

Precursor Screening Analysis - Reject

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research

Donald C. Cook Nuclear Plant Unit 2		A loss of main condenser event occurred due to a storm-induced debris damage of the circulating water system pumps in the forebay.	
Event Date: 11/01/2014	LER: 316-2014-003-00	IR: 05000316/2015001	
Plant Type: WESTINGHOUSE PWR WITH ICE CONTAINMENT			
Plant Operating Mode (Reactor Power Level): Mode 1 (100% Reactor Power)			
Analyst: Erulappa Chelliah	Reviewer: Keith Tetter	Contributors: N/A	BC Approved Date: 06/ /2016

Event Description.

Storm-induced event-related details:

On 11/01/2014, both unit 1 and unit 2 of Donald C. Cook (DC Cook) nuclear plant were operating at 100 percent power. On the same day, the National Weather Service [NWS] predicted a storm of lower magnitude at the licensed site. As the NWS predicted, the storm arrived at the DC Cook site. High winds, water waves of about 20-foot height in Lake Michigan, and a water-surge of two-foot height in the lake, transported large amounts of dune grass and other debris to the intake-areas of plant circulating water system (CWS). The dune grass and debris impinged upon the trash racks (TRs), causing a failure of the TRs, and subsequent rapid fouling of the traveling water screens (TWSs).

The reader may note the following timeline related to the occurred sequence of events, on November 1, 2014:

0015- With the forebay level (FL) lowering due to buildup of debris on the TRs, the operators of Unit 1 and Unit 2 throttled unit-specific CWS outlet valves to lower the total system flow, and to recover FL. The FL recovered slightly, but after a very brief period, the level continued to lower.

0141- The Unit 2 operators stopped one of the four Unit 2 CWS pumps to recover the FL. The FL recovered slightly, but after a very brief period, the level continued to lower.

0154- Due to TWSs failing to maintain normal screen differential pressure, the Unit 2 operators entered the procedure for managing degraded conditions of the FL. The Unit 1 operators also entered the same procedure.

The licensee planned these initial procedural actions to monitor the FL and to control the FL by turning off the running-CWS pumps.

0210- The Unit 2 operators entered the procedure for rapid reactor power reduction response and lowered power at four percent per minute to approximately 50 percent power to establish conditions to stop a second running-CWS pump.

0218- The Unit 2 operators stopped the second of four running-CWS pumps, per the degraded FL-control procedure.

0249- The FL conditions degraded further and met procedure conditions, directing removal of all CWS pumps from service. The procedure required the operators: to manually trip both reactors, to manually close the steam generator (SG) main steam isolation valves (MSIVs), and then to remove all CWS pumps from service. The operators of both Unit 1 and Unit 2 performed these actions successfully.

0258- While performing actions of the reactor-trip response procedure, the Unit 2 operators found an equipment failure that the main generator output-breaker (MG-OB) did not automatically open on unplanned demand. As part of mitigation of this as-found failure of the MG-OB, the Operators manually tripped the main generator, per the reactor-trip procedure of Unit 2.

0323- The Unit 1 operators noted that SG-1 pressure was low, approximately 980 psig. The expected SG pressure was approximately 1000 psig. The operators noted that three of the five SG safety valves (SVs) were leaking. The operators opened SG atmospheric relief valves (SGARVs) to force the valve-seats of the leaked SVs to a leak-tightened position. Then, mechanical agitation of the SVs resulted in a forced-seating of the leaked SVs. SG-1 pressure then increased. The operators controlled SG-1 pressure by opening the SGARVs to keep SG-1 pressure at approximately 1000 psig.

At Unit 2, the TDAFW pump and the MDAFW pumps were delivering cold water to all 4 SGs. However, the operators found that the main condenser (normal heat sink) was not available for steam decay heat removal (DHR) due to their initial manual closure of all four SG-MSIVs, following a storm-induced failure of the CWS pumps. Therefore, the operators opened the SGARVs to achieve a successful steam DHR.

