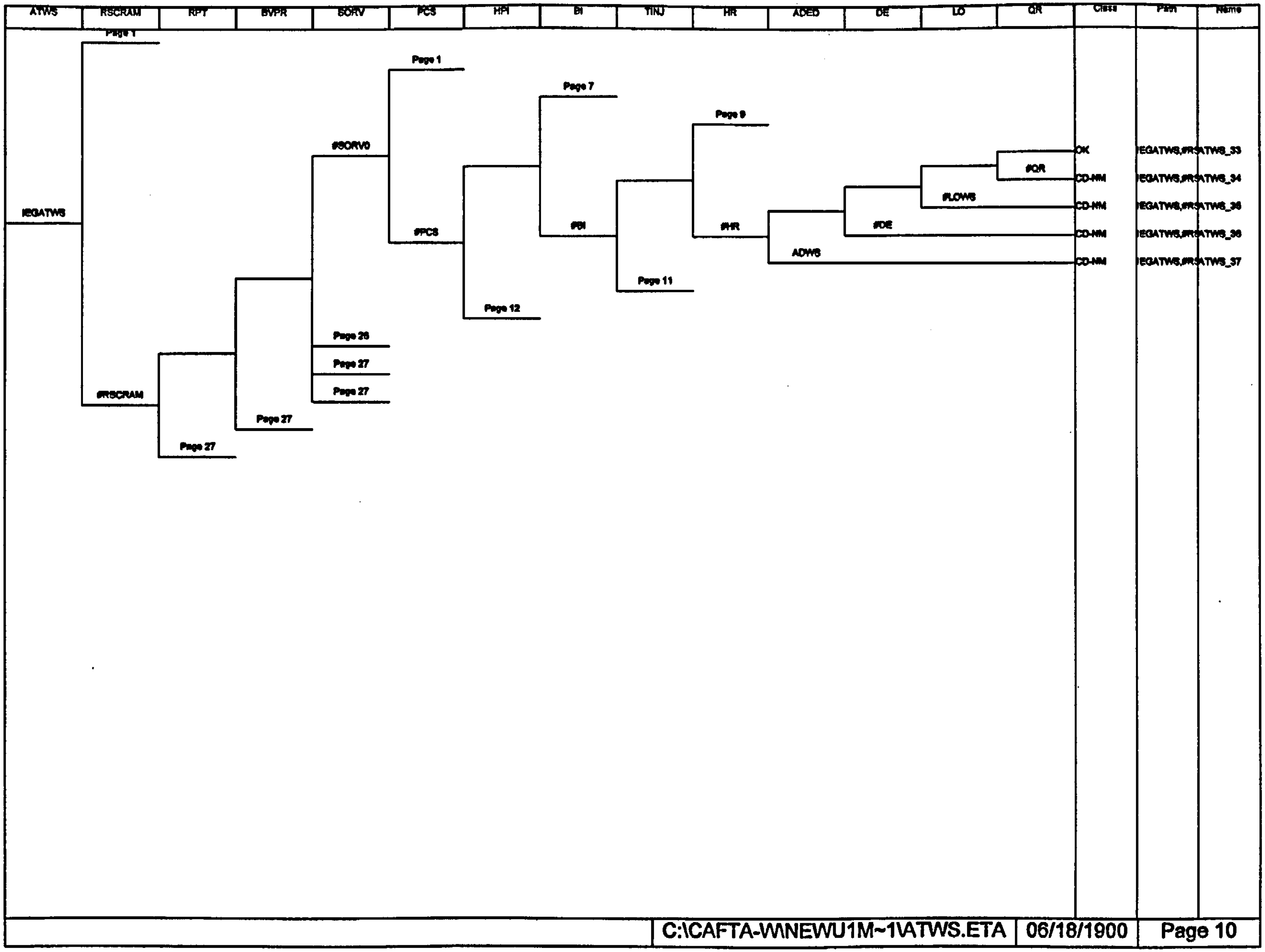
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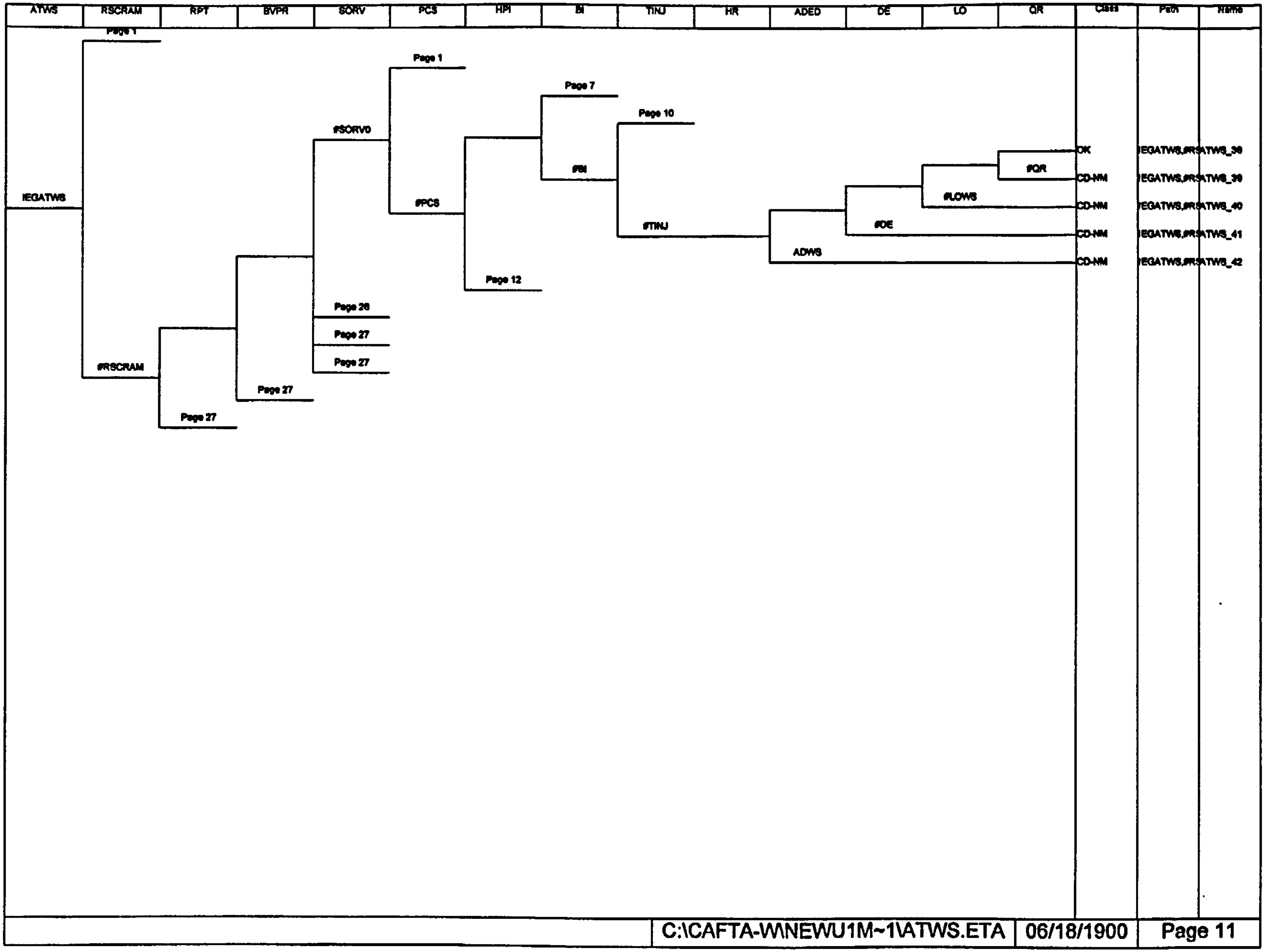
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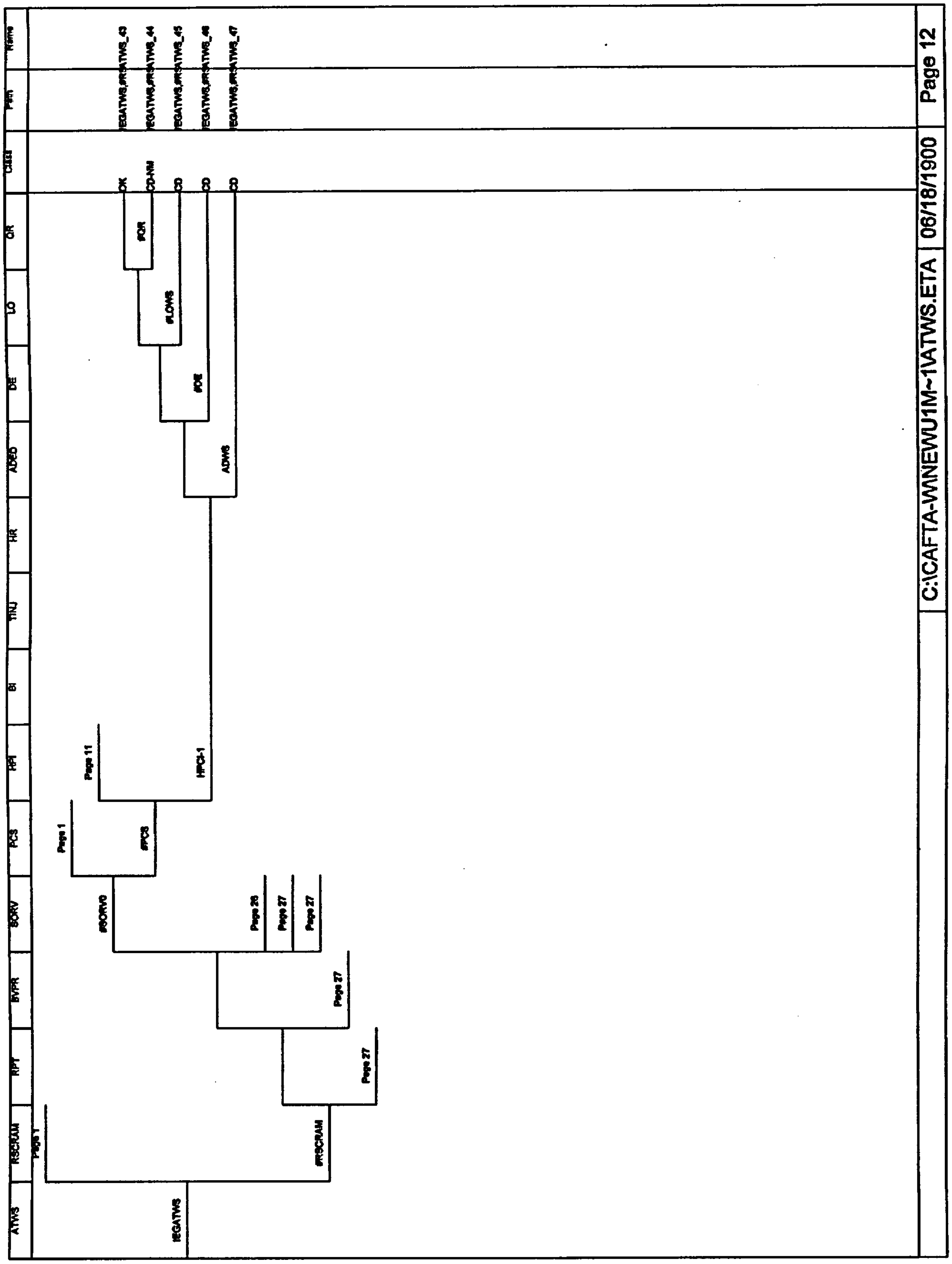
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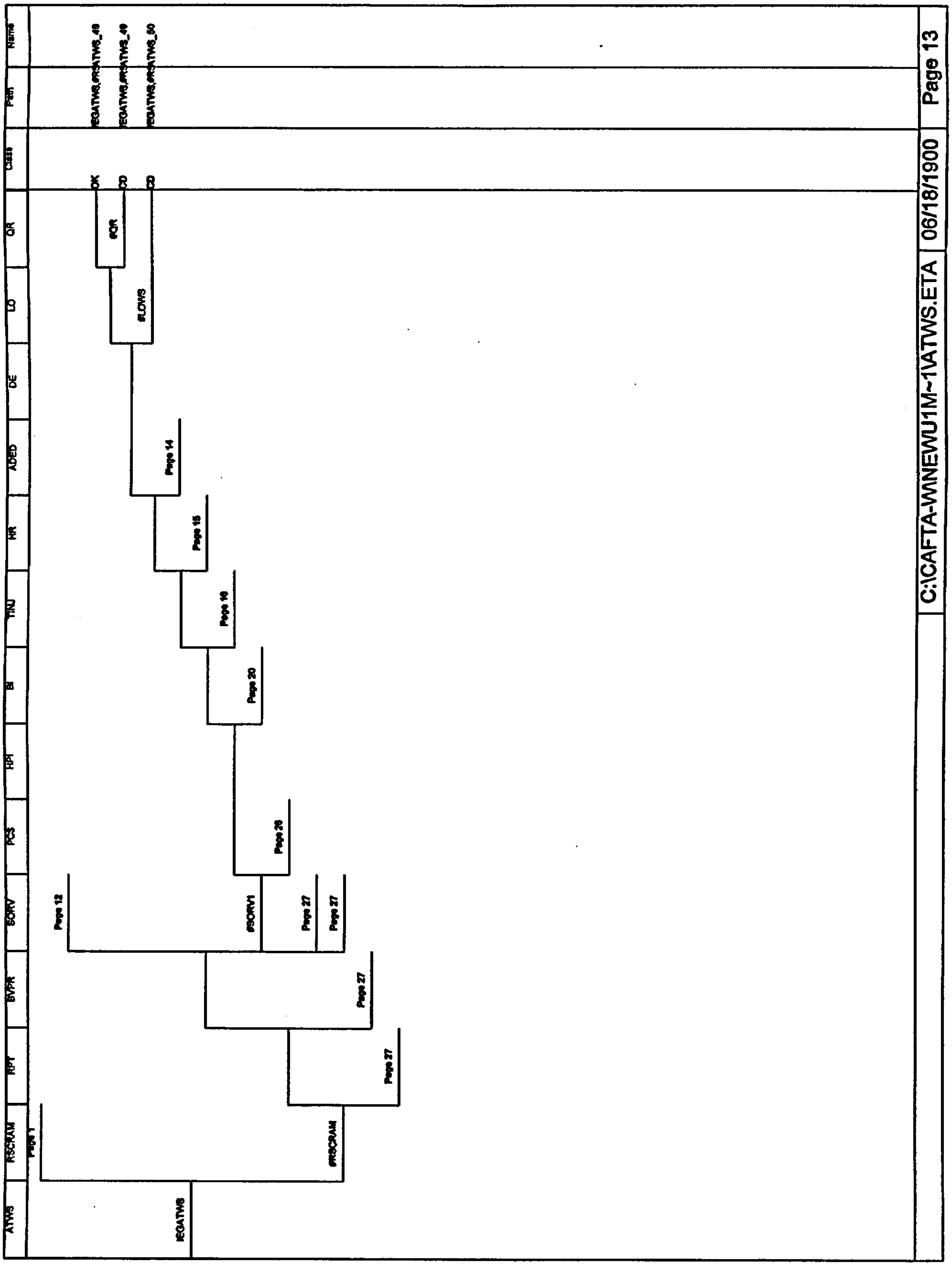
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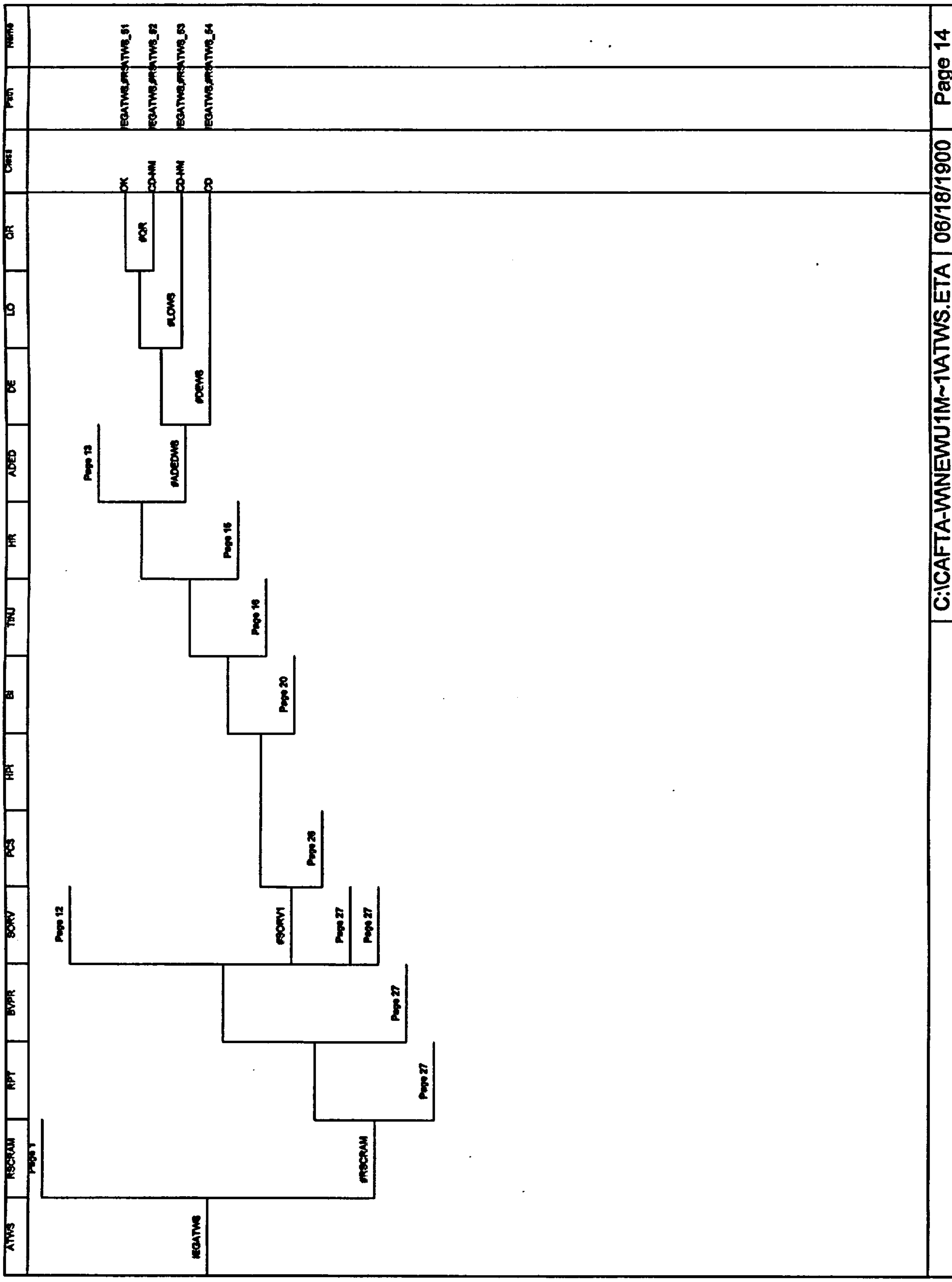
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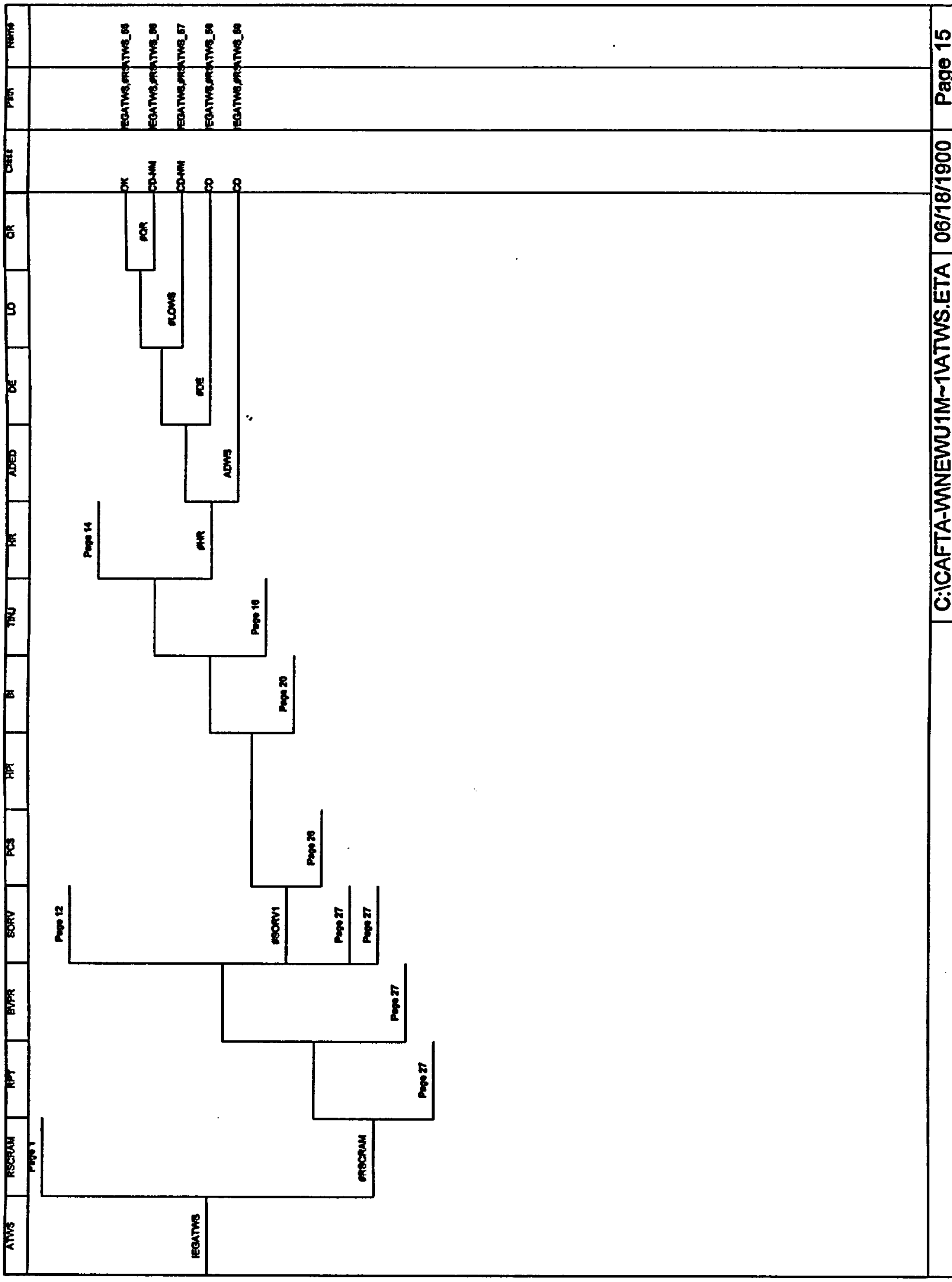
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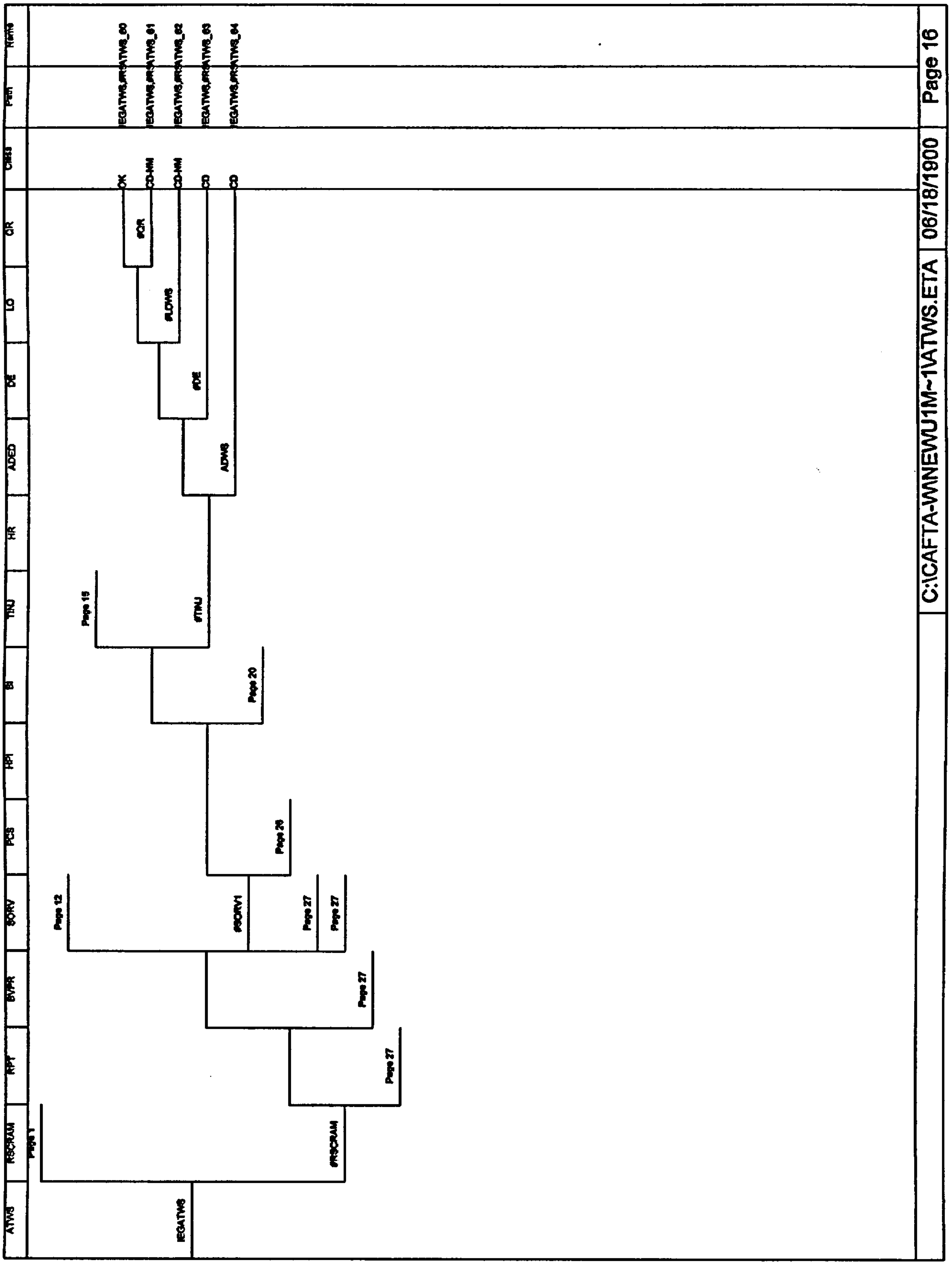
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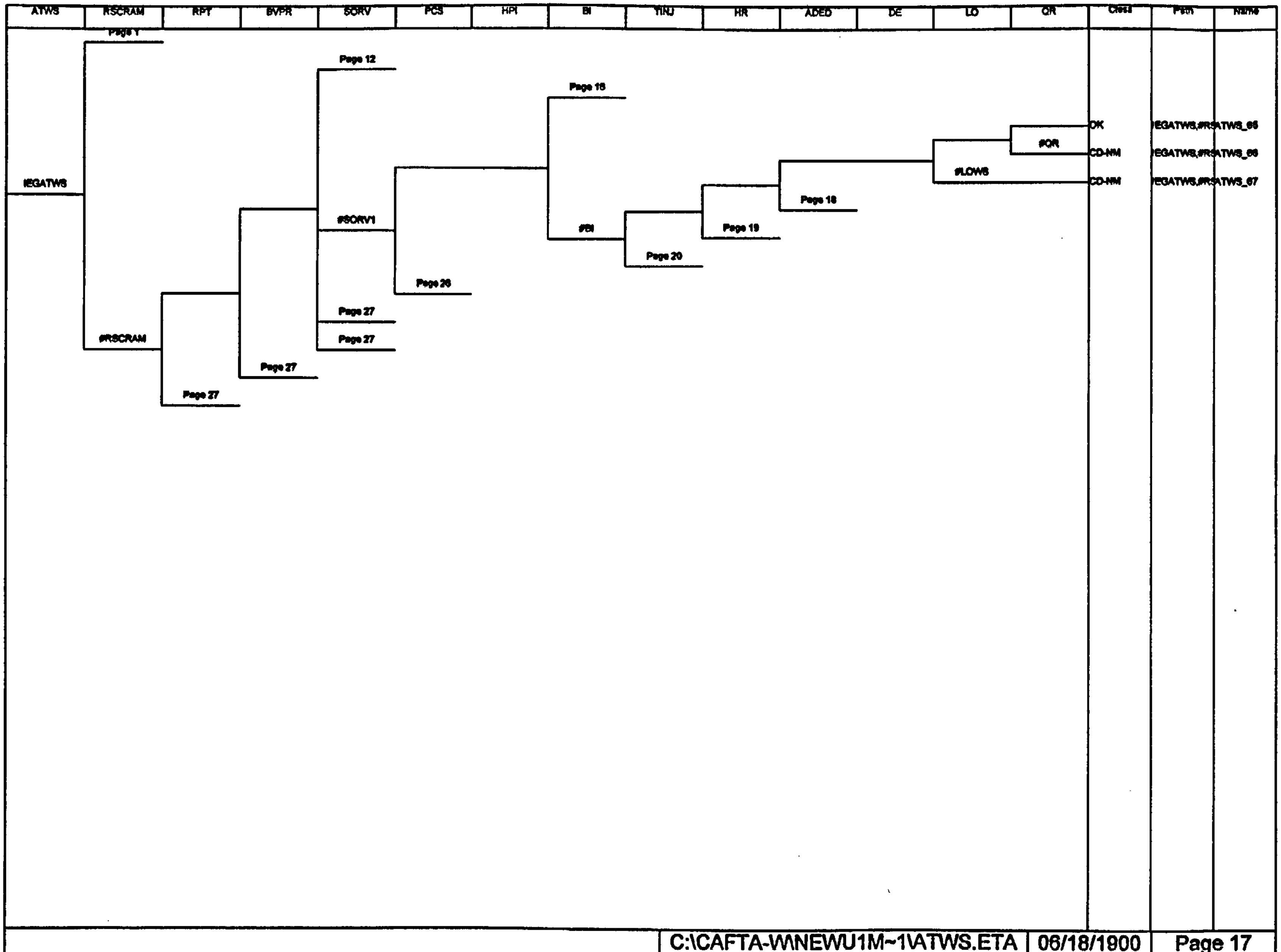
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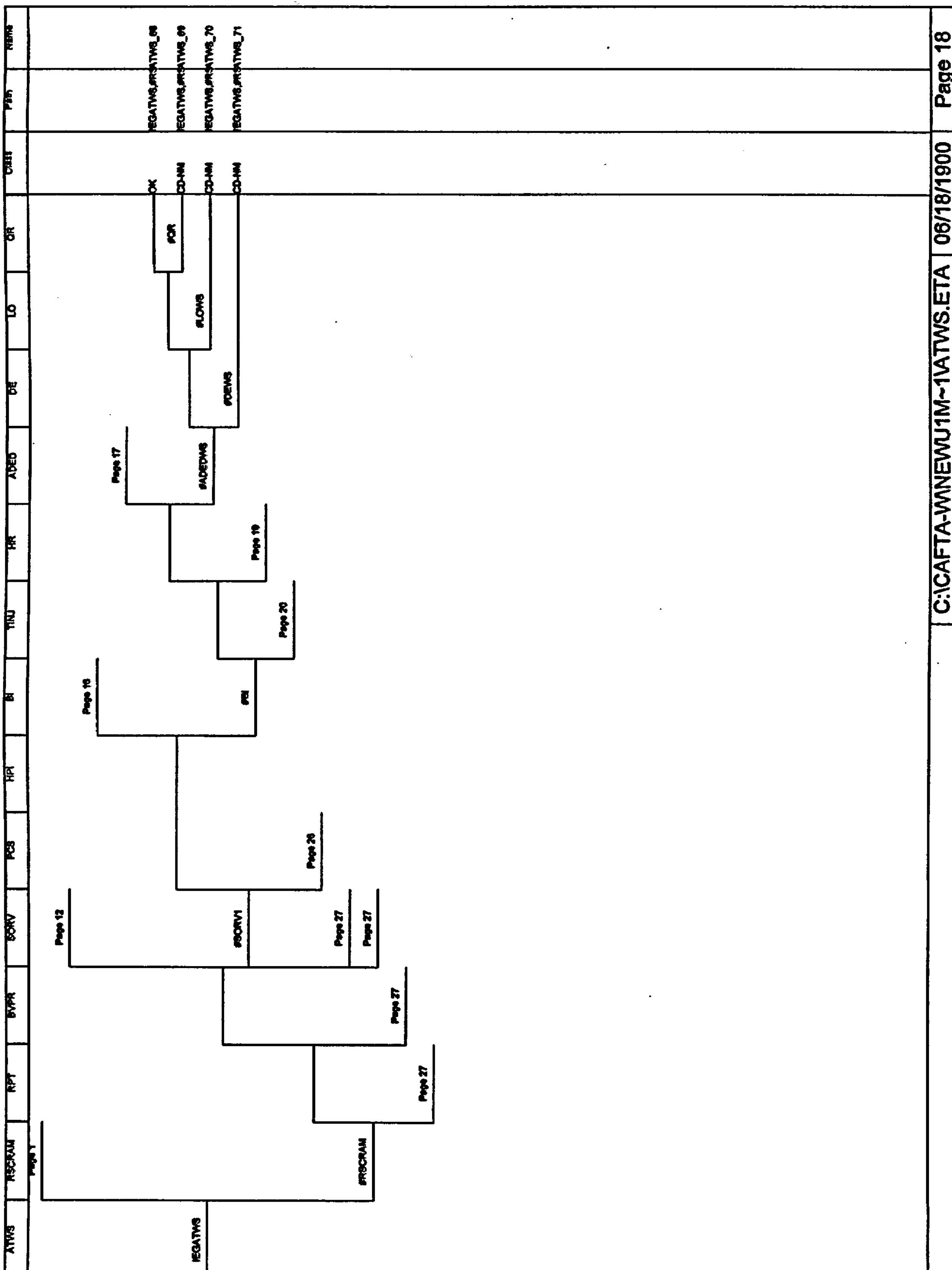
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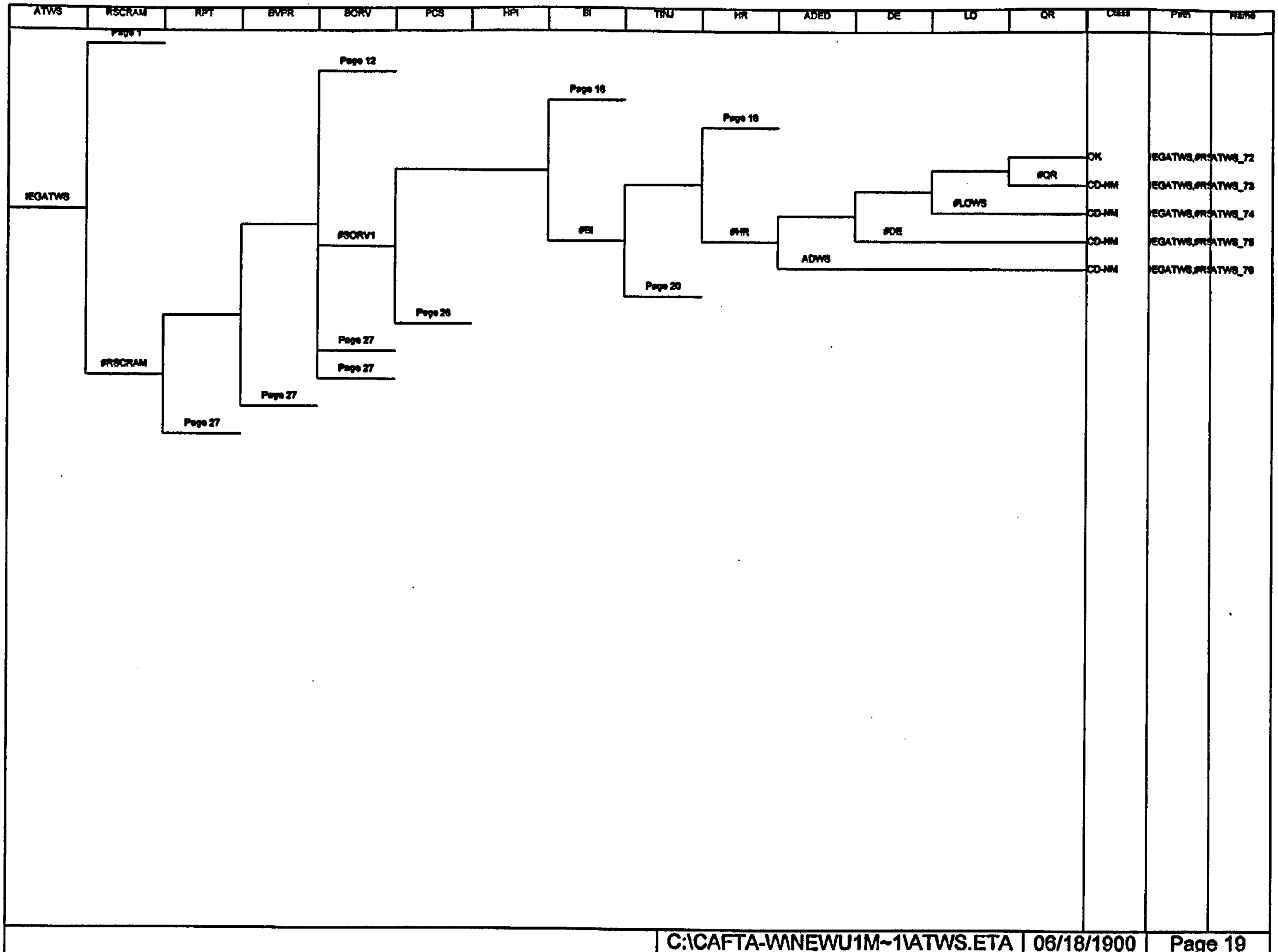
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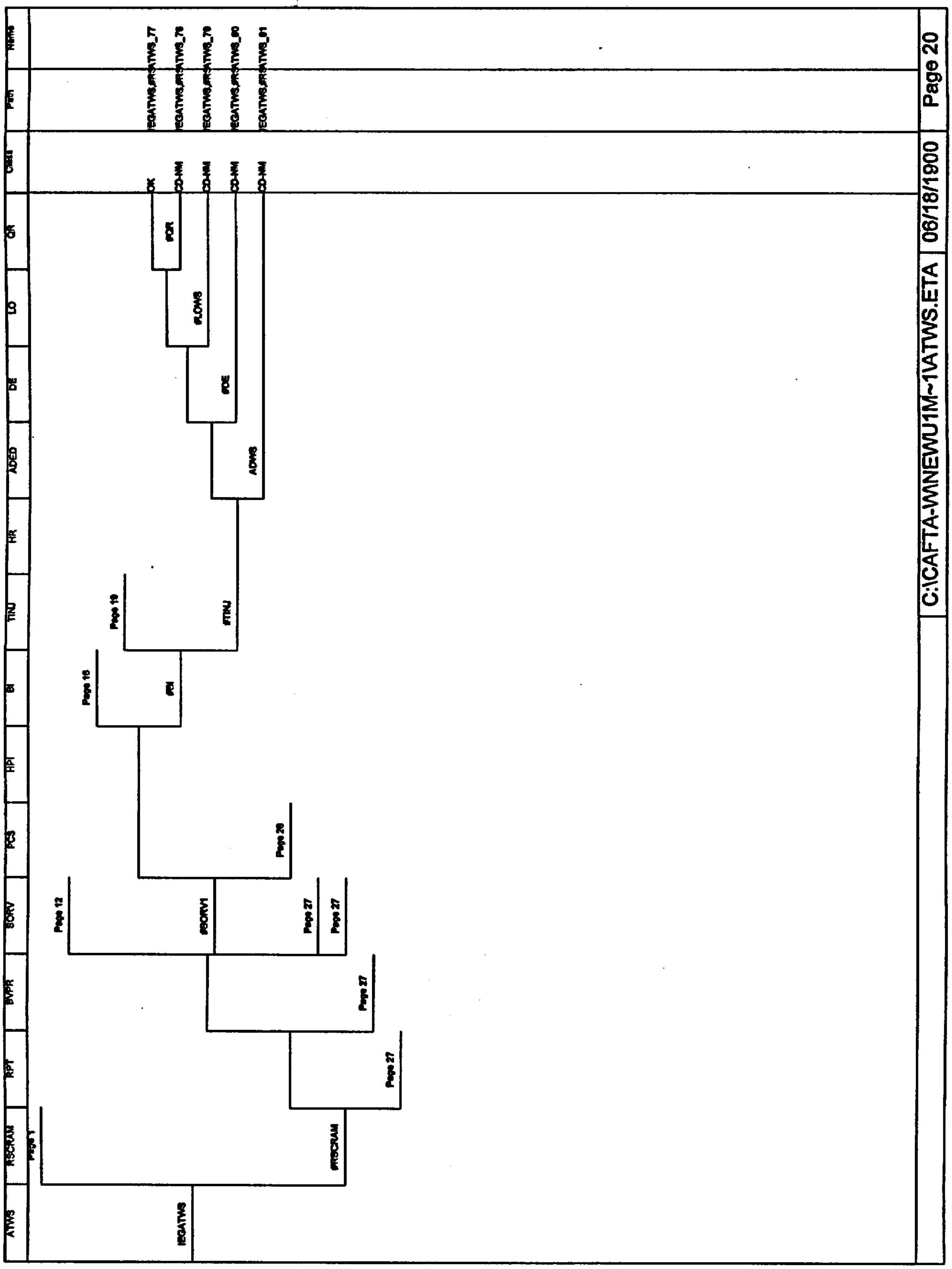
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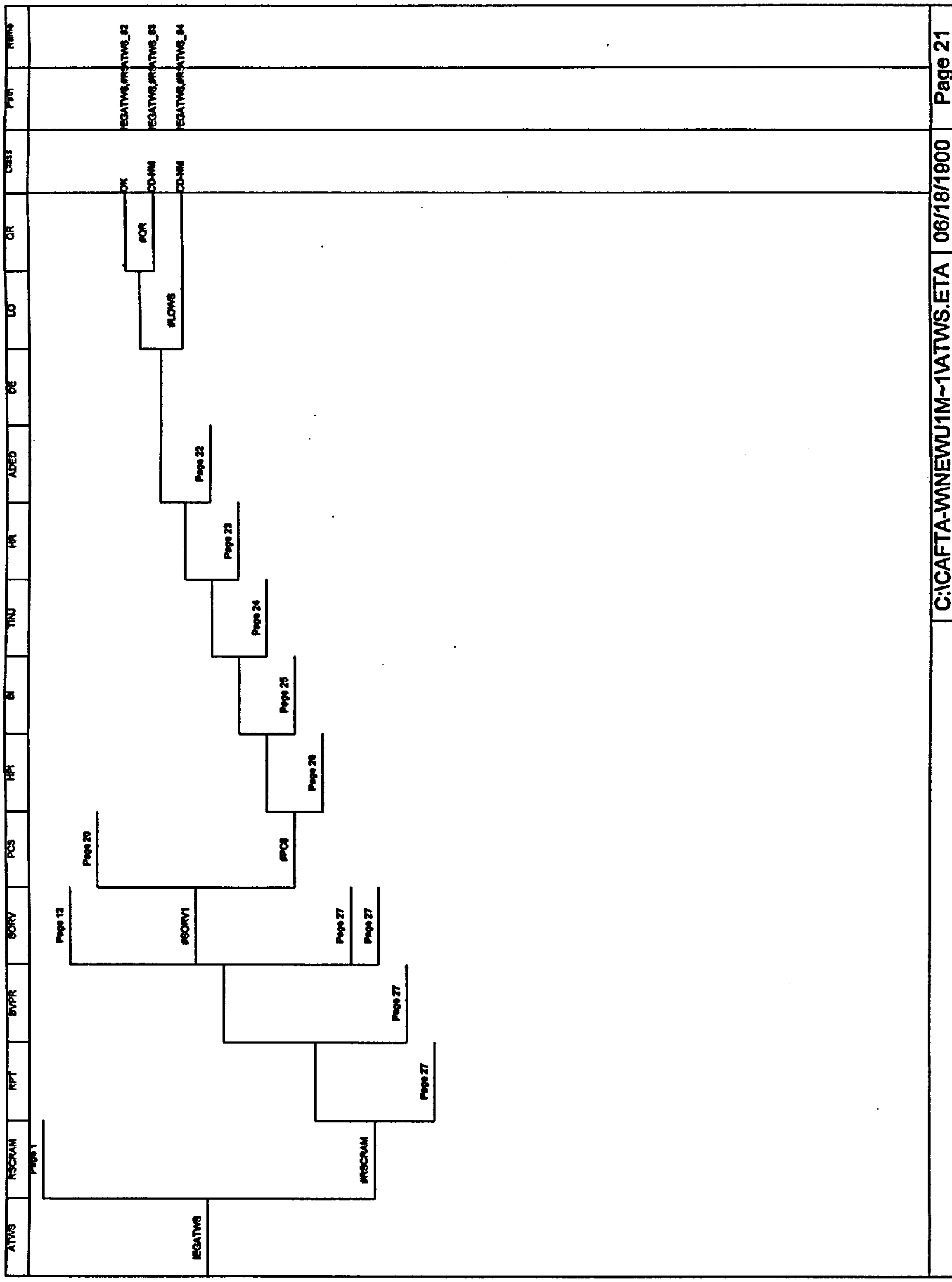
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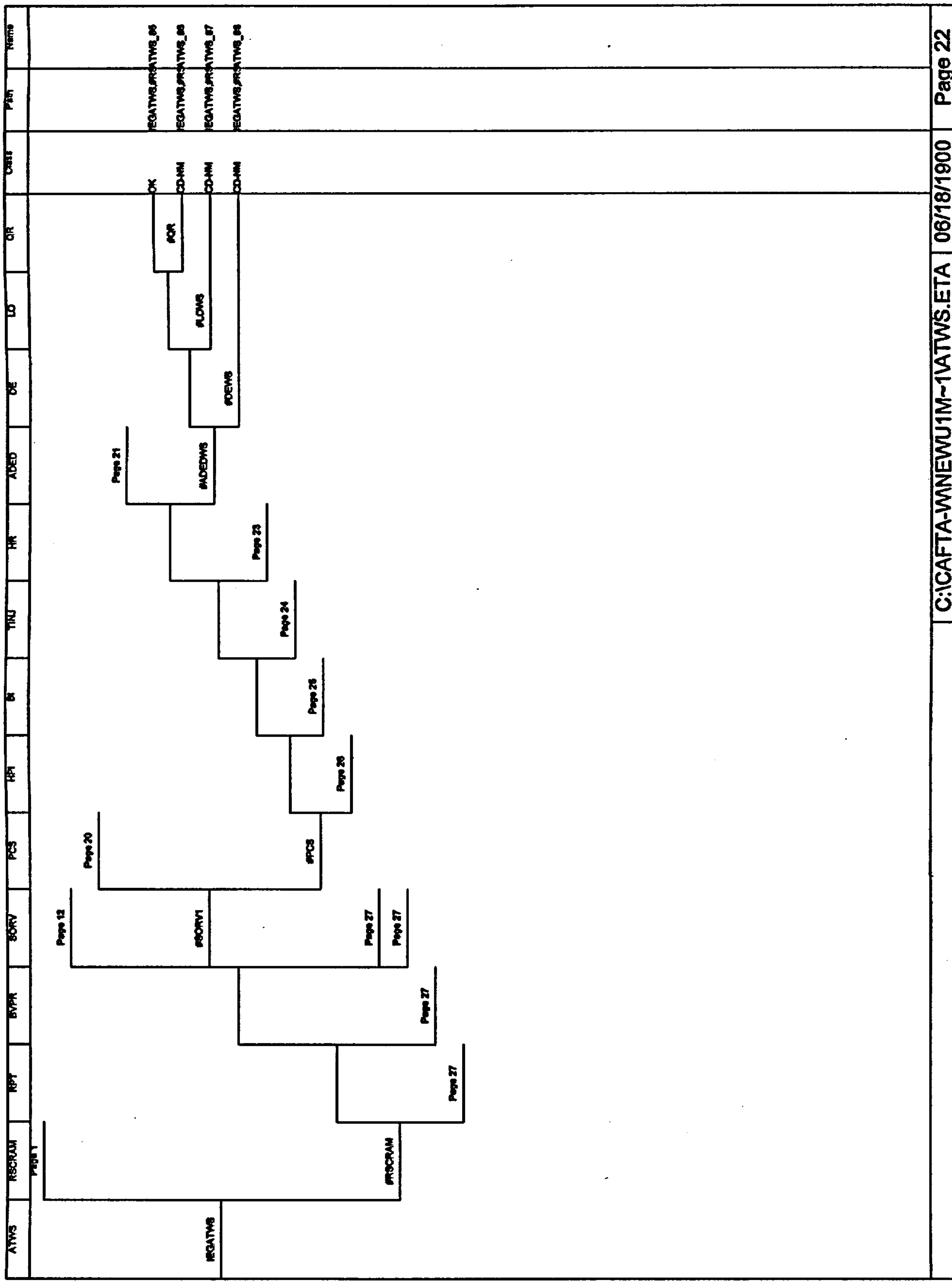
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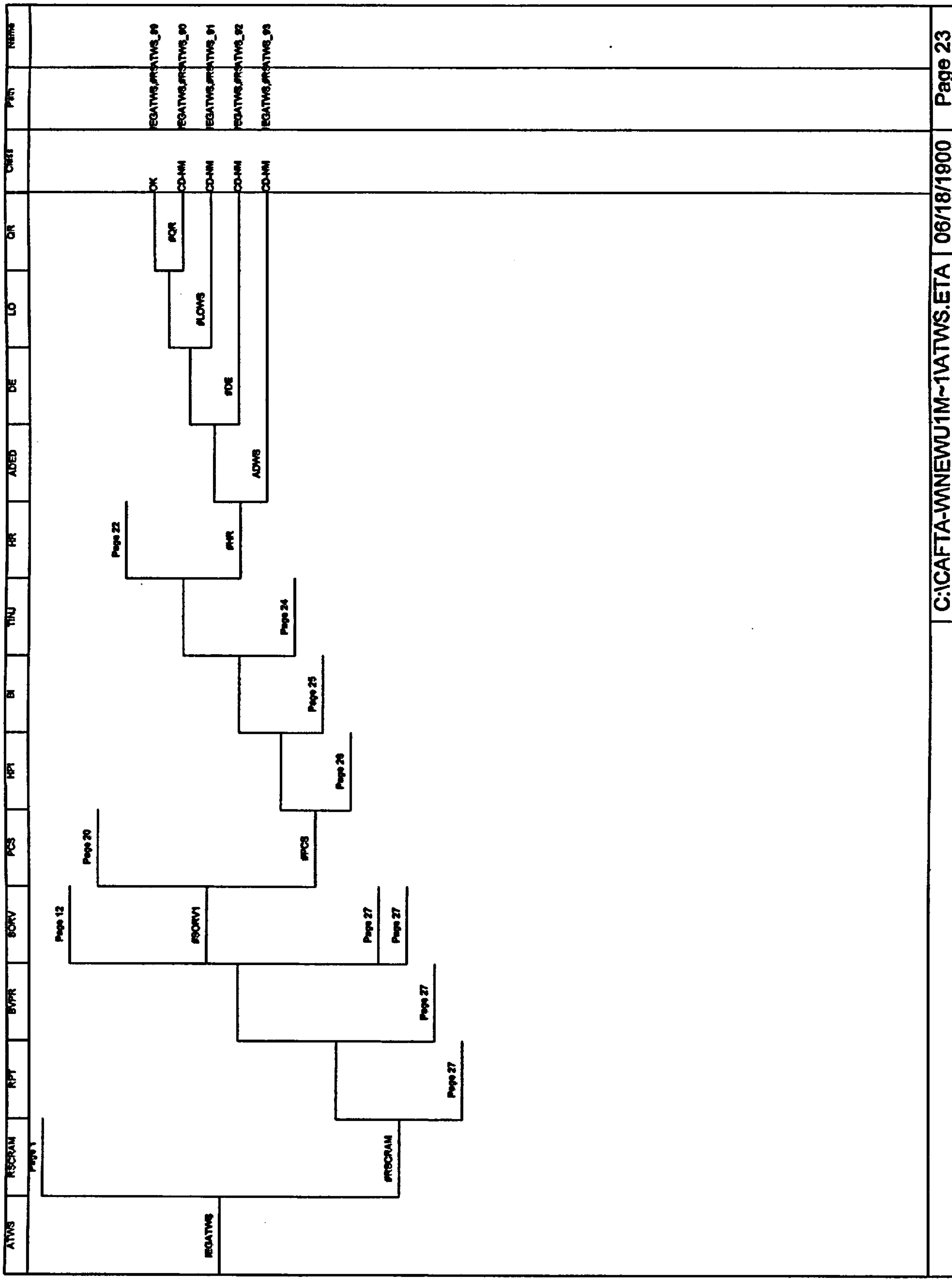
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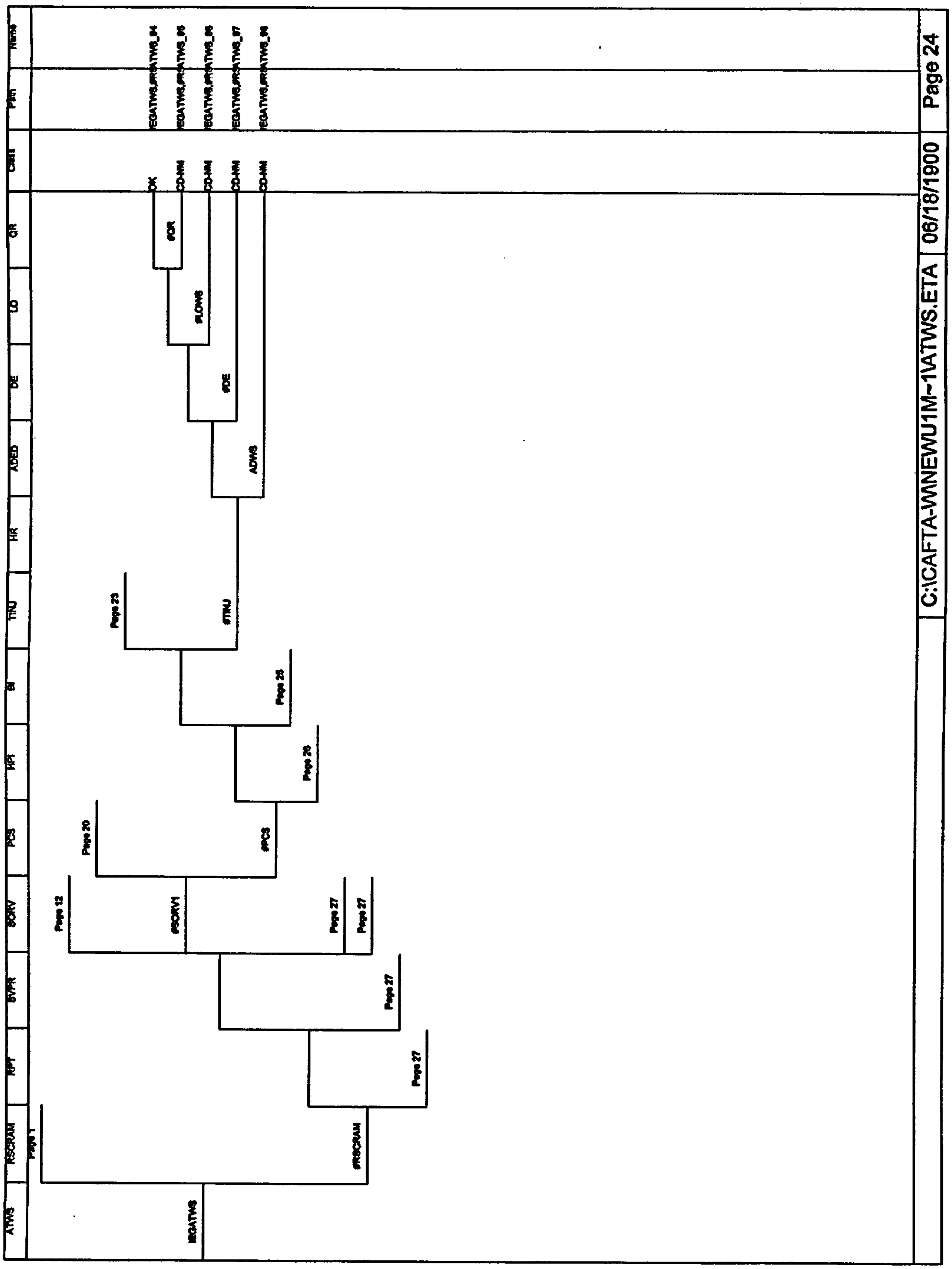
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Page 27
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Page 27
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#SORV1
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#PCS
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#TNJ
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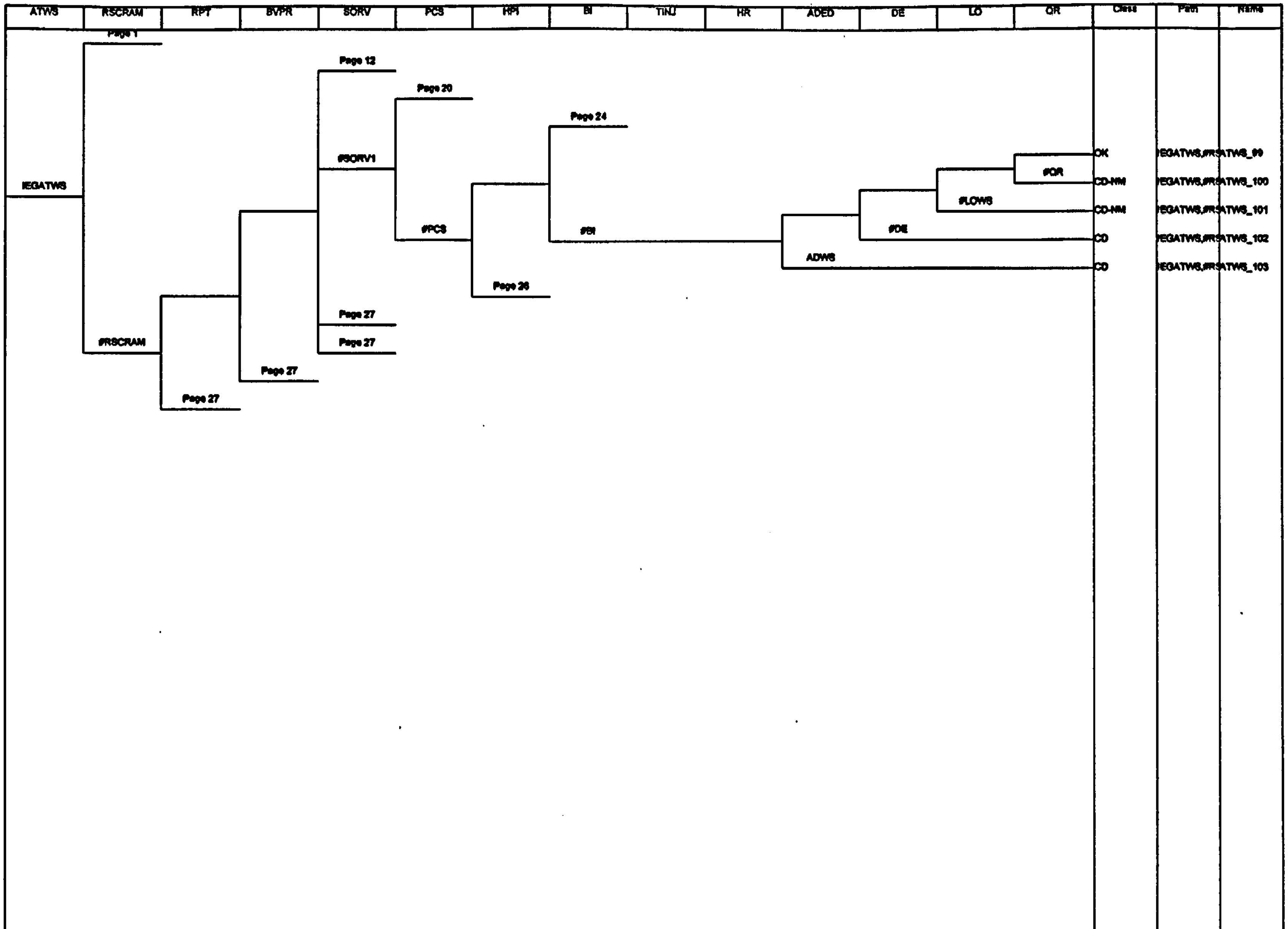

