EVALUATION OF HIGH ENERGY LINE BREAKS AND
CONSEQUENTIAL CONTROL SYSTEMS FAILURES
(IE INFORMATION NOTICE 79-22 SUMMARY REPORT)

WASHINGTON PUBLIC POWER SUPPLY SYSTEM NUCLEAR PLANT NO. 2
RICHLAND, WASHINGTON

Prepared By: James E Parker
J.E. Parker

Reviewed By: SR Kirkendall
S.R. Kirkendall

Approved By: WG Conn 2/28/83
W.G. Conn
Senior Group Supervisor

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1.0 INTRODUCTION

1.1 OBJECTIVE

The objective of this analysis was to determine if any non-safety grade control equipment, if subjected to the adverse environment of a High Energy Line Break (HELB), could impact the WNP-2 safety analysis and/or the adequacy of the protective functions performed by the plants safety grade equipment. Investigations conducted were consistent with concerns identified by IE Information Notice 79-22 and in answer to WNP-2 NRC question 031.137.

1.2 APPROACH

The approach described below outlines the actions completed during this review. The sequence of this approach is shown graphically in Figure 1.

1.2.1 Identify non-safety grade control systems which may impact reactor pressure, water level, Critical Power Ratio (CPR), Feedwater (FW) temperature and/or the performance of safety-grade equipment.

1.2.2 Establish criteria for high energy line determination, break postulation and consequence evaluation.

1.2.3 Identify and locate all high energy lines. For the reactor building, pipe break studies previously completed were referenced for line and break locations as well as targets.

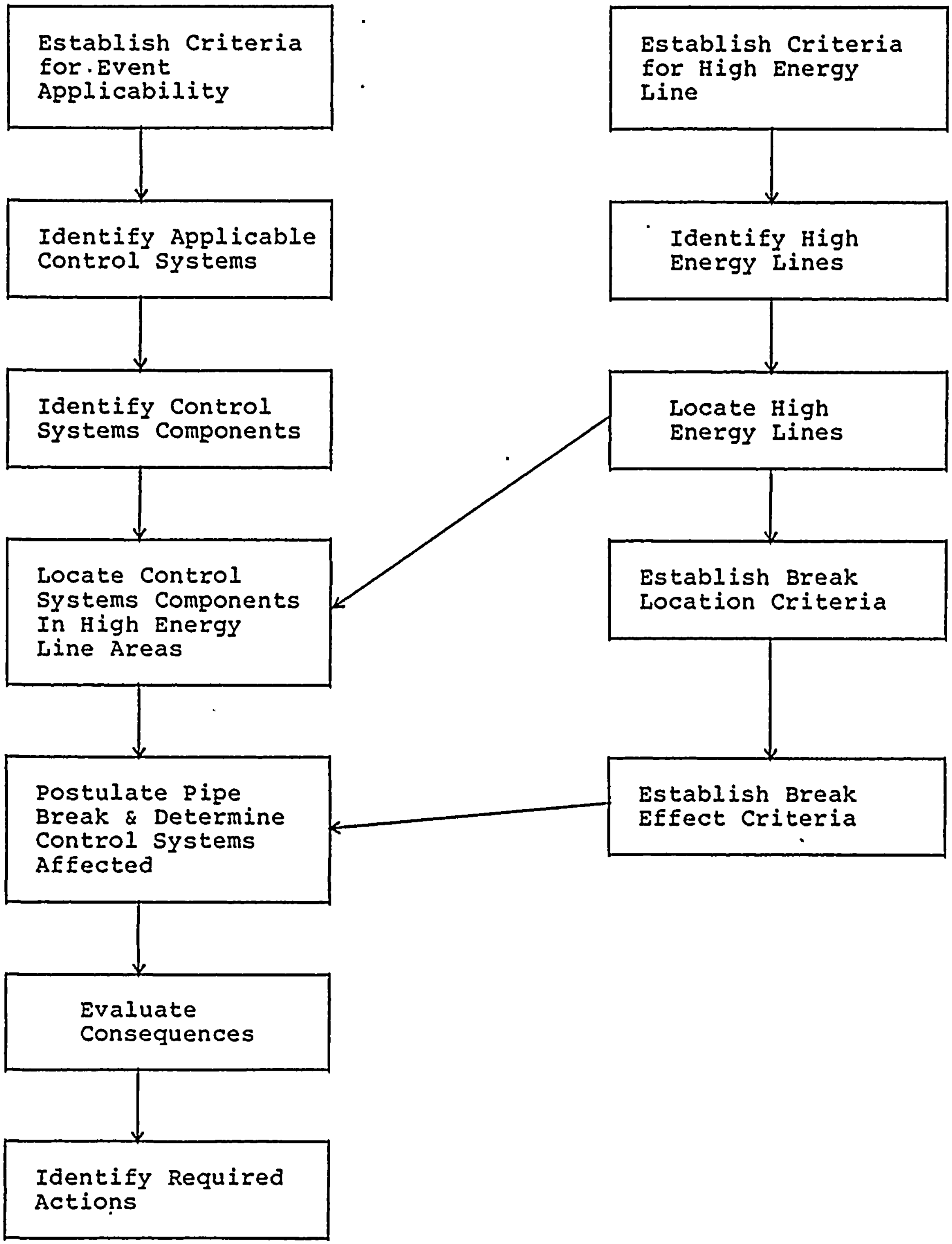

Establish Criteria for Event Applicability
Identify Applicable Control Systems
Identify Control Systems Components
Locate Control Systems Components In High Energy Line Areas
Postulate Pipe Break & Determine Control Systems Affected
Evaluate Consequences
Identify Required Actions
Establish Criteria for High Energy Line
Identify High Energy Lines
Locate High Energy Lines
Establish Break Location Criteria
Establish Break Effect Criteria

FIGURE 1

1.2.4 For each applicable control system, identify and locate instrumentation, equipment, process tubing and control cables from all systems in high energy line areas that could affect the control system's operation.