In summary, the operators observed:

- Unit 2- a loss of main condenser due to storm-induced failures of all CWS pumps, and
- Unit 2- a failure of the main generator output breaker to close on demand, given a manual reactor trip at Unit 2.

The licensee documented storm-induced degraded condition, in a licensee event report [LER], per 10 CFR Part 50.73(a)(2)(v)(D), as an event or condition that could have prevented the fulfillment of the safety function of a system to mitigate an accident or a transient. [Reference-1]

Region III evaluated as-found failures during post-trip response of the occurred storm. Region III closed the LER. [Reference-2]

Failure causes:

Loss of main condenser- The licensee evaluated the primary cause for the occurred loss of main-steam isolation closure event, on 11/01/2014. The DC Cook plant-organization did not establish aggressive preventive methodologies: to identify and mitigate steam generator isolation-risks associated with storm-induced debris intrusion into the forebay area prior to changing forebay level conditions, and to prevent dune grass-induced damage to the forebay-structures during a storm event of the Lake Michigan area.

Failure of the main generator output-breaker- The licensee also determined the primary cause for the occurred main generator output breaker failure-to-open on demand. A pre-existing failure of the non-1E part (a relay in the trip-circuit of the output breaker) contributed to the occurred failure of the output breaker.

Inspection findings:

Region III inspectors reviewed the LER information and other related information. They closed the LER [Reference-2].

Event-related failures at Unit 2:

In their LER, the licensee stated that the output breaker of the main generator failed to open on demand.

Following a storm event, the operator failed to control the FL, using existing level control procedure (an as-found pre-trip operator failure performance). The operators then manually tripped the reactor and closed all MSIVs. The manual reactor-trip demand resulted in an open-demand of the normally closed main generator output breaker. As part of mitigation of a potential damage to the closed-output breaker by the connected-grid system during a long period, the operators immediately tripped main turbine and main generator to isolate the connected-grid system from the main generator system.

Analysis Type. For DC Cook Unit 2, RES\DRA\PRB conducted one event risk analysis (ERA-2 case analysis) in estimating conditional core damage probability (CCDP) due to a loss of main condenser event, with an as-found failure of the main generator output breaker to open on demand. See the ATTACHMENT-1.

Analysis Rules. The ASP Program uses independent analysis, using available failure information and condition duration information which are documented in plant-specific ROP-SDP documents.

Modeling Assumptions.

1. The ERA-2 case analysis did not find and model any other simultaneous failures, other than the main generator output breaker failure event which occurred following the storm event.

Logic model-changes to recent SPAR Model of Unit 2.

Idaho National Laboratory published a recent plant probabilistic failures-model for Donald C. Cook Nuclear Plant Units 1 and 2 [SPAR PWR-B Model Version No. 8.22].

The LOCHS-induced probabilistic analysis (ERA-2 case analysis) did not make any model-changes.

Basic Event Probability-changes.

The ERA-2 analysis set:

1. Initiating event, IE-LOCHS [LOSS OF MAIN CONDENSER], to 1.0. A loss of main condenser event occurred at Unit 2 due to a storm-induced failure of all CWS pumps, on 11/01/2014.

Rejection Basis.

Analysis documented the results of an even risk analysis of the occurred storm-induced loss of main condenser event in the Attachment-1 to this report:

- Analysis estimated a CCDP value of $9.73E-7$ due to the occurred loss of main condenser event followed by the occurred storm in the forebay area (100%).
- Analysis found a contributing dominant sequence, LOCHS-02-02-10, of the LOCHS event tree (loss of main condenser). See the ATTACHMENT-1 of this report.
- Analysis estimated a conditional core damage probability of about $5.57E-7$ due to the dominant sequence of the LOCHS event tree (57.3%).

In summary,

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1. Under the ERA, the point estimate for the conditional core damage probability is 9.73×10^{-7} due to the loss of main condenser at power mode of the DC Cook Unit 2 reactor.

This point estimates is below 1×10^{-6} and therefore, the events described in the LER-316-2014-003-00 does not meet ASP Program criteria to be defined as a precursor.