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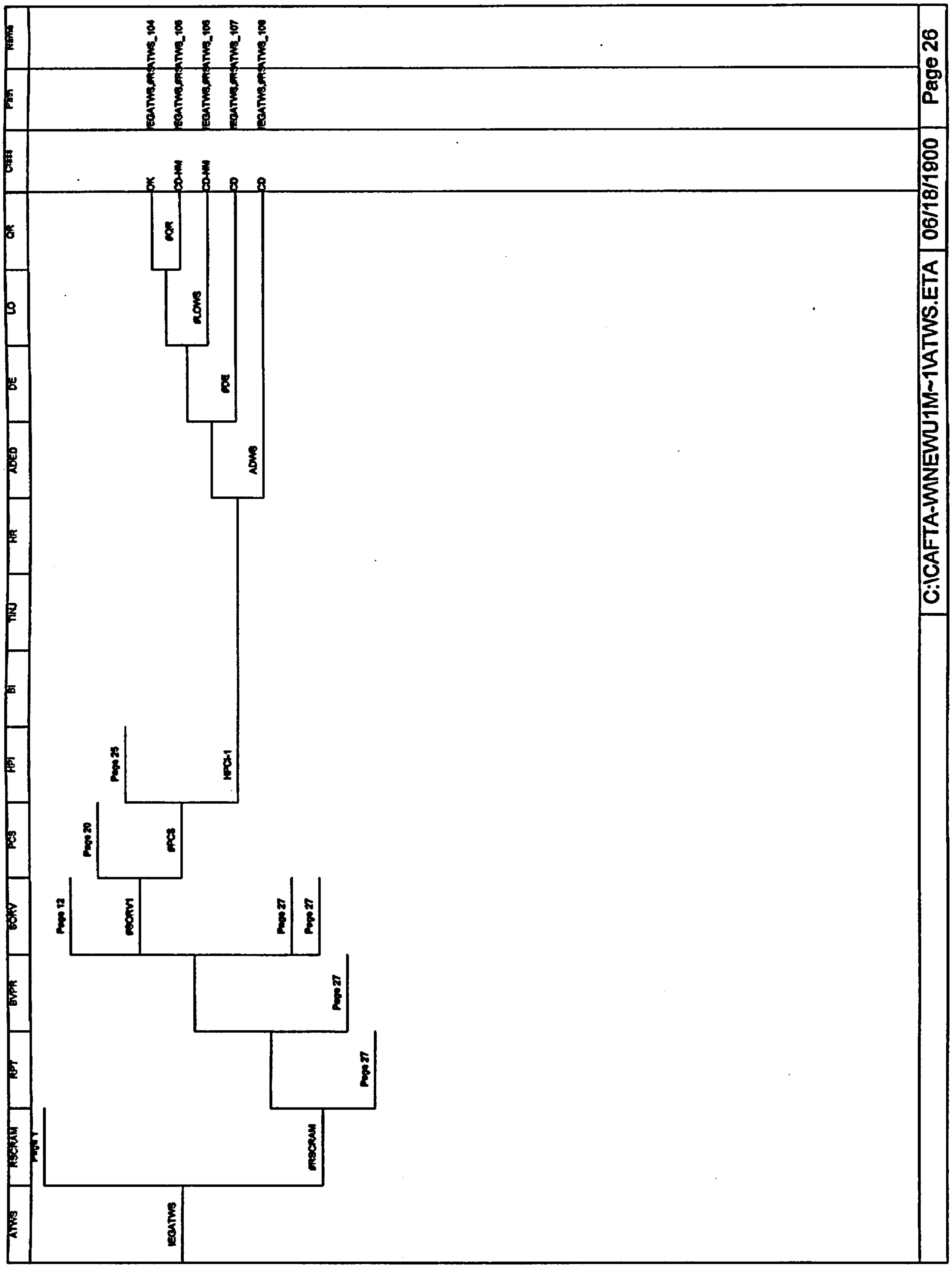
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Page 27
Page 27
Page 12
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Page 27
Page 27
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Page 25
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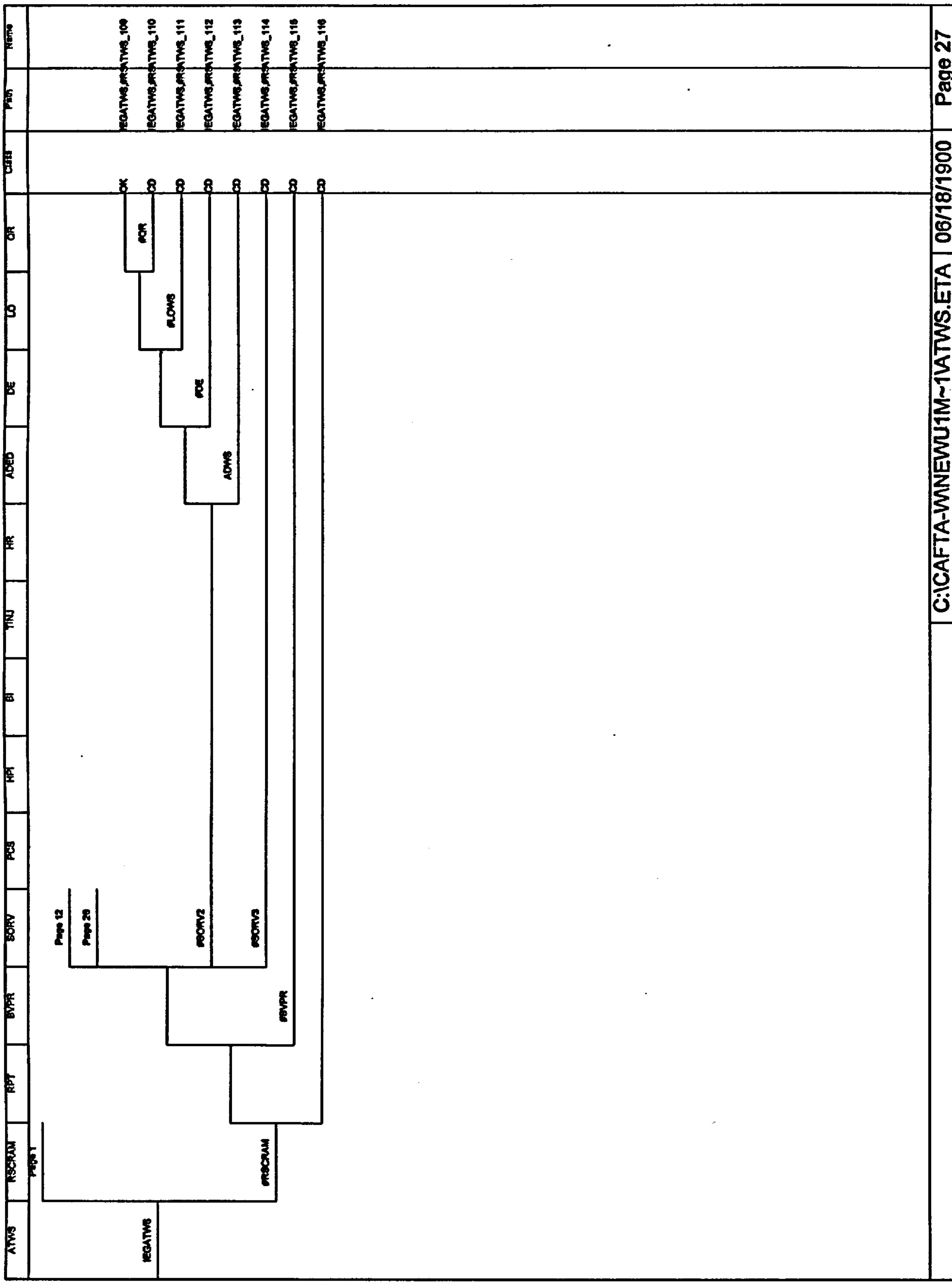
06/18/1900
Page 26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Page 12
Page 26
C:\CAFTA-W\NEWU1M~1\ATWS.ETA
06/18/1900
Page 27

