# **REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION**

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:312-8343SRP Section:SRP 19Application Section:19.1Date of RAI Issue:11/16/2015

# Question No. 19-17

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA. SRP Chapter 19.0, Revision 3 (Draft), Section I. "Areas of Review," states that "In accordance with the Statement of Consideration (72 FR 49387) for the revised 10 CFR Part 52, the U.S. Nuclear Regulatory Commission (NRC) expects that, generally, the information that it needs to perform its review of an application from a PRA perspective is that information contained in the applicant's FSAR Chapter 19. The staff should issue a request for additional information (RAI) and conduct audits of the complete PRA (e.g., models, analyses, data, and codes) to obtain clarifying information as needed."

The staff reviewed both APR1400 DCD Chapter 19 and the PRA Human Reliability Analysis (HRA) notebook posted in the KHNP electronic reading room (ERR) but could not find sufficient information describing the human failure events (HFEs) to reach its conclusion regarding the acceptability of HRA. Therefore, in order for the staff to reach a reasonable assurance finding that the HFEs are complete and appropriate, please provide in detail the HRA, including a list of pre- and post-initiator HFEs, the corresponding probability and its bases, and the screening value. Also, revise the APR 1400 DCD and other supporting documents (i.e., PRA notebooks) to address the information, as necessary.

# Response – (Rev. 1)

The revised PRA Human Reliability Analysis (HRA) notebook (APR1400-K-P-NR-013105-P, Revision 0A) was posted in the electronic reading room (ERR, 01\_PRA/SA/RAP-Audit/No\_2/24.AOR1400-K-P-NR-013105-P (1)).

The pre-initiator HRA results are summarized in Table 2.8-1 of the Human Reliability Analysis (HRA) notebook (APR1400-K-P-NR-013105-P, Revision 0A), with detailed HRA Calculator calculation sheets provided in Appendix D.

The post-initiator HRA results are summarized in Table 3.5-1 of the Human Reliability Analysis (HRA) notebook (APR1400-K-P-NR-013105-P, Revision 0A), with detailed HRA Calculator calculation sheets provided in Appendix L.

Table 1 lists the pre-initiator HFEs and Table 2 lists the post-initiator HFEs. The details for the pre-initiator and post-initiator HFEs are provided as Attachment 1 and 2.

HFE Name	Description	HEP	Remark
CSOPU1A-1015	OPERATOR FAILS TO OPEN V-1015 AFTER IN-SERVICE TEST FOR CSP 01A	9.90E-04	RIHA <sup>*)</sup>
CSOPU1B-1016	OPERATOR FAILS TO OPEN V-1016 AFTER IN-SERVICE TEST FOR CSP 01B	9.90E-04	
SIOPU1A-V218	SI PUMP PP02A MINI FLOW VV 218 NOT RESTORED AFTER T&M	9.90E-04	
SIOPU1B-V219	SI PUMP PP02B MINI FLOW VV 219 NOT RESTORED AFTER T&M	9.90E-04	
SIOPU2A-V254	SI PUMP PP02C MINI FLOW VV 254 NOT RESTORED AFTER T&M	9.90E-04	RIHA <sup>*)</sup>
SIOPU2B-V255	SI PUMP PP02D MINI FLOW VV 255 NOT RESTORED AFTER T&M	9.90E-04	
SIOPU1A-V265	SC PUMP PP01A MINI FLOW VV 265 NOT RESTORED AFTER T&M	8.00E-03	
SIOPU2B-V269	SC PUMP PP01B MINI FLOW VV 269 NOT RESTORED AFTER T&M	8.00E-03	
RPOPU-A-CPCA	OPERATOR ERROR: MISCALIBRATION OF CPC CH.A	5.00E-02	
RPOPU-A-LT1113A	OPERATOR ERROR: MISCALIBRATION OF LO SG1 LVL. CH.A	9.70E-04	
RPOPU-A-LT1123A	OPERATOR ERROR: MISCALIBRATION OF LO SG2 LVL. CH.A	9.70E-04	
RPOPU-A-PDT115A	OPERATOR ERROR: MISCALIBRATION OF LO RCS FLOW SG1. CH.A	9.70E-04	
RPOPU-A-PT1013A	OPERATOR ERROR: MISCALIBRATION OF LO SG1 PRESSURE. CH.A	9.70E-04	
RPOPU-A-PT101A	OPERATOR ERROR: MISCALIBRATION OF HI PZR PR. CH.A	9.70E-04	
RPOPU-A-PT1023A	OPERATOR ERROR: MISCALIBRATION OF LO SG2 PRESSURE. CH.A	9.70E-04	
RPOPU-A-PT102A	OPERATOR ERROR: MISCALIBRATION OF LO PZR PR. CH.A	9.70E-04	
RPOPU-A-PT352A	OPERATOR ERROR: MISCALIBRATION OF Hi-Hi CNT PR. CH.A	9.70E-04	
RPOPU-B-CPCB	OPERATOR ERROR: MISCALIBRATION OF CPC CH.B	5.00E-02	

HFE Name	Description	HEP	Remark
RPOPU-B-LT1113B	OPERATOR ERROR: MISCALIBRATION OF LO SG1 LVL. CH.B	9.70E-04	
RPOPU-B-LT1123B	OPERATOR ERROR: MISCALIBRATION OF LO SG2 LVL. CH.B	9.70E-04	
RPOPU-B-PDT115B	OPERATOR ERROR: MISCALIBRATION OF LO RCS FLOW SG1. CH.A	9.70E-04	
RPOPU-B-PT1013B	OPERATOR ERROR: MISCALIBRATION OF LO SG1 PRESSURE. CH.B	9.70E-04	
RPOPU-B-PT101B	OPERATOR ERROR: MISCALIBRATION OF HI PZR PR. CH.B	9.70E-04	
RPOPU-B-PT1023B	OPERATOR ERROR: MISCALIBRATION OF LO SG2 PRESSURE. CH.B	9.70E-04	
RPOPU-B-PT102B	OPERATOR ERROR: MISCALIBRATION OF LO PZR PR. CH.B	9.70E-04	
RPOPU-B-PT352B	OPERATOR ERROR: MISCALIBRATION OF Hi-Hi CNT PR. CH.B	9.70E-04	
RPOPU-C-CPCC	OPERATOR ERROR: MISCALIBRATION OF CPC CH.C	5.00E-02	
RPOPU-C-LT1113C	OPERATOR ERROR: MISCALIBRATION OF LO SG1 LVL. CH.C	9.70E-04	
RPOPU-C-LT1123C	OPERATOR ERROR: MISCALIBRATION OF LO SG2 LVL. CH.C	9.70E-04	
RPOPU-C-PDT115C	OPERATOR ERROR: MISCALIBRATION OF LO RCS FLOW SG1. CH.C	9.70E-04	
RPOPU-C-PT1013C	OPERATOR ERROR: MISCALIBRATION OF LO SG1 PRESSURE. CH.C	9.70E-04	
RPOPU-C-PT101C	OPERATOR ERROR: MISCALIBRATION OF HI PZR PR. CH.C	9.70E-04	
RPOPU-C-PT1023C	OPERATOR ERROR: MISCALIBRATION OF LO SG2 PRESSURE. CH.C	9.70E-04	
RPOPU-C-PT102C	OPERATOR ERROR: MISCALIBRATION OF LO PZR PR. CH.C	9.70E-04	
RPOPU-C-PT352C	OPERATOR ERROR: MISCALIBRATION OF HI-HI CNT PR. CH.	9.70E-04	
RPOPU-D-CPCD	OPERATOR ERROR: MISCALIBRATION OF CPC CH.D	5.00E-02	
RPOPU-D-LT1113D	OPERATOR ERROR: MISCALIBRATION OF LO SG1 LVL. CH.D	9.70E-04	
RPOPU-D-LT1123D	OPERATOR ERROR: MISCALIBRATION OF LO SG2 LVL. CH.D	9.70E-04	
RPOPU-D-PDT115D	OPERATOR ERROR: MISCALIBRATION OF LO RCS FLOW SG1. CH.A	9.70E-04	
RPOPU-D-PT1013D	OPERATOR ERROR: MISCALIBRATION OF LO SG1 PRESSURE. CH.D	9.70E-04	
RPOPU-D-PT101D	OPERATOR ERROR: MISCALIBRATION OF HI PZR PR. CH.D	9.70E-04	

HFE Name	Description	HEP	Remark
RPOPU-D-PT1023D	OPERATOR ERROR: MISCALIBRATION OF LO SG2 PRESSURE. CH.D	9.70E-04	
RPOPU-D-PT102D	J-D-PT102D OPERATOR ERROR: MISCALIBRATION OF LO PZR PR. CH.D		
RPOPU-D-PT352D	OPERATOR ERROR: MISCALIBRATION OF Hi-Hi CNT PR. CH.D	9.70E-04	
RPOPU-S-CPCABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF CPC	2.88E-04	
RPOPU-S- LT1113ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO SG1 LVL.	3.32E-05	RIHA <sup>*)</sup>
RPOPU-S- LT1123ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO SG2 LVL.	3.32E-05	RIHA <sup>*)</sup>
RPOPU-S- PDT115ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO RCS FLOW SG1	3.32E-05	
RPOPU-S- PT1013ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO SG1 PR. CH.A/B/C/D	3.32E-05	
RPOPU-S- PT101ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF HI PZR PR. CH.A,B,C,D	3.32E-05	
RPOPU-S- PT1023ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO SG2 PR. CH.A/B/C/D	3.32E-05	
RPOPU-S- PT102ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO PZR PR. CH.A/B/C/D	3.32E-05	RIHA <sup>*)</sup>
RPOPU-S- PT352ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF Hi-Hi CNMT PR. CH.A/B/C/D	3.32E-05	

\*) RIHA: Risk-Important Human Action

HFE Name	Description	HEP	Remark
AFOPH-S-ALT-LT	OPERATOR FAIL TO ALIGNE FOR SUPPLYING AN ALTERNATE SOURCE	9.10E-04	RIHA <sup>*)</sup>
AFOPV-S-AFAS-FW	OPERATOR FAILS TO RECOVER AFAS	5.90E-03	RIHA <sup>*)</sup>
CDOPH-S-ALIGN	OPERATOR FAILS TO START FOR PP01,02,03 BY HAND SWITCH	5.60E-04	RIHA <sup>*)</sup>
CSOPV-S-CSAS	OPERATOR FAILS TO ACTUATE CSAS	2.20E-04	
CVOPH-S- BORATION	OPERATOR FAILS TO INITIATE EMERGENCY BORATION TO RCS	1.40E-02	
CVOPH-S-IRWST	OPERATOR FAILS TO REFILL THE IRWST VIA CVCS	1.00E-03	RIHA <sup>*)</sup>
CVOPH-S-RCPSEAL	OPERATOR FAILS TO RECOVER RCP SEAL COOLING (CCW CONNTECT. OR AUX. CHG PUMP)	1.10E-02	RIHA <sup>*)</sup>
DAOPH-S-AACTG	OPERATOR FAILS TO PROVIDE 1E 4.16KV SW01A,B,C,D	7.20E-03	
DAOPH-S-AACTG- SW01BD	OPERATOR FAILS TO PROVIDE 1E 4.16KV SW01A,B,C,D	1.30E-02	
FWOPH-S-ERY	OPERATOR FAILS TO ALINE STARTUP FEEDWATER PUMP PP07 (EARLY PHASE)	5.50E-03	RIHA <sup>*)</sup>
FWOPH-S-LNG	OPERATOR FAILS TO ALINE STARTUP FEEDWATER PUMP PP07 (LATE PHASE)	3.10E-03	
HR-RCSCD1-ISOL	OPERATOR FAILS TO TAKE ACTION FOR SG COOLDOWN, RC DEPRESS AND SG ISOLATION	1.40E-03	RIHA <sup>*)</sup>
HR-RCSCD2	OPERATOR FAILS TO TAKE ACTION FOR SG COOLDOWN, RC DEPRESS	3.20E-03	RIHA <sup>*)</sup>
MSOPH-S-ASC- SGTR	OPERATOR FAILS TO PERFORM AGGRE. SEC. COOLING FOR SGTR	1.50E-03	
MSOPH-S-ASC- SLOCA	OPERATOR FAILS TO PERFORM AGGRE. SEC. COOLING FOR SLOCA	2.30E-02	
MSOPH-S-SGADV	OPERATOR FAILS TO OPEN ADVS	5.50E-03	
MSOPH-S-SGADV- HW	OPERATOR FAILS TO OPEN ADVS USING HAND WHEEL	2.00E-02	
PFOPH-S-UATBKR- LOCAL	OPERATOR FAILS TO RECOVER PCB FOR 1E 4.16KV SW01A,B,C,D AT LOCAL	5.20E-02	RIHA <sup>*)</sup>
RCOPH-S-SDSE-FW	FAILURE OF SDS VALVES EARLY PHASE OPEN (1/4)	9.10E-03	RIHA <sup>*)</sup>
RCOPH-S-SDSL	FAILURE OF SDS VALVES (1/4) LATE PHASE OPEN	8.30E-03	RIHA <sup>*)</sup>
RPOPV-S-RTRIP	OPERATOR FAILS TO MANUALLY INITIATE REACTOR TRIP	1.20E-02	

Table 2 Results of Post-Initiator HFEs Assessr	nent
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HFE Name	Description	HEP	Remark
SIOPH-S-HLI	OPERATOR FAILS TO HOT LEG INJECTION	3.10E-04	
SIOPH-S-INJ	OPERATOR FAILS TO ALIGN SCS FOR INJECTION	2.20E-03	
SIOPH-S- IRWSTCOOL	OPERATE FAILS TO COOL THE IRWST WATER	2.90E-04	
SIOPH-S-LTC-SC	OPERATOR FAILS TO ALIGN SCS FOR LONG TERM COOLING	5.30E-04	
SIOPH-S- SPRAYBACK	OPERATOR FAILS TO CONNECT SCS PUMP FOR CTMT SPRAY	1.90E-04	
SIOPV-S-SIAS	OPERATOR FAILS TO RECOVERY FOR SIAS	5.90E-03	
VDOPV-S-HV	OPERATOR FAILS TO START FOR HV12A/13A, 12B/13B, 12C/13C, 12D/13D BY HAND SWITCH	1.70E-02	
WOOPV-S-1AB2AB	OPERATOR FAILS TO OPERATE ECW PUMPS PP01/2A, PP01/2B	1.70E-02	
CCOPH-S-HX-ALIGN	OPERATOR FAILS TO OPEN CCW HX3A/B ISOL. V1145 /6 /ESW SUPPLYING V1027/8, V1015/6, V3014/5	5.00E-01	
CWOPH-S-PP56	OPERATOR FAILS TO START FOR PP05 BY HAND SWITCH	1.00E-01	
DCOPH-S-BC-ALIGN	OPERATOR FAILS TO TRANSFER SOURCE FROM BC01A/B/C/D TO BC02A/B/C/D	5.00E-01	
DCOPH-S-NSBC- ALIGN	OPERATOR FAILS TO TRANSFER SOURCE FROM BC01M/N TO BC05N	5.00E-01	
ECOPH-S-ALIGN	OPERATOR FAILS TO ALIGN ECSBS FOR CONTAINMENT SPRAY	5.00E-01	
IAOPH-S-ALIGN	OPERATOR FAILS TO RECOVER INSTRUMENT AIR SYSTEM	5.00E-01	
IPOPH-S-TS02ABCD	OPERATOR FAILS TO OPERATE MANUAL TRANSFER SWITCH A/B/C/D	5.00E-01	
IPOPH-S-TS02MN- IN012MN	OPERATOR FAILS TO OPERATE MANUAL TRANSFER SWITCH FOR IN01M, IN02M, IN01N, IN02N	5.00E-01	
IPOPH-S-TS02N- UP03N	OPERATOR FAILS TO OPERATE MANUAL TRANSFER SWITCH N (UP03N)	5.00E-01	
PGOPH-S-LC01B	OPERATOR FAILS TO TRANSFER SOURCE FROM LC01A TO LC01B	5.00E-01	
RPOPH-S-RCPTRIP	OPERATOR FAILS TO MANUALLY INITIATE RCP TRIP	1.00E-01	
SXOPH3A-V3014	OPERATOR FAILS TO OPEN DEBRIS FILTER FT03A VV3014 IN LOCAL	5.00E-01	
SXOPH3B-V3015	OPERATOR FAILS TO OPEN DEBRIS FILTER FT03B VV3015 IN LOCAL	5.00E-01	

HFE Name	Description	HEP	Remark
VKOPH-S-ECCS	OPERATOR FAILS TO ACTUATE ECCS EXHAUST FAN AH01A/B	1.00E-01	
WHOPH-S-BYPASS	OPERATOR FAILS TO OPEN FOR MOV 027/28 BY HAND SWITCH	5.00E-01	
WOOPH-A- CROSSTIE	OPERATOR FAILS TO OPEN 1025A AND ALIGN FLOW PATH	5.00E-01	
WOOPH-B- CROSSTIE	OPERATOR FAILS TO OPEN 1025B AND ALIGN FLOW PATH	5.00E-01	
WOOPH-S- CROSSTIE	OPERATOR FAILS TO OPEN 1025A/B AND ALIGN FLOW PATH	5.00E-01	
WTOPH-S-HE03	OPERATOR FAILS TO OPERATE FOR TGBCCW HX. HE03	1.00E-01	
CCOPV-S- MV181/182/191/192	OPERATOR FAILS TO OPEN FOR EDG 01A/B/C/D INLET MOV 181,182,191,192	1.00E-01	
CCOPV-S-NSMV	OPERATOR FAILS TO CLOSE CC MOV 143~150 (NON-ESSENTIAL LOAD)	1.00E-01	
CCOPV-S-PP12AB	OPERATOR FAILS TO RECOVERY CCW PUMPS PP01A,B/02A,B	1.00E-01	
CDOPV-S-MAKEUP	OPERATOR FAILS TO OPEN FOR AV 05,06,07,21,22,23 BY HAND SWITCH	1.00E-01	
CVOPV-A-MV501	OPERATOR FAILS TO OPEN MOV 501 BY HAND SWITCH	1.00E-01	
CVOPV-A-MV536	OPERATOR FAILS TO OPEN MOV 536 BY HAND SWITCH	1.00E-01	
CVOPV-B-MV504	OPERATOR FAILS TO OPEN MOV 504 BY HAND SWITCH	1.00E-01	
CVOPV-B-MV534	OPERATOR FAILS TO OPEN MOV 534 BY HAND SWITCH	1.00E-01	
CVOPV-M-PP05	OPERATOR FAIL TO START PP05 BY HAND SWITCH	1.00E-01	
CVOPV-N-MV514	OPERATOR FAILS TO OPEN MOV 514 BY HAND SWITCH	1.00E-01	
CVOPV-N-PP06	OPERATOR FAIL TO START PP06 BY HAND SWITCH	1.00E-01	
CWOPV-SPP24	OPERATOR FAILS TO START FOR PP24 BY HAND SWITCH	1.00E-01	
CWOPV-SPP25	OPERATOR FAILS TO START FOR PP25 BY HAND SWITCH	1.00E-01	
DAOPV-S-PP01/2	OPERATOR FAILS TO RECOVER DIESEL FUEL TRANSFER PUMPS PP01/2	1.00E-01	
DOOPV-S- PP01/02ABCD	OPERATOR FAILS TO RECOVER DIESEL FUEL TRANSFER PUMPS PP01/02ABCD	1.00E-01	
MSOPV-S-MSIS	OPERATOR FAILS TO RECOVERY FOR MSIS	1.00E-01	
MSOPV-S-TBVALL	OPERATOR FAILS TO RECOVER MS TBCV AOV 1001~1008 BY HAND SWITCH	1.00E-01	

HFE Name	Description	HEP	Remark
SXOPV-A-DFLTS	OPERATOR FAILS TO OPEARATE DEBRIS FILTER FT01/2/3A, 01/2/3B IN LOCAL	1.00E-01	
SXOPV-S-PP012AB	OPERATOR FAILS TO RECOVERY FOR ESW PP01A/2A/1B/2B BY HAND SWITCH	1.00E-01	
VGOPV-S-AH01/2AB	OPERATOR FAILS TO START FOR AH01A/B, AH02A/B BY HAND SWITCH (IN MCR)	1.00E-01	
VKOPV-B-CHGP	OPERATOR FAILS TO START FOR HV18B(CHGP) BY HAND SWITCH	1.00E-01	
VKOPV-S-BAMP	OPERATOR FAILS TO START FOR HV34A(BAMP) BY HAND SWITCH	1.00E-01	
VKOPV-S-CCWP	OPERATOR FAILS TO START FOR HV14A,14B(CCWP) BY HAND SWITCH	1.00E-01	
VKOPV-S-SCP/CSP	OPERATOR FAILS TO START FOR HV10A,10B,16A,16B (CSP,SCP) BY HAND SWITCH	1.00E-01	
VKOPV-S-SIP	OPERATOR FAILS TO START FOR HV11A,11B,12A,12B(SIP) BY HAND SWITCH	1.00E-01	
VOOPV-S-AFMDP	OPERATOR FAILS TO START FOR HV33A,33B(AF MDP) BY HAND SWITCH	1.00E-01	
VOOPV-S-ECWP	OPERATOR FAILS TO START FOR HV32A,32B(ECWP) BY HAND SWITCH	1.00E-01	
VUOPV-S-AACDG	OPERATOR FAILS TO START FOR AH60,61(AAC DG) BY HAND SWITCH	1.00E-01	
WTOPV-S-PP02	OPERATOR FAILS TO START FOR PP02 BY HAND SWITCH	1.00E-01	

# Impact on DCD

DCD Table 19.1-25 is replaced to this response as shown in the Attachment 3.

# Impact on PRA

There is no impact on the PRA.

## **Impact on Technical Specifications**

There is no impact on the Technical Specifications.

# Impact on Technical/Topical/Environmental Reports

There is no impact on the Technical/Topical/Environmental Report.

# CSOPU1A-1015, CS PUMP PP01A MINI FLOW HEAT EXCHANGER ISOLATION VV 1015 NOT RESTORED AFTER TEST&MAINTENANCE

Cognitive Method	Date	Analyst - Reviewer
THERP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary			
	P <sub>exe</sub>	Error Factor	
Without Recovery	9.9e-04		
With Recovery	9.9e-04	10	

#### **Identification and Definition**

This HFE models restoration failure of valve, CS-V1015, after periodic testing. This valve is classified as "A-class" valve, which means that these valve normally opened during normal operation, low temperature shutdown or refueling outage.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(CONTAINMENT SPRAY PUMP AND SAFETY RELATED VALVES TEST), this valve on train A is opened every 3 months.

The important procedural actions are to check valve position before and after CS pump totally flow test. As a result, this HFE means that miniflow heat exchanger isolation valve restoration of CS-1015 is failed after CS pump flow test, that is, this valve is not reopened after pump flow test.

Procedures and Training				
Performance Procedure				
Period of Performance	3 Months			
Test Procedure	(Revision: 10)			
Period of Testing				
Notes				
The procedure and training information is not available in DC phase. However, good procedure and				
appropriate training is assumed for this operator action.				

### **Related Human Interactions**

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
Stress Level	Low		
Notes			

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, stress level of this HFE is assigned as "Low".

Execution Unrecovered							
Procedure: ,			Comment				
Step No.	Instruction/Comment	Error Type	THERP		HEP	Stress Factor	Ride
			Table	Item			
	Align CS pump PP01A Miniflow Heat Exchanger Isolation Manual Valve CS-V1015						
	Location: Local - Aux. Bldg.	EOM	20-7b	1	4.3e-04	1	
1		EOC	20-13	1	1.3E-3		
	Total Step HEP						1.7e-03
	Confirm the Valve Position						
	Location: Local - Aux. Bldg.	EOM	20-8a	1	1.3e-03	1	
2		EOC	20-22	1	1.6E-1		
					Total S	tep HEP	1.6e-01

Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
1		Align CS pump PP01A Miniflow Heat Exchanger Isolation Manual Valve CS-V1015	1.7e-03				9.9e-04
	2	Confirm the Valve Position		1.6e-01	HD	5.8e-01	
		Total Unrecovered:	1.7e-03			Total Recovered:	9.9e-04

# **RPOPU-A-CPCA**, *Miscalibrate Core Protection Calculator System* (CPCS) Channel A

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary				
Pexe (Median)	5.0e-02			
Total HEP	5.0e-02			
Error Factor	5			

#### **Identification and Definition**

This HFE models miscalibration of the Core Protection Calculator System (CPCS) including datalink, power supply, indicating value and others. All calibration task should be performed on only one channel at a time.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(CORE PROTECTION CALCULATOR SYSTEM LOOP CALIBRATION AND OPERATIONAL TEST), the CPCS on channel A is calibrated every 18 months.

The important procedural actions are (1) Check a channel A bypass function through Plant Protection System (PPS) (2) Check the power supplier and related components (3) Check a connection to I/O Simulator (4) Check the analog input module and digital pulse module of CPS (4) Check a CPCS Trip (5) Check the CEA Deviation (6) Check a CEAC (CEAC inoperation) (7) Check a surveillance test (8) Check a CEAC failure (9) Check a system health (10) Check a cyclic redundancy check (CRC) (11) Check a CPC-IPS datalink (Trip Buffer) (12) Check a CEAC-IPS datalink (snapshot) (13) Check a CPCS bypass function and many test and check tasks are performed. Failure of any one of these actions will lead to miscalibration.

Procedures and Training				
Performance Procedure				
Period of Performance	18 Months			
Test Procedure	(Revision: 1581056)			
Period of Testing				
Notes				
The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.				

### **Related Human Interactions**

### Key Assumptions

Per HRA Notebook (Figure A-1), to determine a specified ASEP case, it's assumed that the worst case is conservatively considered. This is why because of complexity of Core Protection Calculator System (CPCS) that interconnects with various signals such as CEA position, Hot/Cold leg temperature, Neutron Flux and Pressurizer Pressure and thus miscalibration on the each channel is not modeled.

Actually, because a Fussell-Vessely importance is less than 0.005 and a Risk-Achievement Worth (RAW) is less than 2.0 based on quantification results, importance analysis results show that this HFE is not a

critical event although analyst assumed the worst case about this HFE. So, it's concluded that the initiate assumption and final selection of ASEP case is not changed.

It's assumed that there are no recovery actions because the worst case for this HFE is considered based on above results. And thus, basic HEP of ASEP, 3.0E-02, is used to calculate final HEP of this HFE. The "Critical Steps Recovery Factors" window of HRA calculator elucidates these decision process.

Because these CPCs perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-CPCA, is analyzed are identically applied to the following HFEs: RPOPU-B-CPCB, RPOPU-C-CPCC, RPOPU-D-CPCD.

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
BHEP	0.03	
Notes		

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

Critical Steps				
Basic HEP	0.03			
Case	1			
Total Recovered	5.0e-02			

Critical Step No.	Action	Comment
1	Calibrate CPC Channel A	The worst case for this HFE is considered. The detailed explanation is described in Key Assumptions.

# **RPOPU-A-LT1113A, Miscalibration of Steam Generator Level** *Transmitter LT-1113A*

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary				
Pexe (Median)	9.7e-04			
Total HEP	9.7e-04			
Error Factor	5			

### Identification and Definition

This HFE models miscalibration of the steam generator (S/G) level transmitter as a representative case for miscalibrating 2/4 logic.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring S/G level. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the S/G low level trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter is essentially a transducer that converts a S/G level into a corresponding voltage. The converter, LY-1113A, converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The S/G level transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(S/G PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the S/G level transmitter, LT1113A, is calibrated every 18 months. The S/G level transmitter is tested every 3 months, but it's not effective to detect and recover miscalibration.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

Procedures and Training				
Performance Procedure				
Period of Performance				
Test Procedure	(Revision: 1581056)			
Period of Testing	18 Months			
Notes				
The procedure and training informati	ion is not available in DC phase	e. However, good procedure and		

appropriate training is assumed for this operator action.

Calibration for LT-1113A is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

## **Related Human Interactions**

### **Key Assumptions**

Per HRA Notebook (figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal conservatively.

2) Technician performs effective post-maintenance or post-calibration test based on reference plant procedure, SKN34 Surveillance Procedure 6431-02.

3) Technician performs instrumentation calibration and records the results and independent supervisor reviews previous results based on SKN34 Surveillance Procedure 6700-05.

4) Frequent status check would be performed by LCO 3.3.1, but it is assumed to be impossible to recover miscalibraion during normal operation.

Per HRA System Notebook (Figure A-3), to determine a dependency level for multiple latent errors and calibration errors, some assumptions are provided as follows:

1) S/G level transmitter and converter in each channel (A/B/C/D) are arranged in serial configuration. Thus, zero dependency is selected between LT-1113A and LY-1113A based on HRA System Notebook, figure A-3.

If all of the above assumptions are comprehensively considered, then cell 37 for this HFE is selected based on HRA system notebook, figure A-1.

Because these level transmitters perform same functions except for location on different train, the assumptions and procedures to be considered when this HFE, RPOPU-A-LT1113A, is analyzed are identically applied to the following HFEs: RPOPU-B-LT1113B, RPOPU-C-LT1113C, RPOPU-D-LT1113D. And also, the only difference between LT-1113A and LT-1123A is a location, that is LT-1113A is connected to the S/G 1 whereas LT-1123A is connected to S/G 2. Thus, if above assumptions are comprehensively considered, the analytical procedures and assumptions about this HFE are also applied to RPOPU-B-LT1123B, RPOPU-C-LT1123C, RPOPU-D-LT1123D.

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
BHEP	0.03		
Notes			

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of

ASEP method is assigned as 0.03.

Critical Steps		
Basic HEP	0.03	
Case	8	
Total Recovered	9.7e-04	

Critical Step No.	Action	Comment
1	Calibrate level transmitter	
	LT1113A	
2	Calibrate signal converter	
	LY1113A	

# **RPOPU-A-PDT115A, Miscalibration of Steam Generator Pressure** *Differential Transmitter PDT-115A*

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary		
Pexe (Median)	9.7e-04	
Total HEP	9.7e-04	
Error Factor	5	

# Identification and Definition

This HFE models miscalibration of the steam generator (S/G) pressure differential transmitter as a representative case for miscalibrating 2/4 logic.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring steam generator . Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the high/low pressure difference trip setpoint between hot leg injection and cold leg discharge causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter is essentially a transducer that converts pressure difference into a corresponding voltage. The converter, PDY-115A, converts a voltage into a current to read and identify a signal for PPS system.

The pressure difference transmitter and converter need to be calibrated periodically. The pressure difference transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(S/G PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the pressure transmitter, PDT-115A, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

Procedures and Training		
Performance Procedure		
Period of Performance		
Test Procedure	(Revision: 1581056)	
Period of Testing	18 Months	
Notes		

The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.

Calibration for PDT-115A is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

### **Related Human Interactions**

#### Key Assumptions

Per HRA System Notebook (Figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal conservatively.

2) Technician performs effective post-maintenance or post-calibration test based on reference plant procedure, SKN34 Surveillance Procedure 6521.

3) Technician performs instrumentation calibration and records the results and independent supervisor reviews previous results based on SKN34 Surveillance Procedure 6700-05.

4) Frequent status check would be performed by LCO 3.3.1, but it is assumed to be impossible to recover miscalibraion during normal operation.

Per HRA System Notebook (Figure A-3), to determine a dependency level for multiple latent errors and calibration errors, some assumptions are provided as follows:

1) S/G pressure difference transmitter and converter in each channel (A/B/C/D) are arranged in serial configuration. Thus, zero dependency is selected between PDT-115A and PDY-115A based on HRA System Notebook, figure A-3.

If all of the above assumptions are comprehensively considered, then cell 37 for this HFE is selected based on HRA system notebook, figure A-1.

Because these level transmitters perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-PDT115A, is analyzed are identically applied to the following HFEs: RPOPU-B-PDT115B, RPOPU-C-PDT115C, RPOPU-D-PDT115D.

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
BHEP	0.03	
Notes		

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

### **Critical Steps**

Basic HEP	0.03
Case	8
Total Recovered	9.7e-04

Critical Step No.	Action	Comment
1	Calibrate S/G pressure	
	difference transmitter	
	PDT-115A	
2	Calibrate S/G pressure	
	difference signal	
	converter PDY-115A	

# **RPOPU-A-PT1013A**, Miscalibration of Steam Generator Pressure Transmitter PT-1013A

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary		
Pexe (Median)	9.7e-04	
Total HEP	9.7e-04	
Error Factor	5	

## Identification and Definition

This HFE models miscalibration of the steam generator (S/G) pressure transmitter as a representative case for miscalibrating 2/4 logic.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring S/G pressure. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the S/G low pressure trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter is essentially a transducer that converts a S/G pressure into a corresponding voltage. The converter, PY-1013A, converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The S/G pressure transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(S/G PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the S/G level transmitter, PT-1013A, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

Procedures and Training		
Performance Procedure		
Period of Performance		
Test Procedure	(Revision: 1581056)	
Period of Testing	18 Months	
Notes		
The procedure and training informati	ion is not available in DC phase	e. However, good procedure and

appropriate training is assumed for this operator action.

Calibration for PT-1113A is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

## **Related Human Interactions**

#### Key Assumptions

Per HRA System Notebook (Figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal conservatively.

2) Technician performs effective post-maintenance or post-calibration test based on reference plant procedure, SKN34 Surveillance Procedure 6431-02.

3) Technician performs instrumentation calibration and records the results and independent supervisor reviews previous results based on SKN34 Surveillance Procedure 6700-05.

4) Frequent status check would be performed by LCO 3.3.1, but it is assumed to be impossible to recover miscalibraion during normal operation.

Per HRA System Notebook (Figure A-3), to determine a dependency level for multiple latent errors and calibration errors, some assumptions are provided as follows:

1) S/G level transmitter and converter in each channel (A/B/C/D) are arranged in serial configuration. Thus, zero dependency is selected between LT-1113A and LY-1113A based on HRA System Notebook, figure A-3.

If all of the above assumptions are comprehensively considered, then cell 37 for this HFE is selected based on HRA system notebook, figure A-1.

Because these pressure transmitters perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-PT1013A, is analyzed are identically applied to the following HFEs: RPOPU-B-PT1013B, RPOPU-C-PT1013C, RPOPU-D-PT1013D. And also, the only difference between PT-1013A and PT-1023A is a location, that is PT-1013A is connected to the S/G 1 whereas PT-1023A is connected to S/G 2. Thus, if above assumptions are comprehensively considered, the analytical procedures and assumptions about this HFE are also applied to RPOPU-A-PT1023A, RPOPU-B-PT1023B, RPOPU-C-PT1023C and RPOPU-D-PT1023D.

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
BHEP	0.03	
Notes		
BHEP	0.03 Notes	

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of

written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

Critical Steps		
Basic HEP	0.03	
Case	8	
Total Recovered	9.7e-04	

Critical Step No.	Action	Comment
1	Calibrate S/G pressure	
	transmitter PT-1013A	
2	Calibrate S/G pressure	
	signal converter	
	PY-1013A	

# **RPOPU-A-PT101A**, *Miscalibration of High Pressurizer Pressure Transmitter PT-101A*

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary	
Pexe (Median)	9.7e-04
Total HEP	9.7e-04
Error Factor	5

# Identification and Definition

This HFE models miscalibration of the pressurizer pressure transmitter as a representative case for miscalibrating 2/4 logic. To detect a high pressurizer pressure, reactor coolant pressure from narrow range pressurizer pressure measurement such as PT-101A and PY-101A is transferred to PPS (Plant Protection System). If pressurizer is tripped due to high pressure, this activity is to assure the integrity of the RCS boundary for any defined AOO (Anticipated Operational Occurrence) that could lead to an over pressurization of the RCS.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring pressurizer pressure. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the high pressurizer pressure trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter is essentially a transducer that converts a pressurizer pressure into a corresponding voltage. The converter, PY-101A, converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The pressurizer pressure transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(PRESSURIZER PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the pressurizer pressure transmitter, PT-101A, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal increases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

Procedures and Training		
Performance Procedure		

Period of Performance	
Test Procedure	(Revision: 1581056)
Period of Testing	18 Months
Notes	

The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.

Calibration for PT-101A is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

### **Related Human Interactions**

### Key Assumptions

Per HRA System Notebook (Figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal conservatively.

2) Technician performs effective post-maintenance or post-calibration test based on reference plant procedure, SKN34 Surveillance Procedure 6431-02.

3) Technician performs instrumentation calibration and records the results and independent supervisor reviews previous results based on SKN34 Surveillance Procedure 6700-05.

4) Frequent status check would be performed by LCO 3.3.1, but it is assumed to be impossible to recover miscalibraion during normal operation.

Per HRA System Notebook (Figure A-3), to determine a dependency level for multiple latent errors and calibration errors, some assumptions are provided as follows:

1) Pressurizer pressure transmitter and converter in each channel (A/B/C/D) are arranged in serial configuration. Thus, zero dependency is selected between PT-101A and PY-101A based on HRA System Notebook, figure A-3.

If all of the above assumptions are comprehensively considered, then cell 37 for this HFE is selected based on HRA system notebook, figure A-1.

Because these pressure transmitters perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-PT101A, is analyzed are identically applied to the following HFEs: RPOPU-B-PT101B, RPOPU-C-PT101C, RPOPU-D-PT101D.

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
BHEP	0.03	
Notes		
It's assumed that it's expected for human per	formance or human factors to be better than that of	

conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

Critical Steps	
Basic HEP	0.03
Case	8
Total Recovered	9.7e-04

Critical Step No.	Action	Comment
1	Calibrate high pressurizer	
	pressure transmitter	
	PT-101A	
2	Calibrate high pressurizer	
	pressure signal converter	
	PY-101A	

# **RPOPU-A-PT102A**, Miscalibration of Low Pressurizer Pressure Transmitter PT-102A

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary		
Pexe (Median)	9.7e-04	
Total HEP	9.7e-04	
Error Factor	5	

### Identification and Definition

This HFE models miscalibration of the pressurizer pressure transmitter as a representative case for miscalibrating 2/4 logic. To detect a low pressurizer pressure, reactor coolant pressure from wide range pressurizer pressure measurement such as PT-102A and PY-102A is transferred to PPS (Plant Protection System). If pressurizer is tripped due to low pressure, this activity is to provide a reactor trip to assist the ESF systems in the event of reduction in system pressure and a LOCA.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring pressurizer pressure. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the low pressurizer pressure trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter is essentially a transducer that converts a pressurizer pressure into a corresponding voltage. The converter, PY-101A, converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The pressurizer pressure transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(PRESSURIZER PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the pressurizer pressure transmitter, PT-102A, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

	Procedures and Training
Performance Procedure	
Period of Performance	

Test Procedure	(Revision: 1581056)	
Period of Testing	18 Months	
Notos		

The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.

Calibration for PT-102A is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

# **Related Human Interactions**

## Key Assumptions

Per HRA System Notebook (Figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal conservatively.

2) Technician performs effective post-maintenance or post-calibration test based on reference plant procedure, SKN34 Surveillance Procedure 6431-02.

3) Technician performs instrumentation calibration and records the results and independent supervisor reviews previous results based on SKN34 Surveillance Procedure 6700-05.

4) Frequent status check would be performed by LCO 3.3.1, but it is assumed to be impossible to recover miscalibraion during normal operation.

Per HRA System Notebook (Figure A-3), to determine a dependency level for multiple latent errors and calibration errors, some assumptions are provided as follows:

1) Pressurizer pressure transmitter and converter in each channel (A/B/C/D) are arranged in serial configuration. Thus, zero dependency is selected between PT-102A and PY-102A based on HRA System Notebook, figure A-3.

If all of the above assumptions are comprehensively considered, then cell 37 for this HFE is selected based on HRA system notebook, figure A-1.

Because these pressure transmitters perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-PT102A, is analyzed are identically applied to the following HFEs: RPOPU-B-PT102B, RPOPU-C-PT102C, RPOPU-D-PT102D.

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
BHEP	0.03	
Notes		

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of

ASEP method is assigned as 0.03.

Critical Steps		
Basic HEP	0.03	
Case	8	
Total Recovered	9.7e-04	

Critical Step No.	Action	Comment
1	Calibrate low pressurizer	
	PT-102A	
2	Calibrate low pressurizer pressure signal converter PY-102A	

# **RPOPU-A-PT352A, Miscalibration of Reactor Containment Pressure** *Transmitter PT-352A*

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary		
Pexe (Median)	9.7e-04	
Total HEP	9.7e-04	
Error Factor	5	

### Identification and Definition

This HFE models miscalibration of the containment pressure transmitter as a representative case for miscalibrating 2/4 logic. To detect a high containment pressure, pressure inside containment from pressure measurement such as PT-352A and PY-352A is transferred to PPS (Plant Protection System). The high containment pressure trip is provided to trip the reactor when the measured containment pressure reaches a high preset value. The high containment pressure trip setpoint is selected in conjunction with the high-high containment pressure setpoint to prevent exceeding the containment design pressure

during a design basis LOCA or main steam line break accident. That is, the purpose of high containment pressure trip is to assist the ESF systems by tripping the reactor coincident with the initiation of safety injection caused by excessive pressure in containment.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring pressurizer pressure. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the high containment pressure trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter is essentially a transducer that converts a containment pressure into a corresponding voltage. The converter, PY-352A, converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The containment pressure transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(CONTAINMENT PRESSURE LOOP CALIBRATION AND OPERATIONAL TEST), the containment pressure transmitter, PT-352A, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

Procedures and Training		
Performance Procedure		
Period of Performance		
Test Procedure	(Revision: 1581056)	
Period of Testing	18 Months	
Notes		

The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.