Therefore, the storm-induced loss of main condenser at the DC Cook Unit 2, on 11/01/2014, would not have resulted in a precursor event during the power operation.

REFERENCES

1. Donald C. Cook Nuclear Plant Unit 2, "Manual 'Reactor Trip Due To Debris Intrusion Causing Degraded Forebay Conditions – INDIANA-MICHIGAN POWER, LER-316-2014-003-00, Event Date of November 01, 2014", dated December 23, 2014. ML14364A023.
2. U. S. Nuclear Regulatory Commission, Donald C. Cook Nuclear Plant Unit 2 – NRC Inspection report, 05000316/2015001, Dated May 11, 2015.

SYMBOLS

FL	= forebay level
TR	= trash rack
TWS	= travelling water screen
MSIV	= main steam isolation valve
TDAFW	= turbine-driven auxiliary feed-water
MDAFW	= motor-driven auxiliary feed-water
SG-ARV	= steam generator atmospheric relief valve
DHR	= decay heat removal
LOCHS	= loss of main condenser
MG	= main generator
OB	= output breaker
CWS	= circulating water system
SG-SV	= steam generator safety valve
ERA	= event risk analysis
CCDP	= conditional core damage probability
IE	= initiating event
LER	= licensee event report
IR	= inspection report
RCP	= reactor coolant pump
HPI	= high pressure injection
HPR	= high pressure recirculation
LPR	= low pressure recirculation

ATTACHMENT-1: SAPPHIRE8 ANALYSIS REPORT-
DONALD C. COOK NUCLEAR PLANT UNIT 2 – EVENT RISK ANALYSIS OF
LOSS OF MAIN CONDENSER EVENT WITH AN AS-FOUND FAILURE OF
THE MAIN GENERATOR OUTPUT-BREAKER TO OPEN ON DEMAND, ON
11/01/2014 [LER-316-2014-003-00]

Event Tree Dominant Results

Only items contributing at least 1.0% to the total CCDP are displayed.

<u>EVENT TREE</u>	<u>CCDP</u>	<u>% CONTRIBUTION</u>	<u>DESCRIPTION</u>
LOCHS	9.73E-7	100.0%	Cook 1 & 2 PWR B Loss of Condenser Heat Sink
Total	9.73E-7	100.0%	

Dominant Sequence Results

Only items contributing at least 1.0% to the total CCDP are displayed.

<u>EVENT TREE</u>	<u>SEQUENCE</u>	<u>CCDP</u>	<u>% CONTRIBUTION</u>	<u>FLAGSET</u>	<u>DESCRIPTION</u>
LOCHS	02-02-10	5.57E-7	57.3%	LOCHS-SLOCA	/RPS, /AFW, /PORV, LOCS, /RCPT, /RSD, /BP1, BP2, HPI-S, /SSC1, /LPI, RHR, HPR, LPR
LOCHS	13-10	1.41E-7	14.5%	LOCHS-ATWS	RPS, RCSPRESS
LOCHS	13-08	1.04E-7	10.7%	LOCHS-ATWS	RPS, /RCSPRESS, /FW, BORATION
LOCHS	12	9.56E-8	9.8%	LOCHS	/RPS, AFW, FAB
LOCHS	02-03-10	3.47E-8	3.6%	LOCHS-SLOCA	/RPS, /AFW, /PORV, LOCS, /RCPT, /RSD, BP1, /BP2, HPI-S, /SSC1, /LPI, RHR, HPR, LPR
LOCHS	02-02-12	1.96E-8	2.0%	LOCHS-SLOCA	/RPS, /AFW, /PORV, LOCS, /RCPT, /RSD, /BP1, BP2, HPI-S, SSC1
Total		9.73E-7	100.0%		

Referenced Fault Trees

<u>Fault Tree</u>	<u>Description</u>
AFW	AUXILIARY FEEDWATER
BORATION	EMERGENCY BORATION
BP1	RCP SEAL STAGE 1 INTEGRITY (BINDING/POPPING)
BP2	RCP SEAL STAGE 2 INTEGRITY (BINDING/POPPING)
FAB	FEED AND BLEED
HPI-S	HIGH PRESSURE INJECTION
HPR	HIGH PRESSURE RECIRCULATION
LOSC	LOSS OF RCP SEAL COOLING

LPR	LOW PRESSURE RECIRCULATION
RCS PRESS	RCS PRESSURE LIMITED
RHR	RESIDUAL HEAT REMOVAL
RPS	REACTOR SHUTDOWN
SSC1	RCS COOLDOWN TO RHR PRESSURE USING TBVs, ETC.