TABLE 2.2-1
ATWS EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
ATWSSUP IE	Transient Initiator	Incorporated in core damage event tree model under gate IEGATWS.
ATWSSUP HCU	Control rods fail to insert given scram signal (mechanical portion of RPS)	Incorporated in core damage event tree model under gate #RSCRAM (system fault tree model gate HCU).
ATWSSUP ARIA	ARI logic input channel A fails to provide signal	Incorporated in core damage event tree model under gate #RSCRAM (system fault tree model gate ARI).
ATWSSUP ARIB	ARI logic input channel B fails to provide signal	Incorporated in core damage event tree model under gate #RSCRAM (system fault tree model gate ARI).
ATWSSUP BV	Bypass valves fail to open for pressure control	Incorporated in core damage event tree model under gate #BVPR.
ATWSSUP MC	MSIVs fail to remain open/main condenser not available	Incorporated in core damage event tree model under gate #PCS (system fault tree model gate MC-1).
ATWSSUP CO	Condensate system for injection	Incorporated in core damage event tree model under gates #LOWS, and #PCS (system fault tree model gates CO and CO-1).
ATWSSUP FW	Feedwater not available after transient	Incorporated in core damage event tree model under gates #PCS and #PCS-1(system fault tree model gate FW).
ATWSSUP HPCI	HPCI fails	Incorporated in core damage event tree model under gate HPCI-1.
ATWS RPS	Automatic scram signal not available	Incorporated in core damage event tree model under gate #RSCRAM (system fault tree model gate RPSSIG).
ATWS RPT	One or both recirculation pump trips fail to trip	Incorporated in core damage event tree model under gate RPT.
ATWS PR	Pressure relief inadequate	Incorporated in core damage event tree model under gate #BVPR.
ATWS ARI	ARI fails to vent scram air header	Incorporated in core damage event tree model under gate #RSCRAM (system fault tree model gate ARI).
ATWS MT	Manual scram not successful	Incorporated in core damage event tree model under gate #RSCRAM (system fault tree model gate RSCRAM-MANUAL).
ATWS SORV	SRV reclosure status	Incorporated in core damage event tree model as gates #SORV0, #SORV1, #SORV2, and #SORV3.
ATWS FC	Operator fails to control level during ATWS	Incorporated in system fault tree model gates MC-1, FW, and HPIWS.
ATWSBIT BIIT	Suppression pool temperature exceeds BIIT	Incorporated in core damage event tree model under gate #BI (system fault tree model gate BIIT).