Calibration for PT-101A is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

## **Related Human Interactions**

#### **Key Assumptions**

Per HRA System Notebook (Figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal conservatively.

2) Technician performs effective post-maintenance or post-calibration test based on reference plant procedure, SKN34 Surveillance Procedure 6763-01.

3) Technician performs instrumentation calibration and records the results and independent supervisor reviews previous results based on SKN34 Surveillance Procedure 6700-05.

4) Frequent status check would be performed by LCO 3.3.1, but it is assumed to be impossible to recover miscalibraion during normal operation.

Per HRA System Notebook (Figure A-3), to determine a dependency level for multiple latent errors and calibration errors, some assumptions are provided as follows:

1) Containment pressure transmitter and converter in each channel (A/B/C/D) are arranged in serial configuration. Thus, zero dependency is selected between PT-352A and PY-352A based on HRA System Notebook, figure A-3.

If all of the above assumptions are comprehensively considered, then cell 37 for this HFE is selected based on HRA system notebook, figure A-1.

Because these pressure transmitters perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-PT352A, is analyzed are identically applied to the following HFEs: RPOPU-B-PT352B, RPOPU-C-PT352C and RPOPU-D-PT352D.

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
BHEP	0.03		
Notes			
It's assumed that it's expected for human performance or human factors to be better than that of			

it's assumed that it's expected for numan performance of numan factors to be better than that of

conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

Critical Steps		
Basic HEP	0.03	
Case	8	
Total Recovered	9.7e-04	

Critical Step No.	Action	Comment
1	Calibrate containment	
	pressure transmitter	
	PT-352A	
2	Calibrate containment	
	pressure signal converter	
	PY-352A	

# **RPOPU-S-CPCABC, Common Cause Miscalibrate Core Protection** Calculator System (CPCS) Channel A/B/C

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary				
P <sub>exe (Median)</sub>	7.2e-05			
Total HEP	7.2e-05			
Error Factor	10			

## Identification and Definition

This HFE models common cause miscalibration of the Core Protection Calculator System (CPCS) including datalink, power supply, indicating value and others. All calibration task should be performed on only one channel at a time.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(CORE PROTECTION CALCULATOR SYSTEM LOOP CALIBRATION AND OPERATIONAL TEST), the CPCS on channel A/B/C is calibrated every 18 months.

The important procedural actions are (1) Check a channel A bypass function through Plant Protection System (PPS) (2) Check the power supplier and related components (3) Check a connection to I/O Simulator (4) Check the analog input module and digital pulse module of CPS (4) Check a CPCS Trip (5) Check the CEA Deviation (6) Check a CEAC (CEAC inoperation) (7) Check a surveillance test (8) Check a CEAC failure (9) Check a system health (10) Check a cyclic redundancy check (CRC) (11) Check a CPC-IPS datalink (Trip Buffer) (12) Check a CEAC-IPS datalink (snapshot) (13) Check a CPCS bypass function and many test and check tasks are performed. Failure of any one of these actions will lead to miscalibration. Calibration tasks on channel B/C are same from those of channel A.

Procedures and Training					
Performance Procedure					
Period of Performance	18 Months				
Test Procedure	(Revision: 1581056)				
Period of Testing					
Notes					
The procedure and training information is not available in DC phase. However, good procedure and					
appropriate training is assumed for this operator action.					

### **Related Human Interactions**

## Key Assumptions

The probability that both are miscalibrated is the third power of basic HEP of ASEP, 0.03. This is because of the result of miscalibration HEP about each channel such as RPOPU-S-CPCA.

It's assumed that there are no recovery actions because the worst case for single channel miscalibration of CPC is considered. And thus, basic HEP of ASEP, 3.0E-02, is used to calculate final HEP of single channel miscalibration of CPC. The "Critical Steps Recovery Factors" window of HRA calculator elucidates these decision process.

Because the success criteria logic of CPCS is 2/4, the technicians need to miscalibrate 3/4 CPCS in order to fail to defeat CPCS. Because the calibrations (A,B,C,D) are performed in sequence, there are 5 failure sequences that can lead to 3/4 miscalibration namely ABC, ABD, ACD, BCD and ABCD. ABCD is superfluous and need not be considered. Thus, the HEP for one failure sequence namely ABC which is RPOPU-S-CPCABC would need to be multiplied by 4 to reflect that there are 4 dominant failure sequences above described. By which four channel common cause human error probability such as RPOPU-S-CPCABCD would therefore be obtained from this HEP calculation for this HFE.

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
BHEP	0.03		
	Notes		

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

Dependency Factors			
Actions Close in Time	No		
Same Visual Frame of Reference	N/A		
General Area Only	N/A		
Writing Required	N/A		
Level of Dependency	Zero		

Critical Steps			
Basic HEP	0.03		
Case	1		
Total Recovered	7.2e-05		

Critical Step No.	Action	Comment
1	calibrate CPC channel A	
2	calibrate CPC channel B	
3	calibrate CPC channel C	

# RPOPU-S-LT1113ABC, Common Cause Miscalibration of Steam Generator Level Transmitter LT-1113A/B/C

Cognitive Method	Date	Analyst - Reviewer		
THERP	07/25/13	Namcheol Kim		
Analysis File	File Date	File Size (Bytes)		
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056		

HEP Summary				
	P <sub>exe</sub>	Error Factor		
Without Recovery	8.3e-06			
With Recovery	(8.3e-06, which is less than the	10		
	minimum of 1.0e-05)			

### **Identification and Definition**

This HFE models common cause miscalibration of the steam generator (S/G) level transmitter as a representative case for miscalibrating 2/4 logic.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring S/G level. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the S/G low level trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The transmitter such as LT-1113A/B/C is essentially a transducer that converts a S/G level into a corresponding voltage. The converter such as LY-1113A/B/C converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The S/G level transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(S/G PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the S/G level transmitter, LT1113A/B/C, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

In addition to get a HEP for RPOPU-S-LT1113ABC, common cause human error probability (HEP) in all four channels A/B/C/D, RPOPU-S-LT1113ABCD, can be calculated by using final HEP result of ROPU-S-LT1113ABC.

Because the success criteria logic of S/G level sensing is 2/4, the technicians need to miscalibrate 3/4 transmitters including converters in order to fail to control the S/G level. Because the calibrations

(A,B,C,D) are performed in sequence, there are 5 failure sequences that can lead to 3/4 miscalibration namely ABC, ABD, ACD, BCD and ABCD. ABCD is superfluous and need not be considered. Thus, the HEP for one failure sequence namely ABC which is RPOPU-S-LT1113ABC would need to be multiplied by 4 to reflect that there are 4 dominant failure sequences above described. By which four channel common cause human error probability, RPOPU-S-LT1113ABCD would therefore be obtained from this HEP calculation for RCOPU-S-LT1113ABC.

The S/G 2 level transmitter PT-1123A channel is same as S/G 1 level transmitter LT-1113A. Because these level transmitters perform same functions except for location on different channel, the assumptions and procedures to be considered when this HFE, RPOPU-A-LT113A, is analyzed are identically applied to the RPOPU-A-LT1123A. Thus, four (4) dominant failure sequence which lead to failure of S/G 2 level transmitters is identically obtained from above assumptions and then the final HEP of RPOPU-S-LT1123ABCD is calculated.

Procedures and Training					
Performance Procedure					
Period of Performance					
Test Procedure	(Revision: 10)				
Period of Testing	18 Months				
Notes					
The procedure and training information is not available in DC phase. However, good procedure and					

The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.

Each calibration for LT-1113A/B/C is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

### **Related Human Interactions**

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
Stress Level	Low		
Notes			

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, stress level of this HFE is assigned as "Low".

Execution Unrecovered							
	Procedure: ,			Comment			
Ston No.	Instruction (Commont	Error	THE	RP		Stress Factor	Over Ride
Step No.	Instruction/comment	Туре	Table	Item	пср		
	Calibrate transmitter LT1113A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
1		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate transmitter LT1113B by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
2		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate transmitter LT1113C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
3		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate signal converter LY1113A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
4		EOC	20-10	9	1.3E-3		
				•	Total S	Step HEP	2.6e-03
	Calibrate signal converter LY1113B by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
5		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate signal converter LY1113C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
6		EOC	20-10	9	1.3E-3		
	Total Step HEP					2.6e-03	
	Checking by supervisor						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
7		EOC	20-22	1	1.6E-1		
	Total Step HEP					1.6e-01	

Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
1		Calibrate transmitter LT1113A by technician	2.6e-03				4.2e-06	
	2	Calibrate transmitter LT1113B by technician		2.6e-03	LD	5.2e-02		
	3	Calibrate transmitter LT1113C by technician		2.6e-03	LD	5.2e-02		
	7	Checking by supervisor		1.6e-01	HD	5.8e-01		
4		Calibrate signal converter LY1113A by technician	2.6e-03				4.2e-06	
	5	Calibrate signal converter LY1113B by technician		2.6e-03	LD	5.2e-02		
	6	Calibrate signal converter LY1113C by technician		2.6e-03	LD	5.2e-02		
	7	Checking by supervisor		1.6e-01	HD	5.8e-01		
	Total Unrecovered:5.2e-03Total Recovered:8.3e-06							
# **RPOPU-S-PDT115ABC, Common Cause Miscalibration of S/G Pressure Difference Transmitter PDT-115A/B/C**

Cognitive Method	Date	Analyst - Reviewer
THERP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary				
	P <sub>exe</sub>	Error Factor		
Without Recovery	8.3e-06			
With Recovery	(8.3e-06, which is less than the	10		
	minimum of 1.0e-05)			

# Identification and Definition

This HFE models common cause miscalibration of the steam generator (S/G) pressure difference transmitter as a representative case for miscalibrating 2/4 logic.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring S/G pressure difference. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the S/G pressure difference trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The each transmitter such as PDT-115A/B/C is essentially a transducer that converts a S/G pressure difference into a corresponding voltage. The each converter such as PDY-1113A/B/C converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The S/G pressure difference transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(S/G PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the S/G pressure difference transmitter, PDT-115A/B/C, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal increases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

In addition to get a HEP for RPOPU-S-PDT115ABC, common cause human error probability (HEP) in all four channels A/B/C/D, RPOPU-S-PDT115ABCD, can be calculated by using final HEP result of ROPU-S-PDT115ABC.

Because the success criteria logic of S/G pressure difference sensing is 2/4, the technicians need to miscalibrate 3/4 transmitters including converters in order to fail to control the S/G pressure difference. Because the calibrations (A,B,C,D) are performed in sequence, there are 5 failure sequences that can lead to 3/4 miscalibration namely ABC, ABD, ACD, BCD and ABCD. ABCD is superfluous and need not be considered. Thus, the HEP for one failure sequence namely ABC which is RPOPU-S-PDT115ABC would need to be multiplied by 4 to reflect that there are 4 dominant failure sequences above described. By which four channel common cause human error probability, RPOPU-S-PDT115ABCD would therefore be obtained from this HEP calculation for RCOPU-S-PDT115ABC.

Procedures and Training				
Performance Procedure				
Period of Performance				
Test Procedure	(Revision: 10)			
Period of Testing	18 Months			
Notes				
The procedure and training informati	However, good procedure and			
appropriate training is assumed for the	nis operator action.			

Each calibration for LT-1113A/B/C is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

#### **Related Human Interactions**

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
Stress Level	Low		
Notes			

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, stress level of this HFE is assigned as "Low".

	Execution Unrecov	rered					
	Procedure: ,		Com	ment			
Step No.	In struction (Commont	Error	THERP			Stress Factor	Over Ride
Step No.	Instruction/comment	Туре	Table	Item			
	Calibrate transmitter PDT 115A by technician						
1	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
1		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate transmitter PDT115B by technician						
0	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
2		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate transmitter PDT115C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
3		EOC	20-10	9	1.3E-3		
				•	Total S	tep HEP	2.6e-03
	Calibrate signal converter PDY115A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
4		EOC	20-10	9	1.3E-3		
					Total S	tep HEP	2.6e-03
	Calibrate signal converter PDY115B by technician						
_	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
5		EOC	20-10	9	1.3E-3		
					Total S	tep HEP	2.6e-03
	Calibrate signal converter PDY115C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
6		EOC	20-10	9	1.3E-3		
	Total Step HEP						2.6e-03
	Checking by supervisor						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
7		EOC	20-22	1	1.6E-1	]	
		I		1	Total S	tep HEP	1.6e-01

		Exec	ution Recovered				
Critical	Recovery	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step

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Step No.	Step No.						
1		Calibrate transmitter PDT 115A by technician	2.6e-03				4.2e-06
	2	Calibrate transmitter PDT115B by technician		2.6e-03	LD	5.2e-02	
	3	Calibrate transmitter PDT115C by technician		2.6e-03	LD	5.2e-02	
	7	Checking by supervisor		1.6e-01	HD	5.8e-01	
4		Calibrate signal converter PDY115A by technician	2.6e-03				4.2e-06
	5	Calibrate signal converter PDY115B by technician		2.6e-03	LD	5.2e-02	
	6	Calibrate signal converter PDY115C by technician		2.6e-03	LD	5.2e-02	
	7	Checking by supervisor		1.6e-01	HD	5.8e-01	
		Total Unrecovered:	5.2e-03			Total Recovered:	8.3e-06

# **RPOPU-S-PT1013ABC, Common Cause Miscalibration of S/G Pressure** *Transmitter PT-1013A/B/C*

Cognitive Method	Date	Analyst - Reviewer
THERP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary				
	P <sub>exe</sub>	Error Factor		
Without Recovery	8.3e-06			
With Recovery	(8.3e-06, which is less than the	10		
	minimum of 1.0e-05)			

# **Identification and Definition**

This HFE models common cause miscalibration of the steam generator (S/G) pressure transmitter as a representative case for miscalibrating 2/4 logic.

In order to calibrate, the analog subsystem consists of four (4) channels for monitoring S/G pressure. Each analog channel includes a transmitter, converter, and Plant Protection System (PPS) input relays. The energized relays hold open their contacts in the channel inputs to each PPS train. At the S/G pressure trip setpoint causing the input relays to de-energize, which closes the contacts in the PPS channel inputs. The each transmitter such as PT-1013A/B/C is essentially a transducer that converts a S/G pressure into a corresponding voltage. The each converter such as PY-1013A/B/C converts a voltage into a current to read and identify a signal for PPS system.

The transmitter and converter need to be calibrated periodically. The S/G pressure transmitters and converters are calibrated every 18 months using the below described procedures. There are numerous, status lights, indicators and/or computer points in the control room to alert the operators of this condition. Failure to restore from the tripped position can therefore be screened out because it's obvious, and trip function is enhanced because the trip logic is reduced.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(S/G PRESSURE/LEVEL LOOP CALIBRATION AND OPERATIONAL TEST), the S/G pressure transmitter, PT-1013A/B/C, is calibrated every 18 months.

The important procedural actions are (1) Set the scale to zero (2) Record "mA" output current of transmitter on the "Before Calibration" column as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. (3) Compare between values on the "before calibration" column and required values whether two values are identical. Otherwise, set the scale to zero again until two values are same. (4) Record indicating value of digital multimeter on the "After Calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" as the signal increases by 0%, 25%, 50%, 75%, 100%. The other way, record "mA" output current on the "before calibration" column as the signal decreases by 100%, 75%, 50%, 25%, 0%. Failure of any one of these actions will lead to miscalibration.

In addition to get a HEP for RPOPU-S-PT1013ABC, common cause human error probability (HEP) in all four channels A/B/C/D, RPOPU-S-PT1013ABCD, can be calculated by using final HEP result of ROPU-S-PT1013ABC.

Because the success criteria logic of S/G pressure sensing is 2/4, the technicians need to miscalibrate

3/4 transmitters including converters in order to fail to control the S/G pressure. Because the calibrations (A,B,C,D) are performed in sequence, there are 5 failure sequences that can lead to 3/4 miscalibration namely ABC, ABD, ACD, BCD and ABCD. ABCD is superfluous and need not be considered. Thus, the HEP for one failure sequence namely ABC which is RPOPU-S-PT1013ABC would need to be multiplied by 4 to reflect that there are 4 dominant failure sequences above described. By which four channel common cause human error probability, RPOPU-S-PT1013ABCD would therefore be obtained from this HEP calculation for RCOPU-S-PT1013ABC.

The miscalibration scenario of this HFE can be identically applied to other pressure transmitters such as PT-101A/B/C/D, PT-1023A/B/C/D, PT-102A/B/C/D and PT-352A/B/C/D. Thus, other 3/4 transmitter miscalibrations probabilities including converters are same as RPOPU-S-PT1013ABC.

Like the preceding description, when the each pressure transmitter calibrations (A,B,C,D) are performed in sequence, four channel common cause HEPs such as RPOPU-S-PT101ABCD, RPOPU-S-PT1023ABCD, RPOPU-S-PT102ABCD and RPOPU-S-PT352ABCD are calculated by multiplying each 3/4 transmitters miscalibration probability by 4.

Procedures and Training			
Performance Procedure			
Period of Performance			
Test Procedure	(Revision: 10)		
Period of Testing	18 Months		
Notes			
The survey of the second function in formation in	ing in a standblake in DO aboos	المستمينية ومقتر ستمتع والمتعاد والمستحد والم	

The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.

Each calibration for LT-1113A/B/C is performed at each refueling outage, 18 months. Whereas channel function test is performed for each 3 months, but it is not effective to detect and recover miscalibration.

## **Related Human Interactions**

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
Stress Level	Low	
Notes		

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, stress level of this HFE is assigned as "Low".

	Execution Unrecovered						
	Procedure: ,		Com	ment			
Stop No.	Instruction/Commont	Error	THERP			Stress Factor	Over Ride
Step No.	Instruction/comment	Туре	Table	Item	пср		
	Calibrate pressure transmitter PT-1013A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
1		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate pressure transmitter PT-1013B by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
2		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate pressure transmitter PT-1013C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
3		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate pressure signal converter PY-1013A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
4		EOC	20-10	9	1.3E-3		
					Total S	Step HEP	2.6e-03
	Calibrate pressure signal converter PY-1013B by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
5		EOC	20-10	9	1.3E-3		
			1	1	Total S	Step HEP	2.6e-03
	Calibrate pressure signal converter PY-1013C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
6		EOC	20-10	9	1.3E-3		
				1	Total S	Step HEP	2.6e-03
Checking by supervisor						-	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
7		EOC	20-22	1	1.6E-1	1	
		I	1	1	Total S	Step HEP	1.6e-01
						-	

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
1		Calibrate pressure transmitter PT-1013A by technician	2.6e-03				4.2e-06
	2	Calibrate pressure transmitter PT-1013B by technician		2.6e-03	LD	5.2e-02	
	3	Calibrate pressure transmitter PT-1013C by technician		2.6e-03	LD	5.2e-02	
	7	Checking by supervisor		1.6e-01	HD	5.8e-01	
4		Calibrate pressure signal converter PY-1013A by technician	2.6e-03				4.2e-06
	5	Calibrate pressure signal converter PY-1013B by technician		2.6e-03	LD	5.2e-02	
	6	Calibrate pressure signal converter PY-1013C by technician		2.6e-03	LD	5.2e-02	
	7	Checking by supervisor		1.6e-01	HD	5.8e-01	
		Total Unrecovered:	5.2e-03			Total Recovered:	8.3e-06

# SIOPU1A-V218, SI PUMP PP02A MINI FLOW VV 218 NOT RESTORED AFTER TEST&MAINTENANCE

Cognitive Method	Date	Analyst - Reviewer
THERP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary			
	P <sub>exe</sub>	Error Factor	
Without Recovery	9.9e-04		
With Recovery	9.9e-04	10	

## Identification and Definition

This HFE models restoration failure of valve, SI-V218, after periodic testing. This valve is classified as "B-class" valve, which means that these valve only used to check the total flow of SI pump (PP02A) and are normally locked closed.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(SAFETY INJECTION PUMP AND SAFETY RELATED VALVES TEST), this valve on train A is opened every 3 months.

The important procedural actions are (1) Check a flow and SI pump inlet pressure in order to test a safety-related check valve, SI-V424 and SI-451 (2) Start a SI pump 02A (3) Check a discharge flow of pump whether it meets the required range or not through control of SI-V218. The remain procedures are same except for a reverse position. Through these procedures, SI flow path in train A is formed by penetrating into pump miniflow valve SI-V424 from SI pump discharge line to IRWST and in return.

As a result, this HFE means that miniflow valve restoration of SI-218 is failed after SI pump flow test described above, that is, valve is not reclosed after pump flow test.

Procedures and Training			
Performance Procedure			
Period of Performance	3 Months		
Test Procedure	(Revision: 10)		
Period of Testing			
Notes			
The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.			

## **Related Human Interactions**

Performance Shaping Factors			
Equipment Configuration	Good		
I&C Layout	Good		
Quality of Written Procedures	Good		
Quality of Administrative Control	Good		
Stress Level	Low		
Notes			

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, stress level of this HFE is assigned as "Low".

Execution Unrecovered							
	Procedure: ,		Comment				
Stop No.	Instruction/Comment	Error	THE	RP	HEP	Stress Factor	Over Ride
		Туре	Type Table	Item			
	Align SI pump PP02A Miniflow Manual Valve SI-V218						
	Location: Local - Aux. Bldg.	EOM	20-7b	1	4.3e-04	1	
1		EOC	20-13	1	1.3E-3		
	Total Step HEP						1.7e-03
	Confirm the Valve Position						
_	Location: Local - Aux. Bldg.	EOM	20-8a	1	1.3e-03	1	
2		EOC	20-22	1	1.6E-1		
					Total	Step HEP	1.6e-01

	Execution Recovered						
Critical Step No.	Critical Step No.     Recovery Step No.     Action     HEP (Crit)     HEP (Rec)     Dep.     Cond. HEP (Rec)     Total for Step				Total for Step		
1		Align SI pump PP02A Miniflow Manual Valve SI-V218	1.7e-03				9.9e-04
	2	Confirm the Valve Position		1.6e-01	HD	5.8e-01	
		Total Unrecovered:	1.7e-03			Total Recovered:	9.9e-04

# SIOPU1A-V265, SC PUMP PP01A MINI FLOW HEAT EXCHANGER ISOLATION VV 265 NOT RESTORED AFTER TEST&MAINTENANCE

Cognitive Method	Date	Analyst - Reviewer
ASEP	07/25/13	Namcheol Kim
Analysis File	File Date	File Size (Bytes)
APR1400_DC_HRA-Rev.9-Pre.HRA	07/25/13	1581056

HEP Summary		
Pexe (Median)	8.0e-03	
Total HEP	8.0e-03	
Error Factor	10	

## Identification and Definition

This HFE models restoration failure of valve, SI-V265, after periodic testing. This valve is classified as "A-class" valve, which means that these valve normally opened during normal operation, low temperature shutdown or refueling outage.

Reference plant's procedure is used for this analysis because of there are no available procedures for APR1400 in DC phase.

According to the reference plant's procedure(SHUTDOWN COOLING PUMP AND SAFETY RELATED VALVES TEST), this valve on train A should be closed every 3 months.

The important procedural actions are to check valve position before and after SC pump totally flow test. As a result, this HFE means that miniflow heat exchanger isolation valve restoration of SI-265 is failed after SC pump flow test, that is, this valve is not reopened after pump flow test.

Procedures and Training			
Performance Procedure			
Period of Performance	3 Months		
Test Procedure	(Revision: 1581056)		
Period of Testing			
Notes			
The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.			

# **Related Human Interactions**

#### Key Assumptions

Per HRA System Notebook (Figure A-2), to determine a specified ASEP case, some assumptions are provided as follows:

1) There is no compelling signal because this valve is a manual valve without MCR indication or BISI.

2) There are no available procedures and test configuration.

3) This valve is a lock-position valve. Therefore the procedures for locking valves and position verification after test are assumed.

4) Visual verification is assumed as performed every three month for lock state valves.

And also, it's assumed that there are no recovery actions and thus basic HEP of ASEP, 3.0E-02, is used to calculate final HEP of this HFE. The "Critical Steps Recovery Factors" window of HRA calculator elucidates these decision process.

If all of the above assumptions are comprehensively considered, then cell A-11 for this HFE is selected based on HRA system notebook, table A-1.

Because these valves perform same functions except for location on different train, the assumptions and procedures to be considered when this HFE, SIOPU1A-V265, is analyzed are identically applied to the following HFE: SIOPU2B-V269.

Performance Shaping Factors		
Equipment Configuration	Good	
I&C Layout	Good	
Quality of Written Procedures	Good	
Quality of Administrative Control	Good	
BHEP	0.03	
Notes		

It's assumed that it's expected for human performance or human factors to be better than that of conventional plants. And also, new plant design such as APR1400 is expected to continue to improve (or at least not be worsen than conventional plants) with respect to human factor concerns. Thus, on each Performance Shaping Factors (PSFs) branch such as equipment configuration, I&C layout, quality of written procedures, and quality of administrative control, "Good" is selected. So, Basic HEP (BHEP) of ASEP method is assigned as 0.03.

Critical Steps		
Basic HEP	0.03	
Case	3	
Total Recovered	8.0e-03	

Critical Step No.	Action	Comment
1	Align manual valve	
	V218	

# AFOPH-S-ALT-LT, Operator Fails to Transfer AFW Source From AFWST to RWT/CST

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev.10.hra	1806336	07/24/13	07/24/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary								
P <sub>cog</sub> P <sub>exe</sub> Total HEP Error Factor								
Method	CBDTM	THERP	CBDTM+THERP					
Without Recovery	6.0e-03	5.1e-03						
With Recovery	1.7e-04	7.4e-04	9.1e-04	10				

## Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All Initiator, except the LLOCA, MLOCA, TLOCCW, TLOESW, LOOP and SBO

3. Preceding operator error or success in sequence : Failure of shutdown cooling operation

4. Operator action success criterion : Operator should align local valves to transfer AFW source from AFWST to RWT/CST prior to SG depletion.

5. Definition : To maintain secondary heat removal operation, AFW source must be ensured. If it is fails to replenish the AFWSTs from demineralized water storage tank, when the inventory in the tanks decreases to a specified low level, operator must transfer feedwater source to condensate storage tank or raw water tank in order to continue heat removal from the secondary side.

Cues and Indications			
Initial Cue	AFWST low level		
Recovery Cue	EOG step "verify the available AFWST inventory is adequate" in each EOGs		
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training					
Cognitive Procedure	ARP-xx				
Cognitive Step Number	XX				
Cognitive Instruction	Enter into SYS-AF procedure to transfer AFW source.				
Execution Procedure	SYS-AF (Revision: xx)				
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					
The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action.					

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	Turbine operator is required to instruct the action to local operator.
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	1	Loca operator is required to align manual valves.

# Key Assumptions

# Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	65.00 Minutes				
T <sub>delay</sub>	0.00 Minutes				
T <sub>1/2</sub>	5.00 Minutes				
Τ <sub>M</sub>	15.00 Minutes				
Time available for recovery	45.00 Minutes				
SPAR-H Available time	50.00 Minutes				
(cognitive)					
SPAR-H Available time	4.00				
(execution) ratio					
Minimum level of dependence	LD				
for recovery					
Notes					

Conservatively Tsw is calculated based on the AFWST dimension, setpoint and AFWP rated flow, because the mass flow rate of steam would be less than the AFWP rated flow. Pre-empty alarm is assumed for AFW source change.

\* AFWST Water Volume [refer to SKN3&4 Drawing : 9-543-J163-001]

- Low Alarm setting : 124 \* 20 \* (340-18)/12 = 66546.7 ft3 = 497804 Gal
- Pre-Empty Alarm setting : 124 \* 20 \* (49-18)/12 = 6406.7 ft3 = 47925 Gal
- AFWP Rated Flow : 715 gpm

By above results,

- Time from Low alarm to depletion : 497804/715 = 696 min
- Time from pre-empty alarm to depletion : 47925/715 = 67 min

[ARP Driven Action]

\* T0 = Pre-Empty Alarm

\* Tsw = 65 min (Time from pre-empty alarm to depletion)

\* Td = 0 min

\* T1/2 = 5 min (Alarm Procedure)

* Tm = 15 min (conservative time due to uncertainty of local manual valve align)							
Cognitive Analysis							
Be Failure Mechanism	Branch	HED					
P : Availability of Information	Blanch	HEP					
Notos: Operator can access to all inform	ation and required indication	to operate a plant in the main					
control room.							
<b>P</b> <sub>cb</sub> : Failure of Attention	h	neg.					
Notes: If additional procedure is required	l, the high workload is assun	ned.					
This HFE is to connect alternate water so thus the operator only performs an one-ti doesn't need to check the tank level cont	ource to the Auxiliary Feedwa me check of a auxiliary feed inuously.	ater Storage Tank (AFST), and water storage tank level and					
It's assumed that the indicator to be chec because all of the controls in the modern room.	ked is always displayed on t control room are expected t	the front panel of the MCR to be located in the front of the					
Pre-empty alarm is assumed for auxiliary Lo-Lo-Lo alarm is greater than 400,000 g cooling condition and also greater than C auxiliary feedwater source. So, value of t signaled by an annunciator.	r feedwater source change, k jal which is minimum capacit condense Storage Tank (CS he Auxiliary Feedwater Stora	because the water capacity at ty assuring to reach shutdown T), which is an alternative age Tank (AFWST) level is					
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.					
<b>Notes:</b> Required indicator on the control always located easily.	board such as layout, dema	rcation, labeling and others is					
With the advanced digital I&C interface in there are scenario specific considerations deviation will be provided.	n the MCR, the indication is a s to warrant otherwise, in wh	assumed to be "good" unless hich case, justification for the					
It is assumed that formal communications between operators.	s will always be used when the	he specified value is transferred					
P <sub>od</sub> : Information misleading	а	nea.					
Notes: It is assumed that all cues will be	as stated when the operators	s follow the "Instruction" column					
P <sub>m</sub> : Skip a step in procedure	q	6.0e-03					
Notes: It's assumed that it's always trans stand-alone numbered step on the EOGs The MCR operator is required to use an a	parent for operators to proces.	eed the relevant instruction or					
"multiple" branch is selected for this HFE							
Only if there are special or distinct marks "Graphically Distinct" should be selected.	are provided in the procedu	ire, "YES" branch in the					
The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made	assumed to be used due to the ne operator will be required to Scenarios for which deviation will be provided.	ne nature of the computerized o confirm completion of a step ons from this assumption are					
P <sub>cf</sub> : Misinterpret Instructions	a	neg.					
<b>Notes:</b> It is generally assumed that the w for the Misinterpret Instruction decision tr	ording of the procedures will ee, pcf, of the CBDTM.	be standard versus ambiguous					

The step present all information required to identify the actions directed and their objects.						
P <sub>cq</sub> : Misinterpret decision logic k neg.						
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b) because						
"NOT, AND, OR, BOTH AND and OR" an	e present through EOG01 a	nd EOG02. Otherwise, "No"				
branch should be selected on the "NOT S	Statement" branch.					
The operators are always trained and pra	The operators are always trained and practiced about specified scenario to perform.					
<b>P</b> <sub>ch</sub> : Deliberate violation	P <sub>ch</sub> : Deliberate violation a neg.					
Notes: The operators are always assume	ed to believe in the adequac	y of instruction presented.				
Initial P <sub>c</sub> (without recovery credited)		6.0e-03				
Notes						
Equipment Accessibility	MCR: Accessible					

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>c</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>e</sub>	6.0e-03	Х	Х	-	-	-	N/A	LD	2.8e-02		1.7e-04
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 1.7e-04								1.7e-04		
							Note	s			

CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for Pce. In addition, STA or other operators in MCR can also check the skip a step in the procedure.

Execution Performance Shaping Factors					
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	Local (Outside MCR)	Accessible			
Stress	Low				
	Plant Response As	Yes			
	Expected:				
	Workload:	Low			
	Performance Shaping	Optimal			
	Factors:				
	Notes				
The depletion of AFWST means the seconda	ry heat removal is performe	d successfully. Therefore,			
plant response as expected is assumed.					
This operator action is required long time late	r from initiator. Therefore,	it is assumed that sufficient			
operators are available for this action. There	efore, low workload is select	ed.			
Execution Complexity	Simple				

Execution Unrecovered								
		Com		-				
Step No.	Instruction/Comment		THERP		HEP	Stress Factor	Over Ride	
			Table	Item				
	Align valves to provide AFW from RST/CST locally							
	Location: Local (Outside MCR)		20-8a	1	1.3e-03	1		
SYS-AF #XX		EOC	20-13	2	3.8E-3			
	Total Step HEP							
	Check the AFWST and AFW flow	he AFWST and AFW flow						
SYS-AF	Location: MCR	EOM	20-7b	1	4.3e-04	1		
#XX-2		EOC	20-9	2	1.3E-3			
	Total Step HEP							

	Execution Recovered										
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step				
SYS-AF #XX		Align valves to provide AFW from RST/CST locally	5.1e-03				7.4e-04				
	SYS-AF #XX-2	Check the AFWST and AFW flow		1.7e-03	MD	1.4e-01					
		Total Unrecovered:	5.1e-03			Total Recovered:	7.4e-04				

Plant	Data File	File Size	File Date	Record				
				Date				
APR1400-DC	APR1400_DC_HRA-Rev.10.hra	07/17/13						
	Name			Date				
Analyst	Namcheol Kim							
Reviewer	Kisu Kim							

# AFOPV-S-AFAS-FW, Operator Fails to Recover AFAS

HEP Summary								
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor				
Method	CBDTM	THERP	CBDTM+THERP					
Without Recovery	2.2e-02	8.7e-03						
With Recovery	4.6e-03	1.3e-03	5.9e-03	5				

## Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All Initiator, except the LLOCA and MLOCA

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should initiate the AFW system to control SG level.

5. Definition : After initiating event (e.g. Loss of Main Feedwater) which decreases steam generator level by steam relief, Auxiliary Feedwater system (AF) is actuated by automatic signal which is AFAS. If AF components such as pumps and valves were not actuated due to failure of AFAS, operator should actuate them and control AF flow in MCR.

Cues and Indications				
Initial Cue	S/G Low Level			
Recovery Cue	No FW Flow			
Cue Comments				
Degree of Clarity	Very Good			

	Procedures and Training						
Cognitive Procedure	EOG-01 (Revision: 0)						
Cognitive Step Number	6.a						
Cognitive Instruction	Verify that SG meets any of the following conditions.						
	o At least on SG level is within [Post-trip SG level band]						
	o SG level is being restored by a total feedwater flow greater than						
	[post-trip minimum feedwater flowrate] to one or both SGs						
Execution Procedure	EOG-01 (Revision: 0)						
Other Procedure(s)	EOG-07 (Revision: 0)						
Job Performance Measure							
Classroom Training	None						
Simulator Training	None						
Notes							
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.							

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

# **Key Assumptions**

**Operator Interview Insights** 

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	30.00 Minutes				
T <sub>delay</sub>	0.00 Minutes				
T <sub>1/2</sub>	5.00 Minutes				
Τ <sub>M</sub>	1.00 Minutes				
Time available for recovery	24.00 Minutes				
SPAR-H Available time	29.00 Minutes				
(cognitive)					
SPAR-H Available time	25.00				
(execution) ratio					
Minimum level of dependence	MD				
for recovery					

Notes

In LOFW sequence, SG low level alarm is generated shortly after reactor trip. Therefore it is assumed the cognitive procedure step is located on the SPTA. In LOFW sequence, it is assumed that there is no main feedwater flow to SG.

Per MAAP analysis for LOFW sequence, (refer to Table 5-9 case 4(a), 4(b) of the Success Criteria Notebook)

1. Reactor Trip : 0 hr (22.126 sec)

- 2. SG Low Level Alarm (45% WR) : 0 hr (22.126 sec)
- 3. SG Low Level Alarm (25% WR) : 0 hr (152.599 sec)
- 4. SG Dry-Out : 0.6 hr (2086.121 sec)
- 5. Core uncovery : 1.1 hr (3945.3995 sec)
- 6. Core Damage : 1.5 hr (5484.910 sec)

[EOG Driven Action]

- \* T0 = LOFW Occurrence, Rx Trip
- \* Tsw = 30 min (SG dry out timing by MAAP analysis)

\* Td = 0 min

\* T1/2 = 5 min (elapsed time to reach at SPTA EOG step #6, which is because it's assumed that 1 minute will be required to complete one step in EOG)

\* Tm = 1 min (It is assumed that 1 minute will be used as an ESFAS (and similar) signal recovery time due to the action being a simple control room action)

Cognitive Analysis								
Pc Failure Mechanism	Branch	HEP						
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.						
Notes: Operator can access to all information control room.	ation and required indication	to operate a plant in the main						
P <sub>cb</sub> : Failure of Attention	i	neg.						
Notes: In general, within 2 hours from accurate unless the work load relevant to a specific This HFE is to initiate AFAS manually and AFAS alarm and status of related comport continuously	cident initiation, work load is HFE cannot be judged app thus the operator only perf nents and variables. It is not	assumed to be high for CBDTM propriately. orms and one-time check of necessary to check them						
It's assumed that the indicator to be check because all of the controls in the modern room.	ked is always displayed on t control room are expected to	he front panel of the MCR o be located in the front of the						
It is assumed that operators concentrate on Thus operators can not respond to alarms	on EOG and performs EOG s until related parameter are	-driven actions after reactor trip. mentioned in the EOG step.						
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.						
<b>Notes:</b> It is assumed that required indicat and others is always located easily.	or on the control board such	as layout, demarcation, labeling						
With the advanced digital I&C interface in there are scenario specific considerations deviation will be provided.	the MCR, the indication is a to warrant otherwise, in wh	assumed to be "good" unless ich case, justification for the						
between operators.	will always be used when a	ne specified value is transferred						
<b>P</b> <sub>cd</sub> : Information misleading	b	3.0e-03						
Notes: In this HFE, the related parameter and related system does not respond auto recover AFAS manually. The EOG provides contingeny actions wh not as stated	values dose not satisfy the omatically(i.e. Failure of AFA	range of EOG description values S automatically). Thus operators to proceed if the cue states are						
P <sub>ce</sub> : Skip a step in procedure	с	3.0e-03						
<b>Notes:</b> It's assumed that it's always trans stand-alone numbered step on the EOGs	parent for operators to proce	eed the relevant instruction or						
The MCR operator is not required to use a branch is selected for this HFE.	an an additional procedure ir	n addition to the EOG, so "single"						
Only if there are special or distinct marks "Graphically Distinct" should be selected.	are provided in the procedu	re, "YES" branch in the						
The use of placekeeping aids is always as procedure system (CPS) software, i.e., th the procedural items are addressed. Sco possible, justification for the choice made	ssumed to be used due to the operator will be required to enarios for which deviations will be provided.	ne nature of the computerized o confirm completion of a step as from this assumption are						
P <sub>cf</sub> : Misinterpret Instructions	а	neg.						
<b>Notes:</b> It is generally assumed that the we for the Misinterpret Instruction decision tre	ording of the procedures wil ee, pcf, of the CBDTM.	I be standard versus ambiguous						
The step present all information required	to identify the actions directe	ed and their objects.						

P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02					
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b) because							
"NOT, AND, OR, BOTH AND and OR" an	e present through EOG01 a	nd EOG02. Otherwise, "No"					
branch should be selected on the "NOT Statement" branch.							
The operators are always trained and practiced about specified scenario to perform.							
<b>P</b> <sub>ch</sub> : Deliberate violation	P <sub>ch</sub> : Deliberate violation a neg.						
Notes: The operators are always assume	ed to believe in the adequac	y of instruction presented.					
Initial P <sub>c</sub> (without recovery credited) 2.2e-02							
Notes							
Equipment Accessibility	MCR: Accessible						

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>c</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pc <sub>e</sub>	3.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	1.6e-02	-	-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 4.6e-03									4.6e-03	
							Not	es			

STA review is possible using RCS heat removal section in SFSC, by which it's possible to recover information misleading and misinterpret decision logic. And also, CPS provides the tool to prevent skip a step in the procedure and can be reviewed by another operators.

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
This HFE is to recover failed ESF actuation si	gnal. This operator action ha	ave to be performed under limited				
time condition to prevent undesired plant state	Э.					
Execution Complexity	Simple					

Execution Unrecovered								
	Procedure: EOG-01, SPTA	Comment						
Step No.	Instruction/Comment	Error	THERP		HFP	Stress Factor	Over Ride	
		Туре	Table	Item				
	IF SG level is less than or equal to AFAS setpoint, then ensuer AFAS is initiated.							
EOG-01 #6-a.1-3)	Location: MCR	EOM	20-7b	1	4.3e-04	5		
		EOC	20-12	3	1.3E-3	-		
	Total Step HEP							
	Replenish SG inventory in at least one SG by auxiliary feedwater							
	Location: MCR		20-7b	1	4.3e-04	5		
EOG-07 #6		EOC	20-12	4	1.3E-3			
	Total Step HEF							

Execution Recovered										
Critical Step No.	Recovery Step No.	Action	Dep.	Cond. HEP (Rec)	Total for Step					
EOG-01		IF SG level is less than or equal to AFAS setpoint,	8.7e-03				1.3e-03			
#6-a.1-3)		then ensuer AFAS is initiated.								
	EOG-07 #6	Replenish SG inventory in at least one SG by		8.7e-03	MD	1.5e-01				
		auxiliary leeuwalei								
		Total Unrecovered:	8.7e-03			Total Recovered:	1.3e-03			

# CDOPH-S-ALIGN, Operator Fails to Align the Manual Valves and start CD pumps for Hotwell Makeup

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev.10.hra	1806336	07/24/13	07/24/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary									
P <sub>cog</sub> P <sub>exe</sub> Total HEP Error Factor									
Method	CBDTM	THERP	CBDTM+THERP						
Without Recovery	6.0e-03	1.0e-02							
With Recovery	3.6e-05	5.2e-04	5.6e-04	10					

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: GTRN, LOIA, LOCV, PLOCCW, TLOCCW, PLOESW and TLOESW

3. Preceding operator error or success in sequence : Success of supplying feedwater using start-up feedwater pumps

4. Operator action success criterion : Operator should diagnose condenser hotwell and DST level, and then makeup the feedwater flow source.