1.2.5 Postulate breaks in identified high energy lines. Identify control system damage incurred due to jet impingement and/or pipe whip for each break.

1.2.6 Evaluate the consequences resulting from each postulated break. If a single control system is affected, verify that the event incurred is bounded by FSAR Chapter 15. If more than one control system is affected, determine if the combined event is bounded by FSAR Chapter 15 analysis. If the single or combined event is not bounded, analyze an event which is bounding and determine the consequences.

1.2.7 For any single or combined event analyzed as unacceptable, define required operator actions or hardware modifications.

1.3 CONCLUSIONS

A detailed and comprehensive study was completed to determine if any non-safety grade control equipment, if subjected to the adverse environment of a HELB, could impact the WNP-2 safety analysis and/or the adequacy of protective functions performed by the plants safety grade equipment. The entire plant has been evaluated for the effects of high energy line breaks on applicable control systems. Worst case failure of all equipment, instrumentation, process tubing, control cables and power cables was considered.

It was determined, that there are events which fall outside the limits of FSAR Chapter 15 transient analysis. In evaluating these new events, a single bounding event, incorporating the worse case combination of each of the new events, has been postulated and analyzed using a General Electric computer code. The results of this analysis indicated that the reactor Delta Critical Power Ratio (ΔCPR) exceeded the FSAR required operating limit of 0.18 for a very short duration. However, the WNP-2 FSAR Chapter 4.4. indicates that even if boiling transition should occur for a short duration, no fuel damage would be expected to occur. These results are well within the bounds of the design basis accidents analyzed in Chapter 6 of the WNP-2 FSAR.

The protection functions performed by safety grade equipment are not significantly impaired by the effect of any plant HELB. Therefore, safe plant shutdown is assured at all times. No potential event results in any increase in risk to the health and safety of the public.

2.0 ANALYSIS CRITERIA

2.1 APPLICABLE EVENTS

The Chapter 15 transient analysis was used as a guide in establishing the applicable analysis events. Determination of the final list of applicable events was accomplished by evaluating the Chapter 15 transient events against the criteria in Section 2.1.1. These applicable events were then used in the analysis as the bounding events which could affect either a plant safety system or a critical reactor parameter (level, press, CPR, etc.). All plant control systems are then analyzed to determine their ability to result in one of these bounding applicable events.

2.1.1 Criteria for Event Applicability

1. Events must be capable of occurring at 100% reactor power.

2. Events must result from a HELB .

If an event did meet these criteria but tended to reduce the severity of the overall consequence when combined with other events, the single event was analyzed alone.

2.1.2 Applicable Events

1) Loss of Feedwater Heating (Chapter 15.1.1).

Applicable Event

2) Feedwater Controller Failure - Maximum Demand (Chapter 15.1.2).

Applicable Event

3) Pressure Regulator Fail - Open (Chapter 15.1.3).

Applicable Event

4) Inadvertent Opening of a Safety or Relief Valve (Chapter 15.1.4).

Applicable Event

5) RHR Shutdown Cooling Malfunction Decreasing Temperature (Chapter 15.1.6).

This event is not applicable as it cannot occur at 100% reactor power.

6) Pressure Regulator Fail - Closed (Chapter 15.2.1).

Applicable Event

7) Generator Load Rejection, Bypass On (Chapter 15.2.2).

Applicable Event

8) Generator Load Rejection, Bypass Off (Chapter 15.2.2).

Applicable Event

9) Turbine Trip, Bypass On (Chapter 15.2.3).
Applicable Event

10) Turbine Trip, Bypass Off (Chapter 15.2.3).
Applicable Event

11) Inadvertent MSIV Closure (Chapter 15.2.4).
Applicable Event

12) Loss of Condenser Vacuum (Chapter 15.2.5).
Applicable Event

13) Loss of Auxiliary Power Transformers (Chapter 15.2.6).
This event results in an immediate reactor scram decreasing the severity of any other event combined with it. This event is not applicable.

14) Loss of All Grid Connections (Chapter 15.2.6).
This event is not the result of a high energy line break and is therefore not applicable. In addition, this event is bounded by generator load rejection, bypass on.

15) Loss of Feedwater Flow (Chapter 15.2.7).
Applicable Event

16) Feedwater Piping Break (Chapter 15.2.8).
This event is bounded by loss of feedwater flow and is not considered separately.

17) Failure of RHR Shutdown cooling (Chapter 15.2.9). The RHR Shutdown Cooling System is not in operation at 100% power. Therefore, this is not an applicable transient event.

18) Trip of One Recirculation Pump Motor (Chapter 15.3.1). A reduction of recirculation flow reduces the severity of any other event or event combination. This event is bounded by the analysis presented in FSAR Chapter 15.3.1.

19) Trip of Both Recirculation Pump Motors (Chapter 15.3.1). A reduction of recirculation flow reduces the severity of any other event or event combination. This event is bounded by the analysis presented in FSAR Chapter 15.3.1.