TABLE 2.2-1
ATWS EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
ATWSBIT SL	SLCS fails to inject	Incorporated in core damage event tree model under gate #BI (system fault tree model gate SL).
ATWSBIT OS	SLCS not initiated before BIIT reached	Incorporated in core damage event tree model under gate #BI (system fault tree model gate SLOS).
ATWSBIT TINJ	Termination of high-pressure injection called for	Incorporated in core damage event tree model under gate #TINJ (system fault tree model gate TINJ-1).
ATWSBIT HO	Operators fail to terminate flow and control level near TAF	Incorporated in core damage event tree model under gate #TINJ (system fault tree model gate HO).
ATWSBIT HR	HPCI fails to restart following termination of injection to lower water level	Incorporated in core damage event tree model under gate #HR.
INTER3 VC	Drywell cooling inadequate to prevent LOCA signal	Incorporated in core damage event tree model under top logic gates #ADEDWS and #DEWS (system fault tree model gate VCWS).
INTER3 V18	Operators fail to vent via 18" vents to prevent LOCA signal on loss of cooling	Not a functional requirement for core damage mitigation.
INTER3 LOCA	LOCA signal (Level 1 or high drywell pressure) generated	Incorporated in core damage event tree model under gate #ADEDWS and ADWS (system fault tree model gate LOCASIGWS).
INTER3 MS	MSIVs fail to isolate reactor	Incorporated in core damage event tree model under gates #PCS (system fault tree mode gate MS-1 under system model MC-1).
INTER3 L1OP	Status of operator actions following LOCA signal	Incorporated in system fault tree model gates NORDWC4 (under core damage event tree gates #ADEDWS, ADWS, and #DEWS), NOINADS4 (under core damage event tree gates #ADEDWS, ADWS, and #DEWS), NOTBISO4 (under system fault tree model gate MC-1), and NOTBISO1 (under system fault tree model gates NOCRD-1, PSWTB-2, LOCANOCRD, and LOCANOCRDTBRE).
INTER3 CW	RBCCW not available	Not a functional requirement for core damage mitigation.
INTER3 RD	CRD pumps are unavailable for injection	Not a functional requirement for core damage mitigation.
INTER3 RP	Return to power operation not possible or failed	Not a functional requirement for core damage mitigation.
REC0 DCREC	DC power not restored to deenergized bus	Incorporated in system fault tree model gates DC-1R25S001, NBA-NOXFR, and NBA-NOXFR-1.

TABLE 2.2-1
ATWS EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
REC0 NBREC	Normal busses remain deenergized	Incorporated in system fault tree model gates NBA-NOXFR, NBA-NOXFR-1, XD-1, and XD-2.
REC0 SWREC	PSW not restored	Incorporated in system fault tree model for PSW under gates NOSWREC1, NOSWREC2, NOKMCR1, and L-PS-G125.
REC0 RSREC	Motor cooling for RHRSW pumps not available/not restored	Incorporated in system fault tree model for RHRSW under gate RSREC.
REC0 KMCR	Main control room cooling not recovered/purge mode not available	Incorporated in system fault tree models for MCR cooling, PSW, etc. under gates NOKMCR1, NOMCRPURGE, VM-G038, and PSWDISCHKMCR1.
REC0 KRSDP	Transfer of control to remote shutdown panel(s) not accomplished	Incorporated in system fault tree models for LPCI, RCIC, etc. under gate NOKRSDP-1.
RHRCS Z5	Dummy top event – RHR/CS event tree not bypassed	Not a functional requirement for core damage mitigation
RHRCS VA	RHR/CS loop A room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VA.
RHRCS VB	RHR/CS loop B room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VB.
RHRCS VOP	Operators fail to trip unneeded pumps on loss of RHR/CS room cooling	Incorporated in system fault tree models for RHR and core spray under gates CS-VA and CS-VB.
RHRCS NS	LPCI/CS low pressure permissive signal fails	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS NSREC	LPCI/CS low pressure permissive not recovered	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS LC	LPCI/CS initiation signals unavailable	Incorporated in system fault tree models for core spray, LPCI, turbine building PSW isolation, and diesel 1B MCC AC-1R24S026 under gate LC.
RHRCS RA	RHR loop A pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPA, RHRLOOPA-1, and SDCLOOPA.
RHRCS RB	RHR loop B pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPB, RHRLOOPB-1, and SDCLOOPB.
RHRCS JS	LPCI injection paths for both loops unavailable	Incorporated in system fault tree model for RHR under gates LPCI (under core damage event tree gate #LOWS) and QS (under core damage event tree gate #QR).
RHRCS CS	Core spray system fails	Incorporated in system fault tree model for core spray under gate CS which is under core damage event tree gate #LOWS.

TABLE 2.2-1
ATWS EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
RHRCS HA	RHR service water pumps in division I fail	Incorporated in system fault tree model for RHR under gates QT and QS.
RHRCS HB	RHR service water pumps in division II fail	Incorporated in system fault tree model for RHR under gates QT and QS.
LTC3 HI	High pressure core cooling inadequate/not recovered	Not a functional requirement for core damage mitigation.
LTC3 DWTC	Drywell temperature control inadequate – sprays required	Incorporated in core damage event tree model under gates #ADEDWS, ADWS, and #DEWS.
LTC3 OW	Operators fail to initiate drywell sprays on increasing drywell temperature	Incorporated in core damage event tree model under gates #ADEDWS and #DEWS (system fault tree model gate OW).
LTC3 DE	Operators fail to depressurize vessel before core damage occurs	Incorporated in core damage event tree model under gates #DEWS and #DE.
LTC3 DESC2	Emergency depressurization occurs	Not a functional requirement for core damage mitigation.
LTC3 RPOP	Normal cooldown initiated	Not a functional requirement for core damage mitigation.
LTC3 LO	Low pressure injection and control inadequate	Incorporated in core damage event tree model under gate #LOWS.
LTC3 OL	Operators fail to provide adequate long term heat removal	Incorporated in core damage event tree model under gates #QR and #QT.
LTC3 QS	RHR shutdown cooling path not available	Incorporated in core damage event tree model under gate #QR (system fault tree gate QS).
LTC3 QC	Main condenser unavailable	Incorporated in core damage event tree model under gate #QR (system fault tree gate QC).
LTC3 QT	Torus cooling not available	Incorporated in core damage event tree model under gates #QR and #QT (system fault tree gate QT).
LTC3 QV	Containment vent not available for heat removal	Incorporated in core damage event tree model under gate #QR (system fault tree gate QV).
LTC3 DESC1	Containment pressure increases; manual operation of SRVs precluded	Not a functional requirement for core damage mitigation.

TABLE 2.2-1
ATWS EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LTC3 IN1	Injection fails to remain available when reactor repressurizes	Not a functional requirement for core damage mitigation.
LTC3 QR	Heat removal not recovered before ECCS or containment fails	Not a functional requirement for core damage mitigation.
LTC3 CFF	ECCS systems fail before containment fails	Not a functional requirement for core damage mitigation.
LTC3 IN2	Injection fails to remain available after containment failure	Not a functional requirement for core damage mitigation.

2.3 The Loss of Offsite Power Event Tree

This LOSP event tree covers core damage sequences associated with the LOSP initiator and the corresponding Station Blackout (SBO) scenarios.

EVENT TREE

Figure 2.3-1 displays the LOSP core damage event tree.

EVENT TREE MODIFICATION

In the IPE, the frontline system core damage sequences for the LOSP initiator was obtained by linking together 6 RISKMAN frontline systems event trees (LOSP, INTER2, REC3, REC2, RHRCS and LTC1). After reviewing the RISKMAN event trees developed for the LOSP initiating event, the following key changes were made:

- Top events RCIC, HPCI and HP modeled in the RISKMAN event tree LOSP are combined according to the function provided by the individual systems, high-pressure injection (HPI). Similarly, other top events modeled in the RISKMAN event trees are also combined according to the functions provided by the systems.
- With the exception of RP (which is guaranteed to fail during an LOSP event), many of the top events in RISKMAN event tree INTER2 are incorporated into lower level fault tree models for LOCA signal, operator restoration following a LOCA signal, automatic/emergency depressurization, diesel generator availability, etc. Top events V18, CW, and RD are also guaranteed to fail.
- Recovery top events modeled in REC3 are incorporated into the recovery rule file, as necessary, and the appropriate system fault trees (e.g., plant service water).
- Recovery top events modeled in REC2 are incorporated into the appropriate system fault trees.
- Most of the top events modeled in RISKMAN event trees RHRCS and LTC1 are incorporated into the lower level fault trees for ETA headings DE, LO, and QR. RISKMAN top events Z5, DESC2, RPOP, DESC1, CFF, and IN2 were determined to be not functional requirements for core damage.

For the new ETA event tree, LOSP, nodes under each heading may be represented by one or more fault tree gates. The multiple RISKMAN system models were combined into one fault tree gate with additional compression achieved by combining similar functions into one final fault tree gate with multiple inputs. Listed below are the new top logic gates developed for the ETA event tree nodes and the original inputs associated with each (i.e., RISKMAN event tree top events combined into the gate):

#BVPR	(BV failed by LOSP), PR
#SORV0/1/2/3	SORV
#HP-1	RCIC, HPCI, HP, HI, (CW, RD failed by LOSP)
#ADED	VC, V18 (failed by LOSP), LOCA, L1OP, DWTC, OW
#DE	DE
#LO	(CO failed by LOSP), CS, RA, RB, JS, VA, VB, VOP, NS, NSREC,

	LC
#QR/#QT	OL, QS, QT, RA, RB, VA, VB, VOP, HA, HB, QV, IN1, QR
#HP-B	RCIC, HPCI, HP
FL-HPI-B-S	N/A

Table 2.3-1 provides a summary of the disposition for each RISKMAN event tree top event.

EVENT TREE HEADINGS & BRANCHES

The following event tree headings and nodes appear on the tree in the approximate chronological order that would be expected during an LOSP event.

%LOSP Loss of Offsite Power Initiating Event.

PR Pressure Relief. This heading models the pressure control function performed by the SRVs during the initial pressure transient following a plant trip due to an LOSP event. The bypass valves are unavailable due to closure of the MSIVs during an LOSP event. Failure of this event (Branch ID #BVPR) is modeled as resulting in a medium-break LOCA.

SORV SORV Reclosure. This is a multistate heading. It models the reclosure status of SRVs (i.e., the number of stuck open SRVs). The four states applicable to this heading are: all SRVs successfully reclose (Branch ID #SORV0); one SRV fails to reclose (Branch ID #SORV1); two SRVs fail to reclose (Branch ID #SORV2); and three or more SRVs fail to reclose (Branch ID #SORV3).

HPI High Pressure Level Control by RCIC/HPCI. This heading models the high-pressure level control function provided by the RCIC and HPCI systems. Both automatic and manual actuations are considered in this heading. Also included in this heading are the operator actions to control HPCI and RCIC to prevent multiple Level 8 trips. For any stuck-open SRVs and medium LOCAs, RCIC is inadequate for vessel level control. For three or more stuck-open SRVs, HPCI is inadequate, and for one or two SRVs stuck open HPCI recovery is not credited. Success of this event implies that RCIC or HPCI is available to provide the high-pressure level control function. Failure of this event (Branch ID #HP-1) implies that both RCIC and HPCI are unavailable for the vessel level control function and vessel depressurization is required.

ADED Automatic and Emergency Depressurization Conditions. This heading models the automatic and emergency depressurization conditions. The automatic depressurization condition is modeled by generation of the LOCA signal and failure of the operators to inhibit the ADS actuation. LOCA signals include Level 1 and high drywell pressure signals. In addition, it was assumed that loss of the MCR cooling would result in generation of a LOCA signal. Failure of drywell cooling (RISKMAN Top Event VC) and failure of the operators to vent via the 18" vents to prevent a LOCA signal (RISKMAN Top Event V18) were assumed to lead to generation of a high drywell pressure signal.

Emergency vessel depressurization is required by the Plant Hatch procedures if the drywell temperature limit is exceeded. Drywell temperature would increase if drywell cooling fails and the operators fail to initiate drywell spray (RISKMAN Top Event OW). Drywell cooling would also be lost if the operators fail to restore drywell cooling following a LOCA signal.

Success of this event implies that there are no automatic and emergency depressurization conditions, or the operators successfully inhibit ADS and restore drywell cooling given a LOCA signal. Failure of this event (Branch ID #ADED) implies that ADS would be actuated or the operators are required to initiate emergency vessel depressurization. It is assumed in sequences involving failure of this heading that the vessel is depressurized and downstream heading DE is not asked. This heading is not asked if HPI fails requiring a vessel depressurization (downstream heading DE).

DE Depressurization of Vessel before Core Damage. This heading models the reduction of vessel pressure to permit level recovery. This heading includes the manual emergency depressurization actions required when all high-pressure injection sources are lost. This heading is only asked when HPI fails. Success of this event implies that operators successfully depressurize the reactor vessel to allow injection by the low-pressure systems. Failure of this event (Branch ID #DE) implies that reactor vessel remains at high pressure and core damage will result.

LO Low Pressure Injection. This heading models the low pressure injection function provided by the condensate, core spray, and low pressure coolant injection (LPCI) systems. Both automatic and manual actions are considered for core spray and LPCI. Success of this event implies that low-pressure injection is available. Failure of this event (Branch ID #LO) implies that low-pressure injection is unsuccessful.

QR Decay Heat removal. This heading models decay heat removal by shutdown cooling, suppression pool cooling, and the containment hardened vent. Two different top logic gates have been developed to model the nodes under this heading, #QR and #QT.

For sequences in which RCIC or HPCI is successful, there is no stuck-open SRV (or no failure of pressure relief), and low pressure injection is unavailable, decay heat removal can be achieved by suppression pool cooling (modeled by top logic gate #QT). Success implies that, with suppression pool cooling, the long-term operation of RCIC or HPCI can be successful. Failure (Branch ID #QT) implies that high-pressure injection would also be lost due to loss of heat removal.

Top logic gate #QR is used in sequences in which #LO is successful. Success implies that the decay heat removal function is successful due to the success of torus or shutdown cooling or the containment hardened vent. Heat removal via the main condenser is failed by an LOSP event. Failure (Branch ID #QR) implies that no decay heat removal is available.

HPI-B High Pressure Injection until Battery Depletion. This heading models high-pressure injection for the life of the station batteries without AC power for charging. Only RCIC is involved because it can operate without room cooling which depends on AC power. The heading HPI-B is only addressed in sequences in which #BVPR is successful and no SRVs fail to reclose (#SORV0). This heading helps to define the power recovery timing, based on whether HPI is successful for the duration of the battery life, for the Station Blackout cutsets obtained from the integrated model.

<u>SEQUENCES</u>

The following descriptions refer to the core damage sequences presented in figure 2.3-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path.

LOSP_2: %LOSP /#BVPR #SORV0 /#HP-1 /#ADED /#LO #QR

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). High pressure injection by RCIC or HPCI is successful. No automatic or emergency depressurization occurs (/#ADED); therefore, hardware response for the vessel depressurization is not asked in this sequence. Vessel pressure is reduced due to the cooldown operation provided by RCIC/HPCI. Low pressure injection is successful (/#LO). The decay heat removal function is unavailable (#QR) resulting in eventual core damage. Since #HP-1 is successful, a flag event (FL-HPI-B-S) is added to indicate that RCIC would operate until the batteries are depleted, if an SBO event occurs.

LOSP_4: %LOSP /#BVPR #SORV0 /#HP-1 /#ADED #LO #QT

Similar to Sequence LOSP_2 except that low pressure injection is unsuccessful (#LO). Core cooling can only be achieved by high-pressure injection provided by RCIC/HPCI (/#HP-1). To permit long term RCIC/HPCI operation, suppression pool cooling must be successful. However, in this sequence, suppression pool cooling is unavailable (#QT) resulting in eventual core damage. Since #HP-1 is successful, a flag event (FL-HPI-B-S) is added to indicate that RCIC would operate until the batteries are depleted, if an SBO event occurs.

LOSP_6: %LOSP /#BVPR #SORV0 /#HP-1 #ADED /#LO #QR

Same as Sequence LOSP_2 except that the reactor vessel is depressurized by actuation of ADS or the operators were required to initiate emergency vessel depressurization (#ADED). Compared to Sequence LOSP_2, this sequence is not minimal since it involves the additional failure of #ADED.

LOSP_7: %LOSP /#BVPR #SORV0 /#HP-1 #ADED #LO

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). High pressure injection by RCIC or HPCI is successful (/#HP-1), but the reactor vessel depressurizes due to automatic depressurization conditions or emergency depressurization requirements (#ADED). The hardware response for vessel depressurization (modeled in #DE) is assumed successful. Low pressure injection is unsuccessful (#LO) resulting in eventual core damage due to loss of all high and low pressure injection sources . The decay heat removal function is not asked in this sequence. Since #HP-1 is successful, a flag event (FL-HPI-B-S) is added to indicate that RCIC would operate until the batteries are depleted, if an SBO event occurs.

LOSP_9A: %LOSP /#BVPR #SORV0 #HP-1 /#DE /#LO #QR /#HP-B

Same as Sequence LOSP_2 except long term high-pressure injection by RCIC or HPCI is unavailable (#HP-1) and vessel pressure is successfully reduced by the SRVs (/#DE). In the event of an SBO, RCIC would operate successfully until the batteries are depleted (/#HP-B). Compared to Sequence LOSP_2, this sequence is not minimal since it involves the additional failure of high-pressure injection (#HP-1). Since #HP-B is successful, a flag event is added to indicate that RCIC would be available for the duration of the battery life.

LOSP_9B: %LOSP /#BVPR #SORV0 #HP-1 /#DE /#LO #QR #HP-B

Same as Sequence LOSP_2 except long term high-pressure injection by RCIC or HPCI is unavailable (#HP-1) and vessel pressure is successfully reduced by the SRVs (/#DE). Failure of the heat removal function leads to eventual core damage. In the event of an SBO, RCIC would be unavailable for the duration of the battery life (#HP-B).

LOSP_10A: %LOSP /#BVPR #SORV0 #HP-1 /#DE #LO /#HP-B

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). High pressure injection by RCIC or HPCI fails (#HP-1). Vessel depressurization occurs (/#DE) but low pressure injection fails (#LO). If an SBO event occurs, RCIC would operate until the batteries are depleted (/#HP-B).

LOSP_10B: %LOSP /#BVPR #SORV0 #HP-1 /#DE #LO #HP-B

Same as Sequence LOSP_10A except, in the event of an SBO, RCIC would not operate until the batteries are depleted (#HP-B).

LOSP_11A: %LOSP /#BVPR #SORV0 #HP-1 #DE /#HP-B

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by successful SRV reclosure (#SORV0). Long term high-pressure injection by RCIC or HPCI fails (#HP-1) and vessel depressurization fails (#DE). If an SBO occurs, RCIC would operate until the batteries are depleted (/#HP-B).