5. Definition : If AFWP fails to supply feedwater to SG, Start-up Feedwater Pump (SFWP) is used alternatively to supply feedwater to SG. SFWP takes suction from Dearator Storage Tank (DST). For long-term operation of SFWP, DST water must be refilled by Condensate Pump (CDP) using condenser hotwell water before DST depletion. Likewise, condenser hotwell water also must be refilled from Condensate Storage Tank (CST) through valve alignment before depletion.

Cues and Indications						
Initial Cue Condenser Hotwell Low Level/DST Low Level						
Recovery Cue	Check Start-up FW Flow Status					
Cue Comments						
Degree of Clarity	Very Good					

Procedures and Training							
APR-xx1 (Revision: 00)							
XX							
Verify Condenser Hotwell Makeup Valve operation							
SYS-CD (Revision: 00)							
None							
None							
Notes							
The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action							

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	1	

## **Key Assumptions**

Operator Interview Insights

Operator interview is not available in DC pl	hase.
--	-------

Timing Analysis						
T <sub>sw</sub>	180.00 Minutes					
T <sub>delay</sub>	0.00 Minutes					
T <sub>1/2</sub>	5.00 Minutes					
Τ <sub>M</sub>	15.00 Minutes					
Time available for recovery	160.00 Minutes					
SPAR-H Available time	165.00 Minutes					
(cognitive)						
SPAR-H Available time	11.67					
(execution) ratio						
Minimum level of dependence	ZD					
for recovery						
Notoo						

CDP starting and valves align timing to support the start-up FW pump operation prior to DST depletion and CND hotwell depletion.

\* DST Capacity : ~510m3 \* 2 \* 264 = 270,000 gal [SKN3&4 CD system plant manual] - DST Level Setting : ~2.5m(510m3) for Normal, 2.31m(481m3) for Lo Alarm, 0.33m(141m3) for Lo-Lo Alarm (FWP stop setpoint)

\* SFWP : 1000/2800 gpm (min/rated flow) [SKN3&4 FW system plant manual]

\* AFWP : 135/715 gpm (min/rated flow) [SKN3&4 AF system plant manual]

\* CND Hotwell Capacity : 127,000 \* 3 = 381,000 gal [SKN3&4 Drawing : M201-DT-B01-010, BTM to NWL] - CND Hotwell Level Setting : 32.5" for normal, 27" for Lo Alarm, 7.5" for Lo-Lo Alarm (CDP stop setpoint) [SKN3&4 Drawing : 9-531-J163-001/003]

\* DST available time with SFWP = ~ 270000/1000 = 270 min

\* Hotwell water available time with SFWP = ~ 127000\*3/1000 = 381 min

\* DST depletion time from Lo Alarm to Lo-Lo Alarm = (481-141)\*264\*2/1000 = 179.52 min

\* CND Hotwell depletion time from Lo Alarm to Lo-Lo Alarm = (27 - 7.5)\*3900\*3/1000 = 228.15 min

[ARP Driven Action]

\* T0 = DST Lo Alarm

\* Tsw = 180 min (DST Lo-Lo level; DST depletion time is more conservative than condenser hotwell depletion time)

\* Td = 0 min

\* T1/2 = 5 min (It is assumed that 5 minutes will be used to allow the operator to read and process preliminary up front material in the ARP)

\* Tm = 15 min (conservative time due to uncertainty of pump and/or local manual valve align)

Cognitive Analysis										
Pc Failure Mechanism	Branch	HEP								
P <sub>ca</sub> : Availability of Information	а	neg.								
Notes: Operator can access to all information and required indication to operate a plant in the main										
control room.										
<b>P</b> <sub>cb</sub> : Failure of Attention	h	neg.								
Notes: If additional procedure is required, the high workload is assumed.										
This HFE is to align manual valves and initiate CD pump manually and thus the operator only performs and one-time check the status of related components and the values of parameters. It is not necessary to check them continuously.										
It's assumed that the indicator to be check all of the controls in the modern control ro	ked is always displayed on the loca of the	he front panel of the MCR because ted in the front of the room.								
The use of start-up FW pump for seconda well and DST. Alarms for low level of cond these in the MCR. It takes several hours t after secondary heat removal using start- immediately when low level alarms for co	The use of start-up FW pump for secondary heat removal causes the level decrease of condenser hot well and DST. Alarms for low level of condenser hot well and DST are occurred and operators can check these in the MCR. It takes several hours to occur the low level alarms of condenser hot well and DST after secondary heat removal using start-up FW pump. Thus it is assumed that operator can respond immediately when low level alarms for condenser hot well and DST are occurred.									
P <sub>cc</sub> : Misread/miscommunicate data a neg.										
<b>Notes:</b> It is assumed that required indicate and others is always located easily.	tor on the control board such	n as layout, demarcation, labeling								
With the advanced digital I&C interface in are scenario specific considerations to wa will be provided.	With the advanced digital I&C interface in the MCR, the indication is assumed to be "good" unless there are scenario specific considerations to warrant otherwise, in which case, justification for the deviation will be provided.									
It is assumed that formal communications between operators.	s will always be used when t	he specified value is transferred								
<b>P</b> <sub>cd</sub> : Information misleading	а	neg.								
Notes: In this HFE, low level values of ho	t well and DST are used to	determine the make up. Thus it is								
assumed that the procedure describes how the operator response when the indicated values are not satisfy the hot well and DST level.										
<b>P</b> <sub>ce</sub> : Skip a step in procedure	g	6.0e-03								
<b>Notes:</b> It's assumed that it's always trans stand-alone numbered step on the proceed	<b>Notes:</b> It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the procedures.									
The MCR operator is required to use an an additional procedure in addition to the EOG, so "multiple" branch is selected for this HFE.										

Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected.										
The use of placekeeping aids is always as	The use of placekeeping aids is always assumed to be used due to the nature of the computerized									
procedure system (CPS) software, i.e., th	e operator will be required to	o confirm completion of a step as								
the procedural items are addressed. Sce	enarios for which deviations	from this assumption are possible,								
justification for the choice made will be pro-	ovided.									
P <sub>cf</sub> : Misinterpret Instructions	а	neg.								
Notes: It is generally assumed that the wo	ording of the procedures will	be standard versus ambiguous for								
the Misinterpret Instruction decision tree,	pcf, of the CBDTM.									
The step present all information required	to identify the actions directed	ed and their objects.								
P <sub>cg</sub> : Misinterpret decision logic	k	neg.								
Notes: If diagnosis is performed just after	EOG-01 completion, select	t sequence (a) or (b) because								
"NOT, AND, OR, BOTH AND and OR" are	e present through EOG01 ar	nd EOG02. Otherwise, "No" branch								
should be selected on the "NOT Statement	nt" branch. But, in this HFE,	EOG does not considered. Thus it								
is assumed that the "NOT, AND, OR, BO	TH AND and OR" statement	is are not included, because the								
ARP describes clearly related actions.										
The operators are always trained and pra	cticed about specified scena	ario to perform.								
P <sub>ch</sub> : Deliberate violation	а	neg.								
Notes: The operators are always assume	d to believe in the adequac	y of instruction presented.								
Initial P <sub>c</sub> (without recovery credited)		6.0e-03								
	Notes									
	I									
Equipment Accessibility MCR: Accessible										

Cognitive Recovery											
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>e</sub>	6.0e-03	Х	-	-	-	-	N/A	ZD	6.0e-03		3.6e-05
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 3.6e-05								3.6e-05		
	Notes										

CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for Pce.

Execution Performance Shaping Factors								
Special Requirements	Tools	Adequate						
	Parts	Adequate						
	Clothing	Adequate						
Environment	Lighting	Normal						
	Heat	Normal						
	Radiation	Background						

	Atmosphere	Normal			
Equipment Accessibility	Turbine Generator Bldg.	Accessible			
Stress	Low				
	Plant Response As	Yes			
	Expected:				
	Workload:	Low			
	Performance Shaping	Optimal			
	Factors:				
Notes					
This operator action is required to maintain feedwater supply using start-up feedwater pump. In other					
words, this operator action would perform after	words, this operator action would perform after success of start-up feedwater pump operation and operator				
can expect this operator action would be required. Therefore "Yes" branch is chosen at Plant Response As					
Expected node. This operator action is required several hours later from initiator. Therefore, it is					
assumed that sufficient operators are availabl	e for this action. Therefore	e, low workload is selected.			
Execution Complexity	Simple				
Execution Complexity	Simple				

Execution Unrecovered							
Procedure: SYS-CD, Condensate System			Comment				
Step No.	Instruction/Comment	Error	THE	RP	HEP	Stress Factor	Over Ride
	instruction comment	Туре	Table	Item			
	Start Condensate Pump						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
SYS-CD #xx-0		EOC	20-12	4	1.3E-3		
					Total S	Step HEP	1.7e-03
Open condensate pump discharge valve Condensate pump discharge valve is jog control type MOV.							
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
515-CD #XX-1		EOC	20-12	10	3.8E-3		
					Total S	Step HEP	4.2e-03
	Verify condensate pump flow						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
SYS-CD #xx-2		EOC	20-9	2	1.3E-3		
		·			Total S	Step HEP	1.7e-03
	Align Manual Valves for Condenser Hotwell Makeup						
	Location: Turbine Generator Bldg.	EOM	20-7b	1	4.3e-04	1	
SYS-CD #xx-3		EOC	20-13	2	3.8E-3		
					Total S	Step HEP	4.2e-03
	Verify Condenser Hotwell Level						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
SYS-CD #xx-4		EOC	20-9	2	1.3E-3		
			•	•	Total S	Step HEP	1.7e-03

Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
SYS-CD #xx-0		Start Condensate Pump	1.7e-03				8.8e-05
	SYS-CD #xx-2	Verify condensate pump flow		1.7e-03	LD	5.2e-02	
SYS-CD #xx-1		Open condensate pump discharge valve	4.2e-03				2.2e-04
	SYS-CD #xx-2	Verify condensate pump flow		1.7e-03	LD	5.2e-02	
SYS-CD #xx-3		Align Manual Valves for Condenser Hotwell Makeup	4.2e-03				2.2e-04
	SYS-CD #xx-4	Verify Condenser Hotwell Level		1.7e-03	LD	5.2e-02	
		Total Unrecovered:	1.0e-02			Total Recovered:	5.2e-04

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev.10.hra	1806336	07/24/13	07/15/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

# CSOPV-S-CSAS, Operator Fails to Actuate CSAS

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	2.2e-02	8.7e-03				
With Recovery	1.5e-04	7.6e-05	2.2e-04	10		

# Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All Initiator, except the TLOCCW and TLOESW

3. Preceding operator error or success in sequence : Hot leg injection or SI injection success

4. Operator action success criterion : Operator should start containment spray manually.

5. Definition : Containment Spry System (CS) is actuated automatically by CSAS. If CS is not actuated due to failure of CSAS, operator should actuate CSAS or CS components which include pumps and valves in MCR. In this case, operators have long available time for CS operation even though CSAS actuate very rapidly in early stage.

Cues and Indications			
Initial Cue	Containment Pressure		
Recovery Cue No CS Flow, CS Temperature			
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	8.b			
Cognitive Instruction	Verify that continment pressure is less than [high containment			
	pressure alarm setpoint]			
Execution Procedure	EOG-01 (Revision: 0)			
Other Procedure(s)	EOG-04 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.				

Crew Member	Total	Required for	Notes

	Available	Execution	
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

# **Key Assumptions**

## Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	150.00 Minutes			
T <sub>delay</sub>	0.00 Minutes			
T <sub>1/2</sub>	10.00 Minutes			
Τ <sub>M</sub>	1.00 Minutes			
Time available for recovery	139.00 Minutes			
SPAR-H Available time	149.00 Minutes			
(cognitive)				
SPAR-H Available time	140.00			
(execution) ratio				
Minimum level of dependence	ZD			
for recovery				
Notos				

Notes

Per Relap analysis for LOCA sequence, (refer to Table 5-1 case 1 of the Success Criteria Notebook)

core damage does not occur within 24 hours.

Per MAAP analysis for LOFW sequence with Feed&Bleed IRWST cooling, (refer to Table 5-9 case 5(a) of the Success Criteria Notebook)

IRWST is saturated at 2.6 hours from initiator.

[EOG Driven Action]

\* T0 = Accident Occurrence, Rx Trip, CSAS Generation (similar timing)

\* Tsw = 150 min (conservative time window for both LLOCA event and F&B initiation based on MAAP Analysis)

\* Td = 0 min

\* T1/2 = 10 min (within 10 procedure steps in SPTA after LOCA and in FRG HR-3 after F&B initiation.) \* Tm = 1 min (It is assumed that 1 minute will be used as an ESFAS (and similar) signal recovery time due to the action being a simple control room action)

Cognitive Analysis				
Pc Failure Mechanism	Branch	HEP		
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.		
Notes: Operator can access to all inform	ation and required indication	to operate a plant in the main		
control room.				
	1			
P <sub>cb</sub> : Failure of Attention	a	neg.		
<b>Notes:</b> In general, within 2 hours from ac	cident initiation, work load is	assumed to be high for		
CBDTM unless the work load relevant to	a specific HFE cannot be jue	dged appropriately.		
This HFE is to initiate CSAS manually an	d thus the operator only per	forms and one-time check of		
CSAS alarm and status of related compo continuously.	nents and variables. It is not	necessary to check them		
It's assumed that the indicator to be abas	kad is always displayed on t	he front papel of the MCP		
It's assumed that the indicator to be check	antrol room are expected to	he front panel of the MCR		
	control room are expected t			
P.: Misread/miscommunicate data	а	neg		
Notes: It is assumed that required indica	tor on the control board such	as layout demarcation		
labeling and others is always located eas	sily.			
With the advanced digital ISC interface in	the MCD the indication is a	acumed to be "good" uplose		
there are accepting appoint according	to warrant otherwise in wh	ish asso, justification for the		
deviation will be provided	s to warrant otherwise, in wi	ich case, justification for the		
deviation will be provided.				
It is assumed that formal communications	s will always be used when th	a specified value is transferred		
between operators				
P <sub>od</sub> : Information misleading	b	3 0e-03		
P <sub>cd</sub> : Information misleading Notes: In this HFE, the related parameter	b ber values dose not satisfy the	3.0e-03 range of EOG description		
P <sub>cd</sub> : Information misleading <b>Notes:</b> In this HFE, the related parameter values and related system does not resp	b r values dose not satisfy the ond automatically(i.e. Failure	3.0e-03 range of EOG description of CSAS automatically). Thus		
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<ul> <li>P<sub>cd</sub>: Information misleading</li> <li>Notes: In this HFE, the related parameter values and related system does not resp operators recover CSAS manually.</li> <li>The EOG provides contingeny actions when the not as stated.</li> <li>P<sub>ce</sub>: Skip a step in procedure</li> <li>Notes: It's assumed that it's always transs stand-alone numbered step on the EOGs</li> <li>The MCR operator is not required to use "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct markss "Graphically Distinct" should be selected</li> </ul>	b r values dose not satisfy the ond automatically(i.e. Failure hich are instructions on how c sparent for operators to proce an an additional procedure i are provided in the procedu	3.0e-03 range of EOG description e of CSAS automatically). Thus to proceed if the cue states are <u>3.0e-03</u> eed the relevant instruction or n addition to the EOG, so re, "YES" branch in the		
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The operators are always trained and practiced about specified scenario to perform.					
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.			
Notes: The operators are always assumed to believe in the adequacy of instruction presented.					
Initial P <sub>c</sub> (without recovery credited) 2.2e-02					
Notes					

Equipment Accessibility

MCR: Accessible

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	ZD	3.0e-03		9.0e-06
Pce	3.0e-03	Х	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-	Х	Х	-	-	N/A	ZD	8.0e-03		1.3e-04
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 1.5e-04										
							Note	es			

STA review is possible using containment temperature and pressure control section in SFSC, by which it's possible to recover information misleading and misinterpret decision logic. And also, CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for Pce. There is sufficient recovery time for this HFE, so recovery by extra crew is also possible for Pcg.

Execution Performance Shaping Factors					
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			
	Expected:				
	Workload:	N/A			
	Performance Shaping	N/A			
	Factors:				
Notes					
This HFE is to recover failed ESF actuation signal. If containment spray function fails, containment					
pressure lose control and plant approach to undesired condition.					
Execution Complexity	Simple				

Execution Unrecovered							
	Procedure: EOG-01, SPTA		Comment				
Step No	Instruction/Comment		THERP		HEP	Stress Factor	Over Ride
		Туре	Table	Item			
	Ensure CSAS is initiated.						
EOG 01	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#8.2-1)		EOC	20-12	3	1.3E-3		
	Total Step HEI						
	Ensure at least on CSS train is delivering greater than or equal to minimum CS flowrate.						
F0G-01	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#8.2-2)		EOC	20-9	2	1.3E-3		
					Total S	tep HEP	8.7e-03

	Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
EOG-01		Ensure CSAS is initiated.	8.7e-03				7.6e-05	
#8.2-1)								
	EOG-01	Ensure at least on CSS train is delivering greater		8.7e-03	ZD	8.7e-03		
	#8.2-2)	than or equal to minimum CS flowrate.						
		Total Unrecovered:	8.7e-03			Total Recovered:	7.6e-05	

# **CVOPH-S-BORATION, Operator Fails to Initiate Emergency Boration to RCS**

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev.10.hra	1806336	07/24/13	07/23/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	2.2e-02	1.7e-02				
With Recovery	1.1e-02	2.6e-03	1.4e-02	5		

## **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: ATWS

3. Preceding operator error or success in sequence : Failure of reactor trip

4. Operator action success criterion : Operator should inject borated water into RCS using CVCS.

5. Definition : A transient, Loss of Feedwater and so on, has occurred. Reactor trip was not successful, i.e., ATWS occurred. Reactivity control must be established. The Chemical Volume and Control System may be used to inject the contents of the Boric Acid Storage Tank via a charging pump into the RCS. The operator must align a flow path from the Boric Acid Storage Tank to the charging pump suction line. The preferred path is via the boric acid makeup pump to the charging pump, however, if the boric acid makeup pumps are not available, the gravity feed path may be used.

Cues and Indications			
Initial Cue	Rx Core Power Level		
Recovery Cue CEA Position			
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	1.c.1			
Cognitive Instruction	If Rx Trip is not confirmed, inject borated water via CVCS system.			
Execution Procedure	EOG-01 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				

Crew Member	Total	Required for	Notes

	Available	Execution	
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	The reacotr operator aligns valves for
			boration.
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

# **Key Assumptions**

**Operator Interview Insights** 

Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	30.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	1.00 Minutes		
Τ <sub>M</sub>	2.00 Minutes		
Time available for recovery	27.00 Minutes		
SPAR-H Available time	28.00 Minutes		
(cognitive)			
SPAR-H Available time	14.50		
(execution) ratio			
Minimum level of dependence	MD		
for recovery			

# Notes

Refer to the KOPEC/NED/TR/04-006, ANALYSIS REPORT FOR ATWS EVENT OF Shin-kori unit 3&4. The table 4-4 shows that there is no plant undesirable state within 30 minute from initiating event without any operator action.

[EOG Driven Action]

\* T0 = Accident Occurrence, Rx Trip Failure

\* Tsw = 30 min

\* Td = 0 min

\* T1/2 = 1 min (SPTA EOG Step #1)

\* Tm = 2 min (It is assumed that 2 minutes will be used for changing the state of a pump or valve due to the greater involvement on the part of the operator for manipulation.)

Cognitive Analysis							
Pc Failure Mechanism Branch HEP							
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.					
Notes: Operator can access to all information and required indication to operate a plant in the main							
control room.							
<b>P</b> <sub>cb</sub> : Failure of Attention	i	neg.					
Notes: In general, within 2 hours from accident initiation, work load is assumed to be high for							
CBDTM unless the work load relevant to a specific HFE cannot be judged appropriately.							
control room.       i       neg.         P <sub>cb</sub> : Failure of Attention       i       neg.         Notes: In general, within 2 hours from accident initiation, work load is assumed to be high for CBDTM unless the work load relevant to a specific HFE cannot be judged appropriately.							
This HFE is to initiate emergency boration manually for control of reactor power and thus the operator only performs boration and one-time check of boron concentration and reactor power. It is not necessary to check them continuously.							
---	---	---	--	--	--	--	--
It's assumed that the indicator to be chec because all of the controls in the modern room.	It's assumed that the indicator to be checked is always displayed on the front panel of the MCR because all of the controls in the modern control room are expected to be located in the front of the room.						
It is assumed that operators concentrate of Thus operators can not respond to alarms	on EOG and performs EOG- s until related parameter are	-driven actions after reactor trip. e mentioned in the EOG step.					
P <sub>cc</sub> : Misread/miscommunicate data	a	neg.					
Notes: It is assumed that required indicat labeling and others is always located eas	or on the control board such ily.	n as layout, demarcation,					
With the advanced digital I&C interface in there are scenario specific considerations deviation will be provided.	the MCR, the indication is a to warrant otherwise, in wh	assumed to be "good" unless ich case, justification for the					
It is assumed that formal communications between operators.	s will always be used when the	he specified value is transferred					
<b>P</b> <sub>cd</sub> : Information misleading	b	3.0e-03					
<b>Notes:</b> In this HFE, the related paramete values and related system fails to initiate performs boration to control reactivity.	r values dose not satisfy the successfully (i.e. Fails to ins	range of EOG description sert all CEA). Thus operator					
The EOG provides contingeny actions wh not as stated.	nich are instructions on how	to proceed if the cue states are					
<b>P</b> <sub>ce</sub> : Skip a step in procedure	C	3 0e-03					
	0	0:00 00					
Notes: It's assumed that it's always trans stand-alone numbered step on the EOGs The MCR operator is not required to use "single" branch is selected for this HFE.	parent for operators to proc an an additional procedure i	eed the relevant instruction or					
Notes:       It's assumed that it's always trans stand-alone numbered step on the EOGs         The MCR operator is not required to use "single" branch is selected for this HFE.         Only if there are special or distinct marks "Graphically Distinct" should be selected.	parent for operators to proc an an additional procedure i are provided in the procedu	in addition to the EOG, so re, "YES" branch in the					
Notes:       It's assumed that it's always trans stand-alone numbered step on the EOGs         The MCR operator is not required to use "single" branch is selected for this HFE.         Only if there are special or distinct marks "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made	parent for operators to proc an an additional procedure i are provided in the procedu ssumed to be used due to th e operator will be required t Scenarios for which deviatio will be provided.	eed the relevant instruction or in addition to the EOG, so are, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are					
Notes: It's assumed that it's always trans stand-alone numbered step on the EOGs The MCR operator is not required to use "single" branch is selected for this HFE. Only if there are special or distinct marks "Graphically Distinct" should be selected. The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made	an an additional procedure i an an additional procedure i are provided in the procedu ssumed to be used due to th e operator will be required t Scenarios for which deviatio will be provided.	eed the relevant instruction or in addition to the EOG, so re, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are					
Notes: It's assumed that it's always trans         stand-alone numbered step on the EOGs         The MCR operator is not required to use         "single" branch is selected for this HFE.         Only if there are special or distinct marks         "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made         Pcf: Misinterpret Instructions         Notes: It is generally assumed that the we for the Misinterpret Instruction decision to the choice in the misinterpret Instruction decision to the misinterpret Instruction decision to the choice in the misinterpret Instruction decision to the misinterpret Instructinget to the misinterpret Instruction decision	parent for operators to proc an an additional procedure i are provided in the procedu ssumed to be used due to th e operator will be required t Scenarios for which deviation will be provided. a proding of the procedures will ee, pcf, of the CBDTM.	eed the relevant instruction or in addition to the EOG, so re, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are <u>neg.</u> be standard versus ambiguous					
Notes: It's assumed that it's always trans         stand-alone numbered step on the EOGs         The MCR operator is not required to use         "single" branch is selected for this HFE.         Only if there are special or distinct marks         "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made         P <sub>cf</sub> : Misinterpret Instructions         Notes: It is generally assumed that the we for the Misinterpret Instruction decision transmuted to	parent for operators to proc an an additional procedure i are provided in the procedu ssumed to be used due to the e operator will be required to Scenarios for which deviations will be provided. a proding of the procedures will ee, pcf, of the CBDTM. to identify the actions direct	eed the relevant instruction or in addition to the EOG, so are, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are <u>neg.</u> be standard versus ambiguous ed and their objects.					
Notes: It's assumed that it's always trans stand-alone numbered step on the EOGs         The MCR operator is not required to use "single" branch is selected for this HFE.         Only if there are special or distinct marks "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made         P <sub>cf</sub> : Misinterpret Instructions         Notes: It is generally assumed that the work for the Misinterpret Instruction decision for the Step present all information required         P <sub>cg</sub> : Misinterpret decision logic	parent for operators to proc an an additional procedure i are provided in the procedu ssumed to be used due to the e operator will be required to Scenarios for which deviation will be provided. a proding of the procedures will ee, pcf, of the CBDTM. to identify the actions director a	eed the relevant instruction or in addition to the EOG, so are, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are <u>neg.</u> be standard versus ambiguous ed and their objects. 1.6e-02					
Notes: It's assumed that it's always trans stand-alone numbered step on the EOGs         The MCR operator is not required to use "single" branch is selected for this HFE.         Only if there are special or distinct marks "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made         P <sub>cf</sub> : Misinterpret Instructions         Notes: It is generally assumed that the work for the Misinterpret Instruction decision transt required         P <sub>cg</sub> : Misinterpret decision logic         Notes: If diagnosis is performed just after "NOT, AND, OR, BOTH AND and OR" ar branch should be selected on the "NOT se	parent for operators to proc an an additional procedure i are provided in the procedu ssumed to be used due to the operator will be required t Scenarios for which deviation will be provided. a ording of the procedures will ee, pcf, of the CBDTM. to identify the actions direct a r EOG-01 completion, selec e present through EOG01 a Statement" branch.	eed the relevant instruction or in addition to the EOG, so are, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are neg. be standard versus ambiguous ed and their objects. 1.6e-02 t sequence (a) or (b) because nd EOG02. Otherwise, "No"					
Notes: It's assumed that it's always transsected step on the EOGs         The MCR operator is not required to use "single" branch is selected for this HFE.         Only if there are special or distinct marks "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., thas the procedural items are addressed. possible, justification for the choice made         P <sub>cf</sub> : Misinterpret Instructions         Notes: It is generally assumed that the work for the Misinterpret Instruction decision to the the Misinterpret Instruction decision to the step present all information required         P <sub>cg</sub> : Misinterpret decision logic         Notes: If diagnosis is performed just after "NOT, AND, OR, BOTH AND and OR" ar branch should be selected on the "NOT S	parent for operators to proc an an additional procedure i are provided in the procedur ssumed to be used due to the e operator will be required to Scenarios for which deviation will be provided. a ording of the procedures will ee, pcf, of the CBDTM. to identify the actions direct a r EOG-01 completion, select e present through EOG01 a Statement" branch.	eed the relevant instruction or in addition to the EOG, so re, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are <u>neg.</u> be standard versus ambiguous ed and their objects. <u>1.6e-02</u> t sequence (a) or (b) because nd EOG02. Otherwise, "No"					
Notes: It's assumed that it's always trans stand-alone numbered step on the EOGs         The MCR operator is not required to use "single" branch is selected for this HFE.         Only if there are special or distinct marks "Graphically Distinct" should be selected.         The use of placekeeping aids is always a procedure system (CPS) software, i.e., th as the procedural items are addressed. possible, justification for the choice made         P <sub>cf</sub> : Misinterpret Instructions         Notes: It is generally assumed that the we for the Misinterpret Instruction decision transt of the Misinterpret Instruction decision transt of the Misinterpret Instruction decision transt of the Misinterpret decision logic         Notes: If diagnosis is performed just after "NOT, AND, OR, BOTH AND and OR" ar branch should be selected on the "NOT S         The operators are always trained and prage	parent for operators to proc an an additional procedure i are provided in the procedu ssumed to be used due to the e operator will be required t Scenarios for which deviation will be provided. a ording of the procedures will ee, pcf, of the CBDTM. to identify the actions direct a r EOG-01 completion, select e present through EOG01 a Statement" branch.	eed the relevant instruction or in addition to the EOG, so re, "YES" branch in the ne nature of the computerized o confirm completion of a step ons from this assumption are <u>neg.</u> be standard versus ambiguous ed and their objects. <u>1.6e-02</u> t sequence (a) or (b) because nd EOG02. Otherwise, "No"					

Notes: The operators are always assumed to believe in the adequacy of instruction presented.				
Initial P <sub>c</sub> (without recovery credited) 2.2e-02				
Notes				

**Equipment Accessibility** 

MCR:

	Cognitive Recovery										
	Initial HEP	Self	Extra	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>c</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pce	3.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	1.6e-02	-	Х	-	-	-	N/A	-	5.0e-01		8.0e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)							1.1e-02				
Notes											
This	This operator action has high priority and importance, so the extra crew will be needed to prevent any										

human errors when proceeding steps in EOG.

Execution Per	rformance Shaping Facto	rs		
Special Requirements	Tools	Adequate		
	Parts	Adequate		
	Clothing	Adequate		
Environment	Lighting	Normal		
	Heat	Normal		
	Radiation	Background		
	Atmosphere	Normal		
Equipment Accessibility	MCR	Accessible		
Stress	High			
	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			
	Notes			
The Reactor trip was not successful due to in	sert failure of one or more (	CEA. Therefore, plant response		
as unexpected is assumed.				
Execution Complexity	Simple			

Execution Unrecovered								
Procedure: EOG-01, SPTA			Comment					
Step No.	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride	
		Туре	Table	Item				
	Align VVs for CV PPs to take suction from BAST							
EOC 01	Location: MCR	EOM	20-7b	1	4.3e-04	5		
#1.c.1-1		EOC	20-12	4	1.3E-3			
					Total S	Step HEP	8.7e-03	
	Maximize Charging Flow							
E0G-01	Location: MCR	EOM	20-7b	1	4.3e-04	5		
#1.c.1-2		EOC	20-12	4	1.3E-3			
				•	Total S	Step HEP	8.7e-03	
	Commence maximumboration using the CVCS to achieve adequate shutdown margin							
E0G-10 RC-2	Location: MCR	EOM	20-7b	1	4.3e-04	5		
#2		EOC	20-9	2	1.3E-3			
					Total S	Step HEP	8.7e-03	

	Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
EOG-01 #1.c.1-1		Align VVs for CV PPs to take suction from BAST	8.7e-03				1.3e-03	
	EOG-10, RC-2 #2	Commence maximumboration using the CVCS to achieve adequate shutdown margin		8.7e-03	MD	1.5e-01		
EOG-01 #1.c.1-2		Maximize Charging Flow	8.7e-03				1.3e-03	
	EOG-10, RC-2 #2	Commence maximumboration using the CVCS to achieve adequate shutdown margin		8.7e-03	MD	1.5e-01		
		Total Unrecovered:	1.7e-02			Total Recovered:	2.6e-03	

### CVOPH-S-IRWST, Operator Fails to Refill IRWST via CVCS

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/24/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	CBDTM	THERP	CBDTM+THERP	
Without Recovery	6.0e-03	1.3e-02		
With Recovery	3.4e-04	6.6e-04	1.0e-03	10

1. Initial Conditions : Steady state, full power operation

2. Initiating Events : SGTR

3. Preceding operator error or success in sequence : Failure of Shutdown Cooling / RCS cooling and Depressurization

4. Operator action success criterion : Operator should refill IRWST using boric acid makeup pumps and related valves.

5. Definition : To maintain secondary heat removal operation, AFW source must be ensured. If it is fails to replenish the AFWSTs from demineralized water storage tank, when the inventory in the tanks decreases to a specified low level, operator must transfer feedwater source to condensate storage tank or raw water tank in order to continue heat removal from the secondary side.

Cues and Indications				
Initial Cue	IRWST Water Level			
Recovery Cue	IRWST Water Level			
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training				
Cognitive Procedure	APR-xx2 (Revision: 00)			
Cognitive Step Number	XX			
Cognitive Instruction	Enter into CVCS operation : IRWST refill operation			
Execution Procedure	SYS-CV (Revision: xx)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, good procedure and appropriate training is assumed for this operator action				

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	1	
Local Turbine Operator	2	0	

#### Dependencies (Related Human Interactions)

#### Key Assumptions

Operator Interview Insights Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	240.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	5.00 Minutes		
Τ <sub>M</sub>	15.00 Minutes		
Time available for recovery	220.00 Minutes		
SPAR-H Available time	225.00 Minutes		
(cognitive)			
SPAR-H Available time	15.67		
(execution) ratio			
Minimum level of dependence	ZD		
for recovery			

#### Notes

Per MAAP analysis for SGTR Event, (refer to Table 5-7 4(a), 4(b) of the Success Criteria Notebook)

1. Rx Trip : 0.2 hr (879.771 sec)

- 2. IRWST Low Low Level Alarm : 9.0 hr (32384.992 sec)
- 3. IRWST Depletion : 15.8 hr (56934.992 sec)

[ARP Driven Action]

- \* T0 = IRWST Lo-Lo Level Alarm
- \* Tsw = 240 min (Conservative assumption based on timing from Lo-Lo Level to depletion)
- \* Td = 0 min
- \* T1/2 = 5 min (Alarm Procedure)

\* Tm = 15 min (conservative time due to uncertainty of pump and/or local manual valve align)

Cognitive Analysis					
Pc Failure Mechanism	Branch	HEP			
P <sub>ca</sub> : Availability of Information	а	neg.			
Notes: Operator can access to all information and required indication to operate a plant in the					
main control room.					

<b>P</b> <sub>cb</sub> : Failure of Attention	h	neg.
Notes: If Additional procedure is req	uired, the high workload is as	sumed.
This HFE is to initiate IRWST make	up through CVCS and thus th	e operator only performs
and one-time check the status of rela	ated components and variable	es. It is not necessary to
check them continuously.	·	
,		
It's assumed that the indicator to be	checked is always displayed	on the front panel of the
MCR because all of the controls in the	ne modern control room are e	xpected to be located in the
front of the room		
Operator can know the low level of II	RWST by IRWST low level al:	arm. It takes for long time to
dry out IRWST after initiating event	Thus operator uses ARP and	response immediately when
IPW/ST low level alarm occurs	Thus operator uses Arti and	response infinediately when
P : Misroad/miscommunicate data		200
P <sub>cc</sub> . Wisteau/Hisconninuncate data	diaster on the control board a	liey.
<b>Notes:</b> It is assumed that required in	Idicator on the control board s	such as layout, demarcation,
labeling and others is always located	d easily.	
With the advanced digital I&C interfa	ice in the MCR, the indication	is assumed to be "good"
unless there are scenario specific co	onsiderations to warrant other	wise, in which case,
justification for the deviation will be p	provided.	
It is assumed that formal communication	ations will always be used whe	en the specified value is
transferred between operators.		
<b>P</b> <sub>cd</sub> : Information misleading	а	neg.
Notes: In this HFE, ARP and system	n operating procedure are cor	nsidered to perform operator
actions. The IRWST low level is used	d to determine the IRWST ma	ke up. It is assumed that the
ARP and system operating procedur	e describes how the operator	response when the
indicated values are not satisfy the n	normal range level of IRWST.	
P <sub>ce</sub> : Skip a step in procedure	g	6.0e-03
Notes: It's assumed that it's always	transparent for operators to p	roceed the relevant
instruction or stand-alone numbered	step on the procedures.	
The MCR operator is required to use	e an an additional procedure in	n addition to the EOG, so
"multiple" branch is selected for this	HFE.	,
Only if there are special or distinct m	arks are provided in the proc	edure. "YES" branch in the
"Graphically Distinct" should be sele	cted.	,
The use of placekeeping aids is alwa	avs assumed to be used due t	to the nature of the
computerized procedure system (CF	PS) software i.e. the operator	will be required to confirm
completion of a step as the procedure	ral items are addressed Sce	enarios for which deviations
completion of a step as the procedure	ral items are addressed. Sce	enarios for which deviations
completion of a step as the procedure system (or from this assumption are possible, ju	ral items are addressed. Sce ustification for the choice mad	enarios for which deviations e will be provided.
completion of a step as the procedure system (or from this assumption are possible, ju	ral items are addressed. Sce ustification for the choice mad a	enarios for which deviations e will be provided. neg.
completion of a step as the procedure from this assumption are possible, ju <b>P</b> <sub>cf</sub> : Misinterpret Instructions <b>Notes:</b> It is generally assumed that the ambiguous for the Misinterpret Instru-	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures	enarios for which deviations e will be provided. neg. s will be standard versus
<ul> <li>completion of a step as the procedure system (or from this assumption are possible, ju</li> <li>P<sub>cf</sub>: Misinterpret Instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions</li> </ul>	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures uction decision tree, pcf, of the	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM.
<ul> <li>completion of a step as the procedure system (or from this assumption are possible, ju</li> <li>P<sub>cf</sub>: Misinterpret Instructions</li> <li>Notes: It is generally assumed that t ambiguous for the Misinterpret Instruction</li> </ul>	ral items are addressed. Sce <u>ustification for the choice mad</u> a the wording of the procedures uction decision tree, pcf, of the uired to identify the actions dir	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM.
<ul> <li>Completion of a step as the procedure system (or completion of a step as the procedure from this assumption are possible, jupper interpret Instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions</li> <li>The step present all information requirement decision logical</li> </ul>	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures uction decision tree, pcf, of the uired to identify the actions dir	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM. rected and their objects.
<ul> <li>Completion of a step as the procedure system (or completion of a step as the procedure from this assumption are possible, jupper interpret instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions</li> <li>The step present all information require the step present all information require the step present decision logic</li> </ul>	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures uction decision tree, pcf, of the uired to identify the actions dir k	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM. rected and their objects. neg.
<ul> <li>Completion of a step as the procedure system (or from this assumption are possible, jupper from this assumption are possible, jupper interpret instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions</li> <li>The step present all information requirements</li> <li>Pcg: Misinterpret decision logic</li> <li>Notes: If diagnosis is performed just</li> </ul>	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures uction decision tree, pcf, of the uired to identify the actions dir k t after EOG-01 completion, se	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM. rected and their objects. neg. elect sequence (a) or (b)
<ul> <li>Completion of a step as the procedure system (or from this assumption are possible, jupper from this assumption are possible, jupper interpret instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions</li> <li>The step present all information requirements</li> <li>Pcg: Misinterpret decision logic</li> <li>Notes: If diagnosis is performed just because "NOT, AND, OR, BOTH AND"</li> </ul>	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures uction decision tree, pcf, of the uired to identify the actions dir k t after EOG-01 completion, se ID and OR" are present throu	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM. rected and their objects. neg. elect sequence (a) or (b) gh EOG01 and EOG02.
<ul> <li>Completion of a step as the procedure system (or from this assumption are possible, jupper from this assumption are possible, jupper from this assumption are possible, jupper from the set of the misinterpret instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions</li> <li>The step present all information required the step present all information required the step present decision logic</li> <li>Notes: If diagnosis is performed just because "NOT, AND, OR, BOTH AN Otherwise, "No" branch should be set of the step present should be set of the step present and the step present all information required the step present and the step present and the step present all information and the step present all information and the step present and the step present and the step present all information present and the step present all information and the step present and the step present all information present all information and the step present all information present and the step pres</li></ul>	ral items are addressed. Sce ustification for the choice mad a the wording of the procedures uction decision tree, pcf, of the uired to identify the actions dir k t after EOG-01 completion, se ID and OR" are present throu elected on the "NOT Statement	enarios for which deviations e will be provided. neg. s will be standard versus e CBDTM. rected and their objects. neg. elect sequence (a) or (b) gh EOG01 and EOG02. nt" branch. But, in this HFE,

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statements are not included, because the ARP describes clearly related actions.				
The operators are always trained and prace	cticed about specified scena	ario to perform.		
P <sub>ch</sub> : Deliberate violation a neg.				
Notes: The operators are always assumed to believe in the adequacy of instruction				
presented.				
Initial P <sub>c</sub> (without recovery credited) 6.0e-03				
Notes				
Equipment Accessibility MCR: Accessible				

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	6.0e-03	Х	-	-	-	-	N/A	LD	5.6e-02		3.4e-04
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited)3.4e-04					3.4e-04					
	Notes										
CPS	CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for										

CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for pce.