20) Fast Closure of One Main Recirculation Valve (Chapter 15.3.2).
A reduction of recirculation flow reduces the severity of any other event or event combination. This event is bounded by the analysis presented in FSAR Chapter 15.3.2.

21) Fast Closure of Two Main Recirculation Valves (Chapter 15.3.2).
A reduction of recirculation flow reduces the severity of any other event or event combination. This event is bounded by the analysis presented in FSAR Chapter 15.3.2.

22) Seizure of One Recirculation Pump (Chapter 15.3.3).
A reduction of recirculation flow reduces the severity of any other event or event combination. This event is bounded by the analysis presented in FSAR Chapter 15.3.3.

23) Recirculation Pump Shaft Break (Chapter 15.3.4).
A reduction of recirculation flow reduces the severity of any other event or event combination. This event is bounded by the analysis presented in FSAR Chapter 15.3.4.

24) Rod Withdrawal Error - Refueling (Chapter 15.4.1.1).
This event is not applicable as it does not occur at 100% power operation.

25) Rod Withdrawal Error - Startup (Chapter 15.4.1.2).
This event is not applicable as it does not occur at 100% power operation.

26) Rod Withdrawal Error - At Power (Chapter 15.4.2).
This event is not applicable as it is not the result of a HELB.

27) Control Rod Misoperation (Chapter 15.4.3).
This event is not applicable as it is not the result of a HELB.

28) Abnormal Startup of Idle Recirculation Loop (Chapter 15.4.4).

This event is not applicable as it does not occur at 100% power operation.

29) Fast Opening of One Main Recirculation Valve (Chapter 15.4.5).

This event is not applicable as it does not occur at 100% power operation.

30) Fast Opening of Both Main Recirculation Valves (Chapter 15.4.5).

This event is not applicable as it does not occur at 100% power operation.

31) Misplaced Bundle Accident (Chapter 15.4.7).

This event is not applicable as it does not occur at 100% power operation.

32) Rod Drop Accident (Chapter 15.4.9).

This event is not applicable as it is not the result of a HELB.

33) Inadvertent HPCS Pump Start (Chapter 15.5.1).

As described, this event is the result of operator error. However, the event is possible as a result of a HELB and is applicable.

2.1.3 Control System Components Identification

All plant system components were considered in this analysis. For each event found applicable in Section 2.1.2, all components of any plant system which could result in that event were addressed in the analysis. This included all instrumentation, equipment, process tubing, power cables and control cables. Failure modes were considered as follows:

1) Instrumentation - When the instrumentation was mechanically damaged by a HELB, it was assumed to command controlled equipment to the worst failure mode.

2) Equipment - When the equipment was mechanically damaged by a HELB, it was assumed to fail in the worst failure mode.

3) Process Tubing - Process tubing was evaluated for the worst case of two failure mechanisms, crimping and rupture. In the event of crimping, controlled equipment was considered to freeze in place. For rupture, controlled equipment was considered to operate normally for a loss of signal.

4) Power Cables - Failure of power cables was assumed to act as a simple power loss, not necessarily a worst case failure mode. Resultant control actions due to the power loss were considered.

5) Control Cables - Control cables were assumed to command controlled equipment to the worst failure mode.

2.2 HIGH ENERGY LINES

The definition of high energy lines used in this analysis is based on the criteria established in Section 3.6.1 of the Standard Review Plan and Chapter 3.6.2 of the WNP-2 FSAR. A summary of that criteria is presented below.

2.2.1 Criteria for High Energy Lines

High energy lines were defined to include those lines whose process fluid exceeds a temperature of 200°F or a pressure of 275 psig during normal 100% power operation. All piping systems larger than 1 inch NPS which meet this criteria for more than 2% normal 100% power operating time were included.

2.2.2 Criteria for Break Locations

High energy lines not previously analyzed during other pipe break studies (Reference FSAR Chapter 3.6) were assumed to break at terminal ends and intermediate pipe fittings. Those lines evaluated during previous studies for HELB were considered to break as identified in those studies.

2.2.3 Break Effects

HELB effects were evaluated in detail for damage due to pipe whip and jet impingement. The general criteria used in evaluating the effects of pipe whip and jet impingement is presented in Chapter 3.6.2 of the WNP-2 FSAR. A summary of that criteria is provided below.

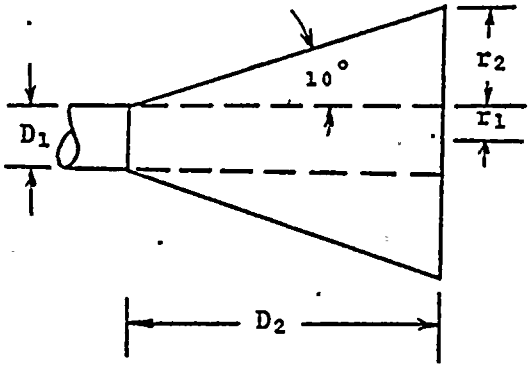
2.2.3.1 Pipe Whip

Pipe whip was analyzed in the plane defined by the piping geometry. Movement was analyzed in the direction of the jet reaction while hinging at the nearest rigid support, anchor, or penetration. The pipe was allowed to move in a radius about the hinge point until hitting a line of equal to or larger size, a reinforced concrete wall or column.