LOSP_11B: %LOSP /#BVPR #SORV0 #HP-1 #DE #HP-B

Same as Sequence LOSP_11A except, in the event of an SBO, RCIC would not operate until the batteries are depleted (#HP-B).

LOSP_13: %LOSP /#BVPR #SORV1 /#HP-1 /#LO #QR

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by one SRV failing to reclose (#SORV1). High-pressure injection by HPCI is successful (/#HP-1). Vessel pressure continues to decrease due to the SRV failing to reclose, so ADED is bypassed. Low-pressure injection is successful (/#LO). The decay heat removal function is unavailable (#QR). Because low pressure injection would lose its suction source (i.e., the suppression pool) due to excessive temperature, the eventual overpressure failure would result in eventual core damage.

LOSP_14: %LOSP /#BVPR #SORV1 /#HP-1 #LO

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by one SRV failing to reclose (#SORV1). High-pressure injection by HPCI is successful (/#HP-1). Vessel pressure continues to decrease due to the SRV failing to reclose, so ADED is bypassed. Low pressure injection is unsuccessful (#LO) resulting in eventual core damage due to loss of all high and low pressure injection sources . The decay heat removal function is not asked in this sequence.

LOSP_16: %LOSP /#BVPR #SORV1 #HP-1 /#DE /#LO #QR

Similar to Sequence LOSP_13 except high-pressure injection by HPCI is unavailable (#HP-1). Manual vessel depressurization is successful. Compared to Sequence LOSP_13, this sequence is not minimal since it involves the additional failure of high-pressure injection (#HP-1).

LOSP_17: %LOSP /#BVPR #SORV1 #HP-1 /#DE #LO

Similar to Sequence LOSP_14 except high-pressure injection by HPCI is unavailable (#HP-1). Manual vessel depressurization is successful. Compared to Sequence LOSP_14, this sequence is not minimal since it involves the additional failure of high-pressure injection (#HP-1).

LOSP_18: %LOSP /#BVPR #SORV1 #HP-1 #DE

Similar to Sequence LOSP_17 except that vessel pressure reduction has failed (#DE), given failure of high-pressure injection. This results in eventual core damage due to the inability to inject low pressure water to the vessel.

LOSP_20: %LOSP /#BVPR #SORV2 /#HP-1 /#LO #QR

Similar to Sequence LOSP_13 except that two SRVs stick open (#SORV2).

LOSP_21: %LOSP /#BVPR #SORV2 /#HP-1 #LO

Similar to Sequence LOSP_14 except that two SRVs stick open (#SORV2).

LOSP_23: %LOSP /#BVPR #SORV2 #HP-1 /#DE /#LO #QR

Similar to Sequence LOSP_16 except that two SRVs stick open (#SORV2). Compared to Sequence LOSP_20, this sequence is non-minimal.

LOSP_24: %LOSP /#BVPR #SORV2 #HP-1 /#DE #LO

Similar to Sequence LOSP_17 except that two SRVs stick open (#SORV2). Compared to Sequence LOSP_21, this sequence is non-minimal.

LOSP_25: %LOSP /#BVPR #SORV2 #HP-1 #DE

Similar to Sequence LOSP_18 except that two SRVs stick open (#SORV2).

LOSP_27: %LOSP /#BVPR #SORV3 /#LO #QR

An LOSP event occurs which causes a reactor trip. The initial pressure relief is successful (/#BVPR) followed by three or more SRVs failing to reclose (#SORV3). All high-pressure injection sources are lost due to vessel depressurization caused by the stuck-open SRVs. Following vessel depressurization, low-pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QR). Due to the loss of the low-pressure injection suction source (i.e., the suppression pool), overpressure resulting in eventual core damage.

LOSP_28: %LOSP /#BVPR #SORV3 #LO

Similar to Sequence LOSP_27 except low-pressure injection is unsuccessful (#LO) resulting in eventual core damage due to loss of all high and low pressure injection sources. The decay heat removal function is not asked in this sequence.

LOSP_30: %LOSP #BVPR /#HP-1 /#LO #QR

Similar to Sequence LOSP_20 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. SRVs are not challenged.

LOSP_31: %LOSP #BVPR /#HP-1 #LO

Similar to Sequence LOSP_21 except that the initial pressure relief has failed (#BVPR). It is assumed that a medium-break LOCA has resulted with failed low-pressure injection. The SRVs are not challenged.

LOSP_33: %LOSP #BVPR #HP-1 /#DE /#LO #QR

Similar to Sequence LOSP_23 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. Compared to Sequence LOSP_30, this sequence is non-minimal.

LOSP_34: %LOSP #BVPR #HP-1 /#DE #LO

Similar to Sequence LOSP_24 except that the initial pressure relief has failed (#BVPR). It was assumed that a medium-break LOCA resulted. Compared to Sequence LOSP_31, this sequence is non-minimal.

LOSP_35: %LOSP #BVPR #HP-1 #DE

Similar to Sequence LOSP_25 except that the initial pressure relief has failed (#BVPR). It is assumed that a medium-break LOCA has resulted.

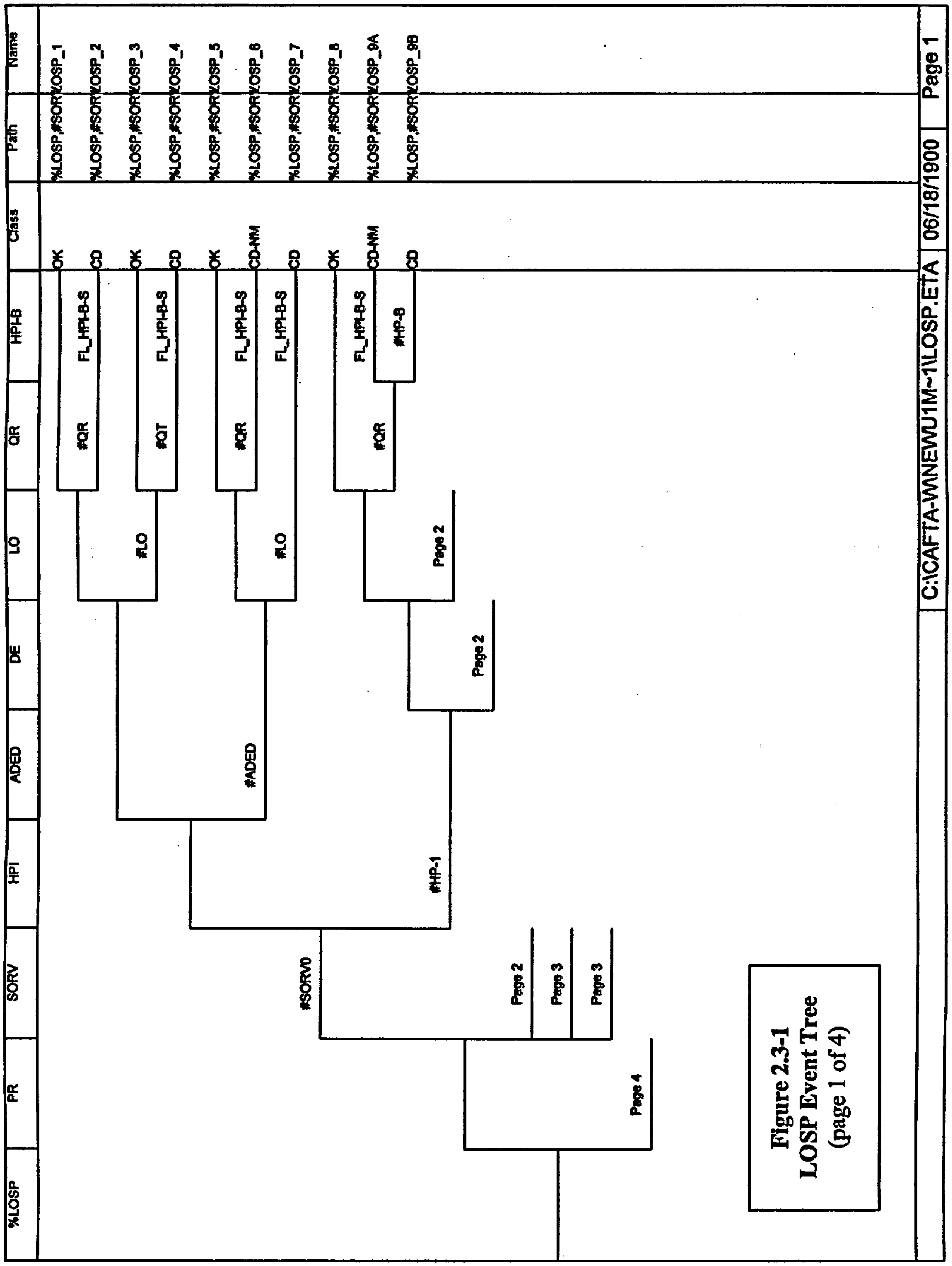

Figure 2.3-1
LOSP Event Tree
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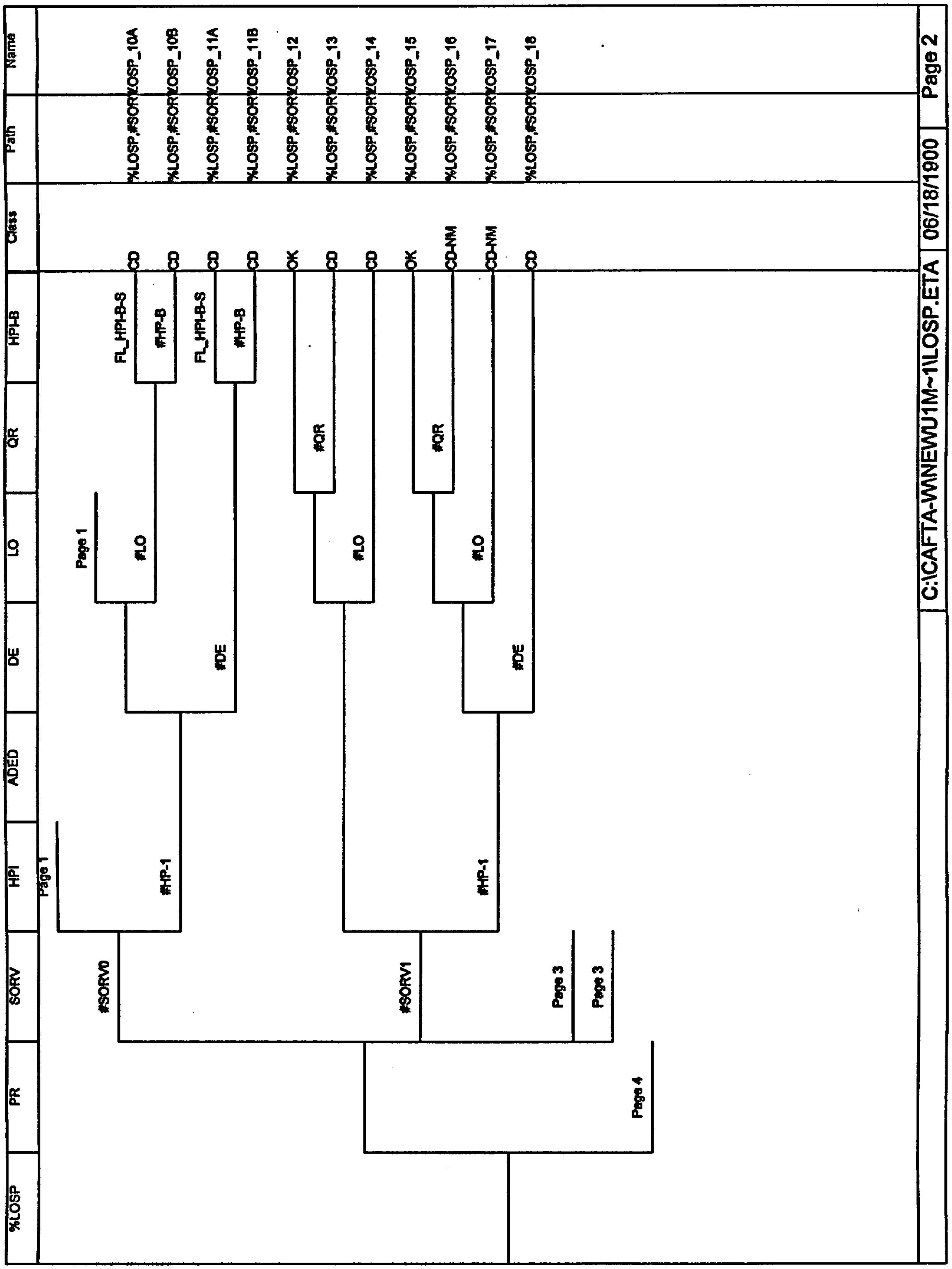
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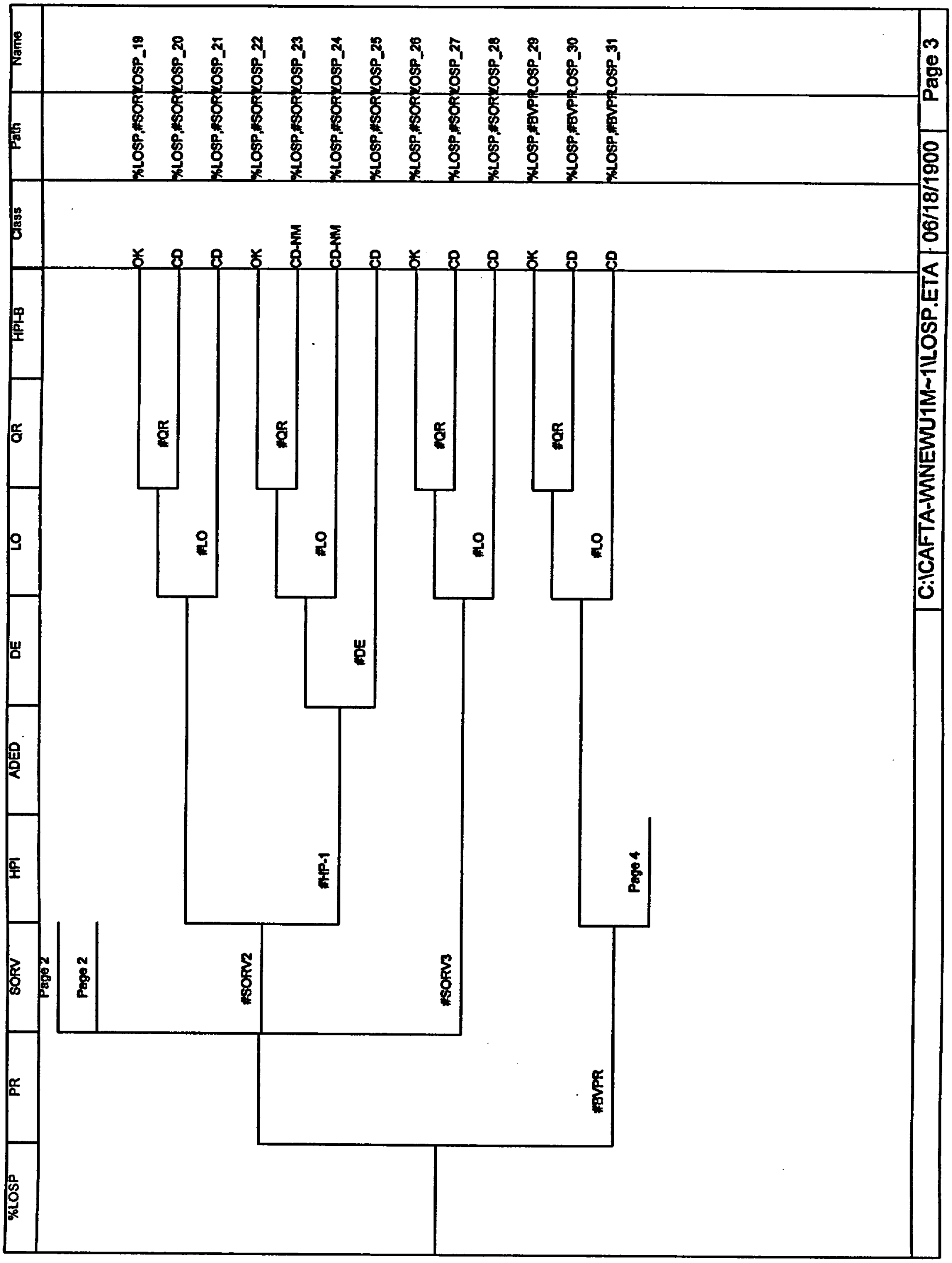
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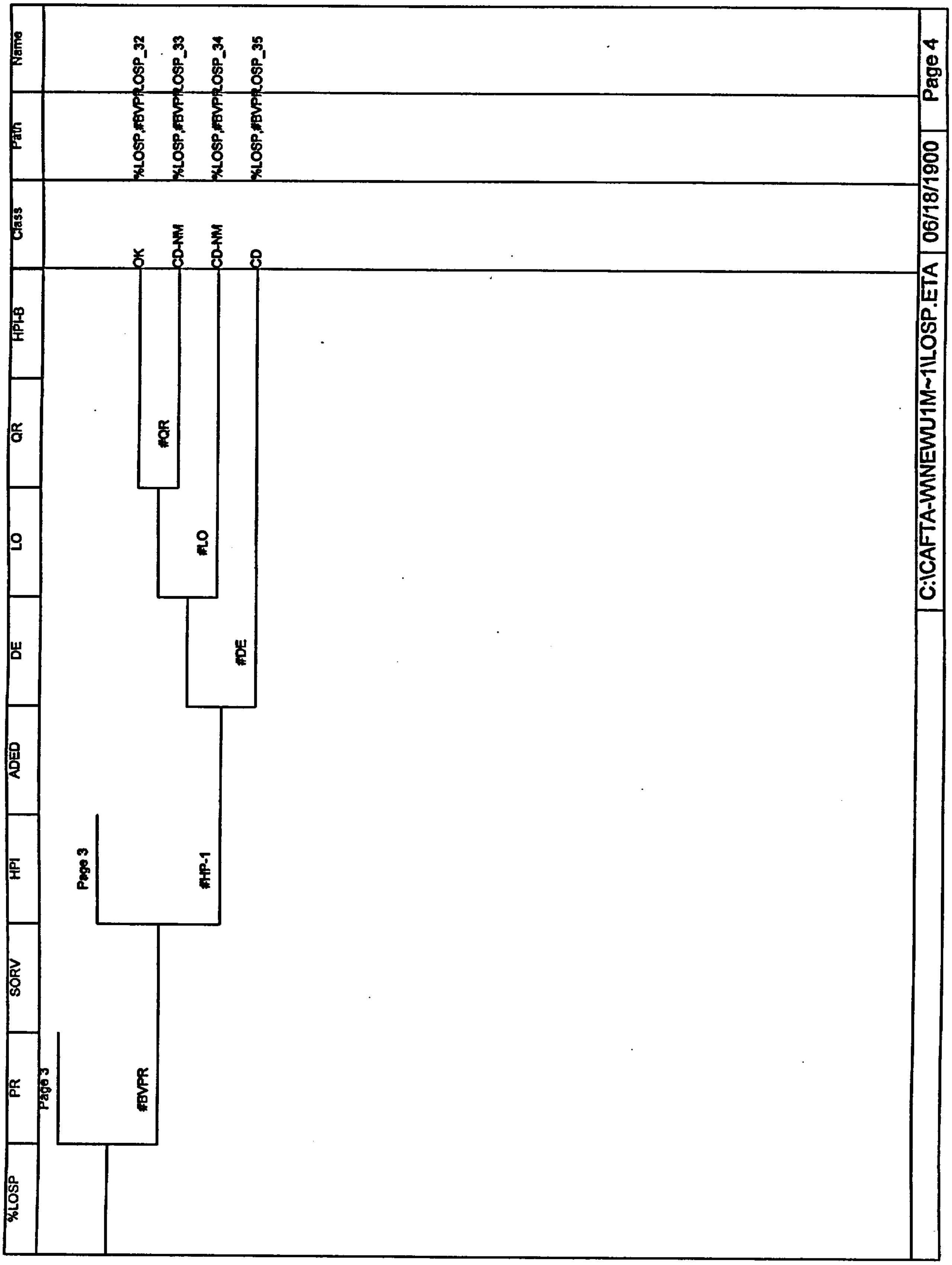
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Page 4

TABLE 2.3-1
LOSP EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LOSP IE	Loss of Offsite Power Initiator	Incorporated in core damage event tree model as basic event %LOSP.
LOSP PR	Pressure relief inadequate	Incorporated in core damage event tree model under gate #BVPR. (LOSP guarantees the failure of the bypass valves.)
LOSP SORV	SRV reclosure status	Incorporated in core damage event tree model as gates #SORV0, #SORV1, #SORV2, and #SORV3.
LOSP RCIC	RCIC fails	Incorporated in core damage event tree model under gates #HP-1 and #HP-B.
LOSP HPCI	HPCI fails	Incorporated in core damage event tree model under gates #HP-1 and #HP-B.
INTER2 VC	Drywell cooling inadequate to prevent LOCA signal	Incorporated in core damage event tree model under top logic gates #ADED and #DE (system fault tree model gate VC).
INTER2 V18	Operators fail to vent via 18" vents to prevent LOCA signal on loss of cooling	Incorporated in core damage event tree model under gate #ADED (system fault tree model gate V18).
INTER2 LOCA	LOCA signal (Level 1 or high drywell pressure) generated	Incorporated in core damage event tree model under gate #ADED (system fault tree model gate LOCASIG).
INTER2 MS	MSIVs fail to isolate reactor	MSIVs guaranteed to close given an LOSP event. Not a functional requirement for core damage mitigation.
INTER2 LBE	DG-A/bus E LOCA load shed & reload	Incorporated in system fault tree model gates DGA and DGB.
INTER2 LBF	DG-B/bus F LOCA load shed & reload	Incorporated in system fault tree model gate DGB.
INTER2 LBG	DG-C/bus G LOCA load shed & reload	Incorporated in system fault tree model gates DGC and DGB.
INTER2 L1OP	Status of operator actions following LOCA signal	Incorporated in system fault tree model gates NORDWC1 (under core damage event tree gates #ADED), NOINADS1 (under core damage event tree gate #ADED), NOTBISO1 (under system fault tree model gate HI-1, NOCRD, and PSWTB-2), and L1OP. HI-1 is under #HP-1 and #HP-B. Gate NOCRD is under gate #DE. L1OP is under HI-G008-1 which is under HI-1
INTER2 CW	RBCCW not available	RBCCW guaranteed to fail given an LOSP event.
INTER2 RD	CRD pumps are unavailable for injection	CRD system guaranteed to fail given an LOSP event.
INTER2 RP	Return to power operation not possible or failed	Not possible for an LOSP event.
REC3 GR	Offsite grid recovery	Incorporated in recovery rules file.