Cut Set Report - LOCHS 02-02-10

Only items contributing at least 1% to the total are displayed.

#	CASES	PROB/FREQ	TOTAL%	CUT SET
		5.57E-7	100	Displaying 72 Cut Sets. (72 Original)
1	C	5.16E-7	92.54	IE-LOCHS,ESW-MDP-CF-RUN,RCS-MDP-LK-BP2
2	C	3.20E-8	5.75	IE-LOCHS,ESW-STR-CF-STR,RCS-MDP-LK-BP2

Cut Set Report - LOCHS 13-10

Only items contributing at least 1% to the total are displayed.

#	CASES	PROB/FREQ	TOTAL%	CUT SET
		1.41E-7	100	Displaying 81 Cut Sets. (81 Original)
1	C	2.25E-8	16.02	IE-LOCHS,RCS-PHN-MODPOOR,RPS-BME-CF-RTBAB
2	C	1.88E-8	13.36	IE-LOCHS,RCS-PHN-MODPOOR,RPS-CBI-CF-60F8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
3	C	1.69E-8	12.04	IE-LOCHS,RCS-PHN-MODPOOR,RPS-ROD-CF-RCCAS
4	C	1.27E-8	9.06	IE-LOCHS,RCS-PHN-MODPOOR,/RPS-CCP-TM-CHA,RPS-CCX-CF-60F8,RPS-XHE-XE-NSGNL
5	C	5.70E-9	4.05	IE-LOCHS,PPR-SRV-CC-PRV151,RPS-BME-CF-RTBAB
6	C	5.70E-9	4.05	IE-LOCHS,PPR-SRV-CC-PRV152,RPS-BME-CF-RTBAB
7	C	5.70E-9	4.05	IE-LOCHS,PPR-SRV-CC-PRV153,RPS-BME-CF-RTBAB
8	C	4.76E-9	3.38	IE-LOCHS,PPR-SRV-CC-PRV152,RPS-CBI-CF-60F8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
9	C	4.76E-9	3.38	IE-LOCHS,PPR-SRV-CC-PRV153,RPS-CBI-CF-60F8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
10	C	4.76E-9	3.38	IE-LOCHS,PPR-SRV-CC-PRV151,RPS-CBI-CF-60F8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
11	C	4.28E-9	3.04	IE-LOCHS,PPR-SRV-CC-PRV151,RPS-ROD-CF-RCCAS
12	C	4.28E-9	3.04	IE-LOCHS,PPR-SRV-CC-PRV152,RPS-ROD-CF-RCCAS
13	C	4.28E-9	3.04	IE-LOCHS,PPR-SRV-CC-PRV153,RPS-ROD-CF-RCCAS
14	C	3.22E-9	2.29	IE-LOCHS,PPR-SRV-CC-PRV152,/RPS-CCP-TM-CHA,RPS-CCX-CF-60F8,RPS-XHE-XE-NSGNL
15	C	3.22E-9	2.29	IE-LOCHS,PPR-SRV-CC-PRV153,/RPS-CCP-TM-CHA,RPS-CCX-CF-60F8,RPS-XHE-XE-NSGNL
16	C	3.22E-9	2.29	IE-LOCHS,PPR-SRV-CC-PRV151,/RPS-CCP-TM-CHA,RPS-CCX-CF-60F8,RPS-XHE-XE-NSGNL
17	C	1.46E-9	1.03	IE-LOCHS,RCS-PHN-MODPOOR,RPS-UVL-CF-UVDAB,RPS-XHE-XE-SIGNL

Cut Set Report - LOCHS 13-08

Only items contributing at least 1% to the total are displayed.