2.2.3.2 Jet Impingment

Jet impingement was considered for all circumferential and longitudinal breaks. Longitudinal breaks were postulated to occur in high energy lines 4 inches NPS and larger with a flow area equal to the flow area of the piping system. Circumferential breaks were postulated to occur in high energy lines larger than 1 inch NPS with the two halves being displaced laterally by a distance of one pipe diameter relative to each other. To simplify the evaluation of the effects of jet impingement on targets, the jets were considered to have an effective cone angle of 10°, with a jet length equal to 2 times the distance required for the pressure of the fluid jet to diminish to 10 psig. A sample calculation is provided below. Table 1 provides a summary of jet lengths considered in the evaluation. Concrete walls were considered to be an effective barrier against further cone propagation.

Sample Calculation:



Line Size = D_1 = 2"

Pressure at D_2 = P_2 = 10 psi

Pressure at Break = P_1 = 1000 psi

$$P_1A_1 = P_1 \pi D_1^2 /4$$
$$P_2A_2 = P_2 \pi 4 (r_1 + r_2)^2 /4$$
$$P_1A_1 = P_2A_2$$
$$P_1 \pi D_1^2 /4 = P_2 \pi 4 (r_1 + r_2)^2 /4$$
$$P_1D_1 = 4P_2 (D_1 /2 + D_2 \text{ Tan } 10°)^2$$
$$D_2 = (\sqrt{P_1/P_2} - 1) D_1 /2 \text{ Tan } 10°$$
$$D_2 = [(\sqrt{1000/10} - 1) 2/12] / 2(.176)$$
$$D_2 = 4.25 \text{ ft.}$$
$$2D_2 = 8.5 \text{ ft.}$$

TABLE 1

PROCESS PRESSURE

Pipe Diameter	1000 psi	900 psi	800 psi	700 psi	600 psi	500 psi	400 psi	300 psi	200 psi	100 psi	50 psi	25 psi
2"	8.5	8	7.5	7	6.4	5.7	5	4.2	3.3	2	1.1	.5
2 1/2"	10.6	10	9.4	8.7	8	7.1	6.3	5.3	4.1	2.5	1.5	.7
3"	12.7	12	11.2	10.4	9.5	8.6	7.5	6.3	5	3	1.7	.8
4"	17	16	15	13.9	12.7	11.5	10	8.5	6.5	4	2.3	1.1
6"	25.5	24	22.5	20.8	19	17.1	15	12.7	9.8	6.1	3.5	1.6
8"	34	32	30	27.8	25.5	23	20	16.9	13.1	8.1	4.7	2.2
10"	42.5	40	37.5	35	31.8	28.6	25	21	16.4	10.2	5.8	2.7
12"	51	48	45	42	38	34.4	30	25.3	19.6	12.2	7	3.3
14"	59.5	56	52.5	48.5	44.5	40	35	30	23	14.3	8.1	3.8
16"	68	64	60	55.5	51	45.8	40	34	26.2	16.3	9.3	4.4
18"	76	72	67.5	62.5	57	51.5	45	38	29.5	18.3	10.5	4.9
20"	85	80	75	69.5	63.5	57.5	50.2	42	33	20.4	11.6	5.4
24"	102	96	90	83.4	76	68.7	60.3	50.5	39	24.5	14	6.6
30"	127	120	112.5	104	95.5	85.9	75.5	63.5	49	30.5	17.5	8.2
42"	178	168	157	146	134	120	105	89	69	43	25	11.5

CONE LENGTH IN FEET

2.3 ZONE DETERMINATION

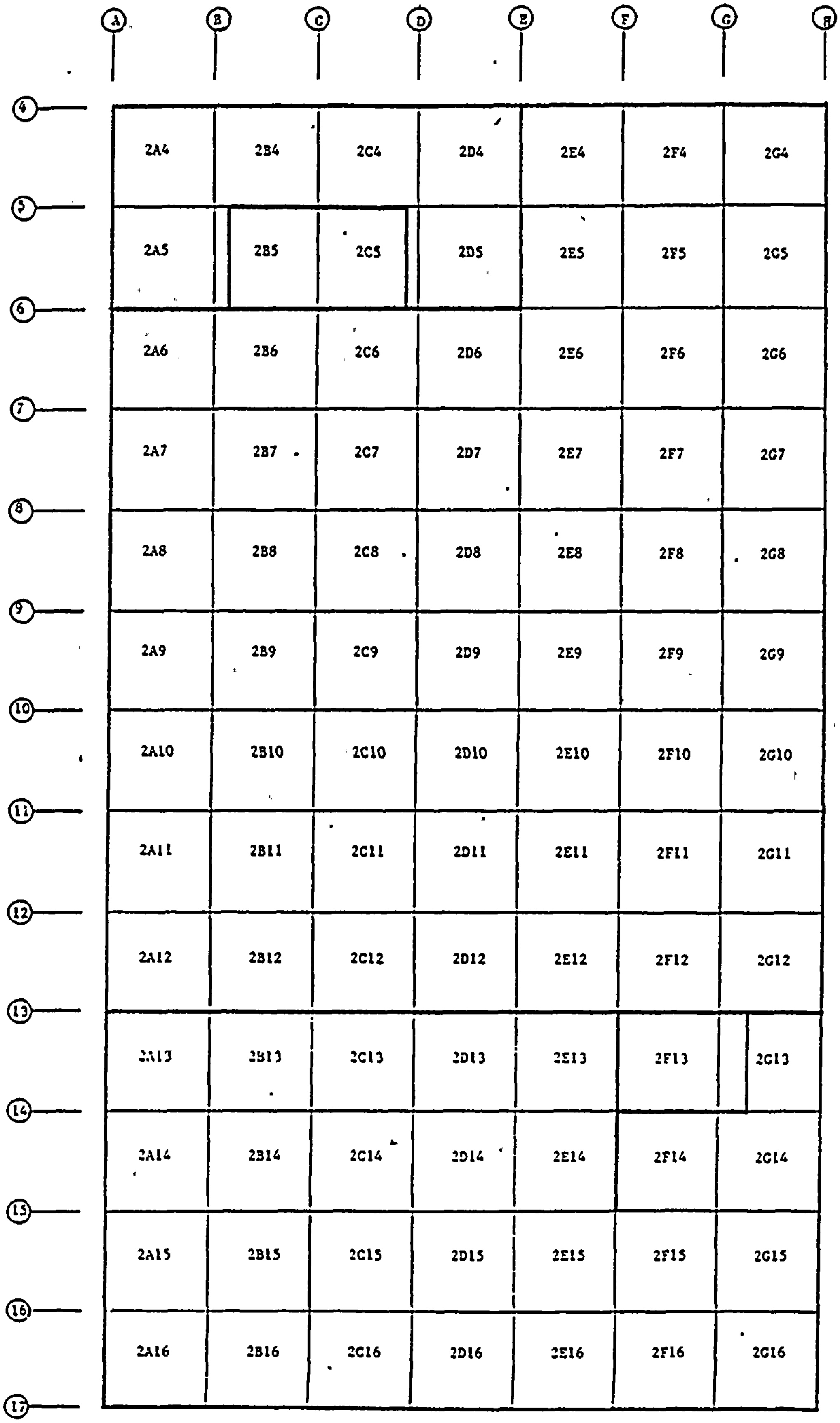
For purposes of this analysis, buildings were divided into zones for reference only (See Figure 2). However, the effects of a given break were not confined to these reference zones. They were instead based on the criteria established in Section 2.2, in the discussions of pipe whip and jet impingement.