TABLE 2.3-1
LOSP EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
REC3 UA	DG A recovery	Insignificant contribution. Not necessary to incorporate.
REC3 UB	DG B recovery	Insignificant contribution. Not necessary to incorporate.
REC3 UC	DG C recovery	Insignificant contribution. Not necessary to incorporate.
REC3 U1	Division I PSW restoration after AC power recovery	Direct linking of PSW and AC power support. Not necessary to incorporate.
REC3 U2	Division II PSW restoration after AC power recovery	Direct linking of PSW and AC power support. Not necessary to incorporate.
REC2 DCREC	Restore DC power	Incorporated under gate DC-1R25S001 (DCREC1) which is eventually input to gate #LO.
REC2 NBREC	Restore normal AC, restart CO after fast transfer failure or load shed failure	Incorporated under gates NBA-NOXFR (NBREC1) and LOADSHED-1 (NBREC2).
REC2 SWREC	Open alternate path to river	Incorporated under gate NOSWREC1 (SWREC1) which is eventually input to gate #QR.
REC2 RSREC	Motor cooling for RHRSW pumps not available/not restored	Incorporated in system fault tree model for RHRSW under gate RSREC.
RHRCS Z5	Dummy top event – RHR/CS event tree not bypassed	Not a functional requirement for core damage mitigation.
RHRCS VA	RHR/CS loop A room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VA.
RHRCS VB	RHR/CS loop B room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VB.
RHRCS VOP	Operators fail to trip unneeded pumps on loss of RHR/CS room cooling	Incorporated in system fault tree models for RHR and core spray under gates CS-VA and CS-VB.
RHRCS NS	LPCI/CS low pressure permissive signal fails	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS NSREC	LPCI/CS low pressure permissive not recovered	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS LC	LPCI/CS initiation signals unavailable	Incorporated in system fault tree models for core spray, LPCI, turbine building PSW isolation, and diesel 1B MCC AC-1R24S026 under gate LC.
RHRCS RA	RHR loop A pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPA-1 and SDCLOOPA.

TABLE 2.3-1
LOSP EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
RHRCS RB	RHR loop B pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPB-1 and SDCLOOPB.
RHRCS JS	LPCI injection paths for both loops unavailable	Incorporated in system fault tree model for RHR under gates LPCI (under core damage event tree gate #LO) and QS (under core damage event tree gate #QR).
RHRCS CS	Core spray system fails	Incorporated in system fault tree model for core spray under gate CS which is under core damage event tree gate #LO.
RHRCS HA	RHR service water pumps in division I fail	Incorporated in system fault tree model for RHR under gates QT and QS (gate HSA).
RHRCS HB	RHR service water pumps in division II fail	Incorporated in system fault tree model for RHR under gates QT and QS (gate HSB).
LTC1 HI	High pressure core cooling inadequate/not recovered	Incorporated in system fault tree model under gate HI-1. HI-1 is under HPCI-1, #HP-1, and #HP-B.
LTC1 DWTC	Drywell temperature control inadequate – sprays required	Incorporated in core damage event tree model under gate #ADED.
LTC1 OW	Operators fail to initiate drywell sprays on increasing drywell temperature	Incorporated in core damage event tree model under gate #ADED (system fault tree model gate OW).
LTC1 DE	Operators fail to depressurize vessel before core damage occurs	Incorporated in core damage event tree model under gate #DE.
LTC1 DESC2	Emergency depressurization occurs	Not a functional requirement for core damage mitigation.
LTC1 RPOP	Normal cooldown initiated	Not possible for an LOSP event.
LTC1 LO	Low pressure injection and control inadequate	Incorporated in core damage event tree model under gate #LO.
LTC1 OL	Operators fail to provide adequate long term heat removal	Incorporated in core damage event tree model under gates #QR and #QT.
LTC1 QS	RHR shutdown cooling path not available	Incorporated in core damage event tree model under gate #QR (system fault tree gate QS).
LTC1 QC	Main condenser unavailable	Incorporated in core damage event tree model under gates #QR (system fault tree gate QC), but guaranteed to fail for LOSP event.
LTC1 QT	Torus cooling not available	Incorporated in core damage event tree model under gates #QR and #QT (system fault tree gate QT).

TABLE 2.3-1
LOSP EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LTC1 QV	Containment vent not available for heat removal	Incorporated in core damage event tree model under gate #QR (system fault tree gate QV).
LTC1 DESC1	Containment pressure increases; manual operation of SRVs precluded	Not a functional requirement for core damage mitigation.
LTC1 IN1	Injection fails to remain available when reactor repressurizes	Not modeled for LOSP events.
LTC1 QR	Heat removal not recovered before ECCS or containment fails	Not modeled for LOSP events.
LTC1 CFF	ECCS systems fail before containment fails	Not a functional requirement for core damage mitigation.
LTC1 IN2	Injection fails to remain available after containment failure	Not a functional requirement for core damage mitigation.

2.4 The Large LOCA Event Tree

This sections contains information regarding the core damage event tree developed for the large LOCA initiators, including %ALOCA and %LLOCA.

EVENT TREE

Figure 2.4-1 displays the large LOCA core damage event tree.

EVENT TREE MODIFICATION

In the IPE, the frontline system core damage sequences for both of the large LOCA initiators were obtained by linking together 5 RISKMAN frontline systems event trees; i.e., event trees LOCA, INTER1, REC0, RHRCS, and LTC1. This same set of linked event trees is also used for the medium LOCA initiator. The only differences are the split fraction assignments for selected top events.

After reviewing the RISKMAN event trees developed for the previously mentioned group of initiating events, the following key changes were made:

- The initiators were combined into a single transient initiator heading LLOCA (with a node designated by IEGALLOCA).
- Top events modeled in RISKMAN event trees are combined according to the functions provided by the individual systems.
- With some (e.g., RP), many of the top events in RISKMAN event tree INTER1 are incorporated into lower level fault tree models for LOCA signal, operator restoration following a LOCA signal, etc.
- Recovery top events modeled in REC0 are incorporated into the appropriate system fault trees throughout the model.
- Most top events listed in RISKMAN event trees RHRCS and LTC1 are incorporated into the lower level fault trees for ETA headings LO and QR. RISKMAN top events Z5, HI, DWTC, OW, DE, DESC2, RPOP, QS, QC, DESC1, IN1, CFF, and IN2 were determined to not be functional requirements for core damage mitigation in this case.

The initiators included in the ETA transient initiator heading LLOCA are %ALOCA and %LLOCA.

For the new ETA event tree LLOCA, nodes under each heading may be represented by one or more fault tree gates. The multiple RISKMAN system models were combined into one fault tree gate with additional compression achieved by combining similar functions into one final fault tree gate with multiple inputs. Listed below are the new top logic gates developed for the ETA event tree nodes and the relevant, original inputs associated with each (i.e., RISKMAN event tree top events combined into the gate):

#LO	CS, RA, RB, JS, VA, VB, VOP, NS, NSREC, LC
#QRQRA	OL, QT, RA, RB, VA, VB, VOP, HA, HB, QV, QR

Table 2.4-1 provides a summary of the disposition for each RISKMAN event tree top event.

EVENT TREE HEADINGS & BRANCHES

The following event tree headings and nodes appear on the tree in the approximate chronological order that would be expected during a transient.

LLOCA Large LOCA Initiating Events. This heading (Branch ID IEGALLOCA) includes both large LOCA initiators.

LO Low Pressure Injection. This heading models the low pressure injection function provided by the core spray and low pressure coolant injection (LPCI) systems. Only automatic actions are considered for core spray and LPCI. Success of this event implies that low pressure injection is available. Failure of this event (Branch ID #LO) implies that low pressure injection is unsuccessful.

QR Decay Heat removal. This heading models decay heat removal by suppression pool cooling, torus vent, etc. Top logic gate #QRQRA has been developed to model the node under this heading. Recovery of decay heat removal during the period prior to containment or ECCS failure is also considered.

SEQUENCES

The following descriptions refer to the core damage sequences presented in figure 2.4-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path.

LLOCA_2: IEGALLOCA /#LO #QRQRA

A large LOCA event occurs (IEGALLOCA). Due to the LOCA break flow, the reactor is shut down and the vessel pressure decreases to the low pressure system shutoff head. Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage.

LLOCA_3: IEGALLOCA #LO

Similar to Sequence LLOCA_2, a large LOCA event occurs (IEGALLOCA). Due to the LOCA break flow, the reactor is shut down and the vessel pressure decreases to the low pressure system shutoff head. Low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence.

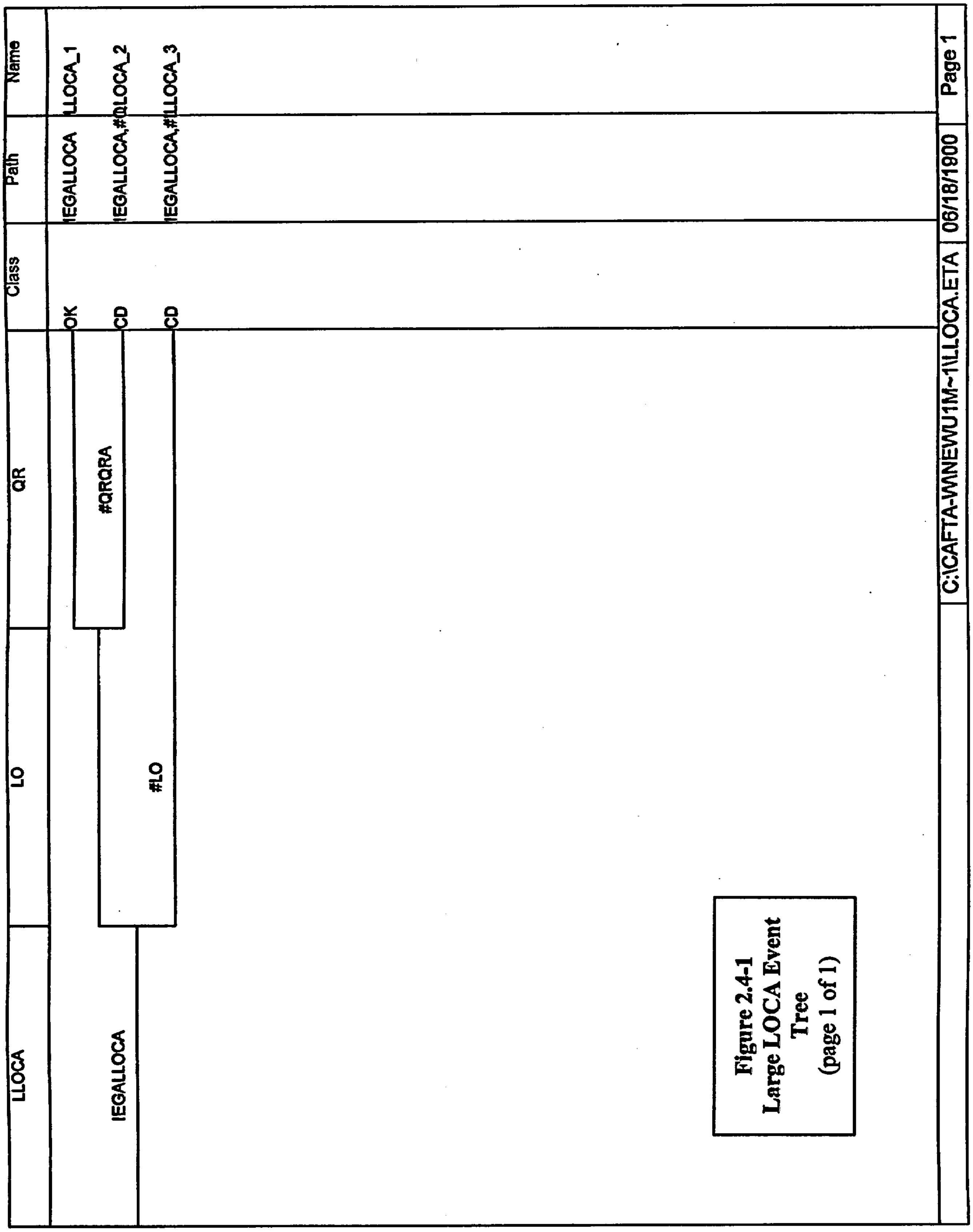

Figure 2.4-1
Large LOCA Event Tree
(page 1 of 1)

TABLE 2.4-1
LARGE LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LOCA IE	LOCA initiator	Incorporated in core damage event tree model under gate IEGALLOCA.
LOCA BV	Bypass valves fail to open for pressure control	Not a functional requirement for core damage mitigation.
LOCA PR	Pressure relief inadequate	Not a functional requirement for core damage mitigation.
LOCA SORV	SRV reclosure status	Not a functional requirement for core damage mitigation.
LOCA CO	Condensate system for injection	Not credited for core damage mitigation.
LOCA FW	Feedwater not available after initiating event	Not available for core damage mitigation.
LOCA FR	Feedwater/Condensate not recovered before Level 2 reached	Not available for core damage mitigation.
LOCA MC	MSIVs fail to remain open/main condenser not available	Not available for core damage mitigation.
LOCA RCIC	RCIC fails	Not available for core damage mitigation.
LOCA HPCI	HPCI fails	Not available for core damage mitigation.
INTER1 VC	Drywell cooling inadequate to prevent LOCA signal	LOCA signal will be generated for the large LOCA initiators. Not a functional requirement for core damage mitigation.
INTER1 V18	Operators fail to vent via 18" vents to prevent LOCA signal on loss of cooling	LOCA signal will be generated for the large LOCA initiators. Not a functional requirement for core damage mitigation.
INTER1 LOCA	LOCA signal (Level 1 or high drywell pressure) generated	Incorporated into system fault tree model gates LOCASIG and LOCASIGVC.
INTER1 MS	MSIVs fail to isolate reactor	Not a functional requirement for core damage mitigation.
INTER1 L1OP	Status of operator actions following LOCA signal	Incorporated in system fault tree model gates NORDWC1, NOINADS1, and NOTBISO1.
INTER1 CW	RBCCW not available	Not a functional requirement for core damage mitigation.

TABLE 2.4-1
LARGE LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
INTER1 RD	CRD pumps are unavailable for injection	Not a functional requirement for core damage mitigation.
INTER1 RP	Return to power operation not possible or failed	Not possible to return to power operation.
REC0 DCREC	DC power not restored to deenergized bus	Incorporated in system fault tree model gates DC-1R25S001, NBA-NOXFR, and NBA-NOXFR-1.
REC0 NBREC	Normal busses remain deenergized	Incorporated in system fault tree model gates NBA-NOXFR, NBA-NOXFR-1, XD-1, and XD-2.
REC0 SWREC	PSW not restored	Incorporated in system fault tree model for PSW under gates NOSWREC1, NOSWREC2, NOKMCR1, and L-PS-G125.
REC0 RSREC	Motor cooling for RHRSW pumps not available/not restored	Incorporated in system fault tree model for RHRSW under gate RSREC.
REC0 KMCR	Main control room cooling not recovered/purge mode not available	Incorporated in system fault tree models for MCR cooling, PSW, etc. under gates NOKMCR1, NOMCRPURGE, VM-G038, and PSWDISCHKMCR1.
REC0 KRSDP	Transfer of control to remote shutdown panel(s) not accomplished	Incorporated in system fault tree models for LPCI, etc. under gate NOKRSDP-1.
RHRCS Z5	Dummy top event – RHR/CS event tree not bypassed	Not a functional requirement for core damage mitigation
RHRCS VA	RHR/CS loop A room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VA.
RHRCS VB	RHR/CS loop B room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VB.
RHRCS VOP	Operators fail to trip unneeded pumps on loss of RHR/CS room cooling	Incorporated in system fault tree models for RHR and core spray under gates CS-VA and CS-VB.
RHRCS NS	LPCI/CS low pressure permissive signal fails	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS NSREC	LPCI/CS low pressure permissive not recovered	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS LC	LPCI/CS initiation signals unavailable	Incorporated in system fault tree models for core spray, LPCI, turbine building PSW isolation, and diesel 1B MCC AC-1R24S026 under gate LC.

TABLE 2.4-1
LARGE LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
RHRCS RA	RHR loop A pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPA and RHRLOOPA-1.
RHRCS RB	RHR loop B pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPB and RHRLOOPB-1.
RHRCS JS	LPCI injection paths for both loops unavailable	Incorporated in system fault tree model for RHR under gate LPCI (under core damage event tree gate #LO).
RHRCS CS	Core spray system fails	Incorporated in system fault tree model for core spray under gate CS which is under core damage event tree gate #LO.
RHRCS HA	RHR service water pumps in division I fail	Incorporated in system fault tree model for RHR under gate QT.
RHRCS HB	RHR service water pumps in division II fail	Incorporated in system fault tree model for RHR under gate QT.
LTC1 HI	High pressure core cooling inadequate/not recovered	High pressure core cooling systems not available.
LTC1 DWTC	Drywell temperature control inadequate – sprays required	Not a functional requirement for core damage mitigation.
LTC1 OW	Operators fail to initiate drywell sprays on increasing drywell temperature	Not a functional requirement for core damage mitigation.
LTC1 DE	Operators fail to depressurize vessel before core damage occurs	Vessel would depressurize. Not a functional requirement for core damage mitigation.
LTC1 DESC2	Emergency depressurization occurs	Not a functional requirement for core damage mitigation.
LTC1 RPOP	Normal cooldown initiated	Not possible for normal cooldown.
LTC1 LO	Low pressure injection and control inadequate	Incorporated in core damage event tree model under gate #LO.
LTC1 OL	Operators fail to provide adequate long term heat removal	Incorporated in core damage event tree model under gate #QRQRA.
LTC1 QS	RHR shutdown cooling path not available	Not sufficient for core damage mitigation.
LTC1 QC	Main condenser unavailable	Not available for core damage mitigation.

TABLE 2.4-1
LARGE LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LTC1 QT	Torus cooling not available	Incorporated in core damage event tree model under gate #QRQRA (system fault tree gate QT).
LTC1 QV	Containment vent not available for heat removal	Incorporated in core damage event tree model under gates #QRQRA (system fault tree gate QV).
LTC1 DESC1	Containment pressure increases; manual operation of SRVs precluded	Not a functional requirement for core damage mitigation.
LTC1 IN1	Injection fails to remain available when reactor repressurizes	Vessel would not repressurize. Not a functional requirement for core damage mitigation.
LTC1 QR	Heat removal not recovered before ECCS or containment fails	Incorporated in core damage event tree model under gates #QRQRA.
LTC1 CFF	ECCS systems fail before containment fails	Not credited for core damage mitigation.
LTC1 IN2	Injection fails to remain available after containment failure	Not credited for core damage mitigation.

2.5 The Medium LOCA Event Tree

This sections contains information regarding the core damage event tree developed for the medium LOCA initiator; i.e., %MLOCA.

EVENT TREE

Figure 2.5-1 displays the medium LOCA core damage event tree.

EVENT TREE MODIFICATION

In the IPE, the frontline system core damage sequences for the medium LOCA initiator were obtained by linking together 5 RISKMAN frontline systems event trees; i.e., event trees LOCA, INTER1, REC0, RHRCS, and LTC1.

After reviewing the RISKMAN event trees developed for this initiating event, the following key changes were made:

- Top events modeled in RISKMAN event trees are combined according to the functions provided by the individual systems.
- With some exceptions (e.g., RP), many top events in RISKMAN event tree INTER1 are incorporated into lower level fault tree models for LOCA signal, operator restoration following a LOCA signal, etc.
- Recovery top events modeled in REC0 are incorporated into the appropriate system fault trees throughout the model.
- Most top events listed in RISKMAN event trees RHRCS and LTC1 are incorporated into the lower level fault trees for ETA headings DE, LO, and QR. RISKMAN top events Z5, DWTC, OW, DESC2, RPOP, QS, QC, DESC1, IN1, CFF, and IN2 were determined to not be functional requirements for core damage mitigation.

For the new ETA event tree MLOCA, nodes under each heading may be represented by one or more fault tree gates. The multiple RISKMAN system models were combined into one fault tree gate with additional compression achieved by combining similar functions into one final fault tree gate with multiple inputs. Listed below are the new top logic gates developed for the ETA event tree nodes and the relevant, original inputs associated with each (i.e., RISKMAN event tree top events combined into the gate):

#HP-1	HPCI
#DEHICO1	DE, HI, CO
#LO	CO, CS, RA, RB, JS, VA, VB, VOP, NS, NSREC, LC
#QRQRA	OL, QT, RA, RB, VA, VB, VOP, HA, HB, QV, QR

Table 2.5-1 provides a summary of the disposition for each RISKMAN event tree top event.

EVENT TREE HEADINGS & BRANCHES

The following event tree headings and nodes appear on the tree in the approximate chronological order that would be expected during a transient.

%MLOCA Medium LOCA Initiating Event. This heading includes only one initiator; i.e., %MLOCA.

HPI High Pressure Level Control by HPCI. This heading models the high-pressure level control as well as cooldown and depressurization functions provided by the HPCI system. For medium LOCA, RCIC is inadequate for vessel level control. Only automatic actuation is considered in this heading and HPCI recovery is not credited for this initiator. Also included in this heading are the operator actions to control HPCI to prevent multiple Level 8 trips. Success of this event implies that HPCI is available to provide the high-pressure level control, cooldown, and depressurization functions. Failure of this event (Branch ID #HP-1) implies that HPCI is unavailable for the vessel level control and cooldown functions and vessel depressurization is required.

DE Depressurization of Vessel Before Core Damage. This heading models the reduction of vessel pressure to permit level recovery. This heading includes the manual emergency depressurization actions required when all high-pressure injection sources are lost. Also included in this heading is the controlled cooldown and pressure reduction with the use of condensate booster pumps. This heading is only asked when HPI fails. Success of this event implies that operators successfully depressurize the reactor vessel to allow injection by the low pressure systems. Failure of this event (Branch ID #DEHICO1) implies that reactor vessel remains at high pressure and core damage would result. #DEHICO1 also accounts for a condensate/condensate booster pump injection at a lower reactor pressure, approximately 500 psig.

LO Low Pressure Injection. This heading models the low pressure injection function provided by the condensate, core spray, and low pressure coolant injection (LPCI) systems. Only automatic actions are considered for core spray and LPCI. Success of this event implies that low pressure injection is available. Failure of this event (Branch ID #LO) implies that low pressure injection is unsuccessful.

QR Decay Heat removal. This heading models decay heat removal by suppression pool cooling, torus vent, etc. Top logic gate #QRQRA has been developed to model the node under this heading. Recovery of decay heat removal during the period prior to containment or ECCS failure is also considered.