#	CASES	PROB/FREQ	TOTAL%	CUT SET
		1.05E-7	100	Displaying 17 Cut Sets. (17 Original)
1	C	3.22E-8	30.80	IE-LOCHS,CVC-XHE-XM-BOR,RPS-BME-CF-RTBAB
2	C	2.69E-8	25.70	IE-LOCHS,CVC-XHE-XM-BOR,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
3	C	2.42E-8	23.15	IE-LOCHS,CVC-XHE-XM-BOR,RPS-ROD-CF-RCCAS
4	C	1.82E-8	17.42	IE-LOCHS,CVC-XHE-XM-BOR,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
5	C	2.08E-9	1.99	IE-LOCHS,CVC-XHE-XM-BOR,RPS-UVL-CF-UVDAB,RPS-XHE-XE-SIGNL

Cut Set Report - LOCHS 12

Only items contributing at least 1% to the total are displayed.

#	CASES	PROB/FREQ	TOTAL%	CUT SET
		9.56E-8	100	Displaying 107 Cut Sets. (107 Original)
1	C	8.03E-8	83.96	IE-LOCHS,DCP-BAT-CF-ALL
2	C	5.98E-9	6.25	IE-LOCHS,AFW-PMP-CF-FRALL,AFW-XHE-XM-XTIEUNIT,HPI-XHE-XM-FB
3	C	3.20E-9	3.35	IE-LOCHS,AFW-SGN-CF-SIGNAL,AFW-XHE-XM-MANSTRT,AFW-XHE-XM-XTIEUNIT,HPI-XHE-XM-FB
4	C	1.50E-9	1.57	IE-LOCHS,AFW-MDP-CF-PP3STRT,AFW-TDP-FR-PP4,AFW-XHE-XM-XTIEUNIT,HPI-XHE-XM-FB

Cut Set Report - LOCHS 02-03-10

Only items contributing at least 1% to the total are displayed.

#	CASES	PROB/FREQ	TOTAL%	CUT SET
		3.47E-8	100	Displaying 16 Cut Sets. (16 Original)
1	C	3.22E-8	92.85	IE-LOCHS,ESW-MDP-CF-RUN,RCS-MDP-LK-BP1
2	C	2.00E-9	5.77	IE-LOCHS,ESW-STR-CF-STR,RCS-MDP-LK-BP1

Cut Set Report - LOCHS 02-02-12

Only items contributing at least 1% to the total are displayed.

<u>#</u>	<u>CASES</u>	<u>PROB/FREQ</u>	<u>TOTAL%</u>	<u>CUT SET</u>
		1.96E-8	100	Displaying 15 Cut Sets. (15 Original)
1	C	1.03E-8	52.73	IE-LOCHS,ESW-MDP-CF-RUN,OPR-XHE-XM-DEPRCS2,RCS-MDP-LK-BP2
2	C	4.00E-9	20.45	IE-LOCHS,CCW-CFG-AP-UNIT1W,CCW-SYS-LK-WEST,CVC-XHE-XM-CVCSXTIE,OPR-XHE-XM-DEPRCS2,RCS-MDP-LK-BP2
3	C	4.00E-9	20.45	IE-LOCHS,CCW-CFG-AP-UNIT1E,CCW-SYS-LK-EAST,CVC-XHE-XM-CVCSXTIE,OPR-XHE-XM-DEPRCS2,RCS-MDP-LK-BP2
4	C	6.40E-10	3.28	IE-LOCHS,ESW-STR-CF-STR,OPR-XHE-XM-DEPRCS2,RCS-MDP-LK-BP2
5	C	2.00E-10	1.02	IE-LOCHS,CCW-CFG-AP-UNIT1E,CCW-SYS-LK-EAST,OPR-XHE-XM-DEPRCS2,RCS-MDP-LK-BP2,UNIT-2-CVCS
6	C	2.00E-10	1.02	IE-LOCHS,CCW-CFG-AP-UNIT1W,CCW-SYS-LK-WEST,OPR-XHE-XM-DEPRCS2,RCS-MDP-LK-BP2,UNIT-2-CVCS