3.0 HELB POSTULATION/CONTROL SYSTEM DAMAGE

HELBs were analyzed for each zone (Section 2.3). Targets were identified due to the resulting pipe whips and jet impingments. The targets were then evaluated with the applicable control system components identified and located in Section 2.1.3; potential transient events resulted from this evaluation. See Example 1 for a typical zone evaluation.

3.1 SINGLE EVENT ANALYSIS FOR POTENTIAL EVENTS

All applicable transient events, as determined by Section 2.1.2, found to be a potential event due to a HELB were analyzed to determine the effect on critical reactor parameters. Each identified event not discussed below was evaluated as a part of the multiple event analysis performed in Section 3.2. Single events bounded by the FSAR Chapter 15 transient analysis are discussed below.



TURBINE BUILDING 471' ELEVATION

FIGURE 2.

Bldg: Turbine
Elev: 471'
Zone: 2E10

ZONE SUMMARY

BREAK/TARGET SUMMARY

Line No.	Temp. (°F)	Press (psig)	No. Breaks	Jet (Feet)	Whip Damage	Targets
12" MS(2)-4	541	955	None	-	-	-
2" BS(6)-1	358	52	None	-	-	-
24" BS(8)-1	216	1	8	0	No	None
16" HD(9)-2	365	148	3	21	Yes	Cable Trays: PB,CB,SB
12" BS(1)-2	448	399	None	-	-	-
18" BS(6)-1	358	52	4	10.5	Yes	Cable Trays: PB,CB,SB,PA,CA,SA
4" HV(9)-1	358	52	None	-	-	-
6" SS(10)-1	216	1	5	0	No	None
20" BS(7)-1	282	27	5	6	No	Cable Trays: PA,CA,SA
2" BS(7)-1	282	27	None	-	-	-
20" COND(4)-3	170	428	1	53	No	None (FW Trip)
2" BS(7)-1	282	27	None	-	-	-
3" HV(12)-2	453	399	4	7.5	Yes	Cable Trays: CA,PA,CB,PB

TARGET EVALUATION

Target	Event Evaluation
Cable Tray PB	None
Cable Tray CB	FW Temperature Reduced, Turbine Trip
Cable Tray SB	None
Cable Tray PA	None
Cable Tray CA	FW Temperature Reduced
Cable Tray SA	None

ZONE POTENTIAL EVENT SUMMARY:

(1) Breaks in 16" HD(9)-2, 18" BS(6)-1 or 3" HV(12)-2 could result in a partial loss of FW heating and a turbine trip with bypass.

(2) Breaks in 20" BS(7)-1 could result in a partial loss of FW heating.

(3) Breaks in 20" COND(4)-3 could result in a total loss of FW.

Example 1

3.1.1 Loss of Feedwater Heating

Feedwater (FW) heating controls are located in the vicinity of high energy lines on the three main levels of the turbine building. The overall FW temperature control system is diversely segregated with each component failure capable of contributing only a small amount to the loss of feedwater temperature. A strategically located high energy line break is potentially capable of damaging several controls resulting in a ramping feedwater temperature decrease. As the temperature decreased, reactor power would increase until the APRMs initiated a reactor scram on high thermal power. Any temperature decrease of approximately 65°F or greater would result in a scram and is therefore bounded by FSAR Chapter 15 transient analysis event 15.1.1, which assumes 100°F temperature decrease.