SEQUENCES

The following descriptions refer to the core damage sequences presented in figure 2.5-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path.

MLOCA_2: %MLOCA /#HP-1 /#LO #QRQRA

A medium LOCA event occurs (%MLOCA). After reactor trip, high-pressure injection by HPCI is successful (/#HP-1). Vessel pressure is reduced due to the cooldown operation provided by HPCI. Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage.

MLOCA_3: %MLOCA /#HP-1 #LO

Similar to Sequence MLOCA_2, a medium LOCA event occurs (%MLOCA). After reactor trip, high-pressure injection by HPCI is successful (/#HP-1). Vessel pressure is reduced to the low pressure system shutoff head due to the cooldown operation provided by HPCI. Low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence.

MLOCA_5: %MLOCA #HP-1 /#DEHICO1 /#LO #QRQRA

A medium LOCA event occurs (%MLOCA). After reactor trip, high-pressure injection by HPCI fails (#HP-1). Vessel pressure is successfully reduced either by the cooldown operation of condensate/condensate booster pumps or by the manual initiation of SRV pressure relief (/#DEHICO1). Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage. Compared to Sequence MLOCA_2, this sequence is not minimal since it involves the additional failure of HPCI (#HP-1).

MLOCA_6: %MLOCA #HP-1 /#DEHICO1 #LO

A medium LOCA event occurs (%MLOCA). After reactor trip, high-pressure injection by HPCI fails (#HP-1). Vessel pressure is successfully reduced to the low pressure system shutoff head either by the cooldown operation of condensate/condensate booster pumps or by the manual initiation of SRV pressure relief (/#DEHICO1). Low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence. Compared to Sequence MLOCA_3, this sequence is not minimal since it involves the additional failure of HPCI (#HP-1).

MLOCA_7: %MLOCA #HP-1 #DEHICO1

A medium LOCA event occurs (%MLOCA). After reactor trip, high-pressure injection by HPCI fails (#HP-1). In addition, vessel pressure reduction is unsuccessful (#DEHICO1) resulting in eventual core damage.

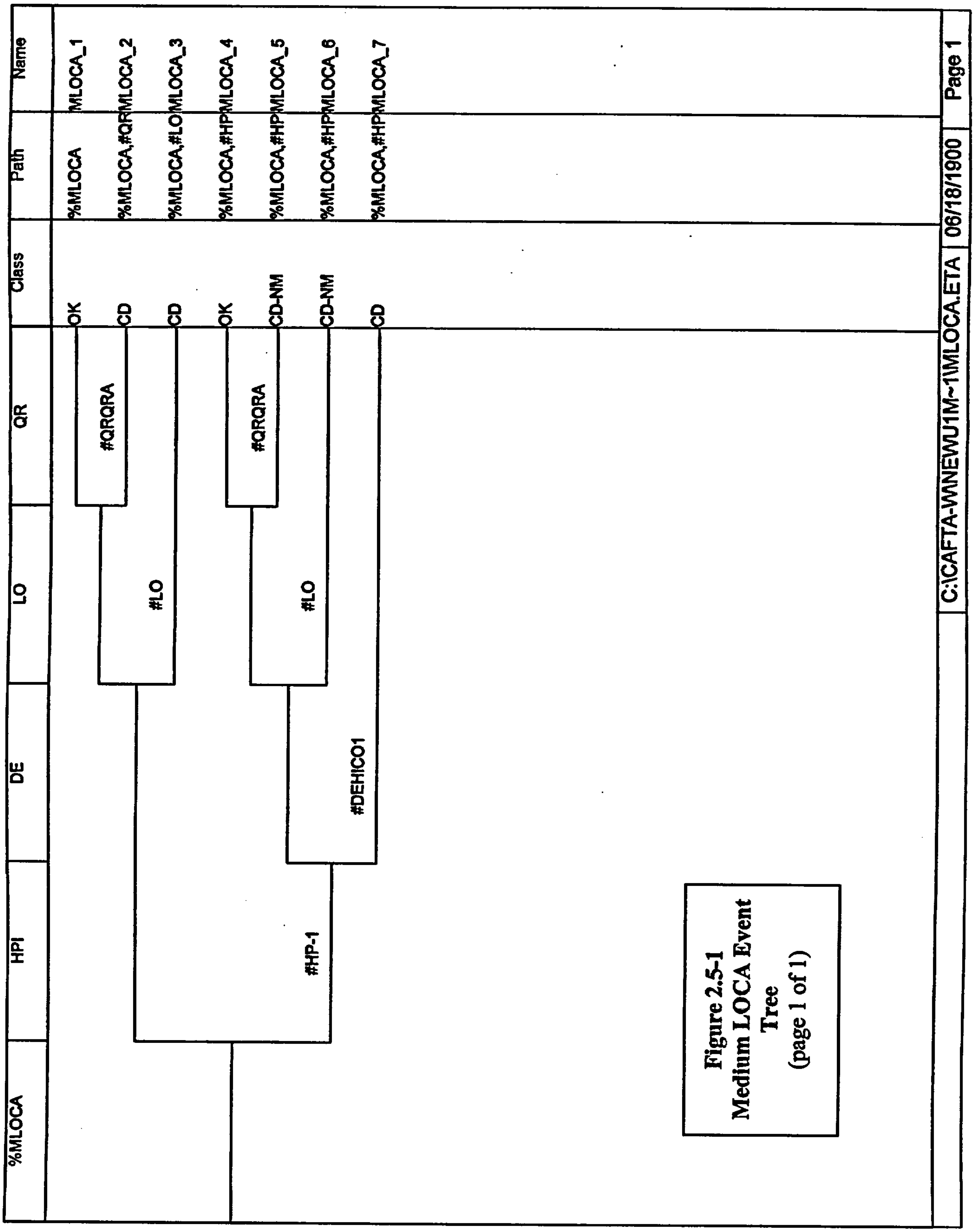

Figure 2.5-1
Medium LOCA Event Tree
(page 1 of 1)

TABLE 2.5-1
MEDIUM LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LOCA IE	LOCA Initiator	Incorporated in core damage event tree model under gate %MLOCA.
LOCA BV	Bypass valves fail to open for pressure control	Not a functional requirement for core damage mitigation.
LOCA PR	Pressure relief inadequate	Not a functional requirement for core damage mitigation.
LOCA SORV	SRV reclosure status	Not a functional requirement for core damage mitigation.
LOCA CO	Condensate system for injection	Incorporated in core damage event tree model under gates #LO and #DEHICO1 (system fault tree model gate CO).
LOCA FW	Feedwater not available after transient	Not available for core damage mitigation.
LOCA FR	Feedwater/Condensate not recovered before Level 2 reached	Not available for core damage mitigation.
LOCA MC	MSIVs fail to remain open/main condenser not available	Not available for core damage mitigation.
LOCA RCIC	RCIC fails	Not sufficient for core damage mitigation.
LOCA HPCI	HPCI fails	Incorporated in core damage event tree model under gates #HP-1.
INTER1 VC	Drywell cooling inadequate to prevent LOCA signal	LOCA signal will be generated for the medium LOCA initiator. Not a functional requirement for core damage mitigation.
INTER1 V18	Operators fail to vent via 18" vents to prevent LOCA signal on loss of cooling	LOCA signal will be generated for the medium LOCA initiator. Not a functional requirement for core damage mitigation.
INTER1 LOCA	LOCA signal (Level 1 or high drywell pressure) generated	Incorporated in system fault tree model gates LOCASIG and LOCASIGVC.
INTER1 MS	MSIVs fail to isolate reactor	Not a functional requirement for core damage mitigation.
INTER1 L1OP	Status of operator actions following LOCA signal	Incorporated in system fault tree model gates NORDWC1 (under core damage event tree gate #DEHICO1) and NOTBISO1 (under system fault tree model gates NOCRD, PSWTB-2, and HI-1). Gate NOCRD is under gate #DE which is under #DEHICO1. HI-1 is under #DEHICO1, HPCI-1, and #HP-1.

TABLE 2.5-1
MEDIUM LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
INTER1 CW	RBCCW not available	Not credited for core damage mitigation.
INTER1 RD	CRD pumps are unavailable for injection	Not credited for core damage mitigation.
INTER1 RP	Return to power operation not possible or failed	Not possible to return to power operation.
REC0 DCREC	DC power not restored to deenergized bus	Incorporated in system fault tree model gates DC-1R25S001, NBA-NOXFR, and NBA-NOXFR-1.
REC0 NBREC	Normal busses remain deenergized	Incorporated in system fault tree model gates NBA-NOXFR, NBA-NOXFR-1, XD-1, and XD-2.
REC0 SWREC	PSW not restored	Incorporated in system fault tree model for PSW under gates NOSWREC1, NOSWREC2, NOKMCR1, and L-PS-G125.
REC0 RSREC	Motor cooling for RHRSW pumps not available/not restored	Incorporated in system fault tree model for RHRSW under gate RSREC.
REC0 KMCR	Main control room cooling not recovered/purge mode not available	Incorporated in system fault tree models for MCR cooling, PSW, etc. under gates NOKMCR1, NOMCRPURGE, VM-G038, and PSWDISCHKMCR1.
REC0 KRSDP	Transfer of control to remote shutdown panel(s) not accomplished	Incorporated in system fault tree models for LPCI, RCIC, etc. under gate NOKRSDP-1.
RHRCS Z5	Dummy top event – RHR/CS event tree not bypassed	Not a functional requirement for core damage mitigation
RHRCS VA	RHR/CS loop A room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VA.
RHRCS VB	RHR/CS loop B room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VB.
RHRCS VOP	Operators fail to trip unneeded pumps on loss of RHR/CS room cooling	Incorporated in system fault tree models for RHR and core spray under gates CS-VA and CS-VB.
RHRCS NS	LPCI/CS low pressure permissive signal fails	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS NSREC	LPCI/CS low pressure permissive not recovered	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.

TABLE 2.5-1
MEDIUM LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
RHRCS LC	LPCI/CS initiation signals unavailable	Incorporated in system fault tree models for core spray, LPCI, turbine building PSW isolation, and diesel 1B MCC AC-1R24S026 under gate LC.
RHRCS RA	RHR loop A pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPA and RHRLOOPA-1.
RHRCS RB	RHR loop B pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPB and RHRLOOPB-1.
RHRCS JS	LPCI injection paths for both loops unavailable	Incorporated in system fault tree model for RHR under gate LPCI (under core damage event tree gate #LO).
RHRCS CS	Core spray system fails	Incorporated in system fault tree model for core spray under gate CS which is under core damage event tree gate #LO.
RHRCS HA	RHR service water pumps in division I fail	Incorporated in system fault tree model for RHR under gate QT.
RHRCS HB	RHR service water pumps in division II fail	Incorporated in system fault tree model for RHR under gate QT.
LTC1 HI	High pressure core cooling inadequate/not recovered	Incorporated in system fault tree model under gate HI-1. HI-1 is under #DEHICO1, HPCI-1 and #HP-1.
LTC1 DWTC	Drywell temperature control inadequate – sprays required	Not a functional requirement for core damage mitigation.
LTC1 OW	Operators fail to initiate drywell sprays on increasing drywell temperature	Not a functional requirement for core damage mitigation.
LTC1 DE	Operators fail to depressurize vessel before core damage occurs	Incorporated in core damage event tree model under gate #DEHICO1.
LTC1 DESC2	Emergency depressurization occurs	Not a functional requirement for core damage mitigation.
LTC1 RPOP	Normal cooldown initiated	Not possible to return to power operation.
LTC1 LO	Low pressure injection and control inadequate	Incorporated in core damage event tree model under gate #LO.
LTC1 OL	Operators fail to provide adequate long term heat removal	Incorporated in core damage event tree model under gate #QRQRA.
LTC1 QS	RHR shutdown cooling path not available	Not sufficient for core damage mitigation.

TABLE 2.5-1
MEDIUM LOCA EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LTC1 QC	Main condenser unavailable	Not available for core damage mitigation.
LTC1 QT	Torus cooling not available	Incorporated in core damage event tree model under gate #QRQRA.
LTC1 QV	Containment vent not available for heat removal	Incorporated in core damage event tree model under gate #QRQRA.
LTC1 DESC1	Containment pressure increases; manual operation of SRVs precluded	Not a functional requirement for core damage mitigation.
LTC1 IN1	Injection fails to remain available when react6or repressurizes	Vessel would not repressurize. Not a functional requirement for core damage mitigation.
LTC1 QR	Heat removal not recovered before ECCS or containment fails	Incorporated in core damage event tree model under gate #QRQRA.
LTC1 CFF	ECCS systems fail before containment fails	Not credited for core damage mitigation.
LTC1 IN2	Injection fails to remain available after containment failure	Not credited for core damage mitigation.

2.6 The Inadvertent Opening of Relief Valve Event Tree

This sections contains information regarding the core damage event tree developed for the inadvertent opening of relief valve initiator; i.e., %IORV.

EVENT TREE

Figure 2.6-1 displays the inadvertent opening of relief valve core damage event tree.

EVENT TREE MODIFICATION

In the IPE, the frontline system core damage sequences for the inadvertent opening of relief valve initiator were obtained by linking together 5 RISKMAN frontline systems event trees; i.e., event trees IORV, INTER1, REC0, RHRCS, and LTC1.

After reviewing the RISKMAN event trees developed for this initiating event, the following key changes were made:

- Top events modeled in RISKMAN event trees are combined according to the functions provided by the individual systems.
- With the exception of RP, most of the top events in RISKMAN event tree INTER1 are incorporated into lower level fault tree models for LOCA signal, operator restoration following a LOCA signal, automatic/emergency depressurization, main condenser availability, etc.
- Recovery top events modeled in REC0 are incorporated into the appropriate system fault trees throughout the model.
- Most top events listed in RISKMAN event trees RHRCS and LTC1 are incorporated into the lower level fault trees for ETA headings DE, LO, and QR. RISKMAN top events Z5, DWTC, OW, DESC2, RPOP, QS, QC, DESC1, IN1, CFF, and IN2 were determined to not be functional requirements for core damage.

For the new ETA event tree IORV, nodes under each heading may be represented by one or more fault tree gates. The multiple RISKMAN system models were combined into one fault tree gate with additional compression achieved by combining similar functions into one final fault tree gate with multiple inputs. Listed below are the new top logic gates developed for the ETA event tree nodes and the relevant, original inputs associated with each (i.e., RISKMAN event tree top events combined into the gate):

BVA	BV
#PCS	CO, FW, FR, MC, MS
#HP-1	HPCI
#DEHICO1	DE, HI, CO
#LO	CO, CS, RA, RB, JS, VA, VB, VOP, NS, NSREC, LC
#QRQRA	OL, QT, RA, RB, VA, VB, VOP, HA, HB, QV, QR

Table 2.6-1 provides a summary of the disposition for each RISKMAN event tree top event.

EVENT TREE HEADINGS & BRANCHES

The following event tree headings and nodes appear on the tree in the approximate chronological order that would be expected during a transient.

%IORV Inadvertent Opening of Relief Valve Initiating Event. This heading includes only one initiator.

BV Pressure Relief. This heading models the pressure control function performed by the turbine bypass valves following a plant trip. Failure of this event (Branch ID BVA) would render the Power Conversion System unavailable.

PCS Power Conversion System. This heading models the availability or unavailability of the power conversion system to provide the core cooling function. Condensate system, feedwater system, and main condenser are included in this heading. One condensate pump and one condensate booster pump are required to support operation of a single feedwater pump. Only one reactor feed pump is required to provide feedwater flow to the reactor for level control. If the feedwater is initially unavailable following a reactor trip, restoration of feedwater prior to initiation of HPCI on Level 2 is also considered in this heading.

Success of this event implies that condensate, feedwater, and main condenser are available for plant response following the reactor trip. For the main condenser to remain available, the MSIVs must remain open, turbine bypass valves must continue to function and all support for the electrohydraulic control system must be available. Turbine bypass valves are modeled in the preceding heading (BV). Failure of this event (Branch ID #PCS) implies that HPCI will be demanded to operate to provide the high-pressure level control function.

HPI High Pressure Level Control by HPCI. This heading models the high-pressure level control function provided by the HPCI system. Only automatic actuation is considered in this heading and HPCI recovery is not credited for this initiator. Also included in this heading are the operator actions to control HPCI to prevent multiple Level 8 trips. RCIC is inadequate for vessel level control. This event is only asked in this event tree when turbine bypass valves or PCS is unsuccessful. Success of this event implies that HPCI is available to provide the high-pressure level control function. Failure of this event (Branch ID #HP-1) implies that HPCI is unavailable for the vessel level control function and vessel depressurization is required.

ADED No branches are included for this heading.

DE Depressurization of Vessel Before Core Damage. This heading models the reduction of vessel pressure to permit level recovery. This heading includes the manual emergency depressurization actions required when all high-pressure injection sources are lost. Also included in this heading is the controlled cooldown and pressure reduction with the use of condensate booster pumps. This heading is only asked when both PCS and HPI fail. Success of this event implies that operators successfully depressurize the reactor vessel to allow injection by the low pressure systems. Failure of this event (Branch ID #DEHICO1) implies that reactor vessel remains at high-pressure and core damage would result. #DEHICO1 also accounts for a condensate/condensate booster pump injection at a lower reactor pressure, approximately 500 psig.

LO Low Pressure Injection. This heading models the low pressure injection function provided by the condensate, core spray, and low pressure coolant injection (LPCI) systems. Both automatic and manual actions are considered for core spray and LPCI. Success of this event implies that low pressure injection is available. Failure of this event (Branch ID #LO) implies that low pressure injection is unsuccessful.

QR Decay Heat removal. This heading models decay heat removal by suppression pool cooling, torus vent, etc. Top logic gate #QRQRA has been developed to model the nodes under this heading. Recovery of decay heat removal during the period prior to containment or ECCS failure is considered.

SEQUENCES

The following descriptions refer to the core damage sequences presented in figure 2.6-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path.

IORV_2: %IORV /BVA /#PCS #QRQRA

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure is successfully maintained by the turbine bypass valves (/BVA). In addition, condensate, feedwater, and main condenser operate successfully (/#PCS). Since the power conversion system is successful, high-pressure injection by HPCI is not necessary. The decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage.

IORV_4: %IORV /BVA #PCS /#HP-1 /#LO #QRQRA

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure is successfully maintained by the turbine bypass valves (/BVA). The power conversion system (condensate, feedwater, and main condenser) fails to operate (#PCS). High pressure injection by HPCI is successful (/#HP-1). Vessel pressure is reduced due to the cooldown operation provided by HPCI. Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage. Compared to Sequence IORV_2, this sequence is not minimal since it involves the additional failure of the power conversion system.

IORV_5: %IORV /BVA #PCS /#HP-1 #LO

Similar to Sequence IORV_4, an inadvertent opening of relief valve event occurs (%IORV). vessel pressure is successfully maintained by the turbine bypass valves (/BVA). The power conversion system (condensate, feedwater, and main condenser) fails to operate (#PCS). High pressure injection by HPCI is successful (/#HP-1). Vessel pressure is reduced due to the cooldown operation provided by HPCI. Low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence.

IORV_7: %IORV /BVA #PCS #HP-1 /#DEHICO1 /#LO #QRQRA

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure is successfully maintained by the turbine bypass valves (/BVA). Both the power conversion system and high-pressure injection by HPCI fail (#PCS and #HP-1). Vessel pressure is successfully reduced either by the controlled cooldown with the use of condensate/condensate booster pumps or by the manual initiation of SRV pressure relief (/#DEHICO1). Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage. Compared to Sequence IORV_2, this sequence is not minimal since it involves the additional failures of the power conversion system and HPCI (#PCS and #HP-1).

IORV_8: %IORV /BVA #PCS #HP-1 /#DEHICO1 #LO

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure is successfully maintained by the turbine bypass valves (/BVA). Both the power conversion system and high-pressure injection by HPCI fail (#PCS and #HP-1). Vessel pressure is successfully reduced either by the controlled cooldown with the use of condensate/condensate booster pumps or by the manual initiation of SRV pressure relief (/#DEHICO1). Low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence. Compared to Sequence IORV_5, this sequence is not minimal since it involves the additional failure of HPCI (#HP-1).

IORV_9: %IORV /BVA #PCS #HP-1 #DEHICO1

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure is successfully maintained by the turbine bypass valves (/BVA). Both the power conversion system and high-pressure injection by HPCI fail (#PCS and #HP-1). In addition, vessel pressure reduction is unsuccessful (#DEHICO1) resulting in eventual core damage.

IORV_11: %IORV BVA /#HP-1 /#LO #QRQRA

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure control by the turbine bypass valves fails (BVA). This also renders the long term heat removal via the main condenser unavailable. Power conversion system is therefore conservatively modeled as unavailable. High pressure injection by HPCI is successful (/#HP-1). Vessel pressure is reduced due to the cooldown operation provided by HPCI. Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage. Compared to Sequence IORV_2, this sequence is not minimal since it involves the additional failure of the turbine bypass valves (BVA).

IORV_12: %IORV BVA /#HP-1 #LO

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure control by the turbine bypass valves fails (BVA). This also renders the long term heat removal via the main condenser unavailable. Power conversion system is therefore conservatively modeled as unavailable. High pressure injection by HPCI is successful (/#HP-1). Vessel pressure is reduced due to the cooldown operation provided by HPCI. Low pressure injection is unavailable (#LO) resulting in eventual core damage.

IORV_14: %IORV BVA #HP-1 /#DEHICO1 /#LO #QRQRA

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure control by the turbine bypass valves fails (BVA). This also renders the long term heat removal via the main condenser unavailable. Power conversion system is therefore conservatively modeled as unavailable. High pressure injection by HPCI fails (#HP-1). Vessel pressure is successfully reduced either by the controlled cooldown with the use of condensate/condensate booster pumps or by the manual initiation of SRV pressure relief (/#DEHICO1). Low pressure injection is successful (/#LO). However, the decay heat removal function is unavailable (#QRQRA) resulting in eventual core damage. Compared to Sequence IORV_2, this sequence is not minimal since it involves the additional failures of the turbine bypass valves and HPCI (BVA and #HP-1).

IORV_15: %IORV BVA #HP-1 /#DEHICO1 #LO

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure control by the turbine bypass valves fails (BVA). This also renders the long term heat removal via the main condenser unavailable. Power conversion system is therefore conservatively modeled as unavailable. High pressure injection by HPCI fails (#HP-1). Vessel pressure is successfully reduced either by the controlled cooldown with the use of condensate/condensate booster pumps or by the manual initiation of SRV pressure relief (/#DEHICO1). Low pressure injection is unsuccessful (#LO) resulting in eventual core damage. The decay heat removal function is not asked in this sequence. Compared to Sequence IORV_5, this sequence is not minimal since it involves the additional failure of HPCI (#HP-1).