Execution Performance Shaping Factors					
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	Local - Aux. Bldg.	Accessible			
Stress	Low				
	Plant Response As	Yes			
	Expected:				
	Workload:	Low			
	Performance Shaping	Optimal			
	Factors:				
	Notes				
The depletion of IRWST means safety injection	on and secondary heat remo	oval is performed			
successfully. Therefore, plant response as expected is assumed.					
This operator action is required long time late	r from initiator. Therefore,	it is assumed that			
sufficient operators are available for this actio	sufficient operators are available for this action. Therefore, low workload is selected.				
Execution Complexity	Simple				

Execution Unrecovered						-		
	Procedure: SYS-CV, Chemical Volume and Control System		Com	ment			_	
Sten No	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride	
	instruction comment	Туре	Table	Item				
	Align Valves in CVCS to transfer borated water of BAST to the IRWST/BAMP (in Local)							
	Location: Local - Aux. Bldg.	EOM	20-8a	1	1.3e-03	1		
SYS-CV #xx-1		EOC	20-13	2	3.8E-3			
					Total S	tep HEP	5.1e-03	
	Align Valves in CVCS to transfer borated water of BAST to the IRWST/BAMP (in MCR)							
0)(0,0)(#0	Location: MCR	EOM	20-7b	1	4.3e-04	1		
SYS-CV #XX-2		EOC	20-12	4	1.3E-3			
					Total S	tep HEP	1.7e-03	
	Start BAMPs							
	Location: MCR	EOM	20-7b	1	4.3e-04	1		
SYS-CV #xx-3		EOC	20-12	4	1.3E-3			
	Total Step HEP							
	Check Flow and IRWST level							
	Location: MCR	EOM	20-7b	1	4.3e-04	1		
SYS-CV #xx-4		EOC	20-9	2	1.3E-3			
	Total Step HEP							
	Throttle SI Flow							
SYS-CV	Location: MCR	EOM	20-7b	1	4.3e-04	1		
#XX-5		EOC	20-12	10	3.8E-3			
	Total Step HEP							
	Verify SI Flow Rate							
SYS-CV	Location: MCR	EOM	20-7b	1	4.3e-04	1		
#XX-6		EOC	20-9	2	1.3E-3			
					Total S	tep HEP	1.7e-03	

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
SYS-CV #xx-1		Align Valves in CVCS to transfer borated water of BAST to the IRWST/BAMP (in Local)	5.1e-03				2.6e-04
	SYS-CV #xx-4	Check Flow and IRWST level		1.7e-03	LD	5.2e-02	
SYS-CV #xx-2		Align Valves in CVCS to transfer borated water of BAST to the IRWST/BAMP (in MCR)	1.7e-03				8.8e-05
	SYS-CV #xx-4	Check Flow and IRWST level		1.7e-03	LD	5.2e-02	
SYS-CV #xx-3		Start BAMPs	1.7e-03				8.8e-05

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	SYS-CV #xx-4	Check Flow and IRWST level		1.7e-03	LD	5.2e-02	
SYS-CV		Throttle SI Flow	4.2e-03				2.2e-04
#XX-5							
	SYS-CV	Verify SI Flow Rate		1.7e-03	LD	5.2e-02	
	#XX-6						
		Total Unrecovered:	1.3e-02			Total Recovered:	6.6e-04

### CVOPH-S-RCPSEAL, Operator Fails to Operate Auxiliary Charging Pump for RCP Seal Injection

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/24/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	6.0e-03	3.5e-02				
With Recovery	6.0e-03	5.2e-03	1.1e-02	5		

#### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: PLOCCW/TLOCCW

3. Preceding operator error or success in sequence : Success of Secondary Heat Removal

4. Operator action success criterion : Operator should align valves and start auxiliary charging pumps for RCP seal injection

5. Definition : In the loss of CCW situation, the RCP seal injection should be performed to prevent LOCA through the failure of RCP seal. The operator should align valves and initiate Aux. Charging pump for RCP seal injection. If the RCP seal injection succeeded and maintained its robustness, secondary heat removal is possible by start up FW and AFW.

Cues and Indications		
Initial Cue	CV Pump Trip or No Charging Flow	
Recovery Cue	RCP Seal Cooling Recovery	
Cue Comments		
Degree of Clarity	Very Good	

Procedures and Training				
Cognitive Procedure	ARP-x			
Cognitive Step Number	All			
Cognitive Instruction	Enter into system operation procedure SYS-CV - Verify			
	RCP seal injection flow or establish seal injection flow with			
	Auxiliary Charging PP			
Execution Procedure	SYS-CV (Revision: xx)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

#### Dependencies (Related Human Interactions)

#### Key Assumptions

Operator Interview Insights
Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	30.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	5.00 Minutes		
T <sub>M</sub>	5.00 Minutes		
Time available for recovery	20.00 Minutes		
SPAR-H Available time	25.00 Minutes		
(cognitive)			
SPAR-H Available time	5.00		
(execution) ratio			
Minimum level of dependence	MD		
for recovery			
Notes			

This action is for seal injection using auxiliary charging pump operation or seal cooling recovery. The background of EOG-08 (Loss of offsite power/ forced circulation recovery guideline) step #6 describes as following.

- The RCP seal cooling integrity can be maintained for a maximum of 30 minutes following the simultaneous loss of seal injection water and cooling water.

Therefore it is assumed that occurrence of RCP seal failure does not occur within 30 minutes after LOOP or loss of CCW or SBO.

[ARP Driven Action]

\* T0 = Loss of CCW

\* Tsw = 30 min (RCP Seal Failure based on EOG background)

\* Td = 0 min

\* T1/2 = 5 min (Alarm procedure)

\* Tm = 5 min

Cognitive Analysis					
Pc Failure Mechanism	Branch	HEP			
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.			

Notes: Operator can access to all information and required indication to operate a plant in the						
B : Eailure of Attention	i	202				
P <sub>cb</sub> . Failure of Attention	I ident initiation, work load in	neg.				
CBDTM unless the work load relevant to a this HFE, additional procedure is required	a specific HFE cannot be ju too.	dged appropriately. In				
This HFE is to initiate RCP seal injection a check the status of related components an them continuously.	and thus the operator only p nd the value of variables. It i	performs and one-time s not necessary to check				
It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	ked is always displayed on t odern control room are expe	the front panel of the ected to be located in the				
It is assumed that operators concentrate or reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG nd to alarms until related pa	-driven actions after arameter are mentioned				
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.				
Notes: It is assumed that required indicat labeling and others is always located easi	or on the control board such ily.	n as layout, demarcation,				
unless there are scenario specific conside justification for the deviation will be provid	erations to warrant otherwise led.	e, in which case,				
It is assumed that formal communications transferred between operators.	will always be used when t	he specified value is				
P <sub>cd</sub> : Information misleading	а	neg.				
Notes: In this HFE, ARP and system ope	rating procedure are consid	ered to perform operator				
actions. The status of CV pump and charge	ging flow are used to detern	nine the need of Aux.				
charging. It is assumed that the ARP and	system operating procedure	e describes how the				
operator response when the normal charge	ging line is failed including C	V pump fail or any				
problem with charging flow.						
P <sub>ce</sub> : Skip a step in procedure	g	6.0e-03				
<b>Notes:</b> It's assumed that it's always trans instruction or stand-alone numbered step	parent for operators to proc on the procedures.	eed the relevant				
The MCR operator is required to use an a "multiple" branch is selected for this HFE.	n additional procedure in a	ddition to the EOG, so				
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected.						
The use of placekeeping aids is always assumed to be used due to the nature of the computerized procedure system (CPS) software, i.e., the operator will be required to confirm						
completion of a step as the procedural ite	ms are addressed. Scena	rios for which deviations				
P <sub>a</sub> : Misinterpret Instructions		neg				
Notes: It is generally assumed that the w	ording of the procedures wil	be standard versus				
ambiguous for the Misinterpret Instruction	decision tree, pcf, of the C	BDTM.				
The step present all information required	to identify the actions direct	ed and their obiects.				
P <sub>cg</sub> : Misinterpret decision logic	k	neg.				

**Notes:** If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b) because "NOT, AND, OR, BOTH AND and OR" are present through EOG01 and EOG02. Otherwise, "No" branch should be selected on the "NOT Statement" branch. But, in this HFE, EOG does not considered. Thus it is assumed that the "NOT, AND, OR, BOTH AND and OR" statements are not included, because the ARP describes clearly related actions.

The operators are always trained and practiced about specified scenario to perform.						
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.				
Notes: The operators are always assumed to believe in the adequacy of instruction						
presented.						
Initial P <sub>c</sub> (without recovery credited)		6.0e-03				
	Notes					

Equipment Accessibility

MCR:

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	6.0e-03	-	-	-	-	-	N/A	-	1.0e+00		6.0e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 6.0e-03							6.0e-03			
	Notes										

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
This HFE is to recover failed RCP seal injection	on by charging pump. This o	perator action have to be				
performed under limited time condition to prev	vent undesired plant state.					
Execution Complexity	Simple					

Execution Unrecovered								
	Procedure: SYS-CV, Chemical Volume and Control System		Com	ment				
Stop No.	Instruction/Commont	Error	THE	RP		Stress Factor	Over Ride	
Step No.			Table	Item				
	Close Charging Line Isolation Valve							
0)/0 0)/#-4	Location: MCR	EOM	20-7b	1	4.3e-04	5		
SYS-CV #x-1		EOC	20-12	4	1.3E-3			
					Total S	tep HEP	8.7e-03	
	Start Aux. Charging Pump							
SYS-CV #x-2	Location: MCR	EOM	20-7b	1	4.3e-04	5		
		EOC	20-12	4	1.3E-3			
					Total S	tep HEP	8.7e-03	
	Check Seal Injection Flow							
	Location: MCR	EOM	20-7b	1	4.3e-04	5		
SYS-CV #x-3		EOC	20-9	2	1.3E-3			
					Total S	tep HEP	8.7e-03	
	Ensure RCP seal cooling							
	Location: MCR	EOM	20-7b	1	4.3e-04	5		
APR-RC #x-1		EOC	20-12	4	1.3E-3			
	Total Step HEP							
	Stop RCP manually							
	Location: MCR	EOM	20-7b	1	4.3e-04	5		
ARP-RC #x-2		EOC	20-12	4	1.3E-3			
					Total S	tep HEP	8.7e-03	
	Check RCP status							
	Location: MCR	EOM	20-7b	1	4.3e-04	5		
ARP-RC #x-3		EOC	20-9	2	1.3E-3			
					Total S	tep HEP	8.7e-03	

	Execution Recovered										
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step				
SYS-CV #x-1		Close Charging Line Isolation Valve	8.7e-03				1.3e-03				
	SYS-CV #x-3	Check Seal Injection Flow		8.7e-03	MD	1.5e-01					
SYS-CV #x-2		Start Aux. Charging Pump	8.7e-03				1.3e-03				
	SYS-CV #x-3	Check Seal Injection Flow		8.7e-03	MD	1.5e-01					
APR-RC #x-1		Ensure RCP seal cooling	8.7e-03				1.3e-03				
	ARP-RC #x-3	Check RCP status		8.7e-03	MD	1.5e-01					
ARP-RC #x-2		Stop RCP manually	8.7e-03				1.3e-03				
	ARP-RC #x-3	Check RCP status		8.7e-03	MD	1.5e-01					
		Total Unrecovered:	3.5e-02			Total Recovered:	5.2e-03				

### DAOPH-S-AACTG, Operate Fails to Provide Power From AAC TG To Class 1E 4.16kv SWGR

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/24/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	2.2e-02	1.7e-02					
With Recovery	4.6e-03	2.6e-03	7.2e-03	5			

#### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: LOOP

3. Preceding operator error or success in sequence : Failure of Emergency Diesel Generator

4. Operator action success criterion : Operator should start AAC TG and operate related circuit breakers

5. Definition : After reactor trip due to LOOP, EDGs may be initiated automatically. But, in this HFE, EDGs are failed and operator tries to initiate AACTG to recover power. This HFE includes supplying power from AACTG to 4.16kV switch gear.

Cues and Indications			
Initial Cue	Rx Trip by LOOP		
Recovery Cue	SWGR Low Voltage		
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training					
Cognitive Procedure	EOG-02 (Revision: 00)				
Cognitive Step Number	All				
Cognitive Instruction	Diagnose Loss of all AC Power				
Execution Procedure	EOG-09 (Revision: 00)				
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.					

Crew Member	Total	Required for	Notes

	Available	Execution	
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	0	
Electrical Operator	1	1	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

#### **Dependencies (Related Human Interactions)**

#### **Key Assumptions**

Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	30.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	1.00 Minutes		
Τ <sub>M</sub>	5.00 Minutes		
Time available for recovery	24.00 Minutes		
SPAR-H Available time	25.00 Minutes		
(cognitive)			
SPAR-H Available time	5.80		
(execution) ratio			
Minimum level of dependence	MD		
for recovery			
	Notos		

The following undesirable plant state definitions are considered

- RCP Seal Failure [Seal LOCA]

- Core Damage [Feed and Bleed]

- SG Dry out [Secondary Heat Removal]

If RCP is trip in hot standby condition, EOG background describes that the RCP seal cooling integrity can be maintained for a maximum of 30 minutes following the simultaneous loss of seal injection water and cooling water. Therefore it is assumed that no occurrence of RCP seal failure within 30 minutes after SBO.

Per MAAP Analysis for SBO Event with no secondary heat removal,

- 1. Rx Trip : 0 hr (0.000 sec)
- 2. SG Dry-Out : 1.4 hr (4899.517 sec)
- 3. Core uncovery : 1.8 hr (6457.938 sec)

4. Core Damage : 2.3 hr (8453.146 sec)

After SBO event, RCP seal recovery time limit is the most conservative condition to endure AAC TG operation. Therefore Tsw for this HFE is defined based on RCP seal failure timing. At the SPTA step #2, vital power availability is checked and operator starts AAC TG as a contingency action.

[EOG Driven Action] \* T0 = LOOP Occurrence, Rx Trip

\* Tsw = 30 min (RCP Seal Failure based on EOG background)

\* Td = 0 min

\* T1/2 = 1 min (well trained scenario by SBO rule, SPTA step #2)

\* Tm = 5 min

Cognit	Cognitive Analysis						
Pc Failure Mechanism	Branch	HEP					
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.					
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the					
main control room.							
P <sub>cb</sub> : Failure of Attention	<u>     i</u>	neg.					
<b>Notes:</b> In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for					
CBDTM unless the work load relevant to a	a specific HFE cannot be ju	dged appropriately. In					
this HFE, additional procedure is required	too.						
This HFE is to initiate AACTG and supply performs and one-time check the status o necessary to check them continuously.	power to 4.16kV bus. Thu frelated components and v	us the operator only ariables. It is not					
It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	ked is always displayed on t odern control room are expe	the front panel of the ected to be located in the					
It is assumed that operators concentrate or reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG nd to alarms until related pa	-driven actions after arameter are mentioned					
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.					
<b>Notes:</b> It is assumed that required indicat	or on the control board such	n as layout, demarcation,					
With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid	the MCR, the indication is a erations to warrant otherwise ed.	assumed to be "good" e, in which case,					
It is assumed that formal communications	will always be used when t	he specified value is					
transferred between operators.		1					
P <sub>cd</sub> : Information misleading	b	3.0e-03					
<b>Notes:</b> In this HFE, the related parameter description values and related system doe	<b>Notes:</b> In this HFE, the related parameter values dose not satisfy the range of EOG description values and related system does not respond automatically(i.e. Failure of EDG).						
The EOG provides contingeny actions wh	ich are instructions on how	to proceed if the cue					
states are not as stated.							
P <sub>ce</sub> : Skip a step in procedure	C	3.0e-03					
instruction or stand-alone numbered step	on the EOGs.	eed the relevant					
The MCR operator is not required to use a "single" branch is selected for this HFE.	in an additional procedure ir	n addition to the EOG, so					
Only if there are special or distinct marks "Graphically Distinct" should be selected.	are provided in the procedu	ire, "YES" branch in the					

Г

The use of placekeeping aids is always as computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific	ssumed to be used due to th oftware, i.e., the operator wil ms are addressed. Scenar ation for the choice made wi	ne nature of the I be required to confirm rios for which deviations ill be provided.				
P <sub>cf</sub> : Misinterpret Instructions	а	neg.				
<b>Notes:</b> It is generally assumed that the wording of the procedures will be standard versus ambiguous for the Misinterpret Instruction decision tree, pcf, of the CBDTM.						
The step present all information required	to identify the actions directed	ed and their objects.				
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02				
<b>Notes:</b> If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b) because "NOT, AND, OR, BOTH AND and OR" are present through EOG01 and EOG02. Otherwise, "No" branch should be selected on the "NOT Statement" branch.						
The operators are always trained and pra						
Notes: The operators are always assume presented.	d to believe in the adequac	y of instruction				
<b>Initial P</b> <sub>c</sub> (without recovery credited)		2.2e-02				
	Notes					
Equipment Accessibility						

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pce	3.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	1.6e-02	-	-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)							4.6e-03				
	Notes										

Execution Performance Shaping Factors					
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			

	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
This HFE is to recover loss of power after LOC	This HFE is to recover loss of power after LOOP and initiating failure of EDG. This operator action					
have to be performed under limited time condition to prevent undesired plant state.						
Execution Complexity	Simple					

Execution Unrecovered									
Procedure: EOG-09, Station Blackout Recovery Guideline			Comment						
Step No.	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride		
•		Туре	Table	Item					
	Ensure Alternative AC (AAC) generator has started.								
EOG-01	Location: MCR	EOM	20-7b	1	4.3e-04	5			
#2-c.1-3)		EOC	20-12	4	1.3E-3				
					Total S	tep HEP	8.7e-03		
	Ensure Alternative AC(AAC) generator operation								
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
EOG-09 #9.a		EOC	20-9	2	1.3E-3				
	Total Step HEP								
	Connection of braker to C1E power bus								
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
SYS-DA #x		EOC	20-12	4	1.3E-3				
					Total S	tep HEP	8.7e-03		
	Verify providing of power source from AAC TG								
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
SYS-DA #xx		EOC	20-9	2	1.3E-3				
	Total Step HEP								

	Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step		
EOG-01 #2-c.1-3)		Ensure Alternative AC (AAC) generator has started.	8.7e-03				1.3e-03		
	EOG-09 #9.a	Ensure Alternative AC(AAC) generator operation		8.7e-03	MD	1.5e-01			
SYS-DA #x		Connection of braker to C1E power bus	8.7e-03				1.3e-03		
	SYS-DA #xx	Verify providing of power source from AAC TG		8.7e-03	MD	1.5e-01			
		Total Unrecovered:	1.7e-02			Total Recovered:	2.6e-03		

### DAOPH-S-AACTG-SW01BD, Operate Fails to Provide Power From AAC TG To Class 1E 4.16kv SWGR B/D

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/24/13
	.10.hra			
	Name	Date		
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary								
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor				
Method	CBDTM	THERP	CBDTM+THERP					
Without Recovery	2.2e-02	1.7e-02						
With Recovery	4.6e-03	8.8e-03	1.3e-02	5				

#### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: LOOP

3. Preceding operator error or success in sequence : Failure of Emergency Diesel Generator

4. Operator action success criterion : Operator should close breaker of AAC TG power bus to switch gear B/D and open open breaker of AAC TG power bus from switch gear A/C

5. Definition : After reactor trip due to LOOP, EDGs may be initiated automatically. But, in this HFE, EDGs are failed and operator tries to initiate AACTG to recover power. This HFE includes supplying power from AACTG to 4.16kV switch gear B/D.

Cues and Indications					
Initial Cue	Rx Trip by LOOP				
Recovery Cue	SWGR Low Voltage				
Cue Comments					
Degree of Clarity	Very Good				

Procedures and Training					
Cognitive Procedure	EOG-02 (Revision: 00)				
Cognitive Step Number	All				
Cognitive Instruction	Diagnose Loss of all AC Power				
Execution Procedure EOG-09 (Revision: 00)					
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.					

Crew Member	Total	Required for	Notes

	Available	Execution	
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	0	
Electrical Operator	1	1	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

#### **Dependencies (Related Human Interactions)**

#### **Key Assumptions**

Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	30.00 Minutes				
T <sub>delay</sub>	0.00 Minutes				
T <sub>1/2</sub>	1.00 Minutes				
Τ <sub>M</sub>	5.00 Minutes				
Time available for recovery	24.00 Minutes				
SPAR-H Available time	25.00 Minutes				
(cognitive)					
SPAR-H Available time	5.80				
(execution) ratio					
Minimum level of dependence	MD				
for recovery					
Notes					

This operator's action is similar to operator action, such as DAOPH-S-AACTG.

Cognitive Analysis						
Pc Failure Mechanism	Branch	HEP				
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.				
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the				
main control room.						
<b>P</b> <sub>cb</sub> : Failure of Attention	i i	neg.				
Notes: In general, within 2 hours from acc CBDTM unless the work load relevant to a this HFE, additional procedure is required This HFE is to change power supply divisi train related SW01AC is unavailable. Thus status of related components and variable It's assumed that the indicator to be check MCR because all of the controls in the mo- front of the room.	cident initiation, work load is a specific HFE cannot be jud , too. ion after successful initiating s the operator only performs es. It is not necessary to che ked is always displayed on t odern control room are expe	assumed to be high for dged appropriately. In g of AACTG because the and one-time check the eck them continuously. the front panel of the ected to be located in the				
	<b>500</b> and <b>500</b>	del como a discono a fito e				

It is assumed that operators concentrate on EOG and performs EOG-driven actions after reactor trip. Thus operators can not respond to alarms until related parameter are mentioned

in the EOG step.									
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.							
Notes: It is assumed that required indicat	or on the control board such	n as layout, demarcation,							
labeling and others is always located eas	ily.								
With the advanced digital I&C interface in	With the advanced digital I&C interface in the MCR, the indication is assumed to be "good"								
unless there are scenario specific conside	erations to warrant otherwise	e, in which case,							
justification for the deviation will be provid	led.								
It is assumed that formal communications	s will always be used when t	ne specified value is							
transferred between operators.	L L	2.02.02							
P <sub>cd</sub> : Information misleading	D D								
<b>Notes:</b> In this HFE, the train which is sup	This is not matched with a								
values as stated in EOC	i. This is not matched with c	ue states of parameter							
values as stated in LOG.									
The EOG provides contingeny actions wh	hich are instructions on how	to proceed if the cue							
states are not as stated									
P <sub>oc</sub> : Skip a step in procedure	c	3 0e-03							
Notes: It's assumed that it's always trans	parent for operators to proc	eed the relevant							
instruction or stand-alone numbered step	on the EOGs.								
The MCR operator is not required to use a	an an additional procedure ir	addition to the EOG, so							
"single" branch is selected for this HFE.									
Only if there are special or distinct marks	are provided in the procedu	re, "YES" branch in the							
"Graphically Distinct" should be selected.									
The use of placekeeping aids is always a	ssumed to be used due to the	he nature of the							
computerized procedure system (CPS) so	oftware, i.e., the operator will	I be required to confirm							
completion of a step as the procedural ite	ms are addressed. Scena	rios for which deviations							
from this assumption are possible, justific	ation for the choice made w	III be provided.							
P <sub>cf</sub> : Misinterpret Instructions	a	neg.							
<b>Notes:</b> It is generally assumed that the w	ording of the procedures wil	l be standard versus							
ambiguous for the Misinterpret Instruction	i decision tree, pcf, of the Cl	BDTM.							
The step present all information required	to identify the entire direct	ad and thair chiests							
ne step present all mormation required									
<b>Notaci</b> If diagnosis is performed just after	EOC 01 completion select								
	COG-UT COmpletion, select								
Otherwise "No" branch should be selected	a on the "NOT Statement"	EUGUT anu EUGUZ.							
The operators are always trained and pra	cticed about specified scen	ario to perform							
P.: Deliberate violation									
Notes: The operators are always assume	a a to believe in the adequac	v of instruction							
nresented		y or mouluouon							
Initial P. (without recovery credited)		2 2e-02							
	Notes	2.20-02							
Equipment Accessibility									
_qa.phone / cooodisiney	1								
Coanit	Cognitive Recovery								

	Initial HEP	Self	Review	Extra Crew	STA	Review Shift	Change ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-		I	-	-	-	N/A	-	1.0e+00		
Pc <sub>c</sub>	neg.	-		I	-	-	-	N/A	-	1.0e+00		
Pc <sub>d</sub>	3.0e-03	-		I	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pc <sub>e</sub>	3.0e-03	-		Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>f</sub>	neg.	-		-	-	-	-	N/A	-	1.0e+00		
PCq	1.6e-02	-		-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pc <sub>h</sub>	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)								4.6e-03				
	Notes											

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
	Notes					
This HFE is to recover loss of power after LO	OP and initiating failure of E	DG. This operator action				
have to be performed under limited time condition to prevent undesired plant state.						
Execution Complexity	Simple					

Execution Unrecovered										
		Comment								
Step No.	Instruction/Comment E		THERP		HEP	Stress Factor	Over Ride			
		Туре	Table	Item						
	Close braker of AAC TG power bus to SWGR B/D									
	Location: MCR	EOM	20-7b	1	4.3e-04	5				
SYS-DA #x		EOC	20-12	4	1.3E-3					
	Total Step HEP									
	Open braker of AAC TG power bus from SWGR A/C									
	Location: MCR	EOM	20-7b	1	4.3e-04	5				
SYS-DA #xx		20-12	4	1.3E-3						
				8.7e-03						
	Verify providing of power source from AAC TG									
	Location: MCR	EOM	20-7b	1	4.3e-04	5				
SYS-DA #xxx	EOC 20-9 2 1.3E-3									
	Total Step HEP									

Execution Recovered									
Critical Step No.	Recovery Step No.	Action HEP (Crit) HEP (Rec) Dep. Cond. HEP (Rec)							
SYS-DA #x		Close braker of AAC TG power bus to SWGR B/D	8.7e-03				4.4e-03		
	SYS-DA #xxx	Verify providing of power source from AAC TG		8.7e-03	HD	5.0e-01			
SYS-DA #xx		Open braker of AAC TG power bus from SWGR A/C	8.7e-03				4.4e-03		
	SYS-DA #xxx	Verify providing of power source from AAC TG		8.7e-03	HD	5.0e-01			
		Total Unrecovered:	1.7e-02			Total Recovered:	8.8e-03		

# FWOPH-S-ERY, Operate Fails to Align Startup Feedwater pump PP07 (Early Phase)

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/23/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary									
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor					
Method	CBDTM	THERP	CBDTM+THERP						
Without Recovery	2.5e-02	8.7e-03							
With Recovery	5.0e-03	5.1e-04	5.5e-03	5					

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: Transient Events excepts Loss of FW

3. Preceding operator error or success in sequence : Failure of Automatic AFWS actuation

4. Operator action success criterion : Operator should supply Feedwater to SGs with Startup PP P07.

5. Consequence of failure : Loss of Secondary Heat Removal (early phase)

6. Definition : The start-up feedwater (SFW) system can be used as a backup of main feedwater system. This SFW system requires operator manual action to perform its function. The SFW pump is normally aligned to take suction from the deaerator storage tank. When the inventory in this tank decreases to a specified low level, pump suction is transferred to the condensate storage tank. Transferring the pump suction source is performed in the MCR by opening motor operated valve. It is assumed that once the specified low level in the deaerator storage tank is reached the operator would initiate transfer of the pump suction source.

Cues and Indications						
Initial Cue	S/G Low Level					
Recovery Cue	Check Start-up FW Flow Status					
Cue Comments						
Degree of Clarity	Very Good					

Procedures and Training						
Cognitive Procedure	EOG-02 (Revision: 00)					
Cognitive Step Number	All					
Cognitive Instruction	Diagnose Loss of All Feedwater using Diagnosis Diagram					
Execution Procedure	EOG-03 (Revision: 00)					
Job Performance Measure						
Classroom Training	None					

Simulator Training	None
	Notes

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

#### Dependencies (Related Human Interactions)

#### Key Assumptions

# Operator Interview Insights Operator interview is not available in DC phase.

Timing Analysis						
T <sub>sw</sub>	50.00 Minutes					
T <sub>delay</sub>	0.00 Minutes					
T <sub>1/2</sub>	15.00 Minutes					
Τ <sub>M</sub>	2.00 Minutes					
Time available for recovery	33.00 Minutes					
SPAR-H Available time	48.00 Minutes					
(cognitive)						
SPAR-H Available time	17.50					
(execution) ratio						
Minimum level of dependence	LD					
for recovery						

Notes

In GTRN sequence, SG low level alarm is generated after delay time from Rx trip. Therefore it is assumed the cognitive procedure step is located on the ORG after performing the SPTA and DA. Feedwater flow is automatically controlled and reduced by FWCS. Therefore SG low level is a cue for this HFE.

Per MAAP Analysis for LOFW sequence, (refer to Table 5-8 5(a), 5(b) of the Success Criteria Notebook)

- 1. Rx Trip : 0 hr (0 sec)
- 2. SG Low Level Alarm (45% WR) : 0.1 hr (287.736 sec)
- 3. SG Low Level Alarm (25% WR) : 0.2 hr (817.736 sec)
- 4. SG Dry-Out : 0.9 hr (3256.177 sec)
- 5. Core uncovery : 1.6 hr (5712.472 sec)
- 6. Core Damage : 2.1 hr (7543.530 sec)

[EOG Driven Action]

\* T0 = Transient Occurrence, Rx Trip

\* Tsw = 50 (SG dry out by MAAP Analysis)

\* Td = 0 (Rx Trip; In the case of ORG action, median response time include the SPTA (and DA) process therefore it is assumed the delay time from transient occurrence to cue generation is included in the median response time)

\* T1/2 = 15 (SPTA EOG (9 min) + Reactor Trip EOG step #7 (6min))

\* Tm = 2 (start-up feedwater pump control)

Cognitive Analysis									
Pc Failure Mechanism	Branch	HEP							
P <sub>ca</sub> : Availability of Information	а	neg.							
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the							
main control room.		•							
P <sub>cb</sub> : Failure of Attention	i	neg.							
<b>Notes:</b> In general, within 2 hours from acc CBDTM unless the work load relevant to a	cident initiation, work load is a specific HFE cannot be ju	assumed to be high for dged appropriately.							
This HFE is to initiate start up FW pump a check the status of related components an continuously.	and thus the operator only p nd variables. It is not neces	erforms and one-time sary to check them							
It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	<pre><ed always="" are="" control="" displayed="" expe<="" is="" odern="" on="" pre="" room="" t=""></ed></pre>	the front panel of the ected to be located in the							
It is assumed that operators concentrate or reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG nd to alarms until related pa	-driven actions after arameter are mentioned							
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.							
Notes: It is assumed that required indicate labeling and others is always located easi With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid It is assumed that formal communications transferred between operators.	<ul> <li>Notes: It is assumed that required indicator on the control board such as layout, demarcation, labeling and others is always located easily.</li> <li>With the advanced digital I&amp;C interface in the MCR, the indication is assumed to be "good" unless there are scenario specific considerations to warrant otherwise, in which case, justification for the deviation will be provided.</li> <li>It is assumed that formal communications will always be used when the specified value is</li> </ul>								
P <sub>cd</sub> : Information misleading	b	3.0e-03							
Notes: The EOG describes about post t level is not satisfied what EOG described. The EOG provides contingency actions w states are not as stated.	rip SG level band. But, in th hich are instructions on how	is HFE, indicated SG							
P <sub>ce</sub> : Skip a step in procedure	С	3.0e-03							
Notes: It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the EOGs.         The MCR operator is not required to use an an additional procedure in addition to the EOG, so "single" branch is selected for this HFE.									
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected.									

The use of placekeeping aids is always as	ssumed to be used due to th	nature of the							
computerized precedure aveta (CDS) asfluere i.e. the energies will be required to confirm									
computenzed procedure system (CPS) software, i.e., the operator will be required to commit									
completion of a step as the procedural items are addressed. Scenarios for which deviations									
from this assumption are possible, justification	ation for the choice made w	ill be provided.							
P <sub>cf</sub> : Misinterpret Instructions	b	3.0e-03							
Notes: It is generally assumed that the we	ording of the procedures wil	l be standard versus							
ambiguous for the Misinterpret Instruction	decision tree, pcf, of the CI	BDTM.							
The step does not mention about using st	art FW pump directly. But it	is assumed that							
operators have enough training opportuni	ty for using start up FW pun	וp.							
<b>P</b> <sub>cq</sub> : Misinterpret decision logic	а	1.6e-02							
Notes: If diagnosis is performed just after	Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b)								
because "NOT, AND, OR, BOTH AND an	d OR" are present through I	EOG01 and EOG02.							
Otherwise, "No" branch should be selecte	ed on the "NOT Statement" t	pranch.							
The operators are always trained and pra	cticed about specified scena	ario to perform.							
P <sub>ch</sub> : Deliberate violation	a	neg.							
Notes: The operators are always assume	Notes: The operators are always assumed to believe in the adequacy of instruction								
presented.									
Initial P <sub>c</sub> (without recovery credited) 2.5e-02									
Notes									
Equipment Accessibility MCR: Accessible									

Cognitive Recovery												
	Initial HEP	Self	Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-		-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pce	3.0e-03	-		Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>f</sub>	3.0e-03	-		-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pcg	1.6e-02	-		-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 5.0e-03							5.0e-03				
Notes												
STA review is possible using RCS heat removal section in SFSC. And also, CPS provides the												
tool t	tool to prevent skip a step in the procedure, so self review is available for Pce.											

Execution Performance Shaping Factors								
Special Requirements	Tools	Adequate						
	Parts	Adequate						
	Clothing	Adequate						
Environment	Lighting	Normal						
	Heat	Normal						
	Radiation	Background						
	Atmosphere	Normal						
Equipment Accessibility	MCR	Accessible						
Stress	High							

	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			
Notes				
This HFE is to recover loss of feedwater for secondary heat removal. This operator action have to				
be performed under limited time condition to prevent undesired plant state.				
Execution Complexity	Simple			

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Execution Unrecovered							
Procedure: EOG-03, Reactor Trip		Comment					
Step No.	Instruction/Comment		THERP		HEP	Factor	Over Ride
otop no.			Table	Item			
Control main feedwater or auxiliary to restore SG level to post trip SG level band.       If SG level is not restore by auxiliary feedwater system, operator will recover the SG level using main feedwater system including startup feedwater pump.		5					
		EOM	20-76	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total S	tep HEP	8.7e-03
EOG-07       #6.1-2)         Location: MCR       Location: MCR		5					
		EOC	20-12	4	1.3E-3		
			I	<u> </u>	Total S	tep HEP	8.7e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-03 #7.1		Control main feedwater or auxiliary to restore SG level to post trip SG level band.	8.7e-03				5.1e-04
	EOG-07 #6.1-2)	Operate start-up feedwater pump		8.7e-03	LD	5.8e-02	
Total Unrecovered:         8.7e-03         Total Recovered:					5.1e-04		

# FWOPH-S-LNG, Operator Fails to Align Startup Feedwater Pump PP07 (Late Phase)

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/24/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary					
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor	
Method	CBDTM	THERP	CBDTM+THERP		
Without Recovery	6.0e-03	8.7e-03			
With Recovery	3.0e-03	7.6e-05	3.1e-03	5	

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: GTRN, Various Initiating Events except Loss of FW

3. Preceding operator error or success in sequence : Failure of Shutdown Cooling or Providing Long Term Water Source for AFW

4. Operator action success criterion : Operator should supply Feedwater to SG(s) using Start-up Feedwater Pump.

5. Consequence of failure : Loss of Secondary Heat Removal (late phase)

6. Definition : The start-up feedwater (SFW) system can be used as a backup of main feedwater system. This SFW system requires operator manual action to perform its function. The SFW pump is normally aligned to take suction from the deaerator storage tank. When the inventory in this tank decreases to a specified low level, pump suction is transferred to the condensate storage tank. Transferring the pump suction source is performed in the MCR by opening motor operated valve. It is assumed that once the specified low level in the deaerator storage tank is reached the operator would initiate transfer of the pump suction source.

Cues and Indications		
Initial Cue	S/G Low Level	
Recovery Cue	Check Start-up FW Flow Status	
Cue Comments		
Degree of Clarity	Very Good	

Procedures and Training			
Cognitive Procedure	ARP-xx3 (Revision: 00)		
Cognitive Step Number	All		
Cognitive Instruction	Diagnose Loss of All Feedwater using Diagnosis Diagram		
Execution Procedure	ARP-xx		
Job Performance Measure			

Classroom Training	None	
Simulator Training	None	
Notes		

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

#### Dependencies (Related Human Interactions)

#### **Key Assumptions**

#### **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis		
T <sub>sw</sub>	160.00 Minutes	
T <sub>delay</sub>	45.00 Minutes	
T <sub>1/2</sub>	5.00 Minutes	
Τ <sub>M</sub>	2.00 Minutes	
Time available for recovery	108.00 Minutes	
SPAR-H Available time	113.00 Minutes	
(cognitive)		
SPAR-H Available time	55.00	
(execution) ratio		
Minimum level of dependence	ZD	
for recovery		
Notes		

In GTRN sequence, SG low level alarm is re-generated if AFWS fails to run.

Per MAAP Analysis for GTRN sequence with initial secondary heat removal success, (refer to Table 5-8 5(a), 5(b) of the Success Criteria Notebook)

1. Rx Trip : 0 hr (0 sec)

- 2. SG Low Level Alarm (before SHR, 45% WR) : 0.1 hr (287.736 sec)
- 3. SG Low Level Alarm (before SHR, 25% WR) : 0.2 hr (817.736 sec)
- 4. SG Low Level Alarm (after SHR, 45% WR) : 9.9 hr (35737.527 sec)
- 5. SG Low Level Alarm (after SHR, 25% WR) : 10.1 hr (36502.527 sec)
- 6. SG Dry-Out : 10.7 hr (38426.605 sec)
- 7. Core uncovery : 11.6 hr (41705.719 sec)
- 8. Core Damage : 12.5 hr (45157.723 sec)

[ARP Driven Action]

\* T0 = AFWS failure to run (A point of AF system failure timing at 8 hours after initiating event is considered as To because success of initial secondary heat removal of 8 hour operation is assumed.)

- \* Tsw = 160 min (SG Dryout after failure of initial SHR based on MAAP analysis)
- \* Td = 45 min (SG low level after failure of initial SHR based on MAAP analysis)

\* T1/2 = 5 min (ARP)

\* Tm = 2 min (pump and valve control)

Cognitive Analysis				
Pc Failure Mechanism	Branch	HEP		
P <sub>ca</sub> : Availability of Information	а	neg.		
Notes: Operator can access to all information and required indication to operate a plant in the				
main control room.				
<b>P</b> <sub>cb</sub> : Failure of Attention	h	neg.		
<b>Notes:</b> In general, within 2 hours from acc	cident initiation, work load is	s assumed to be high for		
CBDTM unless the work load relevant to a	a specific HFE cannot be ju	dged appropriately. In		
this HFE, additional procedure is required	100.			
This HFE is to initiate start up FW pump a check the status of related components an continuously.	and thus the operator only p nd variables. It is not neces	erforms and one-time sary to check them		
It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	ked is always displayed on a odern control room are expe	the front panel of the acted to be located in the		
This HFE is performed in the late phase a for long time to perform this HEE. Thus or	fter initiating event occurred	d. It means that it takes		
P.:: Misread/miscommunicate data	a			
Notes: It is assumed that required indicate	or on the control board such	as layout demarcation		
labeling and others is always located easi	ly.			
With the advanced digital I&C interface in unless there are scenario specific conside	the MCR, the indication is a artition to warrant otherwise	assumed to be "good" e, in which case,		
justification for the deviation will be provid	ed.			
It is assumed that formal communications transferred between operators.	will always be used when t	he specified value is		
P <sub>cd</sub> : Information misleading	а	neg.		
<b>Notes:</b> Value of cues and parameters for	this HFE are described in the	he ARP and system		
operating procedure. It is assumed that cu	ues and parameters are ind	icated on the MCR		
<b>P</b> <sub>ce</sub> : Skip a step in procedure	g	6.0e-03		
Notes: It's assumed that it's always trans	parent for operators to proc	eed the relevant		
instruction or stand-alone numbered step	on the EOGs.			
The MCR operator is not required to use a	n an additional procedure i	n addition to the EOG. so		
"single" branch is selected for this HFE.				
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected				
The use of placekeeping aids is always as	ssumed to be used due to the	he nature of the		
computerized procedure system (CPS) so	oftware, i.e., the operator wi	Il be required to confirm		
completion of a step as the procedural iter	ms are addressed. Scena	rios for which deviations		

from this assumption are possible, justification for the choice made will be provided.					
P <sub>cf</sub> : Misinterpret Instructions a neg.					
Notes: It is generally assumed that the we	ording of the procedures wil	l be standard versus			
ambiguous for the Misinterpret Instruction	decision tree, pcf, of the CI	BDTM.			
The step present all information required	to identify the actions directed	ed and their objects.			
P <sub>cg</sub> : Misinterpret decision logic	k	neg.			
Notes: If diagnosis is performed just after	EOG-01 completion, select	sequence (a) or (b)			
because "NOT, AND, OR, BOTH AND an	d OR" are present through I	EOG01 and EOG02.			
Otherwise, "No" branch should be selecte	d on the "NOT Statement" t	pranch. But, in this HFE,			
EOG does not considered. Thus it is assu	imed that the "NOT, AND, C	R, BOTH AND and OR"			
statements are not included, because the	ARP describes clearly relat	ed actions.			
The operators are always trained and pra-	cticed about specified scena	ario to perform.			
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.			
Notes: The operators are always assume	d to believe in the adequac	y of instruction			
presented.					
Initial P <sub>c</sub> (without recovery credited)		6.0e-03			
Notes					
Equipment Accessibility	MCR: Accessible				

Cognitive Recovery											
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	6.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		3.0e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											3.0e-03
Notes											
Extra	Extra crew, such as STA, can recover to skip a procedure for this action.										

Extra crew, such as STA, can recover to skip a procedure for this action.