For multiple event analysis including loss of feedwater heating, a 65°F reduction in temperature will be considered. This decrease will bring the reactor to a thermal power level just beneath the APRM scram point which is considered worst case for multiple event analysis.

3.1.1.1 Mechanism For Failure

Feedwater heating can be reduced by various mechanisms; all requiring reduced feedwater (tube side) or steam (shell side) flow through the heaters.

Reduced feedwater flow through the heaters requires conductor shorts simulating a valve movement demand signal in the cables controlling heater isolation and bypass valves, or damage to the valves themselves.

Reduced steam flow to the heaters also requires conductor shorts in valve control cables or level controllers, or damage to the valves or controllers themselves. In addition, steam can be bypassed directly to the main condenser if controlling process tubing is ruptured, resulting in FW heater extraction steam bypass valves failing open.

Approximately 165 valves control flow to the 16 feedwater heaters. A single cable short, tubing rupture or component damaged, can in most cases alter the position of only 1 or 2 valves. Valve control cables are normally 9 conductor cables. A short resulting in valve movement requires the proper 2 conductors in these 9 conductor cables to selectively short without blowing circuit protective fuses. Tube rupture cannot isolate heating steam but can dump steam to the main condenser and bypass the heaters.

All heaters are instrumented with high and low level alarms located in the control room. All the major FW heater related motor operated valves have position indication in the control room. Any HELB resulting in significant reduction of feedwater heating would not go unnoticed by plant operators.

3.1.2 Feedwater Controller Failure - Maximum Demand

Feedwater flow controls were reviewed for control system failures which could potentially drive the turbine controls to maximum demand. The feedwater flow controller sums signals from reactor water level, steam line flow and feedwater flow and sends the resultant signal to the reactor feedpump turbines. Reactor water level and steamline flow signals were found to be unaffected by any high energy line breaks. Potential for generating a high feedwater flow demand signal as the result of HELB exists on the 441' and 471' levels of the turbine building. Damage to these signals was considered to result in a feedwater controller failure - maximum demand event. Single event occurrence is bounded by FSAR Chapter 15 transient analysis.

3.1.2.1 Mechanism For Failure

Feedwater controller failure - maximum demand can occur in two ways, loss of feedwater flow signal or loss of feedpump turbine speed feedback to the controller.

Loss of the feedwater flow signal requires open circuit of 2 separate cables or rupture of at least 2 process instrument lines. These controls are located on the 471' level of the turbine building. Due to the nature of the 3-element feedwater flow controls, failure of this signal will not result in the 146% upper limit demand as analyzed in FSAR Chapter 15. The flow demand will be of a lesser degree, decreasing as vessel level increases.

Loss of the feedpump turbine speed feedback to the controller requires open circuit of 2 separate cables. These controls are located on the 441' level of the turbine building. Loss of both of these signals would drive the turbine valves wide open, similar to the event analyzed in FSAR Chapter 15. This failure mechanism can only occur as a single event from a HELB and is bounded by FSAR Chapter 15 transient analysis.

3.1.3 Pressure Regulator Fail - Open

The DEH pressure regulator is designed to switch to manual control on a pressure regulator signal failure. Control system analysis found no credible failures resulting in a pressure regulator fail - open event due to a HELB.

3.1.4 Inadvertent Opening of a Safety Relief Valve

This event cannot occur due to a high energy line break outside of containment.

3.1.5 Pressure Regulator Fail - Closed

Loss of signals positioning the governor and bypass valves could result in this event. These signal cables are located on the 471' elevation of the turbine building and could be damaged by an HELB. Single event occurrence is bounded by FSAR Chapter 15 transient analysis.

3.1.5.1 Mechanism For Failure

A pressure regulator fail-closed event as the result of a HELB would be a slow developing event. Complete failure requires open circuit of the 8 signals (in 8 different cables) used in the positioning of the governor and bypass valves. Open circuit of these cables would allow controlled valves to slowly drift closed due to servo valve leakage.

Should a turbine trip occur during this event, the bypass valves would still remain operable during the trip transient.

3.1.6 Generator Load Rejection, Bypass On

A true generator load rejection cannot result from a high energy line break. However, cable damage or hydraulic line damage could simulate this event and fast close the governor valves. This event is considered and as a single event is bounded by FSAR Chapter 15 transient analysis.

3.1.6.1 Mechanism For Failure

A generator load rejection, bypass-on event due to a HELB can result from control cable damage or damage to the turbine electro-hydraulic (EH) fluid lines. These controls are located on the 471' and 501' elevation of the turbine building.

A single short requesting governor valve fast closure for overspeed protection control would appear as a load rejection to the reactor. For all HELBs resulting in governor valve fast closure, Reactor Protection System (RPS) signal functions remained unaffected.

A rupture of the EH fluid lines controlling trip of the governor valves would also fast close these valves. Again, for all HELBs resulting in governor valve fast closure, RPS signal functions remained unaffected.

3.1.7 Generator Load Rejection, Bypass Off

A true generator load rejection cannot result from a high energy line break. However, hydraulic line damage could simulate this event and fast close the governor valves while disabling the bypass valves. This event is considered and as a single event is bounded by FSAR Chapter 15 transient analysis.

3.1.7.1 Mechanism For Failure

A generator load rejection, bypass off event due to the HELB can result from EH fluid line damage only. These lines are located on the 471' level of the turbine building. The exact location for failure is uncertain as the HELB would have to rupture the governor valve EH fluid trip line and the bypass valve positioning EH fluid lines. The large volume of EH

fluid contained near the bypass valves in accumulators and the positioning of the hydraulic lines makes this event very unlikely. HELBs hitting the bypass valves were assumed to cause this event, however, no break results in a loss of the turbine RPS signals function.