IORV_16: %IORV BVA #HP-1 #DEHICO1

An inadvertent opening of relief valve event occurs (%IORV). After reactor trip, vessel pressure control by the turbine bypass valves fails (BVA). This also renders the long term heat removal unavailable. Power conversion system is therefore conservatively modeled as unavailable. High pressure injection by HPCI fails (#HP-1). In addition, vessel pressure reduction is unsuccessful (#DEHICO1) resulting in eventual core damage.

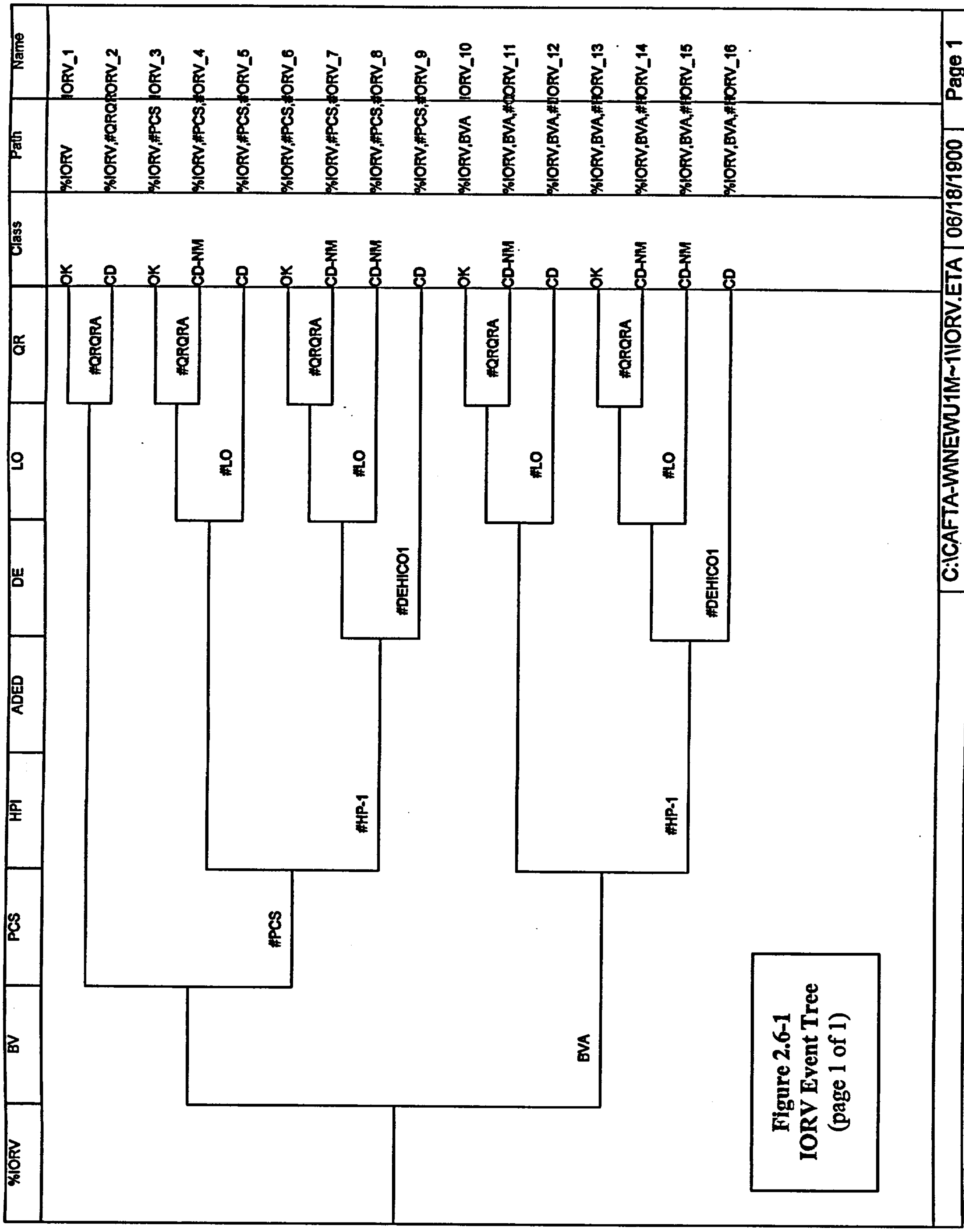

Figure 2.6-1
IORV Event Tree
(page 1 of 1)

TABLE 2.6-1
IORV EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
IORV IE	Transient Initiator	Incorporated in core damage event tree model under gate %IORV.
IORV BV	Bypass valves fail to open for pressure control	Incorporated in core damage event tree model under gate BVA.
IORV PR	Pressure relief inadequate	Not a functional requirement for core damage mitigation
IORV SORV	SRV reclosure status	Not a functional requirement for core damage mitigation
IORV CO	Condensate system for injection	Incorporated in core damage event tree model under gates #LO, #PCS, and #DEHICO1 (system fault tree model gate CO).
IORV FW	Feedwater not available after transient	Incorporated in core damage event tree model under gate #PCS (system fault tree model gate FW).
IORV FR	Feedwater/Condensate not recovered before Level 2 reached	Incorporated in core damage event tree model under gate #PCS (system fault tree model gate FR).
IORV MC	MSIVs fail to remain open/main condenser not available	Incorporated in core damage event tree model under gate #PCS (system fault tree model gate MC-1).
IORV RCIC	RCIC fails	Not credited for core damage mitigation.
IORV HPCI	HPCI fails	Incorporated in core damage event tree model under gates #HP-1 and HPCI-1.
INTER1 VC	Drywell cooling inadequate to prevent LOCA signal	LOCA signal will be generated for the medium LOCA initiator. Not a functional requirement for core damage mitigation.
INTER1 V18	Operators fail to vent via 18" vents to prevent LOCA signal on loss of cooling	LOCA signal will be generated for the medium LOCA initiator. Not a functional requirement for core damage mitigation.
INTER1 LOCA	LOCA signal (Level 1 or high drywell pressure) generated	Incorporated in system fault tree model gates LOCASIG and LOCASIGVC.
INTER1 MS	MSIVs fail to isolate reactor	Incorporated in core damage event tree model under gate #PCS (system fault tree mode gate MS-1 under system model MC-1).
INTER1 L1OP	Status of operator actions following LOCA signal	Incorporated in system fault tree model gates NORDWC1 (under core damage event tree gate #DEHICO1), NOINADS1, and NOTBISO1 (under system fault tree model gates NOCRD, PSWTB-2, and HI-1). Gate NOCRD is under gate #DE which is under #DEHICO1. HI-1 is under #DEHICO1, HPCI-1, and #HP-1.

TABLE 2.6-1
IORV EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
INTER1 CW	RBCCW not available	Not credited for core damage mitigation.
INTER1 RD	CRD pumps are unavailable for injection	Not credited for core damage mitigation.
INTER1 RP	Return to power operation not possible or failed	Not possible to return to power operation.
REC0/REC1 DCREC	DC power not restored to deenergized bus	Incorporated in system fault tree model gates DC-1R25S001, NBA-NOXFR, and NBA-NOXFR-1.
REC0/REC1 NBREC	Normal busses remain deenergized	Incorporated in system fault tree model gates NBA-NOXFR, NBA-NOXFR-1, XD-1, and XD-2.
REC0/REC1 SWREC	PSW not restored	Incorporated in system fault tree model for PSW under gates NOSWREC1, NOSWREC2, NOKMCR1, and L-PS-G125.
REC0/REC1 RSREC	Motor cooling for RHRSW pumps not available/not restored	Incorporated in system fault tree model for RHRSW under gate RSREC.
REC0/REC1 KMCR	Main control room cooling not recovered/purge mode not available	Incorporated in system fault tree models for MCR cooling, PSW, etc. under gates NOKMCR1, NOMCRPURGE, VM-G038, and PSWDISCHKMCR1.
REC0/REC1 KRSDP	Transfer of control to remote shutdown panel(s) not accomplished	Incorporated in system fault tree models for LPCI, RCIC, etc. under gate NOKRSDP-1.
RHRCS Z5	Dummy top event – RHR/CS event tree not bypassed	Not a functional requirement for core damage mitigation
RHRCS VA	RHR/CS loop A room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VA.
RHRCS VB	RHR/CS loop B room cooling unavailable	Incorporated in system fault tree models for RHR and core spray under gate CS-VB.
RHRCS VOP	Operators fail to trip unneeded pumps on loss of RHR/CS room cooling	Incorporated in system fault tree models for RHR and core spray under gates CS-VA and CS-VB.
RHRCS NS	LPCI/CS low pressure permissive signal fails	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.
RHRCS NSREC	LPCI/CS low pressure permissive not recovered	Incorporated in system fault tree models for core spray and LPCI under gates NS, NSRHRA, and NSRHRB.

TABLE 2.6-1
IORV EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
RHRCS LC	LPCI/CS initiation signals unavailable	Incorporated in system fault tree models for core spray, LPCI, turbine building PSW isolation, and diesel 1B MCC AC-1R24S026 under gate LC.
RHRCS RA	RHR loop A pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPA and RHRLOOPA-1.
RHRCS RB	RHR loop B pump trains fail	Incorporated in system fault tree model for RHR under gates RHRLOOPB and RHRLOOPB-1.
RHRCS JS	LPCI injection paths for both loops unavailable	Incorporated in system fault tree model for RHR under gate LPCI (under core damage event tree gate #LO).
RHRCS CS	Core spray system fails	Incorporated in system fault tree model for core spray under gate CS which is under core damage event tree gate #LO.
RHRCS HA	RHR service water pumps in division I fail	Incorporated in system fault tree model for RHR under gates QT.
RHRCS HB	RHR service water pumps in division II fail	Incorporated in system fault tree model for RHR under gates QT.
LTC1 HI	High pressure core cooling inadequate/not recovered	Incorporated in system fault tree model under gate HI-1. HI-1 is under #DEHICO1.
LTC1 DWTC	Drywell temperature control inadequate – sprays required	Not a functional requirement for core damage mitigation.
LTC1 OW	Operators fail to initiate drywell sprays on increasing drywell temperature	Not a functional requirement for core damage mitigation.
LTC1 DE	Operators fail to depressurize vessel before core damage occurs	Incorporated in core damage event tree model under gates #DEHICO1.
LTC1 DESC2	Emergency depressurization occurs	Not a functional requirement for core damage mitigation.
LTC1 RPOP	Normal cooldown initiated	Not possible to return to power operation.
LTC1 LO	Low pressure injection and control inadequate	Incorporated in core damage event tree model under gate #LO.
LTC1 OL	Operators fail to provide adequate long term heat removal	Incorporated in core damage event tree model under gates #QRQRA.
LTC1 QS	RHR shutdown cooling path not available	Not credited for core damage mitigation.

TABLE 2.6-1
IORV EVENT TREE TOP DISPOSITION

EVENT TREE TOP	DESCRIPTION	CORE DAMAGE MODEL DISPOSITION
LTC1 QC	Main condenser unavailable	Not a functional requirement for core damage mitigation.
LTC1 QT	Torus cooling not available	Incorporated in core damage event tree model under #QRQRA (system fault tree gate QT).
LTC1 QV	Containment vent not available for heat removal	Incorporated in core damage event tree model under gates #QRQRA (system fault tree gate QV).
LTC1 DESC1	Containment pressure increases; manual operation of SRVs precluded	Not a functional requirement for core damage mitigation.
LTC1 IN1	Injection fails to remain available when react6or repressurizes	Not a functional requirement for core damage mitigation.
LTC1 QR	Heat removal not recovered before ECCS or containment fails	Incorporated in core damage event tree model under gates #QRQRA.
LTC1 CFF	ECCS systems fail before containment fails	Not a functional requirement for core damage mitigation.
LTC1 IN2	Injection fails to remain available after containment failure	Not a functional requirement for core damage mitigation.

2.7 The Containment Release Event Tree

This section contains information regarding the containment release event tree.

EVENT TREE

Figure 2.7-1 displays the event tree for categorization of containment release sequences. The following discussions describe the modifications, define the event tree headings and describe the sequences presented.

EVENT TREE MODIFICATION

In the IPE model, each core damage sequence was first assigned an accident class. This assignment of the Level I core damage sequences dictated the path through the containment event tree (CET). The CET evaluates the characteristics of the containment response to the core damage sequences. It includes top events modeling those functions needed to support debris coolability and containment heat removal. The plant damage states are assigned to the CET outputs. They are based on the reactor status, the containment status, and the state of debris cooling. In addition, a release mode defining the type and the timing of release is also assigned to the CET outputs.

Due to the desire to collapse the number of unique plant damage states in the converted CAFTA model, it was decided to apply a simplified process of assigning core damage sequences to appropriate end states. SNC contracted Fauske and Associates (FAI) to develop the simplified Level II model. The results of the FAI work (Reference 3.3) was used to derive the simplified containment event tree as shown in figure 2.7-1. The primary purpose of the containment event tree is to identify those sequences resulting in a Large Early Release from the containment (i.e., rapid, unscrubbed release of airborn aerosols within 6 hours or prior to effective implementation of offsite emergency response).

EVENT TREE HEADINGS & BRANCHES

The following event tree headings appear on the tree in the approximate chronological order that would be expected to lead to a release of fission products from the containment.

@H1CDFTOP Core Damage. This event includes all sequences leading to core damage. Since core damage is a prerequisite to the release of fission products, this is the starting point for the release categorization.

BYPASS Containment Bypass. This event represents those core damage sequences resulting in the direct bypass of the containment fission product boundary and a direct release to the environment. This includes all Interfacing Systems LOCA (V sequences) and break outside containment sequences.

VINJEC Vessel Injection. This heading models the availability or unavailability of the vessel injection source. This heading is asked if the containment is not bypassed. If the injection source is available, it would continue until either the vessel pressure increases to above the injection shutoff head or the containment fails due to overpressure since no containment heat removal is available (note that containment heat removal is unavailable if vessel injection is available since a core damage has occurred). In either case (whether the containment failure occurs prior to vessel failure), the containment and vessel failure times would be close with injection available. This would lead to a large release from the containment. If the injection source is unavailable, the containment response would be dependent on the containment heat removal asked in the next heading.

CHR Containment Heat removal. This heading models the containment heat removal by the combination of drywell spray and suppression pool cooling. This heading is asked when the vessel injection is unavailable. If vessel injection is available, loss of containment heat removal is implied since core damage has already occurred. If the containment heat removal is available, the containment would remain intact. The drywell would be maintained at a relatively low pressure (with drywell spray available) minimizing the driving force for the release of fission products through leakage paths. The result is a small release from the containment. With no containment heat removal, venting would be required to limit the containment pressure rise.

VENT Containment Venting. This heading models containment venting via the drywell vent line or the wetwell vent line. It is asked when both the vessel injection and containment heat removal are unavailable. This is a multi-branch heading. The top branch represents successful containment venting via the wetwell vent line. The middle branch models successful venting via the drywell vent line. The bottom branch reflects unsuccessful venting. Venting through the wetwell will provide fission product scrubbing and venting from the drywell will result in an unscrubbed release. If the containment venting is unsuccessful, the containment pressure will continue to rise until the containment fails. However, the timing between the failure of the vessel and that of the containment is affected by the vessel pressure and drywell spray.

VDPR Vessel Depressurization. This heading models the reduction of vessel pressure. The status of this heading affects the timing between the failure of the vessel and that of the containment. This heading is asked when vessel injection, containment heat removal, and containment venting are all unavailable. If the vessel is not depressurized at the time of its failure, the drywell pressure would rise rapidly until the containment fails at time close to that of vessel failure. If the vessel is depressurized at the time of its failure, the rate of drywell pressure increase would not be sufficiently high to result in a containment failure occurring soon after vessel failure. As such, this scenario would not be an early release. Due to the elevated temperature in the containment caused by heatup from the debris bed (radiant heat) and concrete ablation, the containment failure pressure is reduced in this case. There is a long time between the vessel and containment failures. In the event of no vessel depressurization, drywell spray can also limit the pressure increase in the containment.

DWSP Drywell Spray. This heading models the availability or unavailability of drywell spray to limit the rate of containment pressure rise. This heading is asked when vessel injection, containment heat removal, containment venting, and vessel depressurization are all unavailable. If drywell spray is available, it can suppress the initial steam mass and reduce containment pressure rise. The drywell gas space temperature would increase. However, containment fails due to overpressure (not at a reduced pressure) caused by the spray water steaming from contact with the debris bed. This leads to an OPD end state. If drywell spray is unavailable, the drywell pressure rises quickly. Due to the lack of decay heat removal, the drywell gas temperature increases to the point where there is a reduced containment failure pressure due to the escalated temperature. An OT end state results in this case.

CNMT Containment Overpressure Failure. This heading models the containment overpressure failure location. This heading is asked when vessel injection is available and containment heat removal is unavailable. Failure of this heading includes drywell failure and wetwell water space failure. This would result in an unscrubbed release. Success of this heading implies a wetwell airspace failure.

SEQUENCES

The following descriptions refer to the Large Early Release sequences found in figure 2.7-1. The sequence descriptions use a "/" prior to the branch designation to denote the success path of the branch and the branch name alone to designate the failure path. The remaining release categories are included in the event tree, but are not currently incorporated into the converted model as distinct fault tree branches. Therefore, they are not discussed here.

LER_OPD: @H1CDFTOP /BYPASS /VINJEC CNMT

In LER_OPD, vessel injection is available with no containment heat removal following a core damage. Due to overpressure, the containment fails either prior to or soon after the vessel failure. The containment failure location is either in the drywell or in the wetwell water space. As a result, an unscrubbed release occurs.

LER_VD: @H1CDFTOP /BYPASS VINJEC CHR DWVENT

Following the core damage, vessel injection and containment heat removal are unavailable. To reduce the containment pressure, venting via the drywell vent line is performed. This provides no scrubbing.

LER_OT: @H1CDFTOP /BYPASS QV VDPR DWSP

Following the core damage, vessel injection, containment heat removal, containment venting, vessel depressurization, and drywell spray are all unavailable. The drywell pressure rises rapidly. The containment fails at a pressure lower than the design pressure due to the increased temperature in the drywell gas space caused by the loss of containment heat removal.

LER_CB: @H1CDFTOP BYPASS

This sequence involves the occurrence of either a break outside containment or an interfacing systems LOCA.

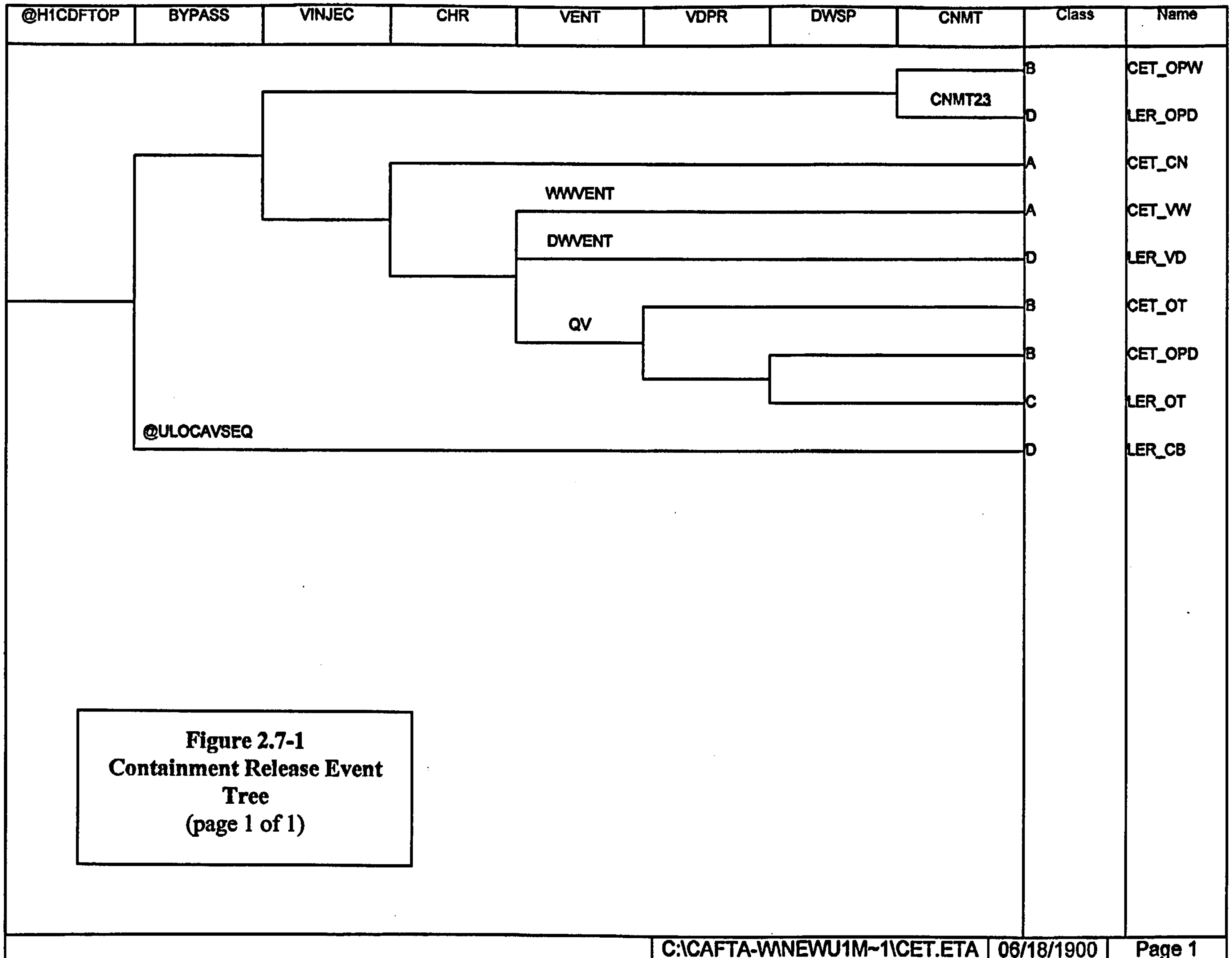

Figure 2.7-1
Containment Release Event Tree
(page 1 of 1)

3.0 References

3.1 Plant Hatch Individual Plant Examination Report in Response to Generic Letter 88-20, Volumes I and II.

3.2 Hatch IPE Work Package H60.7 – Event Trees.

3.3 Level II Process Plant Hatch, FAI/98-88, December 1998.