Execution Performance Shaping Factors								
Special Requirements	Tools	Adequate						
	Parts	Adequate						
	Clothing	Adequate						
Environment	Lighting	Normal						
	Heat	Normal						
	Radiation	Background						
	Atmosphere	Normal						
Equipment Accessibility	MCR	Accessible						
Stress	High							
	Plant Response As	No						
	Expected:							
	Workload:	N/A						
	Performance Shaping	N/A						
---	---------------------	-----	--	--				
	Factors:							
Notes								
This HFE is to recover loss of feedwater for secondary heat removal. This operator action have to								
be performed under limited time condition to prevent undesired plant state.								
Execution Complexity	Simple							

Execution Unrecovered							
Procedure: ARP-xx,		Comment					
Step No.	Instruction/Comment	Error	THERP		HFP	Stress Factor	Over Ride
		Туре	Table	Item			
	Start Start-Up Feedwater Pump						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
ARP-xx #xx-1		EOC	20-12	4	1.3E-3	Ū	
	Total Step HEP						
EOG-07 #6.1-2)	Operate start-up feedwater pump Location: MCR	STA will be specially trained in mitigating the consequences of abnormal events. Feedwater supply is a major event during almost accident. Event if the SG level control is failed by SG low level alarm , supervisor and STA will re-diagnose the event and enter to the EOG-07.5EOM20-7b14.3e-04EOC20-1241.3E-3					
Total Step H				tep HEP	8.7e-03		

Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
ARP-xx #xx-1		Start Start-Up Feedwater Pump	8.7e-03				7.6e-05
	EOG-07 #6.1-2)	Operate start-up feedwater pump		8.7e-03	ZD	8.7e-03	
		Total Unrecovered:	8.7e-03			Total Recovered:	7.6e-05

# HR-RCSCD1-ISOL, Operator Fails to Take Action for SG Cooldown, RC Depressurization and SG Isolation.

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/24/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary					
P <sub>cog</sub> P <sub>exe</sub> Total HEP Error Factor					
Method	CBDTM	THERP	CBDTM+THERP		
Without Recovery	1.9e-02	2.0e-02			
With Recovery	2.7e-04	1.1e-03	1.4e-03	5	

### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SGTR

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should cool down Impacted SG, depressurize RCS to stop leak from RCS to SG.

5. Consequence of failure : Impacted SG overfill and failure of stopping leak

6. Definition : When SGTR occurs, operator should perform RC depressurization and isolate damaged SG to prevent RCS leakage to secondary side through damaged SG and to prevent damaged SG overfill. This HFE is performed before that damaged SG is overfilled.

Cues and Indications				
Initial Cue	Safety Injection Signal			
Recovery Cue	S/G High Level			
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training					
Cognitive Procedure	EOG-02 (Revision: 00)				
Cognitive Step Number	All				
Cognitive Instruction	Perform Accident Diagnosis				
Execution Procedure	EOG-05 (Revision: 00)				
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					
The procedure and training informati	on is not available in DC phase. However, APR1400 EOG is				

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

### Key Assumptions

Operator Interview Insights
Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	210.00 Minutes			
T <sub>delay</sub>	15.00 Minutes			
T <sub>1/2</sub>	25.00 Minutes			
Тм	20.00 Minutes			
Time available for recovery	150.00 Minutes			
SPAR-H Available time	175.00 Minutes			
(cognitive)				
SPAR-H Available time	8.50			
(execution) ratio				
Minimum level of dependence	ZD			
for recovery				
Nataa				

#### Notes

This HFE is ORG driven action by SGTR occurrence and includes actions for SG cooldown and RCS depressurization. Conservatively four SIPs operation is modeled for SG overfill timing

Per MAAP Analysis for SGTR sequence with safety injection and secondary heat removal success, (refer to Table 5-7 3(a), 3(b), 3(c), 3(d) of the Success Criteria Notebook)

- 1. SG overfill time with ADV opening for AFcontrol and no Afcontrol 1-1) AF control : 3.7 hr
- 2. SG overfill time with MSSV operation for Afcontrol and no Afcontrol 2-1) AF control : 3.9 hr

### [EOG Driven Action]

- \* T0 = SGTR occurrence
- \* Tsw = 210 min (SG overfill timing based on MAAP Analysis)
- \* Td = 15 min (Rx Trip)
- \* T1/2 = 25 min (SPTA EOG (9 min) + DA EOG (6 min) + EOG-05 step #11 (10 min))

\* Tm = 20 min (conservative time for RCS depressurization and Cooldown for initial success)

Cognitive Analysis				
Pc Failure Mechanism	Branch	HEP		
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.		

	Notes: Operator can access to all informa	ation and required indication	tion to operate a plant in the
D	Train control room.	:	202
P <sub>cb</sub>	. Failure of Allention		neg.
	CBDTM unless the work load relevant to	a specific HFE cannot be	a is assumed to be high for e judged appropriately.
	This HFE is to perform RCS depressurization only performs and one-time check the state necessary to check them continuously.	ation and to isolate dama atus of related componen	ged SG. Thus the operator ts and variables. It is not
	It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	ked is always displayed o odern control room are e	on the front panel of the xpected to be located in the
	It is assumed that operators concentrate reactor trip. Thus operators can not respo in the EOG step.	on EOG and performs E0 ond to alarms until related	OG-driven actions after d parameter are mentioned
P <sub>cc</sub>	: Misread/miscommunicate data	а	neg.
	<b>Notes:</b> It is assumed that required indicat labeling and others is always located eas	tor on the control board s ily.	uch as layout, demarcation,
	With the advanced digital I&C interface in unless there are scenario specific consider justification for the deviation will be provided.	n the MCR, the indication erations to warrant other ded.	is assumed to be "good" wise, in which case,
	It is assumed that formal communications transferred between operators.	s will always be used whe	en the specified value is
$\mathbf{P}_{cd}$	: Information misleading	а	neg.
P <sub>cd</sub>	: Information misleading <b>Notes:</b> The EOG describes about RCS de SGTR occurs.	epressurization and iso	neg. lation of damaged SG when
P <sub>cd</sub>	: Information misleading Notes: The EOG describes about RCS de SGTR occurs. : Skip a step in procedure	epressurization and iso	neg. lation of damaged SG when 3.0e-03
P <sub>cd</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> </ul>	a epressurization and iso c parent for operators to p on the EOGs.	neg. lation of damaged SG when 3.0e-03 roceed the relevant
P <sub>cd</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur	neg. lation of damaged SG when 3.0e-03 roceed the relevant re in addition to the EOG, so
P <sub>cd</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the
P <sub>cd</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due to oftware, i.e., the operator ems are addressed. Sce cation for the choice made	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.
P <sub>cd</sub> P <sub>ce</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific Misinterpret Instructions</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due t oftware, i.e., the operator ems are addressed. Sce cation for the choice made a	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.         neg.
P <sub>cd</sub> P <sub>ce</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific Misinterpret Instructions</li> <li>Notes: It is generally assumed that the w ambiguous for the Misinterpret Instruction</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due to oftware, i.e., the operator ems are addressed. Sce cation for the choice made a vording of the procedures in decision tree, pcf, of the	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.         neg.         will be standard versus         e CBDTM.
P <sub>cd</sub> P <sub>ce</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific Misinterpret Instructions</li> <li>Notes: It is generally assumed that the w ambiguous for the Misinterpret Instruction</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due to oftware, i.e., the operator ems are addressed. Sce sation for the choice made a vording of the procedures in decision tree, pcf, of the to identify the actions dir	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.         neg.         will be standard versus         e CBDTM.         ected and their objects.
P <sub>cd</sub> P <sub>ce</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always as computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific Misinterpret Instructions</li> <li>Notes: It is generally assumed that the w ambiguous for the Misinterpret Instruction</li> <li>The step present all information required</li> <li>Motes: It diagnosis is performed just after</li> </ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due to oftware, i.e., the operator ems are addressed. Sce cation for the choice made a vording of the procedures of decision tree, pcf, of the to identify the actions dir a	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.         neg.         will be standard versus         e CBDTM.         ected and their objects.         1.6e-02         lect sequence (a) or (b)
P <sub>cd</sub> P <sub>ce</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always ar computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific Misinterpret Instructions</li> <li>Notes: It is generally assumed that the w ambiguous for the Misinterpret Instruction</li> <li>The step present all information required</li> <li>Misinterpret decision logic</li> <li>Notes: If diagnosis is performed just after because "NOT, AND, OR, BOTH AND an Otherwise" [Not and the selected in the selected is a selected in the selected in</li></ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due to oftware, i.e., the operator ems are addressed. Sce cation for the choice made a vording of the procedures of decision tree, pcf, of the to identify the actions dir a r EOG-01 completion, se and OR" are present through	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.         neg.         will be standard versus         e CBDTM.         ected and their objects.         1.6e-02         lect sequence (a) or (b)         gh EOG01 and EOG02.
P <sub>cd</sub> P <sub>ce</sub>	<ul> <li>Information misleading</li> <li>Notes: The EOG describes about RCS de SGTR occurs.</li> <li>Skip a step in procedure</li> <li>Notes: It's assumed that it's always trans instruction or stand-alone numbered step</li> <li>The MCR operator is not required to use a "single" branch is selected for this HFE.</li> <li>Only if there are special or distinct marks "Graphically Distinct" should be selected.</li> <li>The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific Misinterpret Instructions</li> <li>Notes: It is generally assumed that the w ambiguous for the Misinterpret Instruction</li> <li>The step present all information required is procedure in the step present all</li></ul>	a epressurization and iso c sparent for operators to p on the EOGs. an an additional procedur are provided in the proce ssumed to be used due to oftware, i.e., the operator ems are addressed. Sce cation for the choice made a vording of the procedures in decision tree, pcf, of the to identify the actions dir a r EOG-01 completion, se ad OR" are present through ed on the "NOT Statement procedure specified so	neg.         lation of damaged SG when         3.0e-03         roceed the relevant         re in addition to the EOG, so         edure, "YES" branch in the         to the nature of the         will be required to confirm         enarios for which deviations         e will be provided.         neg.         will be standard versus         e CBDTM.         ected and their objects.         1.6e-02         lect sequence (a) or (b)         gh EOG01 and EOG02.         nt" branch.         enarios to perform

P <sub>ch</sub> : Deliberate violation	а	neg.			
Notes: The operators are always assumed to believe in the adequacy of instruction					
presented.					
Initial P <sub>c</sub> (without recovery credited)		1.9e-02			
Notes					
Equipment Accessibility	MCR: Accessible				

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>c</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>e</sub>	3.0e-03	Х	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	1.6e-02	-	-	Х	-	-	N/A	ZD	1.6e-02		2.6e-04
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited) 2.7e-0							2.7e-04				
							Notes				
CDC provides the tool to provent skip a step in the procedure. Therefore call review is available for											

CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for Pce. And also, STA review is possible through RCS inventory control/RCS pressure control section in SFSC.

Execution Performance Shaping Factors				
Special Requirements	Tools	Adequate		
	Parts	Adequate		
	Clothing	Adequate		
Environment	Lighting	Normal		
	Heat	Normal		
	Radiation	Background		
	Atmosphere	Normal		
Equipment Accessibility	MCR	Accessible		
Stress	Moderate			
	Plant Response As	Yes		
	Expected:			
	Workload:	Low		
	Performance Shaping	Negative		
	Factors:			
Notes				
This operator action is required to prevent RCS leakage to secondary side when SGTR occurs.				

In other words, this operator action would perform after success of diagnosis and operator can expect this operator action would be required. Therefore "Yes" branch is chosen at Plant Response As Expected node. It is expected that this operator action has enough time to complete. Therefore, it is assumed that sufficient operators and time are available for this action. Therefore, low workload is selected. To complete this HFE, operator should consider and perform several operator actions. Thus, it is expected that the execution actions are complex. So the negative branch of PSFs is selected.

Execution Complexity

Complex

	Execution Unrecovered						
Pr	Procedure: EOG-05, Steam Generator Tube Rupture Recovery Guideline			Comment			
Sten No	Instruction/Comment		Error THERF		HED	Stress Factor	Over Ride
			Table I	Item			
	Maintain the isolated SG pressure less than upper end of post-trip SG pressure control band by operating TBV or ADV.						
EOG-05 #14.a	Location: MCR	EOM	20-7b	1	4.3e-04	2	
or b		EOC	20-12	10	3.8E-3		
					Total S	tep HEP	8.5e-03
	Operate main or auxiliary pressurizer spary or operate the pressurizer gas vent valve.	Aux. spra	y valve is o	n-off cont	rol SOV.		
FOG-05 #15 b	Location: MCR	EOM	20-7b	1	4.3e-04	2	
or 15.1		EOC	20-12	4	1.3E-3		
		Total Step HE			tep HEP	3.5e-03	
	Control charging flow or throttle SI flow as necessary.	SI MOV 616/626/636/646 is jog control type MOV.					
EOG-05 #15 c	Location: MCR	EOM	20-7b	1	4.3e-04	2	
200-03 #13.0		EOC	20-12	10	3.8E-3		
		Total Step HEP				tep HEP	8.5e-03
	Maintain the isolated SG level within isolated SG level control band						
<b>FOO 07 1107</b>	Location: MCR	EOM	20-7b	1	4.3e-04	2	
EOG-05 #25		EOC	20-9	2	1.3E-3		
			•		Total S	tep HEP	3.5e-03
	If SI pumps are operating and SI termination criteria are satisfied, then throttle SI flow or stop one SI pump at a time.						
EOG 05 #16	Location: MCR	EOM	20-7b	1	4.3e-04	2	
200 00 #10		EOC	20-12	10	3.8E-3		
					Total S	tep HEP	8.5e-03

	Execution Recovered									
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step			
EOG-05 #14.a or b		Maintain the isolated SG pressure less than upper end of post-trip SG pressure control band by operating TBV or ADV.	8.5e-03				4.5e-04			
	EOG-05 #25	Maintain the isolated SG level within isolated SG level control band		3.5e-03	LD	5.3e-02				
EOG-05 #15.b or 15.1		Operate main or auxiliary pressurizer spary or operate the pressurizer gas vent valve.	3.5e-03				1.9e-04			
	EOG-05 #25	Maintain the isolated SG level within isolated SG level control band		3.5e-03	LD	5.3e-02				
EOG-05 #15.c		Control charging flow or throttle SI flow as necessary.	8.5e-03				4.9e-04			
	EOG-05 #16	If SI pumps are operating and SI termination criteria are satisfied, then throttle SI flow or stop one SI pump at a time.		8.5e-03	LD	5.8e-02				
		Total Unrecovered:	2.0e-02			Total Recovered:	1.1e-03			

# *HR-RCSCD2, Operator Fails to Take Action for SG Cooldown, RC Depressurization.*

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	1.9e-02	5.1e-02					
With Recovery	2.7e-04	3.0e-03	3.2e-03	5			

**Identification and Definition** 

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SGTR

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should cool down and depressurize RCS for Shutdown Cooling Operation before IRWST depletion.

5. Consequence of failure : Core Damage

6. Definition : This HFE is performed after damaged SG overfill in SGTR. operator should perform RC depressurization and SG cooldown to minimize RCS leakage through damaged SG.

Cues and Indications				
Initial Cue	S/G Level			
Recovery Cue	RCS Pressure, Temperature			
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training					
Cognitive Procedure	EOG-02 (Revision: 00)				
Cognitive Step Number	All				
Cognitive Instruction	Perform all steps				
Execution Procedure	EOG-05 (Revision: 00)				
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action					

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

### Key Assumptions

**Operator Interview Insights** 

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	240.00 Minutes			
T <sub>delay</sub>	0.00 Minutes			
T <sub>1/2</sub>	22.00 Minutes			
Τ <sub>M</sub>	20.00 Minutes			
Time available for recovery	198.00 Minutes			
SPAR-H Available time	220.00 Minutes			
(cognitive)				
SPAR-H Available time	10.90			
(execution) ratio				
Minimum level of dependence	ZD			
for recovery				

Notes

This HFE includes actions for SG cooldown amd RCS depressurization after SG overfill. However, there is no core damage within 14.9 hours in spite of failure of this action by referring below MAAP analysis, conservatively 240 minutes are assumed for Tsw.

Per MAAP Analysis for SGTR sequence with safety injection and secondary heat removal success, (refer to Table 5-7 3(a), 3(b), 3(c), 3(d) of the Success Criteria Notebook)

- 1. Rx Trip : 0.2 hr (879.771 sec)
- 2. IRWST LOW-LOW SIGNAL : 8.6 hr (30812.881 sec)
- 3. SG overfill time : 3.9 hr (13882.868 sec)
- 4. IRWST depletion time : 14.9 hr (53769.895 sec)

[EOG Driven Action]

- \* T0 = SG overfill
- \* Tsw = 240 min (no core damage based on MAAP Analysis)
- \* Td = 0 min

\* T1/2 = 22 min (It is assumed that operators are already on the EOG-05 (SGTR ORG) and median response time is assumed from EOG-05 first step to EOG-05 step #23)

\* Tm = 20 min (conservative time for RCS depressurization and Cooldown for initial success)

Cognitive Analysis				
Pc Failure Mechanism	Branch	HEP		

P <sub>ca</sub> : Availability of Information	а	neg.			
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the			
main control room.					
<b>P</b> <sub>cb</sub> : Failure of Attention	i	neg.			
Notes: In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for			
CBDTM unless the work load relevant to a	a specific HFE cannot be jud	dged appropriately.			
This HFE is to perform RCS depressuriza	tion and SG cooldown. Thu	s the operator only			
performs and one-time check the status o	f related components and va	ariables. It is not			
necessary to check them continuously.					
It's assumed that the indicator to be check	ked is always displayed on t	he front panel of the			
MCR because all of the controls in the mo	dern control room are expe	cted to be located in the			
front of the room.					
It is assumed that operators concentrate of	on EOG and performs EOG	-driven actions after			
reactor trip. Thus operators can not respo	nd to alarms until related pa	arameter are mentioned			
in the EOG step.					
P <sub>cc</sub> : Misread/miscommunicate data	a	neg.			
<b>Notes:</b> It is assumed that required indicate	or on the control board such	as layout, demarcation,			
labeling and others is always located easi	iy.				
With the advanced digital ISC interface in	the MCP the indication is a	esumed to be "good"			
unloss there are scenario specific conside	the MCR, the indication is a				
iustification for the deviation will be provid		e, in which case,			
	eu.				
It is assumed that formal communications	will always be used when the	he specified value is			
transferred between operators.					
P <sub>ed</sub> : Information misleading	а	nea.			
Notes: The EOG describes about RCS de	epressurization and SG coo	Idown when SGTR			
occurs.	•				
P <sub>ce</sub> : Skip a step in procedure	С	3.0e-03			
Notes: It's assumed that it's always transp	parent for operators to proce	eed the relevant			
instruction or stand-alone numbered step	on the EOGs.				
The MCR operator is not required to use a	in an additional procedure ir	addition to the EOG, so			
"single" branch is selected for this HFE.					
Only if there are special or distinct marks	are provided in the procedu	re, "YES" branch in the			
"Graphically Distinct" should be selected.					
I he use of placekeeping aids is always as	ssumed to be used due to the	ne nature of the			
computerized procedure system (CPS) software, i.e., the operator will be required to confirm					
from this accumption are possible justified	tion for the choice mode wi	ill be provided			
I official assumption are possible, justifica					
P <sub>cf</sub> : Misinterpret instructions	d anding of the procedures will	neg.			
<b>Notes:</b> It is generally assumed that the wo	decision tree procedures will				
	decision tree, per, or the Cr	501101.			
The step present all information required t	to identify the actions directed	ed and their obiects.			
$\mathbf{P}_{cq}$ : Misinterpret decision logic	a	1.6e-02			
Notes: If diagnosis is performed just after	EOG-01 completion, select	sequence (a) or (b)			
because "NOT, AND, OR, BOTH AND an	d OR" are present through F	EOG01 and EOG02.			
Otherwise, "No" branch should be selecte	d on the "NOT Statement" k	pranch.			
,,					

The operators are always trained and practiced about specified scenario to perform.						
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.				
Notes: The operators are always assume	ed to believe in the adequac	y of instruction				
presented.						
Initial P <sub>c</sub> (without recovery credited) 1.9e-02						
Notes						
Equipment Accessibility MCR: Accessible						

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	3.0e-03	Х	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-	-	Х	-	-	N/A	ZD	1.6e-02		2.6e-04
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 2.7e-						2.7e-04				
	Notes										

CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for Pce. And also, STA review is possible through RCS inventory control/RCS pressure control section in SFSC.

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
This HFE is required after failure of damaged SG level control. This operator action have to be						
performed under limited condition to prevent undesired plant state.						
Execution Complexity Complex						

Execution Unrecovered									
Pr	Procedure: EOG-05, Steam Generator Tube Rupture Recovery Guideline		Comment						
Step No.	Instruction/Comment		THE	RP	HEP	Stress Factor	Over Ride		
			Table	Item					
	Perform controlled cooldown within maximum cooldown rate by TBV or ADV.	TBV and	ADV are flo	w control	l valve.				
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
EOG-05 #23		EOC	20-12	10	3.8E-3				
					Total S	tep HEP	2.1e-02		
	Lower pressurizer pressure to below isloated SG pressure Aux. spray valve is on-off control SOV.								
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
EOG-05 #25		EOC	20-12	4	1.3E-3				
	Total Step HEP								
	Throttle SI flow as necessary.	SI MOV 6	616/626/636 /	646 is jo	og control				
	Location: MCR	EOM 20-7b 1 4.3			4.3e-04	5			
EOG-05 #28-b		EOC	20-12	10	3.8E-3				
	Total Step HEP								
	Verify RCS condition for SC operation								
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
EOG-05 #45		EOC	20-9	2	1.3E-3				
			•	•	Total S	tep HEP	8.7e-03		

Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
EOG-05 #23		Perform controlled cooldown within maximum cooldown rate by TBV or ADV.	2.1e-02				1.2e-03	
	EOG-05 #45	Verify RCS condition for SC operation		8.7e-03	LD	5.8e-02		
EOG-05 #25		Lower pressurizer pressure to below isloated SG pressure	8.7e-03				5.1e-04	
	EOG-05 #45	Verify RCS condition for SC operation		8.7e-03	LD	5.8e-02		
EOG-05 #28-b		Throttle SI flow as necessary.	2.1e-02				1.2e-03	
	EOG-05 #45	Verify RCS condition for SC operation		8.7e-03	LD	5.8e-02		
Total Unrecovered: 5.1e-02 Total Recovered: 3.0e-0							3.0e-03	

### MSOPH-S-ASC-SGTR, Operator Fails to Perform Aggressive Secondary Cooling after SGTR

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	2.2e-02	2.1e-02				
With Recovery	2.8e-04	1.2e-03	1.5e-03	5		

### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SGTR

3. Preceding operator error or success in sequence : Failure of Automatic Safety Injection

4. Operator action success criterion : Operator should open and control one or more MSADVs

5. Consequence of failure : Core Damage

6. Definition : After reactor trip and failure of safety injection, it is needed to decrease pressure for shutdown cooling as soon as possible. So the operator should perform aggressive secondary cooling with using TBVs or MSADVs But, in this HFE, it is assumed that TBVs are not available conservatively. Thus operator should perform aggressive secondary cooling within maximum cooldown rate with MSADVs.

Cues and Indications					
Initial Cue	No SI flow				
Recovery Cue	RCS level, Subcooling margin, temperature and pressure				
Cue Comments					
Degree of Clarity	Very Good				

Procedures and Training				
Cognitive Procedure	EOG-10, IC-2 (Revision: 0)			
Cognitive Step Number	3			
Cognitive Instruction	Cooldown RCS			
Execution Procedure	EOG-10, IC-2 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training None				
Notes				
The procedure and training informati	on is not available in DC phase. However, APR1400 EOG is			

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

### **Key Assumptions**

### Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	240.00 Minutes			
T <sub>delay</sub>	17.00 Minutes			
T <sub>1/2</sub>	27.00 Minutes			
T <sub>M</sub>	5.00 Minutes			
Time available for recovery	191.00 Minutes			
SPAR-H Available time	218.00 Minutes			
(cognitive)				
SPAR-H Available time	39.20			
(execution) ratio				
Minimum level of dependence	ZD			
for recovery				

Notes

If the SGTR with failure of SI injection occurs, operator will enter to the FRG for RCS inventory control. Safety function status check is performed before entering to the IC-2 and it is assumed 10 min for Safety Function Status Check (SFSC). FRG IC-2 step #3 is for RCS depressurization.

Per MAAP Analysis for SGTR Event with safety injection failure, (refer to Table 5-4 case 1, 2, 3, 4 of the Success Criteria Notebook)

- 1. Rx Trip : 0.3 hr (991.918 sec)
- 2. Core uncovery : 10.7 hr (38381.949 sec)
- 3. Core Damage : 12.1 hr (43511.582 sec)

### [EOG Driven Action]

- \* T0 = SGTR occurrence
- \* Tsw = 240 min (core damage, conservative assumption based on MAAP Analysis)
- \* Td = 17 min (Rx Trip)

\* T1/2 = 27 min (SPTA EOG (9 min) + DA EOG (6 min) + SFSC (10 min) + FRG IC-2 step #3 (2 min))

\* Tm = 5 min (ADVs Open)

**Cognitive Analysis** 

Pc Failure Mechanism	Branch	HEP					
P <sub>ca</sub> : Availability of Information	а	neg.					
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the					
main control room.							
<b>P</b> <sub>cb</sub> : Failure of Attention	i	neg.					
<b>Notes:</b> In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for					
CBDTM unless the work load relevant to a	a specific HFE cannot be ju	dged appropriately.					
This HFE is to perform aggressive cooldo	wn with MSADVs and thus	the operator only					
performs and one-time check of maximun	n cooldown rate and status	of related components					
and variables. It is not necessary to check them continuously.							
It's assumed that the indicator to be check	ked is always displayed on t	ne front panel of the					
MCR because all of the controls in the mo	odern control room are expe	cted to be located in the					
front of the room.							
It is assumed that approximations concentrate a	on EQC and parforms EQC	driven estions ofter					
It is assumed that operators concentrate o	on EOG and periorns EOG	-unven actions after					
in the EOG stop	ind to alarms until related pa						
P : Misread/miscommunicate data	2	neg					
Notoe: It is assumed that required indicat	or on the control board such	as layout demarcation					
labeling and others is always located easi		ras layout, demarcation,					
	iy.						
With the advanced digital I&C interface in	the MCR, the indication is a	assumed to be "good"					
unless there are scenario specific conside	erations to warrant otherwise	e, in which case.					
iustification for the deviation will be provid	ed.	,					
,							
It is assumed that formal communications	will always be used when t	he specified value is					
transferred between operators.							
P <sub>cd</sub> : Information misleading	b	3.0e-03					
<b>Notes:</b> In this HFE, the related parameter	values dose not satisfy the	range of EOG					
description values and related system doe	es not respond automaticall	y(i.e. Failure of SI). Thus					
operator performs aggressive cooldown w	vith MSADVs						
The EOG provides contingeny actions wh	ich are instructions on how	to proceed if the cue					
states are not as stated.	_	0.0.00					
P <sub>ce</sub> : Skip a step in procedure		3.0e-03					
Notes: It's assumed that it's always trans	parent for operators to proc	eed the relevant					
instruction of stand-alone numbered step	on the EOGS.						
The MCP operator is not required to use a	n an additional procedure in	addition to the EOC so					
"single" branch is selected for this HEE		raddition to the EOG, so					
Only if there are special or distinct marks are provided in the procedure. "YES" branch in the							
"Graphically Distinct" should be selected.							
The use of placekeeping aids is always assumed to be used due to the nature of the							
computerized procedure system (CPS) software, i.e., the operator will be required to confirm							
completion of a step as the procedural items are addressed. Scenarios for which deviations							
from this assumption are possible, justification for the choice made will be provided.							
P <sub>cf</sub> : Misinterpret Instructions a neg.							
Notes: It is generally assumed that the we	ording of the procedures wil	l be standard versus					
ambiguous for the Misinterpret Instruction	decision tree, pcf, of the Cl	BDTM.					
The step present all information required to identify the actions directed and their objects.							

P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02					
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b)							
because "NOT, AND, OR, BOTH AND an	because "NOT, AND, OR, BOTH AND and OR" are present through EOG01 and EOG02.						
Otherwise, "No" branch should be selecte	d on the "NOT Statement" t	oranch.					
The operators are always trained and pra	The operators are always trained and practiced about specified scenario to perform.						
<b>P</b> <sub>ch</sub> : Deliberate violation	P <sub>ch</sub> : Deliberate violation a neg.						
Notes: The operators are always assume	d to believe in the adequac	y of instruction					
presented.							
Initial P <sub>c</sub> (without recovery credited) 2.2e-02							
Notes							
Equipment Accessibility MCR: Accessible							

	Cognitive Recovery												
	Initial HEP	Self	Review	Extra Crew	STA	Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pcb	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pcc	neg.	-		-	-		-	-	N/A	-	1.0e+00		
$Pc_d$	3.0e-03	-		-	Х		-	-	N/A	ZD	3.0e-03		9.0e-06
Pce	3.0e-03	Х	(	I	-		1	-	N/A	ZD	3.0e-03		9.0e-06
Pc <sub>f</sub>	neg.	-		I	-		1	-	N/A	-	1.0e+00		
PCq	1.6e-02	-		I	Х		1	-	N/A	ZD	1.6e-02		2.6e-04
Pch	neg.	-		I	-		1	-	N/A	-	1.0e+00		
Fina	Final Pc (with recovery credited)2.8e-					2.8e-04							
	Notes												
STA	review is po	ssi	ible	e thro	bug	hS	SFS	C for	Pcd and Pc	g. And	also, CPS pro	ovides the to	ol to
preve	ent skip a ste	эр	in f	the p	roc	ed	ure.	Ther	efore self re	eview is a	available for F	ce.	

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
This HFE is to recover failure of SI. This operator action have to be performed under limited						
condition to prevent undesired plant state.						
Execution Complexity Simple						

	Execution Unrecovered								
Procedure: EOG-10, IC-2, Functional Recovery Guideline - RCS Inventory Control, Safety Injection			Com	ment					
Sten No	Instruction/Comment		THERP		HEP	Stress Factor	Over Ride		
		Туре	Table	Item					
	Perform rapid cooldown within maximum cooldown rate								
	Location: MCR	EOM	20-7b	1	4.3e-04	5			
#3.a		EOC	20-12	10	3.8E-3	-			
	Total Step HEP								
EOG-10, SFSC	Check and Write the Safety Functions Status for RCS inventory control by STA	STA will be specially trained in mitigating the consequences of abnormal events. SI injection is a major event during LOCA/SGTR sequence. Therefore recovery by STA for this HFE is possible.				5			
		FOC	20-75	2	1.3E-3				
	Total Step HEP								

	Execution Recovered									
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step			
EOG-10,		Perform rapid cooldown within maximum cooldown	2.1e-02				1.2e-03			
IC-2 #3.a		rate								
	EOG-10, SFSC	Check and Write the Safety Functions Status for RCS inventory control by STA		8.7e-03	LD	5.8e-02				
		Total Unrecovered:	2.1e-02			Total Recovered:	1.2e-03			

## MSOPH-S-ASC-SLOCA, Operator Fails to Perform Aggressive Secondary Cooling After SLOCA

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/16/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	2.2e-02	2.1e-02					
With Recovery	1.3e-02	1.1e-02	2.3e-02	5			

### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SLOCA

3. Preceding operator error or success in sequence : Failure of Automatic Safety Injection

4. Operator action success criterion : Operator should open and control one or more MSADVs

5. Consequence of failure : Core Damage

6. Definition : After reactor trip and failure of safety injection, it is needed to decrease pressure for shutdown cooling as soon as possible. So the operator should perform aggressive secondary cooling with using TBVs or MSADVs But, in this HFE, it is assumed that TBVs are not available conservatively. Thus operator should perform aggressive secondary cooling within maximum cooldown rate with MSADVs.

Cues and Indications					
Initial Cue	No HPSI flow				
Recovery Cue	RCS level, subcooling, temperature and pressure				
Cue Comments					
Degree of Clarity	Very Good				

Procedures and Training				
Cognitive Procedure	EOG-10, IC-2 (Revision: 0)			
Cognitive Step Number	3			
Cognitive Instruction	Cooldown RCS			
Execution Procedure	EOG-10, IC-2 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training None				
Notes				
The procedure and training information is not available in DC phase. However, APR1400 EOG is				

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

### **Key Assumptions**

### Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	40.00 Minutes			
T <sub>delay</sub>	2.00 Minutes			
T <sub>1/2</sub>	27.00 Minutes			
T <sub>M</sub>	5.00 Minutes			
Time available for recovery	6.00 Minutes			
SPAR-H Available time	33.00 Minutes			
(cognitive)				
SPAR-H Available time	2.20			
(execution) ratio				
Minimum level of dependence	HD			
for recovery				
Notes				

If the SLOCA with failure of SI injection occurs, operator will enter to the FRG for RCS inventory control. Safety function status check is performed before entering to the IC-2 and it is assumed 10 min for SFSC. FRG IC-2 step #3 is for RCS depressurization.

Per MAAP Analysis for SLOCA sequence with safety injection failure, (refer to Table 5-3 Case 1 ~ Case 13 and 5-5 2-1(a) ~ 2-1h) of the Success Criteria Notebook)

1. Rx Trip : 0 hr (133.859 sec)

- 2. ASC completion timing for no core damage : 40 min (2403.208 sec)
- 3. RSC Press. To SCP sutoff heed : 2.1 hr (7413.202 sec)

4. Core uncovery : 8.7 hr (31358.119 sec)

5. SCS Injection : 10.5 hr (37801.410 sec)

[EOG Driven Action]

\* T0 = SLOCA occurrence

\* Tsw = 40 (ASC completion time to reach shutdown cooling entry condition by MAAP Analysis)

\* Td = 2 (Rx Trip)

\* T1/2 = 27 (SPTA EOG (9 min) + DA EOG (6 min) + SFSC (10 min) + FRG IC-2 step #3 (2 min)) \* Tm = 5 (ADV Open)

Cognitive Analysis						
Pc Failure Mechanism	Branch	HEP				
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.				
Notes: Operator can access to all information	ation and required indication	to operate a plant in the				
main control room.						
P <sub>cb</sub> : Failure of Attention	i	neg.				
<b>Notes:</b> In general, within 2 hours from ac	cident initiation, work load is	s assumed to be high for				
CBDTM unless the work load relevant to a	a specific HFE cannot be ju	dged appropriately.				
This HFE is to perform aggressive cooldo performs and one-time check of maximum and variables. It is not necessary to check	wn with MSADVs and thus n cooldown rate and status c them continuously.	the operator only of related components				
It's assumed that the indicator to be check MCR because all of the controls in the mo- front of the room.	ked is always displayed on t odern control room are expe	the front panel of the ected to be located in the				
It is assumed that operators concentrate of reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG nd to alarms until related pa	-driven actions after arameter are mentioned				
<b>P</b> <sub>cc</sub> : Misread/miscommunicate data	а	neg.				
<b>Notes:</b> It is assumed that required indicat labeling and others is always located easi	or on the control board such ly.	as layout, demarcation,				
With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid	the MCR, the indication is a erations to warrant otherwise ed.	assumed to be "good" e, in which case,				
It is assumed that formal communications transferred between operators.	will always be used when t	he specified value is				
P <sub>cd</sub> : Information misleading	b	3.0e-03				
<b>Notes:</b> In this HFE, the related parameter description values and related system doe operator performs aggressive cooldown w	<ul> <li>values dose not satisfy the es not respond automaticall vith MSADVs</li> </ul>	e range of EOG y(i.e. Failure of SI). Thus				
The EOG provides contingeny actions wh states are not as stated.	ich are instructions on how	to proceed if the cue				
P <sub>ce</sub> : Skip a step in procedure	С	3.0e-03				
Notes: It's assumed that it's always trans instruction or stand-alone numbered step	parent for operators to proc on the EOGs.	eed the relevant				
The MCR operator is not required to use a "single" branch is selected for this HFE.	an an additional procedure ir	n addition to the EOG, so				
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected.						
The use of placekeeping aids is always as computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justification	ssumed to be used due to th oftware, i.e., the operator wi ms are addressed. Scena ation for the choice made w	he nature of the Il be required to confirm rios for which deviations ill be provided.				
P <sub>cf</sub> : Misinterpret Instructions	а	neg.				
<b>Notes:</b> It is generally assumed that the war ambiguous for the Misinterpret Instruction	ording of the procedures wil decision tree, pcf, of the C	ll be standard versus BDTM.				

The step present all information required to identify the actions directed and their objects.						
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02				
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b)						
because "NOT, AND, OR, BOTH AND an	d OR" are present through I	EOG01 and EOG02.				
Otherwise, "No" branch should be selecte	d on the "NOT Statement" t	branch.				
The operators are always trained and pra-	cticed about specified scena	ario to perform.				
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.				
Notes: The operators are always assume	ed to believe in the adequacy	y of instruction				
presented.						
Initial P <sub>c</sub> (without recovery credited)		2.2e-02				
Notes						
Equipment Accessibility	MCR:					

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	HD	5.0e-01		1.5e-03
Pc <sub>e</sub>	3.0e-03	-	-	-	-	-	N/A	-	1.0e+00		3.0e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
PCq	1.6e-02	-	-	Х	-	-	N/A	HD	5.1e-01		8.2e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)1.3e-							1.3e-02				
	Notes										
STA	review is po	ssibl	e thro	bugh 🕄	SFS	C, so	STA review	is applic	cable to Pcd a	ind Pcg.	

Execution Performance Shaping Factors							
Special Requirements	Tools	Adequate					
	Parts	Adequate					
	Clothing	Adequate					
Environment	Lighting	Normal					
	Heat	Normal					
	Radiation	Background					
	Atmosphere	Normal					
Equipment Accessibility	MCR	Accessible					
Stress	High						
	Plant Response As	No					
	Expected:						
	Workload:	N/A					
	Performance Shaping	N/A					
	Factors:						
Notes							
This HFE is to recover failure of SI. This operator action have to be performed under limited							
condition to prevent undesired plant state.	condition to prevent undesired plant state.						
Execution Complexity	Simple						

Execution Unrecovered							
Procedure: EOG-10, IC-2, Functional Recovery Guideline - RCS Inventory Control, Safety Injection			Com	ment			
Sten No	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride
			Table	Item			
	Perform rapid cooldown within maximum cooldown rate						
EOG 10 IC 2	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#3.a		EOC	20-12	10	3.8E-3	-	
					Total S	tep HEP	2.1e-02
EOG-10, SFSC	Check and Write the Safety Functions Status for RCS inventory control by STA       STA will be specially trained in mitigating the consequences of abnormal events. SI injection is a major event during LOCA/SGTR sequence. Therefore recovery by STA for this HFE is possible.         InG-10, FSC       FOM       20.7b       1       4.3e.04				5		
		EOC	20-9	2	1.3E-3		
	Total Step HEP						8.7e-03

	Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step		
EOG-10, IC-2 #3.a		Perform rapid cooldown within maximum cooldown rate	2.1e-02				1.1e-02		
	EOG-10, SFSC	Check and Write the Safety Functions Status for RCS inventory control by STA		8.7e-03	HD	5.0e-01			
		Total Unrecovered:	2.1e-02			Total Recovered:	1.1e-02		

# MSOPH-S-SGADV, Operator Fails to Open MSADV to remove steam from SGs.

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.nra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
P <sub>cog</sub> P <sub>exe</sub> Total HEP Error Factor							
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	2.2e-02	4.2e-03					
With Recovery	1.3e-03	4.2e-03	5.5e-03	5			

Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All IEs

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should open MSADV(s) to remove steam from SGs to remove decay heat.

5. Consequence of failure : Failure of secondary side

6. Definition : After reactor trip, the operator should control SG pressure. If SG pressure is greater than upper end of post-trip SG pressure control band then operator should control and maintain SG pressure within post-trip SG pressure control band with TBVs or ADVs. But, in this HFE, it is assumed that TBVs are not available conservatively. Thus operator controls SG pressure with ADVs.

Cues and Indications				
Initial Cue	S/G Pressure			
Recovery Cue				
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	6-c.3			
Cognitive Instruction	Operate ADVs			
Execution Procedure	EOG-01 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			

#### Notes

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

### Key Assumptions

### Operator Interview Insights Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	60.00 Minutes			
T <sub>delay</sub>	0.00 Minutes			
T <sub>1/2</sub>	5.00 Minutes			
Τ <sub>M</sub>	5.00 Minutes			
Time available for recovery	50.00 Minutes			
SPAR-H Available time	55.00 Minutes			
(cognitive)				
SPAR-H Available time	11.00			
(execution) ratio				
Minimum level of dependence	LD			
for recovery				

### Notes

Actually, even though operator does not open ADVs, secondary heat removal is achieved by AFWP and MSSV cycling operation.