3.1.8 Turbine Trip, Bypass On

Several high energy line breaks in the turbine building could result in this event by damaging cables and/or hydraulic lines. This event is considered and as a single event is bounded by FSAR Chapter 15 transient analysis.

3.1.8.1 Mechanism For Failure

A turbine trip, bypass on event due to a HELB can result from cable damage, damage to the turbine EH fluid lines, vacuum sensing line damage or condenser damage. These controls and equipment are located on the 471' and 501' elevation of the turbine building.

Several trip signals run from the turbine to the control room in control cables. Shorting of the cable conductors or damage to the controlling equipment could signal a turbine trip. For all HELBs resulting in a turbine trip from control cable damage, RPS signal function was unaffected.

A rupture of the EH fluid lines controlling trip of the turbine valves would also result in a turbine trip. For all

HELBs resulting in a turbine trip due to EH Fluid Line Rupture, RPS single function was unaffected.

Vacuum sensing line damage or condenser damage could result in a turbine trip on low vacuum. The extent of damage would determine the time to trip ranging from immediately to several minutes. For all HELBs resulting in vacuum sensing line damage or condenser damage, RPS signal function was unaffected.

3.1.9 Turbine Trip, Bypass Off

Hydraulic line damage due to a high energy line break in the turbine building could cause this event. This event is considered and as a single event is bounded by FSAR Chapter 15 transient analysis.

3.1.9.1 Mechanism For Failure

A turbine trip, bypass on event due to a HELB can result from damage to the turbine EH fluid lines only. These controls are located on the 471' elevation of the turbine building. The exact location for failure is uncertain as the HELB would have to rupture the turbine trip EH fluid line and the bypass valve positioning EH fluid lines. The large volume of EH fluid contained near the bypass valves in accumulators and the positioning of the hydraulic lines makes this event very unlikely. HELBs hitting the bypass valves were assumed to cause this event, however, no break resulted in a loss of the turbine RPS signal function.

3.1.10 Inadvertent MSIV Closure

The potential for a high energy line break which would inadvertently close the MSIVs exists on the 471' elevation of the turbine building. Damage to the control loops sensing low condenser vacuum, low steamline pressure, high radiation or high room temperature could result in this event. This event is considered and as a single event is bounded by FSAR Chapter 15 transient analysis.

3.1.10.1 Mechanism For Failure

Inadvertent MSIV closure can result from both normal and abnormal initiation. Controls causing this event due to a HELB are located on the 471' and 501' level of the turbine building.

Normal closure will occur for any HELB heating leak detection thermocouples to their trip point. These thermocouples are located over the main steam lines in the turbine building.

Abnormal closure would occur from equipment, control cable or process tubing damage from main steam pressure sensors, vacuum switches or radiation detectors. All components would have to be damaged such that an open circuit is simulated.

All other instrumentation designed to close the MSIVs is protected from the effects of a HELB. RPS signals function normally for all HELBs inadvertently closing the MSIVs.

3.1.11 Loss of Condenser Vacuum

Loss of Condenser Vacuum is a potential event due to a high energy break in the turbine building. This event has no direct effects on reactor parameters. In all cases, a loss of condenser vacuum results in a turbine trip. Therefore the loss of condenser vacuum event is included with the turbine trip event analyses. As a single event it is bounded by FSAR Chapter 15 transient analysis.

3.1.12 Loss of Feedwater Flow

Several high energy line breaks on the 441' and 471' elevation of the turbine building could result in a loss of feedwater (FW) flow. This event is considered and as a single event is bounded by FSAR Chapter 15 transient analysis.

3.1.12.1 Mechanism For Failure

Loss of feedwater flow will occur for any HELB resulting in reactor feedpump turbine (RFPT) trip or feedwater isolation. Any main feedwater line break will cause this event. In addition, any main condensate line break will cause a RFPT trip on low suction pressure.

On the 441' elevation of the turbine building, several spurious signals resulting in a RFPT trip could result from a HELB. In each of these cases, the signals are the result of either shorts or open circuits in the damaged cables.

Damage to level switches, process tubing or control cables on turbine building elevation 471' could simulate FW heater high level and isolate portions of the FW flow. Also, shorts in control cables located on elevations 471' and 501' in the turbine building could result in closing combinations of the FW heating system valves. These valve closures would require selective control cable damage resulting from the proper 2 conductors in a 9 conductor cable shorting together without blowing circuit protective fuses.

3.1.13 Loss of Partial or Total Recirculation Flow

The 6 FSAR Chapter 15 transient events which discuss loss of partial or total recirculation flow were analyzed for single event occurrence only. Note, the vessel water level (L-8) trip and the turbine throttle valve reactor protection switch scram signals, which terminate these events, cannot be lost due a HELB. Any decrease in recirculation flow is bounded by Chapter 15 transient analysis.

3.1.14 Inadvertent HPCS Pump Start

A review of the HPCS pump control system showed that an inadvertent start cannot occur due to a high energy line break.

3.2 MULTIPLE EVENT ANALYSIS

Multiple events were considered to be the result of pipe whip and jet impingement from a high energy line break with reactor scram culminating the events. Each event was considered to have occurred as described in Section 3.1 of this report. Multiple events were not necessarily considered to occur simultaneously but were instead considered to occur at worst case timing until reactor scram. The single active failure assumed per MEB 3-1 in FSAR Chapter 3.6 was not considered.