Referenced Events

Event	Description	Probability
AFW-MDP-CF-PP3STRT	COMMON CAUSE FAILURE OF AFW MDPs TO START	4.76E-5
AFW-PMP-CF-FRALL	COMMON CAUSE FAILURE OF AFW PUMPS	7.47E-6
AFW-SGN-CF-SIGNAL	CCF SG SIGNAL (PSA)	2.00E-4
AFW-TDP-FR-PP4	AFW TDP PP4 FAILS TO RUN	3.95E-2
AFW-XHE-XM-MANSTRT	OPERATOR FAILS TO MANUALLY START AFW PUMPS	2.00E-2
AFW-XHE-XM-XTIEUNIT	OPERATOR FAILS TO XTIE OPPOSITE UNIT AFW SYSTEM	4.00E-2
CCW-CFG-AP-UNIT1E	FRACTION OF TIME UNIT 1 EAST CCW IS INITIALLY OPERATING TRAIN	5.00E-1
CCW-CFG-AP-UNIT1W	FRACTION OF TIME UNIT 1 WEST CCW IS INITIALLY OPERATING TRAIN	5.00E-1
CCW-SYS-LK-EAST	EAST HEADER LEAKAGE REQUIRES ISOLATION (PSA)	1.00E-4
CCW-SYS-LK-WEST	WEST HEADER LEAKAGE REQUIRES ISOLATION (PSA)	1.00E-4
CVC-XHE-XM-BOR	OPERATOR FAILS TO INITIATE EMERGENCY BORATION	2.00E-2
CVC-XHE-XM-CVCSXTIE	OPERATOR FAILS TO ALIGN CVCS XTIE TO ALTERNATE UNIT	2.00E-2
DCP-BAT-CF-ALL	Failure of Batteries in Both Units	8.03E-8
ESW-MDP-CF-RUN	CCF U1&2 ESW PUMPS FAIL TO RUN	2.58E-6
ESW-STR-CF-STR	CCF OF ESW MDP DISCHARGE STRAINERS	1.60E-7
HPI-XHE-XM-FB	OPERATOR FAILS TO INITIATE FEED AND BLEED COOLING	2.00E-2
IE-LOCHS	LOSS OF CONDENSER HEAT SINK INITIATING EVENT	1.00E+0
OPR-XHE-XM-DEPRCS2	OPERATOR FAILS TO DEPRESSURIZE RCS/SECONDARY SIDE (RAPID)	2.00E-2
PPR-SRV-CC-PRV151	PORV 151 FAILS TO OPEN ON DEMAND	3.54E-3
PPR-SRV-CC-PRV152	PORV 152 FAILS TO OPEN ON DEMAND	3.54E-3
PPR-SRV-CC-PRV153	PORV 153 FAILS TO OPEN ON DEMAND	3.54E-3
RCS-MDP-LK-BP1	RCP SEAL STAGE 1 INTEGRITY (BINDING/POPPING OPEN) FAILS	1.25E-2
RCS-MDP-LK-BP2	RCP SEAL STAGE 2 INTEGRITY (BINDING/POPPING OPEN) FAILS	2.00E-1
RCS-PHN-MODPOOR	MODERATOR TEMP COEFFICIENT NOT ENOUGH NEGATIVE	1.40E-2
RPS-BME-CF-RTBAB	CCF OF RTB-A AND RTB-B (MECHANICAL)	1.61E-6
RPS-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.70E-6
RPS-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.83E-6
RPS-ROD-CF-RCCAS	CCF 10 OR MORE RCCAS FAIL TO DROP	1.21E-6
RPS-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.04E-5
RPS-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.00E-1
RPS-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.00E-2
UNIT-2-CVCS	UNDEVELOPED EVENT FOR U2 CVCS HARDWARE	1.00E-3