Per MAAP Analysis for LOFW sequence with MSSV operation, (refer to Table 5-9 4(a), 4(b) of the Success Criteria Notebook)

- 1. Rx Trip : 0 hr (22.126 sec)
- 2. AFAS Generation : 0 hr (152.599 sec)

3. SG Dry-Out : 0.6 hr (2106.862 sec)

- 4. Core uncovery : 1.1 hr (3944.701 sec)
- 5. Core Damage : 1.5 hr (5517.066 sec)

[EOG Driven Action]

- \* T0 = LOFW occurrence
- \* Tsw = 60 min (Conservative assumption)
- \* Td = 0 min (Rx Trip)
- \* T1/2 = 5 min (SPTA EOG step #6 (5min))
- \* Tm = 5 min (ADV control)

Cogni	tivo Analysis					
Bc Failure Mechanism	Branch	HED				
P : Availability of Information						
Notes: Operator can access to all information	ation and required indication	to operate a plant in the				
main control room						
P <sub>ob</sub> : Failure of Attention	i	neg				
<b>Notes:</b> In general, within 2 hours from ac CBDTM unless the work load relevant to	cident initiation, work load is a specific HFE cannot be jud	assumed to be high for dged appropriately.				
This HFE is to open ADVs and thus the o pressure and status of related componen continuously.	perator only performs and o ts and variables. It is not nee	ne-time check of SG cessary to check them				
It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	ked is always displayed on t odern control room are expe	he front panel of the cted to be located in the				
It is assumed that operators concentrate reactor trip. Thus operators can not respo in the EOG step.	on EOG and performs EOG and to alarms until related pa	-driven actions after arameter are mentioned				
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.				
Notes: It is assumed that required indicat labeling and others is always located eas With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid	or on the control board such ily. the MCR, the indication is a erations to warrant otherwise led.	a as layout, demarcation, assumed to be "good" e, in which case,				
It is assumed that formal communications transferred between operators.	s will always be used when t	he specified value is				
<b>P</b> <sub>cd</sub> : Information misleading	b	3.0e-03				
<b>Notes:</b> In this HFE, the related parameter description values and related system do Thus operator controls SG pressure with	r values dose not satisfy the es not respond automatically ADVs.	range of EOG y(i.e. High SG pressure).				
The EOG provides contingeny actions whe states are not as stated.	ich are instructions on how	to proceed if the cue				
<b>P</b> <sub>ce</sub> : Skip a step in procedure	С	3.0e-03				
<b>Notes:</b> It's assumed that it's always trans instruction or stand-alone numbered step	parent for operators to proce on the EOGs.	eed the relevant				
The MCR operator is not required to use an an additional procedure in addition to the EOG, so "single" branch is selected for this HFE.						
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected.						
The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible justific	ssumed to be used due to the optimate of the operator will ms are addressed. Scenar ation for the choice made will be the optimate of the opti	ne nature of the I be required to confirm rios for which deviations ill be provided				
<b>P</b> <sub>cf</sub> : Misinterpret Instructions	a	neq.				

<b>Notes:</b> It is generally assumed that the wording of the procedures will be standard versus				
ambiguous for the Misinterpret Instruction decision tree, pcf. of the CBDTM.				
	······			
The step present all information required	to identify the actions directed	ed and their objects.		
<b>P</b> <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02		
Notes: If diagnosis is performed just after	EOG-01 completion, select	sequence (a) or (b)		
because "NOT AND OR BOTH AND an	d OR" are present through I	= OG01  and  FOG02		
Othorwise "No" branch should be selected	d on the "NOT Statement" k			
The operators are always trained and pra	cticed about specified scena	ario to perform.		
The operators are always trained and pra <b>P</b> <sub>ch</sub> : Deliberate violation	cticed about specified scena a	ario to perform. neg.		
The operators are always trained and pra <b>P</b> <sub>ch</sub> : Deliberate violation <b>Notes:</b> The operators are always assume	cticed about specified scena a d to believe in the adequac	ario to perform. neg. v of instruction		
The operators are always trained and pra <b>P</b> <sub>ch</sub> : Deliberate violation <b>Notes:</b> The operators are always assume presented	cticed about specified scena a d to believe in the adequac	ario to perform. neg. y of instruction		
The operators are always trained and prace <b>P</b> <sub>ch</sub> : Deliberate violation <b>Notes:</b> The operators are always assume presented.	cticed about specified scena a d to believe in the adequac	ario to perform. neg. y of instruction		
The operators are always trained and prace P <sub>ch</sub> : Deliberate violation Notes: The operators are always assume presented. Initial P <sub>c</sub> (without recovery credited)	cticed about specified scena a ed to believe in the adequac	ario to perform. neg. y of instruction 2.2e-02		
The operators are always trained and prace P <sub>ch</sub> : Deliberate violation Notes: The operators are always assume presented. Initial P <sub>c</sub> (without recovery credited)	cticed about specified scena a ed to believe in the adequace Notes	ario to perform. neg. y of instruction 2.2e-02		

Equipment Accessibility

MCR: Accessible

	Cognitive Recovery											
	Initial HEP	Self	Review	Extra Crew	STA Dovicent	Shift	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-		-	-	-	-	N/A	-	1.0e+00		
$Pc_d$	3.0e-03	-		-	Х	-	-	N/A	LD	5.3e-02		1.6e-04
Pce	3.0e-03	Х	(	-	-	-	-	N/A	LD	5.3e-02		1.6e-04
Pc <sub>f</sub>	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-		-	Х	-	-	N/A	LD	6.5e-02		1.0e-03
Pch	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 1.3e-03					1.3e-03						
	Notes											
CPS	provides the	e to	ol	to pre	even	t skip	o a ste	ep in the pro	cedure.	Therefore self	review is av	ailable for
Pce.	In addition	i, S	TΑ	or o	ther	oper	ators	also can ch	eck the s	skip a step in	the procedui	re.

Execution Performance Shaping Factors					
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	Low				
	Plant Response As	Yes			
	Expected:				
	Workload:	Low			
	Performance Shaping	Optimal			
	Factors:				
Notes					

This operator action is required to control SG pressure and secondary heat removal with ADVs.		
Usually, secondary heat removal is required in various situation. Thus, this operator action is not		
specially required action for failure of specific components. Therefore "Yes" branch is chosen at		
Plant Response As Expected node. It is expected that this operator action is simple and has		
enough time to complete. Thus low workload is selected.		
Execution Complexity	Simple	

Execution Unrecovered							
	Procedure: EOG-01, SPTA		Com	ment			
Sten No Instruction/Comment		Error	THE	RP	HEP	Stress Factor	Over Ride
		Туре	Table	Item			
	To maintain SG pressure within post trip SG pressure control band, operate ADVs.						
EOG 01	Location: MCR	EOM	20-7b	1	4.3e-04	1	
#6-c.3-2)		EOC	20-12	10	3.8E-3		
					Total S	Step HEP	4.2e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-01         To maintain SG pressure within post trip SG           #6-c.3-2)         pressure control band, operate ADVs.		4.2e-03				4.2e-03	
Total Unrecovered:			4.2e-03			Total Recovered:	4.2e-03

## MSOPH-S-SGADV-HW, Operator Fails to Open MSADV to remove steam from SGs using hand wheel.

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THE	
			RP	
Without Recovery	7.5e-03	1.3e-02		
With Recovery	7.5e-03	1.3e-02	2.0e-02	5

### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All IEs

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should open MSADV(s) to remove steam from SGs to remove decay heat using hand wheel.

5. Consequence of failure : Failure of secondary side

6. Definition : After reactor trip, the operator should control SG pressure. If SG pressure is greater than upper end of post-trip SG pressure control band then operator should control and maintain SG pressure within post-trip SG pressure control band with TBVs or ADVs. But, in this HFE, it is assumed that TBVs are not available conservatively and ADVs are not operated in MCR. Thus operator opens ADVs in local.

Cues and Indications		
Initial Cue	S/G Pressure	
Recovery Cue		
Cue Comments		
Degree of Clarity	Very Good	

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	6-c.3			
Cognitive Instruction	Open ADVs			
Execution Procedure	EOG-01 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			

#### Notes

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	TO diagnoses the need of local action for ADV open and orders to local TO.
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	1	Local TO recieves order from TO adn open ADVs in local.

### Dependencies (Related Human Interactions)

### Key Assumptions

### Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	60.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	5.00 Minutes		
T <sub>M</sub>	40.00 Minutes		
Time available for recovery	15.00 Minutes		
SPAR-H Available time	20.00 Minutes		
(cognitive)			
SPAR-H Available time	1.38		
(execution) ratio			
Minimum level of dependence	HD		
for recovery			
Notes			

Actually, even though operator does not open ADVs, secondary heat removal is achieved by AFWP and MSSV cycling operation. If SBO occurs, Rx is tripped immediately. There are no core damage and SG dry out with MSSV operation within 24 hours. [Refer to MAAP Analysis which is Table 5-10 2(a) of the Success Criteria Notebook]

[EOG Driven Action]

\* T0 = SBO

\* Tsw = 60 min (Conservative assumption by MAAP Analysis Table 5-10 2(a) in the Success Criteria Notebook)

\* Td = 0 min (Rx Trip)

\* T1/2 = 5 min (SPTA EOG step #6 (5 min))

\* Tm = 40 min (Time to move, preparation of tool for ADV operation)

Sigma Table						
Plant Type	Response	LB	Sigma	UB		
	Туре					
BWR	CP1	0.4	0.7	1		
	CP2	0.2	0.58	0.96		
	CP3	0.59	0.75	0.91		
PWR	CP1	0.26	0.57	0.88		
	CP2	0.07	0.38	0.69		
	CP3		0.77			
Sigma:	5.7e-01					
HEP:	7.5e-03					
Notes/Assumpt	ions:					

Execution Performance Shaping Factors						
Special Requirements	Tools	Required				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Steam				
Equipment Accessibility	Local - Aux. Bldg.	Accessible				
Stress	High					
	Plant Response As	Yes				
	Expected:					
	Workload:	High				
	Performance Shaping	Negative				
	Factors:					
Notes						
This operator action is required to control SG	pressure and secondary he	at removal with ADVs.				
Usually, secondary heat removal is required in	n various situation. Thus, th	s operator action is not				
specially required action for failure of specific	components. Therefore "Ye	s" branch is chosen at				
Plant Response As Expected node. This operator actions is performed in local due to failure of						
ADV control in the MCR. Thus high workload is selected. This operator action preformed in local						
needs some tools. Therefore negative PSFs branch is selected.						
Execution Complexity	Simple					

	Execution Unrecovered						
Procedure: EOG-01, SPTA			Comment				
Stan No. Instruction/Commant		Error	THERP		HEP	Stress Factor	Over Ride
			Table	Item			
Operate SG ADVs to maintain RCS Tavg within post-trip RCS Tavg control band.		ADV is unique E/H operated type valve. Therefore, THERP table 20-13 item 1 is chosen.			5		
EOG-09 #6	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03	J	
		EOC	20-13	1	1.3E-3		
Total Step HEP					1.3e-02		

Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
EOG-09		Operate SG ADVs to maintain RCS Tavg within	1.3e-02				1.3e-02	
#6	#6     post-trip RCS Tavg control band.       Total Unrecovered:     1.3e-02       Total Recovered:     1.3e-02							

## *PFOPH-S-UATBKR-LOCAL, OPERATOR FAILS TO RECOVER PCB FOR 1E 4.16KV BUSES AT LOCAL*

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THE	
			RP	
Without Recovery	2.7e-02	2.6e-02		
With Recovery	2.7e-02	2.6e-02	5.2e-02	5

### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SBO

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should open circuit breaker for 1E 4.16kV buses at local.

5. Consequence of failure : Loss of 4.16 kV power

6. Definition : In this HFE, 4.16kV power recovery is failed because the PCB for 1E 4.16 kV fails to open. Thus operator should open UAT circuit breaker in local to recover 4.16 kV power from EDG or AACTG.

Cues and Indications					
Initial Cue					
Recovery Cue					
Cue Comments					
Degree of Clarity	Very Good				

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	2.c.2			
Cognitive Instruction	initiate plant sepcific actioins to restore electrical power to			
	the affected bus as time and resouces permit.			
Execution Procedure				
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			

Notes

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	1	
STA	1	1	
Reactor Operator	1	0	
Turbine Operator	1	0	
Electrical Operator	1	1	
Local Reactor Operator	2	0	
Local Turbine Operator	2	1	

### Dependencies (Related Human Interactions)

### **Key Assumptions**

### **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	30.00 Minutes				
T <sub>delay</sub>	6.00 Minutes				
T <sub>1/2</sub>	3.00 Minutes				
T <sub>M</sub>	15.00 Minutes				
Time available for recovery	6.00 Minutes				
SPAR-H Available time	9.00 Minutes				
(cognitive)					
SPAR-H Available time	1.40				
(execution) ratio					
Minimum level of dependence	HD				
for recovery					
Notos					

Tsw = 30 (assumed by the time to maintain robustness of RCP Seal in SBO)

Td = 6 (T1/2 of AACTG + Tm of AACTG)

T1/2 = 3 (the time to diagnose the reason of EDG/AACTG failure and to recognize the need of UAT circuit breaker open.)

Tm = 15 (the time for opening circuit breaker in local. Assumed that it takes similar time to control local manual valve.)

Sigma Table						
Plant Type	Response Type	LB	Sigma	UB		
BWR	CP1	0.4	0.7	1		
	CP2	0.2	0.58	0.96		
	CP3	0.59	0.75	0.91		
PWR	CP1	0.26	0.57	0.88		
	CP2	0.07	0.38	0.69		
	CP3		0.77			
Sigma:	5.7e-01					
HEP:	2.7e-02					

Notes/Assumptions:	

Execution Performance Shaping Factors								
Special Requirements	Tools	Adequate						
	Parts	Adequate						
	Clothing	Adequate						
Environment	Lighting	Normal						
	Heat	Normal						
	Radiation	Background						
	Atmosphere	Normal						
Equipment Accessibility	Local - SWGR Room	Accessible						
Stress	High							
	Plant Response As	No						
	Expected:							
	Workload:	N/A						
	Performance Shaping	N/A						
	Factors:							
Notes								
This HFE is to recover loss of power after the failure of EDG/AACTG due to PCB for 1E 4.16kV.								
This operator action have to be performed under limited time condition to prevent undesired plant								
state.								
Execution Complexity	Simple							
	Execution Unrecovered							
--------------	--	-------	-------	------	---------	------------------	-----------	--
Procedure: ,			Com	nent				
Sten No	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride	
otop no.		Туре	Table	Item				
	Open 1E 4.16KV bus breaker from UAT manually							
	Location: Local - SWGR Room	EOM	20-8a	1	1.3e-03	5		
SYS-AP #xx		EOC	20-13	2	3.8E-3	-		
					Total S	tep HEP	2.6e-02	

	Execution Recovered									
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step			
SYS-AP #xx		Open 1E 4.16KV bus breaker from UAT manually	2.6e-02				2.6e-02			
		Total Unrecovered:	2.6e-02			Total Recovered:	2.6e-02			

# RCOPH-S-SDSE-FW, Operator Fails to Open POSRVs in Early Phase for F&B Operation

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/24/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary								
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor				
Method	CBDTM	THERP	CBDTM+THERP					
Without Recovery	2.0e-02	3.4e-02						
With Recovery	4.1e-03	5.1e-03	9.1e-03	5				

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: GTRN, SGTR, SLOCA, SBO, PR-SL, PLOESW, PLOCCW, LSSB-U, LSSB-D, LOOP, LOIA, LOFW, LODCA, LODCB, LOCV, GRID-LOOP, FWLB

- 3. Preceding operator error or success in sequence : N/A
- 4. Operator action success criterion : Operator should open POSRV(s) for RCS heat removal.
- 5. Consequence of failure : Core Damage

6. Definition : In this HFE, RCS heat removal using SG is failed and temperature of RCS cold leg rises. Thus operator opens POSRVs for RCS heat removal. The POSRVs operation is performed with FRG HR-3.

Cues and Indications					
Initial Cue	S/G Low Level				
Recovery Cue	Step 7 of HR-3 in EOG-10				
Cue Comments					
Degree of Clarity	Very Good				

Procedures and Training					
Cognitive Procedure	EOG-07 (Revision: 0)				
Cognitive Step Number	7				
Cognitive Instruction	Entry into EOG-10, HR-03				
Execution Procedure	EOG-10, HR3 (Revision: 0)				
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					
The procedure and training information is not available in DC phase. However, APR1400 EOG is					

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	1	
Local Turbine Operator	2	0	

#### Dependencies (Related Human Interactions)

#### **Key Assumptions**

#### **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	60.00 Minutes				
T <sub>delay</sub>	0.00 Minutes				
T <sub>1/2</sub>	28.00 Minutes				
Τ <sub>M</sub>	15.00 Minutes				
Time available for recovery	17.00 Minutes				
SPAR-H Available time	45.00 Minutes				
(cognitive)					
SPAR-H Available time	2.13				
(execution) ratio					
Minimum level of dependence	MD				
for recovery					

#### Notes

MAAP analysis shows that if F&B is succeeded within 60 min, it is possible to prevent core damage.

For LOFW Event with Early F&B, (refer to Table 5-9  $1(a) \sim 1(f)$  of the Success Criteria Notebook) 1. Rx Trip : 0 hr (22.126 sec)

2. Core Uncovery : 0.88 hr (3171.808 sec)

3. F&B completion timing : 70 min

- 4. Core Damage : no occurrence within 24 hours
- 5. CSAS Generation : 7.2 hr (28162.430 sec)

#### [EOG Driven Action]

\* T0 = LOFW

\* Tsw = 60 min (F&B completion by MAAP Analysis)

\* Td = 0 min

\* T1/2 = 28 min (SPTA EOG + DA EOG + EOG-07 steps #7 + FRG HR-3 step #7, 15+7+6)

\* Tm = 15 min (power recovery at local and manual opening of POSRVs)

Cognitive Analysis

Pc Failure Mechanism	Branch	HEP						
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.						
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the						
main control room.								
P <sub>cb</sub> : Failure of Attention	i	neg.						
<b>Notes:</b> In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for						
CBDTM unless the work load relevant to a	a specific HFE cannot be jue	dged appropriately.						
This HEE is to open POSRVs manually a	nd thus the operator only pe	rforms and one-time						
check of SG level and status of related co	mponents and variables. It is	s not necessary to check						
them continuously.	•							
It's assumed that the indicator to be check	ked is always displayed on t	he front panel of the						
MCR because all of the controls in the mo	odern control room are expe	cted to be located in the						
front of the room.								
It is assumed that operators concentrate of	on EOG and performs EOG	-driven actions after						
reactor trip. Thus operators can not respo	nd to alarms until related pa	arameter are mentioned						
In the EOG step.	_							
P <sub>cc</sub> : Misread/miscommunicate data	a ar an the control beard such	neg.						
Notes: It is assumed that required indicat	or on the control doard sucr	as layout, demarcation,						
labeling and others is always located easi	iy.							
With the advanced digital I&C interface in	the MCP the indication is a	esumed to be "good"						
unless there are scenario specific conside	erations to warrant otherwise	in which case						
iustification for the deviation will be provid	ed	s, in which case,						
It is assumed that formal communications	will always be used when t	he specified value is						
transferred between operators.	5	·						
P <sub>cd</sub> : Information misleading	b	3.0e-03						
Notes: In this HFE, the related parameter	values dose not satisfy the	range of EOG						
description values and related system doe	es not respond automatically	(i.e. Failure of RCS heat						
removal by secondary side). Thus operate	ors recover RCS heat remov	val with POSRVs.						
The EOG provides contingeny actions wh	ich are instructions on how	to proceed if the cue						
states are not as stated.	_	1.0 - 00						
P <sub>ce</sub> : Skip a step in procedure		1.0e-03						
notes: It's assumed that it's always trans	on the EOCs	eed the relevant						
	on the EOGS.							
The MCR operator is not required to use a	an an additional procedure ir	addition to the EOG so						
"single" branch is selected for this HEF								
Only if there are special or distinct marks	are provided in the procedu	re, "YES" branch in the						
"Graphically Distinct" should be selected.	For this operator action, rela	ated procedure step is						
hold point step and has graphically distinct	st.							
The use of placekeeping aids is always assumed to be used due to the nature of the								
computerized procedure system (CPS) software, i.e., the operator will be required to confirm								
completion of a step as the procedural items are addressed. Scenarios for which deviations								
trom this assumption are possible, justification	ation for the choice made w	ill be provided.						
P <sub>cf</sub> : Misinterpret Instructions	a	neg.						
<b>Notes:</b> It is generally assumed that the we	ording of the procedures wil	I be standard versus						
ambiguous for the Misinterpret Instruction decision tree, pcf, of the CBDTM.								

The step present all information required to identify the actions directed and their objects.								
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02						
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b)								
because "NOT, AND, OR, BOTH AND and OR" are present through EOG01 and EOG02.								
Otherwise, "No" branch should be selected on the "NOT Statement" branch.								
The operators are always trained and practiced about specified scenario to perform.								
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.						
Notes: The operators are always assume	d to believe in the adequac	y of instruction						
presented.								
Initial P <sub>c</sub> (without recovery credited)		2.0e-02						
Notes								
Equipment Accessibility MCR: Accessible								

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc <sub>c</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pc <sub>e</sub>	1.0e-03	-	-	-	-	-	N/A	-	1.0e+00		1.0e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-	-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)							4.1e-03				
	Notes										
STA	STA review is possible through RCS heat removal section of SFSC.										

Execution Perfor	rmance Shaping Factors	
Special Requirements	Tools	Adequate
	Parts	Adequate
	Clothing	Adequate
Environment	Lighting	Normal
	Heat	Normal
	Radiation	Background
	Atmosphere	Normal
Equipment Accessibility	Local - SWGR Room	Accessible
Stress	High	
	Plant Response As	No
	Expected:	
	Workload:	N/A
	Performance Shaping	N/A
	Factors:	
	Notes	
This HFE is to recover RCS heat removal aft	er the failure of RCS heat r	emoval with secondary
side. This operator action have to be perform	ed under limited condition	to prevent undesired plant
state.		
Execution Complexity	Simple	

	Execution Unrecovered							
Procedur	e: EOG-10, HR3, Functional Recovery Guideline - Core and RCS Heat Removal Once-Through-Cooling		Com	ment		0		
Sten No	Instruction/Comment	Error	THERP		HEP	Factor	Over Ride	
otep No.		Туре	Table	Item	- ··-·			
	Ensure electrical pwer is available to motor operated pilot valves.							
EOG-10.	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03	5		
HR-3, #2-d.1		EOC	20-12	8a	2.7E-4			
		Step HEP	7.9e-03					
	Confirm POSRV open status - POSRV leakage alarm and associated POSRV discharge line temperature							
EOG-10,	Location: MCR	EOM	20-7b	1	4.3e-04	5		
HR-3, #7-1		EOC	20-9	2	1.3E-3			
					Total S	Step HEP	8.7e-03	
	Manually open ALL motor operated pilot valves.							
EOG-10.	Location: MCR	EOM	20-7b	1	4.3e-04	5		
HR-3, #7-2		EOC	20-12	4	1.3E-3			
				•	Total S	Step HEP	8.7e-03	
	Verify the motor operated pilot valves are fully opened.							
EOG-10.	Location: MCR	EOM	20-7b	1	4.3e-04	5		
HR-3, #8		EOC	20-9	2	1.3E-3			
					Total S	Step HEP	8.7e-03	
	If pressurizer pressure is less than or equal to low pressurizer pressure SIAS setpoint, then ensure SIAS is actuated.							
EOG-10,	Location: MCR	EOM	20-7b	1	4.3e-04	5		
HR-3, #9		EOC	20-12	3	1.3E-3			
					Total S	Step HEP	8.7e-03	
	Verify SI flow of each pump is greater than SI flow delivery curve.							
EOG-10.	Location: MCR	EOM	20-7b	1	4.3e-04	5		
HR-3, #10-b		EOC	20-9	2	1.3E-3			
					Total S	Step HEP	8.7e-03	

	Execution Recovered										
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step				
EOG-10, HR-3, #2-d.1		Ensure electrical pwer is available to motor operated pilot valves.	7.9e-03				1.2e-03				
	EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.		8.7e-03	MD	1.5e-01					
EOG-10, HR-3, #7-1		Confirm POSRV open status - POSRV leakage alarm and associated POSRV discharge line temperature	8.7e-03				1.3e-03				
	EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.		8.7e-03	MD	1.5e-01					
EOG-10, HR-3, #7-2		Manually open ALL motor operated pilot valves.	8.7e-03				1.3e-03				
	EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.		8.7e-03	MD	1.5e-01					
EOG-10, HR-3, #9		If pressurizer pressure is less than or equal to low pressurizer pressure SIAS setpoint, then ensure SIAS is actuated.	8.7e-03				1.3e-03				
	EOG-10, HR-3, #10-b	Verify SI flow of each pump is greater than SI flow delivery curve.		8.7e-03	MD	1.5e-01					
		Total Unrecovered:	3.4e-02			Total Recovered:	5.1e-03				

# RCOPH-S-SDSL, Operator Fails to Open POSRVs in Late Phase for F&B Operation

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/24/13
	.10.hra			
	Name	Date		
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary									
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor					
Method	CBDTM	THERP	CBDTM+THERP						
Without Recovery	2.0e-02	3.4e-02							
With Recovery	3.2e-03	5.1e-03	8.3e-03	5					

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: GTRN, SGTR, SLOCA, SBO, PR-SL, PLOESW, PLOCCW, LSSB-U, LSSB-D, LOOP, LOIA, LOFW, LODCA, LODCB, LOCV, GRID-LOOP, FWLB

- 3. Preceding operator error or success in sequence : N/A
- 4. Operator action success criterion : Operator should open POSRV(s) for RCS heat removal.
- 5. Consequence of failure : Core Damage

6. Definition : In this HFE, RCS heat removal using SG is failed and temperature of RCS cold leg rises. Thus operator opens POSRVs for RCS heat removal. The POSRVs operation is performed with FRG HR-3.

Cues and Indications						
Initial Cue	S/G Low Level					
Recovery Cue	Step 8 of HR-3 in EOG-10					
Cue Comments						
Degree of Clarity	Very Good					

Procedures and Training						
Cognitive Procedure	EOG-07 (Revision: 0)					
Cognitive Step Number	7					
Cognitive Instruction	Entry into EOG-10, HR-03					
Execution Procedure	EOG-10, HR3 (Revision: 0)					
Job Performance Measure						
Classroom Training	None					
Simulator Training	None					
Notes						
The procedure and training informati	The procedure and training information is not available in DC phase. However, APR1400 EOG is					

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	1	
Local Turbine Operator	2	0	

#### **Dependencies (Related Human Interactions)**

#### **Key Assumptions**

# **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis						
T <sub>sw</sub>	240.00 Minutes					
T <sub>delay</sub>	0.00 Minutes					
T <sub>1/2</sub>	31.00 Minutes					
T <sub>M</sub>	15.00 Minutes					
Time available for recovery	194.00 Minutes					
SPAR-H Available time	225.00 Minutes					
(cognitive)						
SPAR-H Available time	13.93					
(execution) ratio						
Minimum level of dependence	ZD					
for recovery						

#### Notes

For LOFW Event with Late F&B, (refer to Table 5-9 2(a) ~ 2(f) of the Success Criteria Notebook) 1. Rx Trip : 0 hr (22.126 sec)

2. AFAS Generation : 0 hr (152.599 sec)

3. SHR Failure : 8.5 hr (30604.176 sec)

4. F&B completion timing : 12.5 hr

5. Core Damage : no core damage

[EOG Driven Action]

\* T0 = SHR Failure

\* Tsw = 240 min (F&B completion, assumption based on MAAP Analysis)

\* Td = 0 min

\* T1/2 = 31 min (SPTA EOG + DA EOG + SFSC + FRG HR-3 step #7, 15+10+6)

\* Tm = 15 min (power recovery at local and manual opening of POSRVs)

Cognitive Analysis											
Pc Failure Mechanism Branch HEP											
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.									
Notes: Operator can access to all information and required indication to operate a plant in the											

main control room.									
P <sub>cb</sub> : Failure of Attention	а	neg.							
Notes: In general, within 2 hours from ac	cident initiation, work load is	assumed to be high for							
CBDTM unless the work load relevant to a	a specific HFE cannot be jue	dged appropriately.							
This HFE is to open POSRVs manually and thus the operator only performs and one-time									
check of SG level and status of related co	mponents and variables. It is	s not necessary to check							
them continuously.									
It's assumed that the indicator to be check	ked is always displayed on t	he front panel of the							
MCR because all of the controls in the mo	odern control room are expe	cted to be located in the							
Tront of the room.	-	202							
P <sub>cc</sub> : Misread/miscommunicate data	a ar on the control board such	neg.							
<b>Notes:</b> It is assumed that required indicat		r as layout, demarcation,							
	ny.								
With the advanced digital I&C interface in	the MCP the indication is a	esumed to be "good"							
unless there are scenario specific conside	rations to warrant otherwise	a in which case							
iustification for the deviation will be provid	led	e, in which case,							
It is assumed that formal communications	will alwavs be used when t	he specified value is							
transferred between operators.									
<b>P</b> <sub>cd</sub> : Information misleading	b	3.0e-03							
Notes: In this HFE, the related parameter	values dose not satisfy the	range of EOG							
description values and related system doe	description values and related system does not respond automatically(i.e. Failure of RCS heat								
removal by secondary side). Thus operate	ors recover RCS heat remov	al with POSRVs.							
The EOG provides contingeny actions wh	lich are instructions on how	to proceed if the cue							
states are not as stated.	1								
P <sub>ce</sub> : Skip a step in procedure	a	1.0e-03							
<b>Notes:</b> It's assumed that it's always trans	parent for operators to proce	eed the relevant							
instruction or stand-alone numbered step	on the EOGs.								
The MCD exercise net required to use a	an an additional procedure in	addition to the FOC as							
"aingle" branch is selected for this HEE	an an additional procedure in	raddition to the EOG, so							
Only if there are special or distinct marks	are provided in the procedu	re "YES" branch in the							
"Graphically Distinct" should be selected	For this operator action reli	ated procedure step is							
hold point step and has graphically disting	t.								
<b>P</b> <sub>cf</sub> : Misinterpret Instructions	а	neg.							
Notes: It is generally assumed that the w	ording of the procedures wil	l be standard versus							
ambiguous for the Misinterpret Instruction	decision tree, pcf, of the CI	BDTM.							
The step present all information required	to identify the actions directed	ed and their objects.							
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02							
Notes: If diagnosis is performed just after	EOG-01 completion, select	t sequence (a) or (b)							
because "NOT, AND, OR, BOTH AND an	d OR" are present through I	EOG01 and EOG02.							
Otherwise, "No" branch should be selecte	ed on the "NOT Statement" t	oranch.							
I ne operators are always trained and pra	cticed about specified scena	ario to perform.							
P <sub>ch</sub> : Deliberate violation		neg.							
Notes: The operators are always assume	to believe in the adequac	y of instruction							
presented.	[								
Initial P <sub>c</sub> (without recovery credited)		2.0e-02							

Notes													
10105													
Equipment Accessibility													
Equi	Equipment Accessibility MCR: Accessible												
								0.					
		-			1		1	00	gnitive Rec	overy	1		
	Initial HEP	Self	Review	Extra Crew	STA	Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pc <sub>a</sub>	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pch	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pc	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-		-	Х		-	-	N/A	MD	1.5e-01		4.5e-04
Pc	1.0e-03	Х		-	-		-	-	N/A	MD	1.4e-01		1.4e-04
PCf	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pca	1.6e-02	-		-	Х		-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited) 3.2e-03								3.2e-03					
Notes													
STA preve	STA review is possible through RCS heat removal section of SFSC. CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for pce.												

Execution Performance Shaping Factors								
Special Requirements	Tools	Adequate						
	Parts	Adequate						
	Clothing	Adequate						
Environment	Lighting	Normal						
	Heat	Normal						
	Radiation	Background						
	Atmosphere	Normal						
Equipment Accessibility	Local - SWGR Room	Accessible						
Stress	High							
	Plant Response As	No						
	Expected:							
	Workload:	N/A						
	Performance Shaping	N/A						
	Factors:							
	Notes							
This HFE is to recover RCS heat removal after	er the failure of RCS heat re	moval with secondary						
side. This operator action have to be performed under limited condition to prevent undesired plant								
state.								
Execution Complexity	Simple							

Execution Unrecovered							
Procedure: EOG-10, HR3, Functional Recovery Guideline - Core and RCS Heat Removal Once-Through-Cooling			Com	ment			
Step No.	Instruction/Comment	Error	or THERP		HEP	Stress Factor	tor Over Ride
		Туре	Table	Item			
	Ensure electrical pwer is available to motor operated pilot valves.						
EOG-10.	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03	5	
HR-3, #2-d.1		EOC	20-12	8a	2.7E-4		
					Total S	Step HEP	7.9e-03
	Confirm POSRV open status - POSRV leakage alarm and associated POSRV discharge line temperature						
EOG-10,	Location: MCR	EOM	20-7b	1	4.3e-04	5	
HR-3, #7-1		EOC	20-9	2	1.3E-3		
			•		Total S	Step HEP	8.7e-03
	Manually open ALL motor operated pilot valves.						
FOG-10	Location: MCR	EOM	20-7b	1	4.3e-04	5	
HR-3, #7-2		EOC	20-12	4	1.3E-3		
	Total Step HEP						8.7e-03
	Verify the motor operated pilot valves are fully opened.						
FOG-10	Location: MCR	EOM	20-7b	1	4.3e-04	5	
HR-3, #8		EOC	20-9	2	1.3E-3		
			•		Total S	tep HEP	8.7e-03
	If pressurizer pressure is less than or equal to low pressurizer pressure SIAS setpoint, then ensure SIAS is actuated.						
EOG-10,	Location: MCR	EOM	20-7b	1	4.3e-04	5	
HR-3, #9		EOC	20-12	3	1.3E-3		
					Total S	Step HEP	8.7e-03
	Verify SI flow of each pump is greater than SI flow delivery curve.						
EOG-10.	Location: MCR	EOM	20-7b	1	4.3e-04	5	
HR-3, #10-b		EOC	20-9	2	1.3E-3		
					Total S	Step HEP	8.7e-03

		Exect	ution Recovered	1			
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-10, HR-3, #2-d.1		Ensure electrical pwer is available to motor operated pilot valves.	7.9e-03				1.2e-03
	EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.		8.7e-03	MD	1.5e-01	
EOG-10, HR-3, #7-1		Confirm POSRV open status - POSRV leakage alarm and associated POSRV discharge line temperature	8.7e-03				1.3e-03
	EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.		8.7e-03	MD	1.5e-01	
EOG-10, HR-3, #7-2		Manually open ALL motor operated pilot valves.	8.7e-03				1.3e-03
	EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.		8.7e-03	MD	1.5e-01	
EOG-10, HR-3, #9		If pressurizer pressure is less than or equal to low pressurizer pressure SIAS setpoint, then ensure SIAS is actuated.	8.7e-03				1.3e-03
	EOG-10, HR-3, #10-b	Verify SI flow of each pump is greater than SI flow delivery curve.		8.7e-03	MD	1.5e-01	
		Total Unrecovered:	3.4e-02			Total Recovered:	5.1e-03

# **RPOPV-S-RTRIP**, Operater Fails to manually initiate reactor trip

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	1.6e-02	8.7e-03				
With Recovery	7.3e-03	4.4e-03	1.2e-02	5		

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All IEs except ATWS, SBO, RVR, PR-SL, LLOCA, ISLOCA, GRID-SBO, GRID-LOOP

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator initiates reactor trip signal manually.

5. Definition : Although reactor trip signal is not occurred, Operator should perform reactor trip when any clear cues or symptoms related reactor trip are detected. Operator knows how to perform reactor trip well and it is assumed that operator do it well. Once operator judged that reactor trip is needed, operator should perform this action immediately.

Cues and Indications			
Initial Cue	Reactor Power, CEA position		
Recovery Cue			
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	1.a.1			
Cognitive Instruction	Trip Rx			
Execution Procedure	EOG-01 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.				

Crew Member	Total	Required for	Notes
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	Available	Execution	
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

#### **Key Assumptions**

CBDTM is used for this HFE analysis. Reactor trip is the first action of SPTA and very well trained action. Therefore, diagnosis failure for this action will be low. Finally, CBDTM is chosen for this HFE action in spite of short diagnosis time.

Operator Interview Insights
Operator interview is not available in DC phase.
Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	74.00 Seconds			
T <sub>delay</sub>	30.70 Seconds			
T <sub>1/2</sub>	0.00 Seconds			
Τ <sub>M</sub>	15.00 Seconds			
Time available for recovery	0.47 Minutes			
SPAR-H Available time	0.47 Minutes			
(cognitive)				
SPAR-H Available time	2.89			
(execution) ratio				
Minimum level of dependence	HD			
for recovery				
Notes				

Tsw : Table 4-4, Analysis Report for ATWS Event of SKN 3&4, KOPEC/NED/TR/04-006

Cognitive Analysis				
Pc Failure Mechanism	Branch	HEP		
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.		
Notes: Operator can access to all informa	tion and required indication	to operate a plant in the		
main control room.				
<b>P</b> <sub>cb</sub> : Failure of Attention	i	neg.		
Notes: In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for		
CBDTM unless the work load relevant to a	a specific HFE cannot be jud	dged appropriately.		
This HFE is to initiate reactor trip signal manually and thus the operator only performs and one-time check of reactor trip alarm and status of related components and variables. It is not necessary to check them continuously.				
MCR because all of the controls in the modern control room are expected to be located in the front of the room.				
It is assumed that operators concentrate of	on EOG and performs EOG	-driven actions after		

reactor trip. Thus operators can not respo	ond to alarms until related p	arameter are mentioned
in the EOG step.		
P <sub>cc</sub> : Misread/miscommunicate data	a	neg.
Notes: It is assumed that required indica	tor on the control board suc	h as layout, demarcation,
labeling and others is always located eas	ily.	
With the advanced digital I&C interface in	the MCR, the indication is	assumed to be "good"
uniess there are scenario specific consid	erations to warrant otherwis	e, in which case,
Justification for the deviation will be provid	ded.	
transforred between energian	s will always be used when	the specified value is
liansierred between operators.	h	2.02.02
<b>P</b> <sub>cd</sub> . Information misleading	U r values does not estisfy the	
<b>Notes:</b> In this HFE, the related parameter	r values dose not satisfy the	e range of EOG
description values and related system do	es not respond automatical	ly(i.e. Failure of reactor
trip automatically). Thus operators recove	er reactor trip manually.	
The FOC provides contingenty actions wi	aich ara instructions on hour	to proceed if the aug
The EOG provides contingeny actions wi	lich are instructions on now	to proceed in the cue
States are not as stated.	2	3.02.03
Notos: It's assumed that it's always trans	naront for operators to proc	S.0E-03
instruction or stand along numbered stop	on the ECCs	
	on the EOGs.	
The MCR operator is not required to use	an an additional procedure i	n addition to the EOG so
"single" branch is selected for this HEE		
Only if there are special or distinct marks	are provided in the procedu	ire "YES" branch in the
"Graphically Distinct" should be selected		
The use of placekeeping aids is always a	ssumed to be used due to t	he nature of the
computerized procedure system (CPS) s	oftware, i.e., the operator wi	ill be required to confirm
completion of a step as the procedural ite	ems are addressed. Scena	rios for which deviations
from this assumption are possible, justific	ation for the choice made w	ill be provided.
P <sub>cf</sub> : Misinterpret Instructions	а	neg.
Notes: It is generally assumed that the w	ording of the procedures wi	Il be standard versus
ambiguous for the Misinterpret Instruction	n decision tree, pcf, of the C	BDTM.
	•••	
The step present all information required	to identify the actions direct	ed and their objects.
P <sub>cg</sub> : Misinterpret decision logic	g	1.0e-02
Notes: If diagnosis is performed just afte	r EOG-01 completion, selec	t sequence (a) or (b)
because "NOT, AND, OR, BOTH AND ar	nd OR" are present through	EOG01 and EOG02.
Otherwise, "No" branch should be selected	ed on the "NOT Statement"	branch. But this operator
action is considered and performed at the	e first step of EOG-01. Thus	it does not include NOT
statement.		
The operators are always trained and pra	cticed about specified scen	ario to perform.
P <sub>ch</sub> : Deliberate violation	а	neg.
Notes: The operators are always assume	ed to believe in the adequad	cy of instruction
presented.		
Initial P <sub>c</sub> (without recovery credited)		1.6e-02
	Notes	
Equipment Accessibility	MCR:	

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>e</sub>	3.0e-03	Х	Х	-	-	-	N/A	HD	2.5e-01		7.5e-04
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.0e-02	-	Х	-	-	-	N/A	-	5.0e-01		5.0e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited) 7.3e-					7.3e-03						
	Notes										

Execution Perfor	mance Shaping Factors			
Special Requirements	Tools	Adequate		
	Parts	Adequate		
	Clothing	Adequate		
Environment	Lighting	Normal		
	Heat	Normal		
	Radiation	Background		
	Atmosphere	Normal		
Equipment Accessibility	MCR	Accessible		
Stress	High			
	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			
Notes				
This HFE is to recover failed reactor trip actuation signal. This operator action have to be				
performed under limited time condition to prevent undesired plant state.				
Execution Complexity	Simple			

	Execution Unrecovered						
Procedure: EOG-01, SPTA			Comment				
Sten No	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride
otop no.			Table	Item			
	Trip Rx manually						
EOC 01	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#1.a.1		EOC	20-12	4	1.3E-3		
		Total Step HEP					
	Check Power Rate						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
EOG-01 #1.b		EOC	20-9	2	1.3E-3		
					Total S	tep HEP	8.7e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-01 #1.a.1		Trip Rx manually	8.7e-03				4.4e-03
	EOG-01 #1.b	Check Power Rate		8.7e-03	HD	5.0e-01	
		Total Unrecovered:	8.7e-03			Total Recovered:	4.4e-03

	<i>,</i> 1	5		
Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/23/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

# SIOPH-S-HLI, Operator Fails to Hot Leg Injection

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	CBDTM	THERP	CBDTM+THERP	
Without Recovery	1.3e-02	4.2e-03		
With Recovery	9.6e-05	2.2e-04	3.1e-04	10

#### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: LLOCA

3. Preceding operator error or success in sequence : Success of safety injection operation

4. Operator action success criterion : Operator should align valves of hot leg and DVI injection.

5. Definition : A large LOCA has occurred. The SITs successfully injected and Safety injection successfully started. Following the initial blowdown and recovery phase, simultaneous hot leg and direct vessel injection must be established to provide a recirculation flow through the core to prevent boron crystallization. Based on the post-LOCA long-term cooling analysis, it is estimated that hot leg injection should be initiated within 2-3 hours post-LOCA to prevent boric acid crystallization. Hot leg injection flow must be established through one of the two flow paths to prevent crystallization.