Breaks in main steam lines were considered to activate RPS signals prior to the development of multiple events. Reviews indicated that in no case can the RPS system be incapacitated due to any high energy line breaks. Breaks in main condensate or feedwater lines which would trip the feedwater pumps or terminate feedwater to the reactor were not considered capable of resulting in the loss of feedwater temperature event. Leak detection system temperature detectors designed to close MSIVs in case of high temperature were considered to activate for breaks in their immediate vicinity.

3.2.1 Worst Case Event Combinations

On the 471' level of the turbine building, one set of Division A trays (power, control and signal) and one set of

Division B trays (power, control and signal) run the length of the floor gathering cables in route to the control room. A strategically located HELB could hit both sets of trays. Assuming worst case cable failures in all trays, either open circuit or short, the following events, or any combination thereof, are possible:

1) Loss of Feedwater Heating
2) Feedwater Controller Failure-Maximum Demand
3) Pressure Regulator Fail-Closed
4) Loss of Feedwater Flow
5) MSIV Closure
6) Turbine Trip, Bypass On

Using the above events, an analysis using a General Electric Computer Code was run to establish a bounding event combination which resulted in the worst impact on critical reactor parameters. The initial conditions and input parameters used in this analysis are consistent with those used in Chapter 15. In establishing this bounding combination, events 1 through 4 above are taken in a worst combination to bring the reactor to a power level just beneath Thermal Power Monitor Analytical Scram Limit (122% NBR). At this power level, events 5 and 6 above were assumed to occur. For this event, the Delta Critical Power Ratio (ΔCPR) exceeded 0.18 for less than 5 seconds (0.18 ΔCPR sets the present FSAR

required operating limit). The peak vessel pressure was less than 1207 psig and the peak cladding temperature was less than °F, which is considerably less than the allowable peak vessel pressure (1375 psig) and the allowable peak cladding temperature (1500°F). At these levels, WNP-2 FSAR Chapter 4.4 has indicated that no fuel damage is expected. The reactor can be brought to cold shutdown with no increase in the risk to the health and safety of the public.

Considering the low probability that such a break could occur: i.e., the selective combination of cable shorts and open circuits required, the assumption of worst possible event combination and the extremely conservative initial reactor parameters used, the occurrence of this combination can be classified as low frequency. As such, this event should be evaluated as an accident and is bounded by the design basis accidents analyzed in the FSAR.

3.2.2 Other Event Combinations

Various other breaks could result in combinations of the events considered in Section 3.2.1. Individual computer analyses were not run for each of these combinations but many are within the bounds of FSAR Chapter 15; all are bounded by the analysis in Section 3.2.1.

3.2.2.1 Loss of Feedwater Heating and Loss of Feedwater Flow

This combined event is bounded by the loss of feedwater heating transient event as described in FSAR Chapter 15. The loss of feedwater flow can only reduce the severity of the loss of feedwater heating event. The sequence of events after the loss of feedwater flow will be as described in FSAR Table 15.2-11 resulting in a safe reactor shutdown.

3.2.2.2 Loss of Feedwater Heating and Turbine Trip, Bypass On

The worst case combination of these two events would be a loss of feedwater heating raising reactor power to a level just beneath the Thermal Power Monitor Analytical Scram Point followed by the turbine trip, bypass on. Occurrence of this event requires cable shorting on the 471' level of the turbine building.

Such an event is bounded by the analysis in Section 3.2.1.

3.2.2.3 Loss of Feedwater Heating and Inadvertent MSIV Closure

The worst case combination of these two events would be a loss of feedwater heating raising reactor power to a level just beneath the Thermal Power Monitor Analytical Scram Point followed by MSIV closure. Occurrence of this event requires cable shorting or process tubing damage on the 471' level of the turbine building.

This combination of events is bounded by the analysis in Section 3.2.1.

3.2.2.4 Loss of Feedwater Heating, Turbine Trip, Bypass On, and Inadvertent MSIV Closure

This combination of events is bounded by Sections 3.2.2.2 or 3.2.2.3 above, depending on event sequence.

3.2.2.5 Loss of Feedwater Heating and Pressure Regulator Fail - Closed

The pressure regulator fail - closed event described in Section 3.1.5 of this report results in a very mild transient. Reactor scram would occur on high pressure or APRM RPS signals. This combined event is bounded by FSAR Chapter 15 transient analysis.

3.2.2.6 Loss of Feedwater Heating and Feedwater Controller Failure, Maximum Demand

This combination of events worst case could result in a turbine trip with bypass valves and reactor power just below Thermal Power Monitor Analytical scram levels. This combined event is bounded by Section 3.2.2.2 above.

3.2.2.7 Loss of Feedwater Heating, Inadvertent MSIV Closure, Pressure Regulator Fail - Closed and Loss of Feedwater Flow

The worst case sequence of these potential combined events would be a loss of feedwater heating, then a pressure regulator fail - closed culminated by an inadvertent MSIV closure. Loss of feedwater flow could only reduce the severity of the transient. The worst case combination would require the loss of feedwater heating and pressure regulator fail - closed events to raise reactor power and pressure to levels just beneath RPS Scram followed by MSIV closure. Occurrence of this event requires cable shorts and open circuits on the 471' level of the turbine building.

Such an event is bounded by the analysis of Section 3.2.1.