Two of the four Safety Injection (SI) trains have hot leg injection paths. The basic operator actions involved in establishing simultaneous hot leg and direct vessel injection include throttling SI flow to the DVI nozzle in the SI trains that will provide the hot leg injection by closing the injection valves and establishing flow to the hot legs by opening the appropriate valves. All required actions can be performed from the control room. Establishing simultaneous hot leg and DVI injection is covered in the Post-LOCA recovery procedures. The operators have been trained in the use of the procedures. Thus it is inferred that the operators have had training in establishing simultaneous hot leg and DVI injection.

This event represents failure of the operator to open the two motor-operated valves, in series, in each of the two hot leg paths. Operator actions to open the valves in each path are assumed to be completely coupled. Therefore, failure to perform these actions is considered as a single event.

	Cues and Indications
Initial Cue	Diagnosis of LOCA
Recovery Cue	
Cue Comments	

Degree of Clarity	Very Good

Procedures and Training				
Cognitive Procedure	EOG-04 (Revision: 0)			
Cognitive Step Number	38			
Cognitive Instruction	Perform Hot Leg Injection			
Execution Procedure	EOG-04 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, good procedure				

and appropriate training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

#### Dependencies (Related Human Interactions)

#### **Key Assumptions**

#### **Operator Interview Insights**

Operator interview is not available in DC phase.

	Timing Analysis				
T <sub>sw</sub>	180.00 Minutes				
T <sub>delay</sub>	120.00 Minutes				
T <sub>1/2</sub>	5.00 Minutes				
T <sub>M</sub>	10.00 Minutes				
Time available for recovery	45.00 Minutes				
SPAR-H Available time	50.00 Minutes				
(cognitive)					
SPAR-H Available time	5.50				
(execution) ratio					
Minimum level of dependence	LD				
for recovery					
Notes					
After 2 ~ 3 hour from SI injection operation on LLOCA or MLOCA sequence, the hot leg injection is					
required with DVI injection to prevent	t boron precipitation. APR1400 SSAR section 6.3.3.4.4				
deicribes that boric acid would begin	deicribes that boric acid would begin to precipitate about 3.25 hours post-LOCA with no core				

deicribes that boric acid would begin to precipitate about 3.25 hours post-LOCA with no core flushing flow. Therefore, when the operator initiates hot leg and direct vessel injection by three hours, there is no potential for hot leg entrainment and boric acid has not begun to precipitate. Delay time of 2 hours is assumed, becasuse EOG-04 step #4 require elapse time to initiate hot leg and direct vessel injection.

[EOG Driven Action] * T0 = LOCA occurrence
<ul> <li>* Tsw = 180 (Assumption)</li> <li>* Td = 120 (elapse time from LOCA to perform EOG-04 step #4)</li> <li>* T1/2 = 5 (Re-visitation to EOG-04 step #4 after elapse time of 2 hours)</li> <li>* Tm = 10 (conservative time to align SI flow path and verify)</li> </ul>
<ul> <li>TO = LOCA occurrence</li> <li>Tsw = 180 (Assumption)</li> <li>Td = 120 (elapse time from LOCA to perform EOG-04 step #4)</li> <li>T1/2 = 5 (Re-visitation to EOG-04 step #4 after elapse time of 2 hours)</li> <li>Tm = 10 (conservative time to align SI flow path and verify)</li> </ul>

Cognit	tive Analysis			
Pc Failure Mechanism	Branch	HEP		
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.		
Notes: Operator can access to all information	ation and required indication	to operate a plant in the		
main control room.				
<b>P</b> <sub>cb</sub> : Failure of Attention	а	neg.		
Notes: In general, within 2 hours from ac	cident initiation, work load is	s assumed to be high for		
CBDTM unless the work load relevant to	a specific HFE cannot be ju	dged appropriately.		
This HFE is to align valves of hot leg and performs and one-time check the status of necessary to check them continuously.	DVI injection manually and f related components and v	thus the operator only ariables. It is not		
MCR because all of the controls in the mo	odern control room are expe	ected to be located in the		
front of the room.				
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.		
Notes: It is assumed that required indicat	or on the control board such	n as layout, demarcation,		
labeling and others is always located eas	ily.			
With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid It is assumed that formal communications transferred between operators.	the MCR, the indication is a erations to warrant otherwise led. will always be used when t	assumed to be "good" e, in which case, he specified value is		
P <sub>cd</sub> : Information misleading	а	neg.		
Notes: Value of cues and parameters for	this HFE are described in the	he EOG. It is assumed		
that cues and parameters are indicated of	n the MCR.			
P <sub>ce</sub> : Skip a step in procedure	С	3.0e-03		
<b>Notes:</b> It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the EOGs.				
"single" branch is selected for this HFE. Only if there are special or distinct marks are provided in the procedure. "YES" branch in the				
"Graphically Distinct" should be selected.				
The use of placekeeping aids is always as	ssumed to be used due to the operator will	ne nature of the		
completion of a step as the procedural ite	ms are addressed Scena	rios for which deviations		
from this assumption are possible justific	ation for the choice made w	ill be provided		
$\mathbf{P}_{cf}$ . Misinterpret Instructions	a	neg.		

<b>Notes:</b> It is generally assumed that the we ambiguous for the Misinterpret Instruction	ording of the procedures w decision tree, pcf, of the C	ill be standard versus BDTM.			
The step present all information required to identify the actions directed and their objects.					
<b>P</b> <sub>cg</sub> : Misinterpret decision logic	g	1.0e-02			
<b>Notes:</b> This action is performed 2 hour af step #38 is considered for this tree.	ter DA procedure. Theref	ore, only the LOCA EOG			
The operators are always trained and pra-	cticed about specified scen	ario to perform.			
P <sub>ch</sub> : Deliberate violation	a	neg.			
<b>Notes:</b> The operators are always assumed to believe in the adequacy of instruction presented.					
Initial P <sub>c</sub> (without recovery credited)		1.3e-02			
Notes					
Equipment Accessibility	MCR: Accessible				

	Cognitive Recovery											
	Initial HEP	Self	Review	Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pc <sub>e</sub>	3.0e-03	Х		Х	-	-	-	N/A	LD	2.6e-02		7.8e-05
Pc <sub>f</sub>	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Pcq	1.0e-02	-		Х	Х	-	Х	N/A	LD	1.8e-03		1.8e-05
Pch	neg.	-		-	-	-	-	N/A	-	1.0e+00		
Fina	Pc (with re	COV	ery	cre	dited	)						9.6e-05
	Notes											
STA	STA review is possible through SFSC regarding RCS. CPS provides the tool to prevent skip a											
step	in the proce	dure	e. T	her	efore	self	revie	w is availab	le for pc	e.		

**Execution Performance Shaping Factors Special Requirements** Adequate Tools Parts Adequate Clothing Adequate Lighting Normal Environment Heat Normal Background Radiation Atmosphere Normal **Equipment Accessibility** MCR Accessible Stress Low Plant Response As Yes Expected: Workload: Low Performance Shaping Optimal Factors: Notes This operator action is required after 2 hours from initiator and success of SI. Thus, the plant

response as expected is assumed. It is expected that this operator action has enough available			
time and the action to be completed is simple. Therefore, low workload is selected.			
Execution Complexity Simple			

	Execution Unrecovered						
	Procedure: EOG-04, Loss of Coolant Accident		Com	ment			
Step No	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride
			Table	Item			
	Establish simulaneous hot leg and direct vessel injection						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
EOG-04 #38.a		EOC	20-12	10	3.8E-3		
					Total S	tep HEP	4.2e-03
EOG-04, SFSC	STA supervise "Establish simulaneous hot leg and direct vessel injection"	STA will t the conse Hot leg in LOCA see STA is po	be specially equences of jection is a quence. The pssible.	trained ir abnorma major eve erefore re	n mitigating al events. ent during ecovery by	1	
		EOM	20-70	1	4.30-04		
		FOC	20-9	2	1.3E-3		
					Total S	tep HEP	1.7e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-04 #38.a		Establish simulaneous hot leg and direct vessel injection	4.2e-03				2.2e-04
	EOG-04, SFSC	STA supervise "Establish simulaneous hot leg and direct vessel injection"		1.7e-03	LD	5.2e-02	
		Total Unrecovered:	4.2e-03			Total Recovered:	2.2e-04

	•	•	•	
Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/23/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

# SIOPH-S-INJ, Operator Fails to Align SCS for Injection

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	3.7e-02	3.0e-02				
With Recovery	5.1e-04	1.7e-03	2.2e-03	5		

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SLOCA, SGTR

3. Preceding operator error or success in sequence : Success of aggressive cooldown

4. Operator action success criterion : Operator aligns SCS system for injection.

5. Definition : A small LOCA or Steam Generator Tube Rupture (SGTR) has occurred and then secondary side heat removal is being successfully accomplished. However, the Safety Injection (SI) system fails to provide injection for inventory control. The Shutdown Cooling (SDC) pumps can be used for injection if the RCS can be depressurized below the SDC pump shutoff head before the core is uncovered and core damage begins. This can be accomplished if an aggressive cooldown using both steam generators is performed. During the Aggressive secondary cooldown, the operators must align the Shutdown Cooling (SDC) System for injection operation.

Cues and Indications				
Initial Cue	EOG-10, IC-2 Step 3			
Recovery Cue	RCS subcooling, temperature and pressure			
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training		
Cognitive Procedure	EOG-10, IC-2 (Revision: 0)	
Cognitive Step Number	9	
Cognitive Instruction	Check SI flow	
Execution Procedure	EOG-10, IC-2 (Revision: 0)	
Job Performance Measure		
Classroom Training	None	
Simulator Training	None	
Notes		

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## Dependencies (Related Human Interactions)

#### Key Assumptions

**Operator Interview Insights** 

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	240.00 Minutes			
T <sub>delay</sub>	136.00 Minutes			
T <sub>1/2</sub>	5.00 Minutes			
T <sub>M</sub>	30.00 Minutes			
Time available for recovery	69.00 Minutes			
SPAR-H Available time	74.00 Minutes			
(cognitive)				
SPAR-H Available time	3.30			
(execution) ratio				
Minimum level of dependence	ZD			
for recovery				

Notes

For this operator action, the ASC action must be performed previously. This action is performed at FRG IC-2 step #9 as a contingency action and the ACS action is performed at FRG IC-2 step #3.

Per MAAP Analysis for SLOCA sequence, (refer to Table 5-5 3(a)~4(p) of the Success Criteria Notebook)

1. Rx Trip : 0 hr (133.859 sec)

2. ASC completion timing for no core damage : 40 min (2403.208 sec)

3. Core uncovery : 1.25 hr (4511.184 sec)

4. RCS press. To SCP shutoff head : 2.2 hr (8183.782 sec)

[EOG Driven Action]

- \* T0 = Accident occurrence
- \* Tsw = 240 min (conservative assumption based on MAAP Analysis)
- \* Td = 136 min (RCS Press to SCP shutoff head)
- \* T1/2 = 5 min (FRG IC-2 step #4~8 after ASC success)
- \* Tm = 30 min (sufficient conservative time for pump start and valve alignment)

#### **Cognitive Analysis**

Pc Failure Mechanism	Branch	HEP			
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.			
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the			
main control room.					
<b>P</b> <sub>cb</sub> : Failure of Attention	m	1.5e-02			
Notes: In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for			
CBDTM unless the work load relevant to a	a specific HFE cannot be jue	dged appropriately.			
Operator have to monitor the depressurize	ation of RCS.				
It's assumed that the indicator to be check	ked is always displayed on t	he front panel of the			
MCR because all of the controls in the mo	odern control room are expe	cted to be located in the			
front of the room.					
It is assumed that operators concentrate (	on EOG and performs EOG	driven actions after			
reactor trin. Thus operators can not respo	and to alarms until related pa	rameter are mentioned			
in the EOG step	ind to alarms until related pa	arameter are mentioned			
P · Misread/miscommunicate data	а	neg			
Notes: It is assumed that required indicat	or on the control board such	as layout demarcation			
labeling and others is always located easi		rus layeat, demarcation,			
With the advanced digital I&C interface in	the MCR, the indication is a	assumed to be "good"			
unless there are scenario specific conside	erations to warrant otherwise	e, in which case,			
iustification for the deviation will be provided.					
It is assumed that formal communications	will always be used when t	he specified value is			
transferred between operators.	-				
P <sub>cd</sub> : Information misleading	b	3.0e-03			
Notes: In this HFE, the related parameter	values dose not satisfy the	range of EOG			
description values and related system doe	es not respond automaticall	y(i.e. Failure of SIP			
operation). Thus operators performs aggr	essive cooldown and use S	CS.			
	ish and is the discussion of here.				
The EOG provides contingeny actions wh	ich are instructions on now	to proceed if the cue			
States are not as stated.	2	2.02.02			
P <sub>ce</sub> . Skip a step in procedure	U Descent for exercises to press	3.0E-03			
instruction or stand along numbered stan	on the EQCs				
	on the EOGs.				
The MCR operator is not required to use a	an an additional procedure ir	addition to the EOG so			
"single" branch is selected for this HEF					
Only if there are special or distinct marks	are provided in the procedu	re. "YES" branch in the			
"Graphically Distinct" should be selected.		-,			
The use of placekeeping aids is always as	ssumed to be used due to the	ne nature of the			
computerized procedure system (CPS) software, i.e., the operator will be required to confirm					
completion of a step as the procedural items are addressed. Scenarios for which deviations					
from this assumption are possible, justification	ation for the choice made w	ill be provided.			
P <sub>cf</sub> : Misinterpret Instructions a neg.					
Notes: It is generally assumed that the wording of the procedures will be standard versus					
ambiguous for the Misinterpret Instruction decision tree, pcf, of the CBDTM.					
I he step present all information required	to identify the actions directer	ed and their objects.			
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02			

**Notes:** If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b) because "NOT, AND, OR, BOTH AND and OR" are present through EOG01 and EOG02. Otherwise, "No" branch should be selected on the "NOT Statement" branch.

The operators are always trained and pra	cticed about specified scena	ario to perform.		
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.		
Notes: The operators are always assumed to believe in the adequacy of instruction				
presented.				
Initial P <sub>c</sub> (without recovery credited)		3.7e-02		
Notes				
Equipment Accessibility	MCR: Accessible			

						Cog	gnitive Reco	overy			
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	1.5e-02	-	-	Х	-	-	N/A	ZD	1.5e-02		2.3e-04
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc <sub>e</sub>	3.0e-03	Х	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-	-	Х	-	-	N/A	ZD	1.6e-02		2.6e-04
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 5.1e-04										
	Notes										
STA	STA review is possible through RCS inventory control section of SFSC. CPS provides the tool to										

prevent skip a step in the procedure. Therefore self review is available for pce.

Execution Performance Shaping Factors				
Special Requirements	Tools	Adequate		
	Parts	Adequate		
	Clothing	Adequate		
Environment	Lighting	Normal		
	Heat	Normal		
	Radiation	Background		
	Atmosphere	Normal		
Equipment Accessibility	MCR	Accessible		
Stress	High			
	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			
	Notes			
Although this operator action is required after success of aggressive cooldown, aggressvie				
cooldown and this operator action are needed to recover the failure of Safety injection operation				
after initiator.				
Execution Complexity	Simple			

	Execution Unrecovered						
Procedure: EO	Procedure: EOG-10, IC-2, Functional Recovery Guideline - RCS Inventory Control, Safety Injection		Com	ment	Stress Factor		
Sten No	No Instruction/Comment		THERP			HEP	Over Ride
etop nor		Туре	Table	Item	1		
	SCS Valves align (in MCR)	Jog contr	ol type MO	/			
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#9.2.4-1		EOC	20-12	10	3.8E-3		
					Total S	Step HEP	2.1e-02
	SCS Pump Start						
EOG-10 IC-2	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#9.2.4-3		EOC	20-12	4	1.3E-3		
					Total S	Step HEP	8.7e-03
	Check and Write the Safety Function Status						
EOG-10,IC2 #10	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-9	2	1.3E-3		
					Total S	Step HEP	8.7e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-10,I C-2 #9.2.4-1		SCS Valves align (in MCR)	2.1e-02				1.2e-03
	EOG-10,IC2 #10	Check and Write the Safety Function Status		8.7e-03	LD	5.8e-02	
EOG-10,I C-2 #9.2.4-3		SCS Pump Start	8.7e-03				5.1e-04
	EOG-10,IC2 #10	Check and Write the Safety Function Status		8.7e-03	LD	5.8e-02	
		Total Unrecovered:	3.0e-02			Total Recovered:	1.7e-03

# SIOPH-S-IRWSTCOOL, Operator Fails to Cool IRWST Water Using SCS Pump

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/23/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary						
P <sub>cog</sub> P <sub>exe</sub> Total HEP Error Factor						
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	6.0e-03	3.0e-02				
With Recovery	3.6e-05	2.6e-04	2.9e-04	10		

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SLOCA, SGTR, SBO, PR-SL, PLOESW, PLOCCW, LSSB-U, LSSB-D, LOOP, LOIA, LOFW, LODCA, LODCB, LOCV, GTRN, GRID-LOOP, FWLB

3. Preceding operator error or success in sequence : Success of Feed and Bleed operation.

4. Operator action success criterion : Operator should align valves and initiate SC pump.

5. Definition : A transient (Loss of Feedwater, Loss of CCW, etc.) has occurred and then reactor trip was successful. Auxiliary Feedwater failed and was not restored. Feed & Bleed operation to cool the RCS was successfully established. It is assumed that operators are trained to initiate the IRWST cooling after during F&B operation because it is one of SC system functions.

Cues and Indications		
Initial Cue	Success of F&B, IRWST Water Temperature	
Recovery Cue		
Cue Comments		
Degree of Clarity	Very Good	

Procedures and Training			
Cognitive Procedure	EOG-10, HR3 (Revision: 0)		
Cognitive Step Number	XXX		
Cognitive Instruction	Cool the IRWST using SDC system		
Execution Procedure	EOG-10, HR3 (Revision: 0)		
Job Performance Measure			
Classroom Training	None		
Simulator Training	None		
Notes			
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.			

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	1	

## Dependencies (Related Human Interactions)

## Key Assumptions

**Operator Interview Insights** 

Operator interview is not available in DC phase.

	Timing Analysis	
T <sub>sw</sub>	150.00 Minutes	
T <sub>delay</sub>	70.00 Minutes	
T <sub>1/2</sub>	5.00 Minutes	
T <sub>M</sub>	2.00 Minutes	
Time available for recovery	73.00 Minutes	
SPAR-H Available time	78.00 Minutes	
(cognitive)		
SPAR-H Available time	37.50	
(execution) ratio		
Minimum level of dependence	ZD	
for recovery		
	Notes	
Per MAAP analysis for LOFW sequence, (refer to Table 5-9 case 5(a) of the Success Criteria Notebook) 1. Rx Trip : 0 hr (22.126 sec) 2. Core uncovery : 0.88 hr (3171.808 sec) 3. F&B completion timing : 70 min 4. IRWST cooling failure : 2.6 hr ( 9397.431 sec) 5. Core Damage : 3.4 hr (13017.929 sec) [System Operating Procedure Driven Action] * T0 = Accident occurrence		
<ul> <li>Tsw = 150 min (based on MAAP Analysis)</li> <li>* Td = 70 min (based on MAAP Analysis)</li> <li>* T1/2 = 5 min (step location assumption for IRWST cooling within 20 procedure steps after F&amp;B completion)</li> <li>* Tm = 2 min (time for pump start and valve alignment)</li> </ul>		

Cognitive Analysis						
Pc Failure Mechanism	Branch	HEP				
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.				
Notes: Operator can access to all information and required indication to operate a plant in the						

main control room.							
<b>P</b> <sub>cb</sub> : Failure of Attention	h	neg.					
<b>Notes:</b> In general, within 2 hours from ac CBDTM unless the work load relevant to	cident initiation, work load is a specific HFE cannot be jud	assumed to be high for dged appropriately.					
This HFE is to perform IRWST cooling and thus the operator only performs and one-time check of IRWST temperature alarm and status of related components and variables. It is not necessary to check them continuously.							
It's assumed that the indicator to be chec MCR because all of the controls in the mo front of the room.	ked is always displayed on t odern control room are expe	he front panel of the cted to be located in the					
It is assumed that operators concentrate reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG and to alarms until related pa	-driven actions after arameter are mentioned					
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.					
Notes: It is assumed that required indicat labeling and others is always located eas With the advanced digital L&C interface in	or on the control board such ily.	as layout, demarcation,					
unless there are scenario specific conside justification for the deviation will be provid	erations to warrant otherwise led.	e, in which case,					
It is assumed that formal communications transferred between operators.	will always be used when t	he specified value is					
P <sub>cd</sub> : Information misleading	а	neg.					
<b>Notes:</b> The step of procedure for this action	on is not available now. But	it is assumed that					
P : Skip a stop in procedure							
Notoc: It's assumed that it's always traps	y	0.0e-03					
The MCR operator is required to use an a "multiple" branch is selected for this HFE.	an additional procedure in ad	ddition to the EOG, so					
Only if there are special or distinct marks "Graphically Distinct" should be selected.	are provided in the procedu	re, "YES" branch in the					
The use of placekeeping aids is always a computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justific	ssumed to be used due to the optimate of the operator will make and dressed. Scenariation for the choice made w	ne nature of the I be required to confirm rios for which deviations ill be provided.					
P <sub>cf</sub> : Misinterpret Instructions	а	neg.					
<b>Notes:</b> It is generally assumed that the w ambiguous for the Misinterpret Instruction	ording of the procedures wil decision tree, pcf, of the CI	l be standard versus 3DTM.					
The step present all information required	to identify the actions direct	ed and their objects.					
P <sub>cg</sub> : Misinterpret decision logic	k	neg.					
Notes: If diagnosis is performed just after because "NOT, AND, OR, BOTH AND ar Otherwise "No" branch should be selected	r EOG-01 completion, select d OR" are present through I ed on the "NOT Statement" t	t sequence (a) or (b) EOG01 and EOG02. Dranch But in this HEE					

EOG does not considered. Thus it is assumed that the "NOT, AND, OR, BOTH AND and OR" statements are not included, because the system operating procedure describes clearly related actions.

The operators are always trained and practiced about specified scenario to perform.					
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.			
Notes: The operators are always assumed to believe in the adequacy of instruction					
presented.					
Initial P <sub>c</sub> (without recovery credited)		6.0e-03			
Notes					
It is assumed that this action is performed according to the alarm response procedure/system operation procedure.					

Equipment Accessibility

MCR: Accessible

	Cognitive Recovery												
	Initial HEP	Self	Review	Extra Crew	STA	Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pcb	neg.	-		I	-		-	-	N/A	-	1.0e+00		
Pcc	neg.	-		I	-		-	-	N/A	-	1.0e+00		
Pcd	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pce	6.0e-03	Х	2	-	-		-	-	N/A	ZD	6.0e-03		3.6e-05
Pc <sub>f</sub>	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pcg	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Pch	neg.	-		-	-		-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)					3.6e-05								
Notes													
CPS for po	CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for pce.												

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
This operator action is required to recover the failure of IRWST temperature and has some delay						
time due to POSRVs operation. Thus, This operator action have to be performed under limited						
condition to prevent undesired plant state.						
Execution Complexity	Simple					

	Execution Unrecovered							
Procedure: EOG-10, HR3, Functional Recovery Guideline - Core and RCS Heat Removal Once-Through-Cooling			Com	01				
Step No.	Instruction/Comment		THERP		HEP	Factor	Over Ride	
			Table	Item				
	Align Valves (in MCR)							
	Location: MCR	EOM	20-7b	1	4.3e-04	5		
SYS-xx, #xx-1		EOC	20-12	10	3.8E-3			
					Total Step HEP		2.1e-02	
	Start SDC PP							
EVE w the 2	Location: MCR	EOM	20-7b	1	4.3e-04	5		
515-XX, #XX-2		EOC	20-12	4	1.3E-3			
					Total S	Step HEP	8.7e-03	
	Check SDC flow and IRWST Temp							
0.40 // 0	Location: MCR	EOM	20-7b	1	4.3e-04	5		
SYS-xx, #xx-3		EOC	20-9	2	1.3E-3			
	Total Step HEP							

	Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step		
SYS-xx, #xx-1		Align Valves (in MCR)	2.1e-02				1.8e-04		
	SYS-xx, #xx-3	Check SDC flow and IRWST Temp		8.7e-03	ZD	8.7e-03			
SYS-xx, #xx-2		Start SDC PP	8.7e-03				7.6e-05		
	SYS-xx, #xx-3	Check SDC flow and IRWST Temp		8.7e-03	ZD	8.7e-03			
		Total Unrecovered:	3.0e-02			Total Recovered:	2.6e-04		

# SIOPH-S-LTC-SC, Operator Fails to Align SCS For Long Term Cooling

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	$P_{cog}$	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	3.3e-03	1.0e-02					
With Recovery	9.1e-06	5.2e-04	5.3e-04	10			

#### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SGTR, LSSB-D

3. Preceding operator error or success in sequence : success of RCS cooldown

4. Operator action success criterion : Operator aligns valves and initiates SC pump for long term cooling.

5. Consequence of failure : Core Damage

6. Definition : Following an accident or a transient, the plant will be brought down to shutdown cooling entry conditions using secondary side heat removal in about 6 to 8 hours. Shutdown cooling is then initiated by aligning the SCS for the long-term decay heat removal.

## **Assigned Basic Events**

	Cues and Indications
Initial Cue	RCS pressure and temperature, RVUH Level, Subcooling
	Margin
Recovery Cue	
Cue Comments	
Degree of Clarity	Very Good

Procedures and Training				
Cognitive Procedure	EOG-05 (Revision: 00)			
Cognitive Step Number	45			
Cognitive Instruction Enter into SCS operation procedure				
Execution Procedure	SYS-SDC (Revision: xx)			
Job Performance Measure				
Classroom Training	None			
Simulator Training None				
Notes				
The procedure and training informati	on is not available in DC phase. However, APR1400 ECC is			

The procedure and training information is not available in DC phase. However, APR1400 EOG is

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	1	

## Dependencies (Related Human Interactions)

#### **Key Assumptions**

#### **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis		
T <sub>sw</sub>	240.00 Minutes	
T <sub>delay</sub>	0.00 Minutes	
T <sub>1/2</sub>	20.00 Minutes	
T <sub>M</sub>	30.00 Minutes	
Time available for recovery	190.00 Minutes	
SPAR-H Available time	210.00 Minutes	
(cognitive)		
SPAR-H Available time	7.33	
(execution) ratio		
Minimum level of dependence	ZD	
for recovery		
Notes		
Asservition to the MAAD evolution there is usual times for this LICC in the same of valuated excident		

According to the MAAP analysis, there is much time for this HFE in the case of related accident scenarios. Thus the Tsw is conservatively assumed 4 hours.

Cognitive Analysis			
Pc Failure Mechanism	Branch	HEP	
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.	
<b>Notes:</b> Operator can access to all information and required indication to operate a plant in the			
main control room.			
<b>P</b> <sub>cb</sub> : Failure of Attention	а	neg.	
<ul> <li>Notes: In general, within 2 hours from accident initiation, work load is assumed to be high for CBDTM unless the work load relevant to a specific HFE cannot be judged appropriately.</li> <li>This HFE is to align and initiate SCS and thus the operator only performs and one-time check of RCS temperature, pressure and subcooling and status of related components and variables. It is not necessary to check them continuously.</li> <li>It's assumed that the indicator to be checked is always displayed on the front panel of the MCR because all of the controls in the modern control room are expected to be located in the front of the room.</li> </ul>			
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.	
**Notes:** It is assumed that required indicator on the control board such as layout, demarcation, labeling and others is always located easily. With the advanced digital I&C interface in the MCR, the indication is assumed to be "good" unless there are scenario specific considerations to warrant otherwise, in which case, justification for the deviation will be provided. It is assumed that formal communications will always be used when the specified value is transferred between operators. **P**<sub>cd</sub>: Information misleading а neg. Notes: Value of cues and parameters for this HFE are described in the EOG. It is assumed that cues and parameters are indicated on the MCR. P<sub>ce</sub>: Skip a step in procedure 3.0e-03 C Notes: It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the EOGs. The MCR operator is not required to use an an additional procedure in addition to the EOG, so "single" branch is selected for this HFE. Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected. The use of placekeeping aids is always assumed to be used due to the nature of the computerized procedure system (CPS) software, i.e., the operator will be required to confirm completion of a step as the procedural items are addressed. Scenarios for which deviations from this assumption are possible, justification for the choice made will be provided. **P**<sub>cf</sub>: Misinterpret Instructions а neg. Notes: It is generally assumed that the wording of the procedures will be standard versus ambiguous for the Misinterpret Instruction decision tree, pcf, of the CBDTM. The step present all information required to identify the actions directed and their objects. **P**<sub>ca</sub>: Misinterpret decision logic 3.0e-04 Notes: SDC entry is last step for accident mitigation. Therefore, the step for SDC entry only is considered for this tree. The operators are always trained and practiced about specified scenario to perform. **P**<sub>ch</sub>: Deliberate violation neq. а **Notes:** The operators are always assumed to believe in the adequacy of instruction presented. Initial P<sub>c</sub>(without recovery credited) 3.3e-03 Notes Equipment Accessibility MCR: Accessible

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		

Pce	3.0e-03	Х	-	-	-	-	N/A	ZD	3.0e-03	9.0e-06
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00	
Pcg	3.0e-04	-	-	Х	-	-	N/A	ZD	3.0e-04	9.0e-08
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00	
Fina	Final Pc (with recovery credited) 9.1e-06									
	Notes									
STA review is possible through RCS pressure and heat removal section of SFSC. CPS provides										
the to	the tool to prevent skip a step in the procedure. Therefore self review is available for pce.									

Execution Performance Shaping Factors						
Special Requirements	Tools	Adequate				
	Parts	Adequate				
	Clothing	Adequate				
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	Low					
	Plant Response As	Yes				
	Expected:					
	Workload:	Low				
	Performance Shaping	Optimal				
	Factors:					
Notes						
This operator action is required after the success of RCS cooling, therefore, plant response as						
expected is assumed. This operator actions has enough time and sufficient operators are						
available to complete. Thus low workload is selected.						
Execution Complexity Simple						

	Execution Unrec	covered					
	Procedure: SYS-SDC, Shutdown Cooling System		Com	ment			
Step No.	Instruction/Comment	Error	THERP		HED	Stress Factor	Over Ride
		Туре	Table	Item			
	Align Valves (in MCR)						
SYS-SDC #xx-1	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-12	10	3.8E-3		
					Total S	Step HEP	4.2e-03
SYS-SDC #xx-2	Start SDC PP						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-12	4	1.3E-3		
			•		Total S	Step HEP	1.7e-03
	Check SDC flow and RCS Temp						
SYS-SDC	Location: MCR	EOM	20-7b	1	4.3e-04	1	
#xx-3		EOC	20-9	2	1.3E-3		
		<u>.</u>			Total S	Step HEP	1.7e-03
	Throttle SI Flow						
SYS-SDC	Location: MCR	EOM	20-7b	1	4.3e-04	1	
#XX-4		EOC	20-12	10	3.8E-3		
					Total S	Step HEP	4.2e-03
	Verify SI Flow Rate						
SYS-SDC	Location: MCR	EOM	20-7b	1	4.3e-04	1	
#XX-5		EOC	20-9	2	1.3E-3		
			-		Total S	Step HEP	1.7e-03

	Execution Recovered									
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step			
SYS-SD C #xx-1		Align Valves (in MCR)	4.2e-03				2.2e-04			
	SYS-SDC #xx-3	Check SDC flow and RCS Temp		1.7e-03	LD	5.2e-02				
SYS-SD C #xx-2		Start SDC PP	1.7e-03				8.8e-05			
	SYS-SDC #xx-3	Check SDC flow and RCS Temp		1.7e-03	LD	5.2e-02				
SYS-SD C #XX-4		Throttle SI Flow	4.2e-03				2.2e-04			
	SYS-SDC #XX-5	Verify SI Flow Rate		1.7e-03	LD	5.2e-02				
		Total Unrecovered:	1.0e-02			Total Recovered:	5.2e-04			

# SIOPH-S-SPRAYBACK, Operator Fails to Connect SCS Pump for Containment Spray

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/24/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	6.0e-03	1.7e-02					
With Recovery	3.6e-05	1.5e-04	1.9e-04	10			

### **Identification and Definition**

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SLOCA, SGTR. SBO, PR-SL, PLOESW, PLOCCW, LSSB-U, LSSB-D, LOOP, LOIA, LOFW, LODCA, LODCB, LOCV, GTRN, GRID-LOOP, FWLB

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should align valves and initiate SC pump for containment spray flow.

5. Definition : When CS operation is needed, if CS is unavailable, SC can perform containment spray. SC has motor operated pumps and heat exchangers which are same type of CS. They are connected through cross-line for replacing when one is failed. To use SC for containment spray, operator should open related valves.

Cues and Indications					
Initial Cue	Containment Pressure				
Recovery Cue					
Cue Comments					
Degree of Clarity	Very Good				

Procedures and Training						
Cognitive Procedure	ARP-xxxx (Revision: 00)					
Cognitive Step Number	XX					
Cognitive Instruction	Initive Instruction Establish CS Flow					
Execution Procedure SYS-CS (Revision: xx)						
Job Performance Measure						
Classroom Training	None					
Simulator Training	None					
Notes						
The procedure and training informati	The procedure and training information is not available in DC phase. However, good procedure					

and appropriate training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## Dependencies (Related Human Interactions)

## **Key Assumptions**

#### **Operator Interview Insights**

Timing Analysis					
T <sub>sw</sub>	240.00 Minutes				
T <sub>delay</sub>	17.00 Minutes				
T <sub>1/2</sub>	20.00 Minutes				
T <sub>M</sub>	30.00 Minutes				
Time available for recovery	173.00 Minutes				
SPAR-H Available time	193.00 Minutes				
(cognitive)					
SPAR-H Available time	6.77				
(execution) ratio					
Minimum level of dependence	ZD				
for recovery					
Notes					

Delay - CSAS

This event is a backup action for containment spray. Usually this action is required after the failure of CS system.

Per MAAP analysis for MLOCA sequence, (refer to Table 5-6 1(b) of the Success Criteria Notebook)

- 1. Rx Trip : 0 hr (14.840 sec)
- 2. CSAS Generation : 0.3 hr (1000.124 sec)
- 3. Core Damage : no occurrence within 24 hours

[ARP/System Operating Procedure Driven Action]

- \* T0 = Accident Occurrence, Rx Trip
- \* Tsw = 240 min (Core damage does not occur within 24 hours based on MAAP Analysis)
- \* Td = 17 min (CS operation time)
- \* T1/2 = 20 min (more 10 minutes is assumed after CS system failure)
- \* Tm = 30 min (sufficient conservative time due to uncertainty of pump and valve alignment)

Cogni	tive Analysis	
Pc Failure Mechanism	Branch	HEP
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.
Notes: Operator can access to all information	ation and required indication	to operate a plant in the
main control room.		
<b>P</b> <sub>cb</sub> : Failure of Attention	h	neg.
Notes: If additional procedure is required	, the high workload is assun	ned.
I his HFE is to aligh valves and initiate Su	pump and thus the operate	or only performs and
one-time check of CS now and the status	or related components and	variables. It is not
necessary to check them continuously.		
It's assumed that the indicator to be chec	ked is always displayed on t	the front nanel of the
MCR because all of the controls in the m	ndern control room are expe	acted to be located in the
front of the room		
This HFE is performed in the late phase a	after initiating event occurred	d. It means that it takes
for long time to perform this HFE. Thus of	perator response related ala	irms with ARP.
P <sub>cc</sub> : Misread/miscommunicate data	a	neg.
Notes: It is assumed that required indicat	or on the control board such	n as layout, demarcation,
labeling and others is always located eas	ily.	•
	2	
With the advanced digital I&C interface in	the MCR, the indication is a	assumed to be "good"
unless there are scenario specific conside	erations to warrant otherwise	e, in which case,
justification for the deviation will be provid	led.	
It is assumed that formal communications	s will always be used when t	he specified value is
transferred between operators.	1	
P <sub>cd</sub> : Information misleading	a a	neg.
Notes: Value of cues and parameters for	this HFE are described in the	he ARP and system
operating procedure. It is assumed that c	ues and parameters are indi	
P <sub>ce</sub> : Skip a step in procedure	g	6.0e-03
<b>Notes:</b> It's assumed that it's always trans	parent for operators to proc	eed the relevant
Instruction of stand-alone numbered step	on the EOGs.	
The MCP operator is not required to use a	an an additional procedure in	$\mathbf{r}$
"single" branch is selected for this HEE		raddition to the LOG, so
Only if there are special or distinct marks	are provided in the procedu	re "YES" branch in the
"Graphically Distinct" should be selected.		,
The use of placekeeping aids is always a	ssumed to be used due to the	ne nature of the
computerized procedure system (CPS) se	oftware, i.e., the operator will	Il be required to confirm
completion of a step as the procedural ite	ms are addressed. Scena	rios for which deviations
from this assumption are possible, justific	ation for the choice made w	ill be provided.
P <sub>cf</sub> : Misinterpret Instructions	а	neg.
Notes: It is generally assumed that the w	ording of the procedures wil	l be standard versus
ambiguous for the Misinterpret Instruction	n decision tree, pcf, of the Cl	BDTM.
The step present all information required	to identify the actions direct	ed and their objects.
P <sub>cq</sub> : Misinterpret decision logic	k k	neg.
Notes: If diagnosis is performed just after	r EOG-01 completion, select	t sequence (a) or (b)
because "NOT, AND, OR, BOTH AND ar	d OR" are present through	EOG01 and EOG02.
Otherwise, "No" branch should be selected	ed on the "NOT Statement" I	branch. But, in this HFE,

EOG does not considered. Thus it is assumed that the "NOT, AND, OR, BOTH AND and OR" statements are not included, because the ARP describes clearly related actions.

The operators are always trained and practiced about specified scenario to perform.				
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.		
Notes: The operators are always assumed to believe in the adequacy of instruction				
presented.				
Initial P <sub>c</sub> (without recovery credited)		6.0e-03		
Notes				
Equipment Accessibility	MCR: Accessible			

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	6.0e-03	Х	-	-	-	-	N/A	ZD	6.0e-03		3.6e-05
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)3.6e-05											
	Notes										
CDG	CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available										

CPS provides the tool to prevent skip a step in the procedure. Therefore self review is available for pce.

Execution Perfor	Execution Performance Shaping Factors				
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			
	Expected:				
	Workload:	N/A			
	Performance Shaping	N/A			
	Factors:				
Notes					
This HFE is to recover the failure of CS system. This operator action have to be performed under					
limited condition to prevent undesired plant state.					
Execution Complexity	Simple				

	Execution Unrecovered						
	Procedure: SYS-CS, Containment Spray System			ment			
Sten No	Instruction/Comment	Error	THERP		LED	Stress Factor	Over Ride
Step No.			Table	Item			
	Align Valves (in MCR)						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
SYS-CS #xx-1		EOC	20-12	4	1.3E-3		
					Total S	Step HEP	8.7e-03
	Start SDC PP						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
SYS-CS #xx-2		EOC	20-12	4	1.3E-3		
				•	Total S	step HEP	8.7e-03
	Check CS flow and Containment Pressure						
SYS-CS #xx-3	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-9	2	1.3E-3		
			-	•	Total S	Step HEP	8.7e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
SYS-CS #xx-1		Align Valves (in MCR)	8.7e-03				7.6e-05
	SYS-CS #xx-3	Check CS flow and Containment Pressure		8.7e-03	ZD	8.7e-03	
SYS-CS #xx-2		Start SDC PP	8.7e-03				7.6e-05
	SYS-CS #xx-3	Check CS flow and Containment Pressure		8.7e-03	ZD	8.7e-03	
		Total Unrecovered:	1.7e-02			Total Recovered:	1.5e-04

# SIOPV-S-SIAS, Operator Fails to Manually Initiate all channels via MCR for SIAS

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/17/13
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary						
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor		
Method	CBDTM	THERP	CBDTM+THERP			
Without Recovery	2.2e-02	8.7e-03				
With Recovery	4.6e-03	1.3e-03	5.9e-03	5		

### Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: SLOCA, SGTR, PR-SL, PLOESW, PLOCCW, MLOCA, LSSB-U, LSSB-D, LLOCA, FWLB

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should initiate the SIAS manually.

5. Definition : After LOCA and reactor trip, SIAS will be automatically actuated in short time. For RCS inventory, SI pumps are started and MOVs are opened. If SIAS is failed and these are not actuated, operator should actuate them manually in MCR.

Cues and Indications			
Initial Cue	PZR Pressure		
Recovery Cue	SI Flow		
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training				
Cognitive Procedure	EOG-01 (Revision: 0)			
Cognitive Step Number	4			
Cognitive Instruction	struction Check PZR pressure and initiate SIAS			
Execution Procedure	EOG-01 (Revision: 0)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action				
used and training is assumed for this				

Crew Member	Total	Required for	Notes

	Available	Execution	
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## **Dependencies (Related Human Interactions)**

## **Key Assumptions**

Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub>	20.00 Minutes			
T <sub>delay</sub>	0.00 Minutes			
T <sub>1/2</sub>	3.00 Minutes			
T <sub>M</sub>	1.00 Minutes			
Time available for recovery	16.00 Minutes			
SPAR-H Available time	19.00 Minutes			
(cognitive)				
SPAR-H Available time	17.00			
(execution) ratio				
Minimum level of dependence	MD			
for recovery				
Notos				

In the LLOCA sequence, SIT injection function for RCS inventory control is considered in the accident sequence analysis. However, in the MLOCA sequence, SIT injection function is not considered as a RCS inventory control based on the success criteria analysis. Therefore, MLOCA without SIT injection is the most severe sequence for this HFE, because time to core damage is the shortest in MLOCA sequence without SIT injection.

Per MAAP analysis for MLOCA sequence, (refer to Table 5-6 1(a) of the Success Criteria Notebook)

- 1. Rx Trip : 0 hr (14.840 sec)
- 2. SIAS Generation : 0 hr (15.305 sec)
- 3. Core uncovery : 0.2 hr (673.463 sec)
- 4. Core Damage : 0.3 hr (1244.255 sec)

[EOG Driven Action]

- \* T0 = Accident Occurrence, Rx Trip
- \* Tsw = 20 min (core damage by MAAP Analysis)
- \* Td = 0 min
- \* T1/2 = 3 min (SPTA step #4)
- \* Tm = 1 min

## **Cognitive Analysis**

Pc Failure Mechanism	Branch	HEP					
P <sub>ca</sub> : Availability of Information	а	neg.					
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the					
main control room.							
P <sub>cb</sub> : Failure of Attention	i	neg.					
<b>Notes:</b> In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for					
CBDTM unless the work load relevant to a	a specific HFE cannot be jue	dged appropriately.					
This HFE is to initiate SIAS manually and	thus the operator only perfo	orms and one-time check					
of SIAS alarm and status of related compo	onents and variables. It is no	ot necessary to check					
them continuously.							
It's assumed that the indicator to be abeal	red is always displayed on t	be front popul of the					
MCR because all of the controls in the mo	dorn control room are even	ne itoni panel of the					
front of the room	dem control room are expe						
It is assumed that operators concentrate of	on EOG and performs EOG	-driven actions after					
reactor trip. Thus operators can not respo	ind to alarms until related pa	arameter are mentioned					
in the EOG step.							
P <sub>oc</sub> : Misread/miscommunicate data	а	nea.					
Notes: It is assumed that required indicat	or on the control board such	as layout, demarcation.					
labeling and others is always located easi	ly.	,,					
	,						
With the advanced digital I&C interface in	the MCR, the indication is a	assumed to be "good"					
unless there are scenario specific conside	erations to warrant otherwise	e, in which case,					
justification for the deviation will be provid	ed.						
It is assumed that formal communications	will always be used when t	he specified value is					
transferred between operators.	L	0.0.00					
P <sub>cd</sub> : Information misleading		3.0e-03					
<b>Notes:</b> In this HFE, the related parameter	values dose hot satisfy the	range of EUG					
automatically). Thus operators recover SI		y(i.e. Failure of SIAS					
automatically). Thus operators recover St.	AS manually.						
The EOG provides contingeny actions wh	ich are instructions on how	to proceed if the cue					
states are not as stated							
$\mathbf{P}_{aa}$ Skip a step in procedure	C	3 0e-03					
Notes: It's assumed that it's always transp	parent for operators to proce	eed the relevant					
instruction or stand-alone numbered step	on the EOGs.						
The MCR operator is not required to use a	an an additional procedure ir	n addition to the EOG, so					
"single" branch is selected for this HFE.							
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the							
"Graphically Distinct" should be selected.							
The use of placekeeping aids is always as	ssumed to be used due to the	ne nature of the					
computerized procedure system (CPS) so	oftware, i.e., the operator will	l be required to confirm					
completion of a step as the procedural ite	ms are addressed. Scenar	rios for which deviations					
Trom this assumption are possible, justification	ation for the choice made w	iii de provided.					
P <sub>cf</sub> : IVIISINTERPRET INSTRUCTIONS	a and in a soft the same soft was a soft	neg.					
<b>Notes:</b> It is generally assumed that the We	or uning of the procedures will	I be standard Versus					
	decision tree, pci, of the Cl	ועס וועו.					

The step present all information required to identify the actions directed and their objects.							
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02					
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b)							
because "NOT, AND, OR, BOTH AND an	d OR" are present through I	EOG01 and EOG02.					
Otherwise, "No" branch should be selecte	ed on the "NOT Statement" t	branch.					
The operators are always trained and pra	cticed about specified scena	ario to perform.					
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.					
Notes: The operators are always assume	ed to believe in the adequac	y of instruction					
presented.							
Initial P <sub>c</sub> (without recovery credited)		2.2e-02					
Notes							
Equipment Accessibility	MCR:						

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	3.0e-03	-	-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
Pce	3.0e-03	-	Х	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-	-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 4.6e-0					4.6e-03					
	Notes										

Execution Performance Shaping Factors					
Special Requirements	Tools	Adequate			
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			
	Expected:				
	Workload:	N/A			
	Performance Shaping	N/A			
	Factors:				
Notes					
This HFE is to recover ESF actuation signal. This operator action have to be performed under					
under limited time condition to prevent undes	ired plant state.				
Execution Complexity	Simple				

Execution Unrecovered								
	Procedure: EOG-01, SPTA		Com	ment				
Step No.	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride	
		Туре	Table	Item				
	Ensure SIAS is initiated							
EOG-01 #4.3	Location: MCR	EOM	20-7b	1	4.3e-04	5		
		EOC	20-12	3	1.3E-3			
	Total Step HEP							
	Verify and Ensure SIAS Actuation							
	Location: MCR	EOM	20-7b	1	4.3e-04	5		
EOG-04 #4.a		EOC	20-9	2	1.3E-3			
	Total Step HEP							

Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-01 #4.3		Ensure SIAS is initiated	8.7e-03				1.3e-03
	EOG-04 #4.a	Verify and Ensure SIAS Actuation		8.7e-03	MD	1.5e-01	
		Total Unrecovered:	8.7e-03			Total Recovered:	1.3e-03

# VDOPV-S-HV, OPERATOR FAILS TO START EDG ROOM CUBILC COOLER BY HAND SWITCH

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev .10.hra	1806336	07/24/13	07/17/13
	Name			Date
Analyst	Namcheol Kim			04-26-2013

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THE RP	
Without Recovery	1.2e-02	8.7e-03		
With Recovery	1.2e-02	4.4e-03	1.7e-02	5

## Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: LOOP, GRID-LOOP

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should initiate cubicle cooler for EDG room.

5. Definition : In LOOP, EDG should be initiated. But in this HFE, the EDG can not maintain its work due to EDG room heat up. This HFE is recovery for the failure of EDG room cubicle cooler.

	Cues and Indications
Initial Cue	No ECW Flow
Recovery Cue	
Cue Comments	
Degree of Clarity	Very Good

Procedures and Training					
Cognitive Procedure ARP-xx7 (Revision: 00)					
Cognitive Step Number xx					
Cognitive Instruction Verify ECW pumps, chillers and related valves					
Execution Procedure SYS-WO (Revision: xx)					
Job Performance Measure					
Classroom Training	None				
Simulator Training None					
Notes					
The procedure and training information is not available in DC phase. However, APR1400 EOG is					
used and training is assumed for this operator action.					

Crow Marshar	Total Required for		Notos	
	Available	Execution	Notes	

Shift Supervisor	1	0	
STA	1	1	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## Dependencies (Related Human Interactions)

## **Key Assumptions**

## **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	20.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	5.00 Minutes		
Τ <sub>M</sub>	2.00 Minutes		
Time available for recovery	13.00 Minutes		
SPAR-H Available time	18.00 Minutes		
(cognitive)			
SPAR-H Available time	7.50		
(execution) ratio			
Minimum level of dependence	HD		
for recovery			
Notes			
It is bread to provide the Theorem at the break of the failt we refer to a section of a state of AAAAD			

It is hard to estimate Tsw exactly because it is the failure of supporting system and related MAAP analysis is not available now. Thus Tsw is assumed 20 minutes.

Sigma Table				
Plant Type	Response	LB	Sigma	UB
	Туре			
BWR	CP1	0.4	0.7	1
	CP2	0.2	0.58	0.96
	CP3	0.59	0.75	0.91
PWR	CP1	0.26	0.57	0.88
	CP2	0.07	0.38	0.69
	CP3		0.77	
Sigma:	5.7e-01			
HEP:	1.2e-02			
Notes/Assumpt	ions:			

Execution Performance Shaping Factors					
Special Requirements Tools Adequate					
	Parts	Adequate			
	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			

	Radiation	Background		
	Atmosphere	Normal		
Equipment Accessibility	MCR	Accessible		
Stress	High			
	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			
Notes				
This HFE is to recover failed supporting system. This operator action have to be performed under				
limited time condition to prevent undesired plant state.				
Execution Complexity	Simple			

	Execution Unrecovered						
	Procedure: SYS-WO, Essential Chilled Water System		Comment				
Step No.	Instruction/Comment	Error THE		RP	HEP	Stress Factor	Over Ride
		Туре	Table	Item			
	Ensure EDG Room HVAC.						
SYS-HV #xx-0	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3	-	
	Total Step HEP						
	Verify the EDG room temperature.						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
SYS-HV #xx-1		EOC	20-9	2	1.3E-3		
					Total S	tep HEP	8.7e-03

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
SYS-HV		Ensure EDG Room HVAC.	8.7e-03				4.4e-03
#xx-0							
	SYS-HV #xx-1	Verify the EDG room temperature.		8.7e-03	HD	5.0e-01	
		Total Unrecovered:	8.7e-03			Total Recovered:	4.4e-03

# WOOPV-S-1AB2AB, OPERATOR FAILS TO ECW PUMPS, CHILLERS AND RELATED VALVES

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-Rev	1806336	07/24/13	07/23/13
	.10.hra			
	Name			Date
	Indino			Date
Analyst	Namcheol Kim			04-26-2013

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THE RP	
Without Recovery	1.2e-02	8.7e-03		
With Recovery	1.2e-02	4.4e-03	1.7e-02	5

## Identification and Definition

1. Initial Conditions : Steady state, full power operation

2. Initiating Events: All IEs

3. Preceding operator error or success in sequence : N/A

4. Operator action success criterion : Operator should align essential chilled water system manually.

5. Definition : If operating train of ECW is unavailable due to failure of related pumps, chillers or valves, standby components will be operated automatically. In this HFE, the standby components actuation signal is failed. Thus operators align related valves and initiate pumps and chillers manually.

Cues and Indications			
Initial Cue	No ECW Flow		
Recovery Cue			
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training			
Cognitive Procedure	ARP-xx7 (Revision: 00)		
Cognitive Step Number	XX		
Cognitive Instruction	Verify ECW pumps, chillers and related valves		
Execution Procedure	SYS-WO (Revision: xx)		
Job Performance Measure			
Classroom Training	None		
Simulator Training	None		
Notes			
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action			

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	1	
STA	1	1	
Reactor Operator	1	0	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## Dependencies (Related Human Interactions)

## Key Assumptions

Operator Interview Insights Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	20.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	5.00 Minutes		
Τ <sub>M</sub>	2.00 Minutes		
Time available for recovery	13.00 Minutes		
SPAR-H Available time	18.00 Minutes		
(cognitive)			
SPAR-H Available time	7.50		
(execution) ratio			
Minimum level of dependence	HD		
for recovery			
	Notes		
· · · · · · · · · · · · · · · · · · ·			

It is hard to estimate Tsw exactly because it is the failure of supporting system and related MAAP analysis is not available now. Thus Tsw is assumed 20 minutes.

Sigma Table					
Plant Type	Response	LB	Sigma	UB	
	Туре				
BWR	CP1	0.4	0.7	1	
	CP2	0.2	0.58	0.96	
	CP3	0.59	0.75	0.91	
PWR	CP1	0.26	0.57	0.88	
	CP2	0.07	0.38	0.69	
	CP3		0.77		
Sigma:	5.7e-01				
HEP:	1.2e-02				
Notes/Assumpt	ions:				

Execution Performance Shaping Factors						
Special Requirements	pecial Requirements Tools Adequate					
	Parts	Adequate				

	Clothing	Adequate			
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			
	Expected:				
	Workload:	N/A			
	Performance Shaping	N/A			
	Factors:				
	Notes				
This HFE is to recover failed supporting system. This operator action have to be performed under					
limited time condition to prevent undesired pla	ant state.				
Execution Complexity Simple					

Execution Unrecovered							
Procedure: SYS-WO, Essential Chilled Water System		Comment					
Sten No	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride
etop nor		Туре	Table	Item			
	Start ECW Pump and/or Chiller						
eve MO	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#xx-0		EOC	20-12	4	1.3E-3		
	Total Step HEP						
	Verify the essential chilled water flow						
SYS-WO	Location: MCR	EOM	20-7b	1	4.3e-04	5	
#xx-1		EOC	20-9	2	1.3E-3		
					Total S	tep HEP	8.7e-03

	Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
SYS-WO #xx-0		Start ECW Pump and/or Chiller	8.7e-03				4.4e-03	
	SYS-WO #xx-1	Verify the essential chilled water flow		8.7e-03	HD	5.0e-01		
		Total Unrecovered:	8.7e-03			Total Recovered:	4.4e-03	

# CIOPV-S-CIAS, Operator Fails to Recovery CIS Valve by ESFAS-CIAS

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
				Dutt
Analyst	Namcheol Kim			Buto

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	1.9e-02	8.7e-03					
With Recovery	3.1e-03	5.1e-04	3.6e-03	5			

## Identification and Definition

1. Initial Conditions : Before core damage, at full power operation

2. Initiating Events: All Initiators

3. Preceding operator error or success in sequence : Signal / Alarm for Containment Pressure High-High, Pressurizer Pressure Low, Containment Radiation High

4. Operator action success criterion : Operator should manually actuate the containment isolation actuation signal (CIAS) in MCR prior to core damage.

5. Definition : The containment isolation valves are designed to close automatically by containment isolation actuation signal (CIAS). However, if the CIAS fails to operate, operator can recover to actuate the CIAS by operating the MCR switch, EFHS-104A/104B/104C/104D. The emergency operating procedure of "EOG-10, CI-01" describes this operator action. The containment isolation valves which should be isolated during accident are presented in the CI system notebook.

Cues and Indications				
Initial Cue	Containment Pressure			
Recovery Cue				
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training					
Cognitive Procedure	EOG-10, CI-1 (Revision: 00)				
Cognitive Step Number	FRG (EOG-10), SFSC				
Cognitive Instruction	Verify the satisfaction of SFSC acceptance criteria.				
	- SFSC #6 Containment Isolation				
Execution Procedure	EOG-10, CI-1 (Revision: 00)				
Job Performance Measure					
Classroom Training	None				
Simulator Training	None				
Notes					

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## Dependencies (Related Human Interactions)

#### **Key Assumptions**

#### **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	60.00 Minutes				
T <sub>delay</sub>	2.00 Minutes				
T <sub>1/2</sub>	20.00 Minutes				
Τ <sub>M</sub>	1.00 Minutes				
Time available for recovery	37.00 Minutes				
SPAR-H Available time	57.00 Minutes				
(cognitive)					
SPAR-H Available time	38.00				
(execution) ratio					
Minimum level of dependence	LD				
for recovery					

Notes

In this analysis, Tsw is assumed to be one hour for simplicity. In most accident sequence, it is founded that it takes greater than one hour to occur core damage after accident initiations, so this will generally result in a conservative results. In few accident sequences such as Large LOCA without SI, the core damage can occur within one hour after accident initiation. However, the frequency of these accident sequences is relatively small.

\* T0 = Accident occurrence

\* Tsw = 60 min (Time from alarm/signal to core damage)

\* Td = 2 min (CIAS Generation)

\* T1/2 = 20 min (SPTA EOG (9 min) + DA EOG (6 min) + SFSC and transfer to FRG (5 min) = 20 min)

\* Tm = 1 min (It is assumed that 1 minute will be used as an ESFAS (and similar) signal recovery time due to the action being a simple control room action)

Cognitive Analysis					
Pc Failure Mechanism	Branch	HEP			
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.			

Notes: Operator can access to all inf	ormation and required	l indication to operate a plant in the					
main control room.							
P <sub>cb</sub> : Failure of Attention	<u> </u>	neg.					
Notes: In general, within 2 hours from CBDTM unless the work load relevant	n accident initiation, w it to a specific HFE ca	ork load is assumed to be high for not be judged appropriately.					
This HFE is to initiate CIAS manually of CIAS alarm and status of related c them continuously.	This HFE is to initiate CIAS manually and thus the operator only performs and one-time check of CIAS alarm and status of related components and variables. It is not necessary to check them continuously.						
It's assumed that the indicator to be on MCR because all of the controls in the front of the room.	checked is always dis e modern control roor	played on the front panel of the n are expected to be located in the					
It is assumed that operators concentr reactor trip. Thus operators can not re in the EOG step.	ate on EOG and perfection espond to alarms unti	orms EOG-driven actions after related parameter are mentioned					
<b>P</b> <sub>cc</sub> : Misread/miscommunicate data	а	neg.					
Notes: It is assumed that required included labeling and others is always located	dicator on the control easily.	board such as layout, demarcation,					
With the advanced digital I&C interface unless there are scenario specific con justification for the deviation will be p	ce in the MCR, the inc nsiderations to warrar rovided.	lication is assumed to be "good" t otherwise, in which case,					
It is assumed that formal communica transferred between operators.	tions will always be us	sed when the specified value is					
<b>P</b> <sub>cd</sub> : Information misleading	а	neg.					
P <sub>cd</sub> : Information misleading Notes: It is assumed that all cues wil column of the EOGs.	l be as stated when th	e operators follow the "Instruction"					
P <sub>cd</sub> : Information misleading <b>Notes:</b> It is assumed that all cues wil column of the EOGs. P <sub>ce</sub> : Skip a step in procedure	l be as stated when th	e operators follow the "Instruction"					
P <sub>cd</sub> : Information misleading         Notes: It is assumed that all cues wil         column of the EOGs.         P <sub>ce</sub> : Skip a step in procedure         Notes: It's assumed that it's always to	a I be as stated when th c ransparent for operate	e operators follow the "Instruction"					
P <sub>cd</sub> : Information misleading         Notes: It is assumed that all cues will column of the EOGs.         P <sub>ce</sub> : Skip a step in procedure         Notes: It's assumed that it's always t instruction or stand-alone numbered	a I be as stated when th c ransparent for operato step on the EOGs.	e operators follow the "Instruction" 3.0e-03 ors to proceed the relevant					
P <sub>cd</sub> : Information misleading         Notes: It is assumed that all cues will column of the EOGs.         P <sub>ce</sub> : Skip a step in procedure         Notes: It's assumed that it's always t instruction or stand-alone numbered         The MCR operator is not required to the "single" branch is selected for this HF	I be as stated when the constant of the consta	rocedure in addition to the EOG, so					
P <sub>cd</sub> : Information misleading         Notes: It is assumed that all cues will column of the EOGs.         P <sub>ce</sub> : Skip a step in procedure         Notes: It's assumed that it's always t instruction or stand-alone numbered         The MCR operator is not required to u "single" branch is selected for this HF         Only if there are special or distinct maging         "Graphically Distinct" should be selected	I be as stated when the constraint of the constraint for operate constraint for operate constraint of the EOGs. Use an an additional present for constraint of the EOGs. Use an an additional present of the EOGs.	rocedure in addition to the EOG, so					
<ul> <li>P<sub>cd</sub>: Information misleading</li> <li>Notes: It is assumed that all cues will column of the EOGs.</li> <li>P<sub>ce</sub>: Skip a step in procedure</li> <li>Notes: It's assumed that it's always t instruction or stand-alone numbered</li> <li>The MCR operator is not required to u "single" branch is selected for this HF</li> <li>Only if there are special or distinct ma "Graphically Distinct" should be selected</li> <li>The use of placekeeping aids is alwa computerized procedure system (CP-completion of a step as the procedura from this assumption are possible, justice</li> </ul>	a         I be as stated when the local state of the	rocedure in addition to the EOG, so be procedure, "YES" branch in the ed due to the nature of the perator will be required to confirm d. Scenarios for which deviations be made will be provided.					
P <sub>cd</sub> : Information misleading         Notes: It is assumed that all cues will column of the EOGs.         P <sub>ce</sub> : Skip a step in procedure         Notes: It's assumed that it's always t instruction or stand-alone numbered         The MCR operator is not required to u "single" branch is selected for this HF         Only if there are special or distinct ma "Graphically Distinct" should be selected         The use of placekeeping aids is alwa computerized procedure system (CP-completion of a step as the procedura from this assumption are possible, justification of the selected for the selected for the selected for the selected for the selected procedure system (CP-completion of a step as the procedura from the selected for the sele	a         I be as stated when the local state of the constraint for operate step on the EOGs.         use an an additional pressure and an additional pressure and the constraint of	rocedure in addition to the EOG, so be procedure, "YES" branch in the ed due to the nature of the perator will be required to confirm d. Scenarios for which deviations be made will be provided. neg.					
Pcd: Information misleading         Notes: It is assumed that all cues will column of the EOGs.         Pce: Skip a step in procedure         Notes: It's assumed that it's always t instruction or stand-alone numbered         The MCR operator is not required to u "single" branch is selected for this HF         Only if there are special or distinct material         "Graphically Distinct" should be selected         The use of placekeeping aids is alway computerized procedure system (CP-completion of a step as the proceduration from this assumption are possible, justifications         Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions	a         I be as stated when the local state of the	neg. ne operators follow the "Instruction" 3.0e-03 ors to proceed the relevant rocedure in addition to the EOG, so ne procedure, "YES" branch in the ed due to the nature of the perator will be required to confirm d. Scenarios for which deviations ce made will be provided. neg. redures will be standard versus f, of the CBDTM.					
P <sub>cd</sub> : Information misleading         Notes: It is assumed that all cues will column of the EOGs.         P <sub>ce</sub> : Skip a step in procedure         Notes: It's assumed that it's always t instruction or stand-alone numbered         The MCR operator is not required to u "single" branch is selected for this HF         Only if there are special or distinct material         "Graphically Distinct" should be selected         The use of placekeeping aids is alwat computerized procedure system (CP-completion of a step as the procedura from this assumption are possible, justified the misinterpret Instructions         Notes: It is generally assumed that the ambiguous for the Misinterpret Instructions         The step present all information required to require the step present all information required to require the step present all information required to represent all information required to represent all information required the step present all information required the required the step present all information required the represent all information required represent all information represent all information represent represent all informating represent represent represent represent	a         I be as stated when the local state of the state of the step on the EOGs.         ransparent for operate step on the EOGs.         use an an additional percent of the step.         arks are provided in the sted.         ys assumed to be used of the step.         S) software, i.e., the call items are addressed stification for the choice of the production decision tree, point of the production decision tree, point of the step.	neg. ne operators follow the "Instruction" 3.0e-03 ors to proceed the relevant rocedure in addition to the EOG, so ne procedure, "YES" branch in the ed due to the nature of the perator will be required to confirm d. Scenarios for which deviations be made will be provided. neg. redures will be standard versus f, of the CBDTM. ions directed and their objects. 1.6e-02					
<ul> <li>P<sub>cd</sub>: Information misleading</li> <li>Notes: It is assumed that all cues will column of the EOGs.</li> <li>P<sub>ce</sub>: Skip a step in procedure</li> <li>Notes: It's assumed that it's always t instruction or stand-alone numbered</li> <li>The MCR operator is not required to u "single" branch is selected for this HF</li> <li>Only if there are special or distinct ma "Graphically Distinct" should be selected</li> <li>The use of placekeeping aids is alwa computerized procedure system (CP-completion of a step as the procedura from this assumption are possible, just P<sub>cf</sub>: Misinterpret Instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instruction required the misinterpret Instruction of the misinterpret Instruction of the misinterpret Instructions</li> <li>Notes: It is generally assumed that the ambiguous for the Misinterpret Instruction required the misinterpret decision logic</li> </ul>	a         I be as stated when the log as stated when the log as stated when the log as an an additional present on the EOGs.         use an an additional present and additional present and additional present and additional present and the log as a sumed to be used as a stification for the choice and the log as a stification for the choice and the production decision tree, pr	neg. neg. ne operators follow the "Instruction" 3.0e-03 ors to proceed the relevant rocedure in addition to the EOG, so ne procedure, "YES" branch in the ed due to the nature of the perator will be required to confirm d. Scenarios for which deviations be made will be provided. neg. redures will be standard versus f, of the CBDTM. ions directed and their objects. 1.6e-02 tion, select sequence (a) or (b)					
$\mathbf{P}_{cd}$ : Information misleadingNotes: It is assumed that all cues will column of the EOGs. $\mathbf{P}_{ce}$ : Skip a step in procedureNotes: It's assumed that it's always t instruction or stand-alone numberedThe MCR operator is not required to u "single" branch is selected for this HFOnly if there are special or distinct ma "Graphically Distinct" should be selectThe use of placekeeping aids is alwa computerized procedure system (CP- completion of a step as the procedura from this assumption are possible, just $\mathbf{P}_{cf}$ : Misinterpret InstructionsNotes: It is generally assumed that the ambiguous for the Misinterpret Instru The step present all information required because "NOT, AND, OR, BOTH AN Otherwise, "No" branch should be selection	a         a         be as stated when the construction operated step on the EOGs.         use an an additional perfected.         arks are provided in the ted.         ys assumed to be used stification for the choice stification for the choice stification for the choice stification for the production decision tree, point of the productin decision tree, point decision tree, point of the productin deci	rocedure in addition to the EOG, so be procedure, "YES" branch in the ed due to the nature of the perator will be required to confirm d. Scenarios for which deviations be made will be provided. endewill be standard versus f, of the CBDTM. fons directed and their objects. 1.6e-02 tion, select sequence (a) or (b) at through EOG01 and EOG02. iatement" branch.					

The operators are always trained and practiced about specified scenario to perform.						
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.				
Notes: The operators are always assumed to believe in the adequacy of instruction						
presented.						
Initial P <sub>c</sub> (without recovery credited)		1.9e-02				
Notes						
Equipment Accessibility MCR: Accessible						

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	3.0e-03	Х	-	-	-	-	N/A	MD	1.5e-01		4.5e-04
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcg	1.6e-02	-	-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)					3.1e-03						
	Notes										

Execution Performance Shaping Factors					
Environment	Lighting	Normal			
	Heat	Normal			
	Radiation	Background			
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			
	Expected:				
	Workload:	N/A			
	Performance Shaping	N/A			
	Factors:				
Notes					
It is assumed that plant response is not expected, because this event is for Level 2 PRA.					
Execution Complexity	Simple				

	Execution Unrecovered						
Proce	dure: EOG-10, CI-1, Functional Recovery Guideline - Containment Isolation		Com	ment			
Sten No	Step No Instruction/Comment		THE	RP	ЦЕР	Stress Factor	Over Ride
otop No.		Туре	Table	Item			
	Ensure CIAS is initiated.						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
# 1-a		EOC	20-12	3	1.3E-3	-	
					Total S	tep HEP	8.7e-03
	Ensure all containment isloation valves receiving CIAS are closed.						
EOG-10 CI-1	Location: MCR	EOM	20-7b	1	4.3e-04	5	
# 1-b		EOC	20-9	3	1.3E-3		
					Total S	tep HEP	8.7e-03

	Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
EOG-10,		Ensure CIAS is initiated.	8.7e-03				5.1e-04	
CI-1 #								
1-a								
	EOG-10, CI-1	Ensure all containment isloation valves receiving		8.7e-03	LD	5.8e-02		
	# 1-b	CIAS are closed.						
		Total Unrecovered:	8.7e-03			Total Recovered:	5.1e-04	

# H-CIS-OPEN, Operator Fails to Recovery CIS Valve by Local Manual Operation

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	CBDTM	THERP	CBDTM+THERP	
Without Recovery	3.2e-02	2.1e-02		
With Recovery	5.0e-03	2.1e-02	2.6e-02	5

## Identification and Definition

1. Initial Conditions : Before core damage, at full power operation

2. Initiating Events: All the Initiating Events except for ISLOCA

3. Preceding operator error or success in sequence : Signal / Alarm for Containment Pressure High-High, Pressurizer Pressure Low, Containment Radiation High

4. Operator action success criterion : Operator should manually isolate the CIS valves in LOCA prior to core damage.

5. Definition : If the containment isolation valves fail to close even though the CIAS is actuated automatically or manually, the operator must isolate the failed CIS valves to maintain containment integrity. If the containment is not isolated prior to core damage, the fission product would release into environment via these unisolated containment penetration. The emergency operating procedure of "EOG-10, CI-01" describes this operator action for manual containment isolation in the local. The containment isolation valves which should be isolated during accident are presented in the CI system notebook.

Cues and Indications				
Initial Cue	CIAS - Containment Pressure			
Recovery Cue				
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training				
Cognitive Procedure EOG-07 (Revision: 0)				
Cognitive Step Number #1				
Cognitive Instruction	Verify the satisfaction of SFSC acceptance criteria.			
- SFSC #7 Containment Isolation				
Execution Procedure	EOG-10, CI-1 (Revision: 00)			

Job Performance Measure	
Classroom Training	None
Simulator Training	None
	Notes

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	1	
Local Turbine Operator	2	0	

## Dependencies (Related Human Interactions)

## Key Assumptions

## **Operator Interview Insights**

Operator interview is not available in DC phase.

Timing Analysis		
T <sub>sw</sub>	60.00 Minutes	
T <sub>delay</sub>	2.00 Minutes	
T <sub>1/2</sub>	20.00 Minutes	
Τ <sub>M</sub>	20.00 Minutes	
Time available for recovery	18.00 Minutes	
SPAR-H Available time	38.00 Minutes	
(cognitive)		
SPAR-H Available time	1.90	
(execution) ratio		
Minimum level of dependence	MD	
for recovery		
Notes		

In this analysis, Tsw is also assumed to be one hour for simplicity, same as operator action of "CIOPV-S-CIAS". It is very difficult to accurately define the time from T0 (the actuation of High-High containment pressure, etc) to Tsw (core damage), because that time depends on the accident progression. In most accident sequence, it is founded that it takes greater than one hour to occur core damage after accident initiations, so this will generally result in a conservative results. In few accident sequences such as Large LOCA without SI, the core damage can occur within one hour after accident initiation, however, the frequency of these accident sequences is relatively small. In addition, for an early core damage sequences such as LLOCA without SI, no

\* T0 = Accident occurrence

\* Tsw = 60 min (Time from alarm/signal to core damage)

credit is given for this operator action in the Level 2 PRA.

\* Td = 2 min (CIAS Generation)

\* T1/2 = 20 min (SPTA EOG (9 min) + DA EOG (6 min) + SFSC and transfer to FRG (5 min) = 20

min)
\* Tm = 20 min (It is assumed that 20 minute will be used as recovery time including local operation.)

Cognit	ive Analysis					
Pc Failure Mechanism	Branch	HEP				
P <sub>ca</sub> : Availability of Information	а	neg.				
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the				
main control room.						
P <sub>cb</sub> : Failure of Attention	i	neg.				
Notes: In general, within 2 hours from acc	cident initiation, work load is	assumed to be high for				
CBDTM unless the work load relevant to a	a specific HFE cannot be ju	dged appropriately.				
This HFE is to initiate CIAS manually and of CIAS alarm and status of related compo- them continuously.	thus the operator only perfo onents and variables. It is n	orms and one-time check ot necessary to check				
It's assumed that the indicator to be check MCR because all of the controls in the mo front of the room.	ked is always displayed on t odern control room are expe	the front panel of the ected to be located in the				
It is assumed that operators concentrate or reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG nd to alarms until related pa	-driven actions after arameter are mentioned				
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.				
Notes: It is assumed that required indicate labeling and others is always located easi With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid	<ul> <li>Notes: It is assumed that required indicator on the control board such as layout, demarcation, labeling and others is always located easily.</li> <li>With the advanced digital I&amp;C interface in the MCR, the indication is assumed to be "good" unless there are scenario specific considerations to warrant otherwise, in which case, instification for the deviation will be provided.</li> </ul>					
It is assumed that formal communications transferred between operators.	will always be used when t	he specified value is				
<b>P</b> <sub>cd</sub> : Information misleading	С	1.0e-02				
Notes: This operator action is required aff           EOG does not describe that this action is           the MCR. Thus, "no" is selected at the all           branch.           Additional information for training program           when isolation is preformed in local. And t           operation.	ter failure of recovery for CI performed at local after failu cues as stated branch and ns describes that the radiation he resource tree includes th	AS in the MCR. The ure of recovery CIAS in warning of differences on should be checked ne path for local manual				
<b>P</b> <sub>ce</sub> : Skip a step in procedure	С	3.0e-03				
Notes: It's assumed that it's always transp instruction or stand-alone numbered step The MCR operator is not required to use a	parent for operators to proc on the EOGs. In an additional procedure ir	eed the relevant n addition to the EOG, so				
Only if there are special or distinct marks "Graphically Distinct" should be selected.	are provided in the procedu	re, "YES" branch in the				
I he use of placekeeping aids is always as	ssumed to be used due to th	ne nature of the				

computerized procedure system (CPS) so	oftware, i.e., the operator wi	I be required to confirm				
completion of a step as the procedural items are addressed. Scenarios for which deviations						
from this assumption are possible, justification	ation for the choice made w	ill be provided.				
P <sub>cf</sub> : Misinterpret Instructions	b	3.0e-03				
Notes: It is generally assumed that the we	ording of the procedures wil	I be standard versus				
ambiguous for the Misinterpret Instruction	decision tree, pcf, of the C	BDTM.				
The step does not present about local ope	eration for the failure of CIA	S recovery in the MCR.				
But it is assumed that the operator has en	ough training for this action	-				
P <sub>cg</sub> : Misinterpret decision logic	а	1.6e-02				
Notes: If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b)						
because "NOT, AND, OR, BOTH AND an	d OR" are present through	EOG01 and EOG02.				
Otherwise, "No" branch should be selected on the "NOT Statement" branch.						
The operators are always trained and practiced about specified scenario to perform.						
<b>P</b> <sub>ch</sub> : Deliberate violation	а	neg.				
Notes: The operators are always assumed to believe in the adequacy of instruction						
presented.						
<b>Initial P</b> <sub>c</sub> (without recovery credited)		3.2e-02				
Notes						

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	1.0e-02	-	-	Х	-	-	N/A	MD	1.5e-01		1.5e-03
Pc <sub>e</sub>	3.0e-03	Х	-	-	-	-	N/A	MD	1.5e-01		4.5e-04
Pc <sub>f</sub>	3.0e-03	-	-	Х	-	-	N/A	MD	1.5e-01		4.5e-04
PCq	1.6e-02	-	-	Х	-	-	N/A	MD	1.6e-01		2.6e-03
Pc <sub>h</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final	Final Pc (with recovery credited) 5.0e-03						5.0e-03				
Notes											

Execution Performance Shaping Factors				
Environment	Lighting	Normal		
	Heat	Normal		
	Radiation	Background		
	Atmosphere	Normal		
Equipment Accessibility	Local - Out of MCR	Accessible		
Stress	High			
	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			

Notes				
It is assumed that no plant response as expected, because this event is for Level 2 PRA.				
Execution Complexity	Simple			
	· ·			

Execution Unrecovered							
Procee	Procedure: EOG-10, CI-1, Functional Recovery Guideline - Containment Isolation		Comment				
Sten No Instruction/Comment		Error	THERP		HEP	Stress Factor	Over Ride
otop no.		Туре	Table	Item			
	The feasibility of isolating containemtn peenetration(s) by alternate means.						
EOG-10, CI-1 Cont. Act. #2.c	Location: Local - Aux. Bldg.	EOM	20-7b	1	4.3e-04	5	
		EOC	20-13	2	3.8E-3	-	
					Total S	tep HEP	2.1e-02

	Execution Recovered						
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step
EOG-10, CI-1 Cont. Act. #2.c		The feasibility of isolating containemtn peenetration(s) by alternate means.	2.1e-02				2.1e-02
		Total Unrecovered:	2.1e-02			Total Recovered:	2.1e-02

# H-SDR-3WAY, Operator Fails to Open 3way Valve

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THE	
			RP	
Without Recovery	1.3e-02	1.3e-02		
With Recovery	1.3e-02	2.0e-03	1.5e-02	5

Identification and Definition
1. Initial Conditions : After core damage, at full power operation
2. Initiating Events:
Medium LOCA SLOCA SGTR GTRN Loss of FW Loss of CV MAIN FEED WATER LINE BREAK (INSIDE CTMT) LARGE SECONDARY SIDE BREAK (MSIV UPSTREAM) LARGE SECONDARY SIDE BREAK (MSIV UPSTREAM) PLOESW PLOCCW TLOESW TLOCCW Loss of IA Loss of 1E 125DC VITAL BUS B Loss of 1E 125DC VITAL BUS A LOOP SBO GRID-SBO GRID-SBO GRID-SBO GRID-LOOP POSRV CHALLENGE INDUCED SLOCA ATWS
3. Preceding operator error or success in sequence : The success of bleed operation before core damage & Core Exit Thermocouples (CET) exceeds 1,200°F
4. Operator action success criterion : Operators should manually open the 3-way valves within 30 minutes after severe accident initiation (CET > 1,200 $^{\circ}$ F).

5. Definition : The operator action of "H-SDR-3WAY" is very similar to "H-SDR-POSRV-3WAY".

However, there is no need to consider to open the POSRVs in this operator action. Because this action is only considered under the situation in which two or more POSRVs have been open for F&B operation before core damage. Therefore, this operator action only considers the operation of 3-way valves to convert the release point of RCS inventory from IRWST to SG compartment (i.e., containment atmosphere).

## Assigned Basic Events

Cues and Indications		
Initial Cue	CET Temperature	
Recovery Cue		
Cue Comments		
Degree of Clarity	Very Good	

Procedures and Training					
Cognitive Procedure EOG-10, HR3 (Revision: 0)					
Cognitive Step Number	Continuing Action for HR # 4-b.1				
Cognitive Instruction If representative CET temperature is increasing					
	uncontrollably, then implement appropriate procedure as				
	directed by TSC or PNSC.				
Execution Procedure SAMG-xx (Revision: xx)					
Job Performance Measure					
Classroom Training None					
Simulator Training None					
Notes					
The procedure and training information is not available in DC phase. However, APR1400 EOG is					

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes	
Shift Supervisor	1	0		
STA	1	0		
Reactor Operator	1	1		
Turbine Operator	1	0		
Electrical Operator	1	0		
Local Reactor Operator	2	0		
Local Turbine Operator	2	0		

Dependencies (Related Human Interactions)

### **Key Assumptions**

It is assumed that the procedure for this HFE is described in the Control Room Guideline for Severe Accident, which is performed by MCR operators when FRG actions fails and CET is increasing uncontrollably.

## **Operator Interview Insights**

Operator interview is not available in DC phase.

## **Timing Analysis**

T <sub>sw</sub>	30.00 Minutes			
T <sub>delay</sub>	0.00 Minutes			
T <sub>1/2</sub>	5.00 Minutes			
T <sub>M</sub>	2.00 Minutes			
Time available for recovery	23.00 Minutes			
SPAR-H Available time	28.00 Minutes			
(cognitive)				
SPAR-H Available time	12.50			
(execution) ratio				
Minimum level of dependence	MD			
for recovery				
Notes				

For simplicity, Tsw for this action is determined to be 30 minutes as same as "H-SDR-POSRV-3WAY".

\* T0 = Accident occurrence

\* Tsw = 30 min (Time from severe accident initiation to opening 3way valves)

\* Td = 0 min

\* T1/2 = 5 min (SFSC and transfer to SAMG = 5 min)

\* Tm = 2 min (It is assumed that 2 minute will be used to open 3way valves in the MCR.)

Sigma Table							
Plant Type	Response Type	LB	Sigma	UB			
BWR	CP1	0.4	0.7	1			
	CP2	0.2	0.58	0.96			
	CP3	0.59	0.75	0.91			
PWR	CP1	0.26	0.57	0.88			
	CP2	0.07	0.38	0.69			
	CP3		0.77				
Sigma:	7.7e-01						
HEP:	1.3e-02						
Notes/Assumpt	ions:						

Execution Performance Shaping Factors						
Environment	Lighting Emergency					
	Heat	Hot / Humid				
	Radiation	Green				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
It is assumed that plant response is not expected, because this event is for Level 2 PRA.						
Execution Complexity Simple						

Execution Unrecovered								
Procedure: SAMG-xx, Severe Accident Mitigation Guideline		Comment						
Step No.	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride	
		Туре	Table	Item				
	Open 3-way valve							
SAMC vv #	Location: MCR	EOM	20-7	1	1.3e-03	5		
x-5		EOC	20-12	4	1.3E-3			
	Total Step HEP							
	verify flow							
SAMG-xx, # x-6	Location: MCR	EOM	20-7	1	1.3e-03	5		
		EOC	20-9	2	1.3E-3			
	Total Step HEP							

Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
SAMG-xx , # x-5		Open 3-way valve	1.3e-02				2.0e-03	
	SAMG-xx, # x-6	verify flow		1.3e-02	MD	1.5e-01		
		Total Unrecovered:	1.3e-02			Total Recovered:	2.0e-03	
# H-SDR-POSRV-3WAY, Operator Fails to Open POSRV and 3way Valve

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	HCR/ORE	THERP	HCR/ORE+THE				
			RP				
Without Recovery	1.1e-01	3.4e-02					
With Recovery	1.1e-01	3.4e-02	1.4e-01	1			

Identification and Definition
1. Initial Conditions : After core damage, at full power operation
2. Initiating Events:
Medium LOCA SLOCA SGTR GTRN Loss of FW Loss of CV MAIN FEED WATER LINE BREAK (INSIDE CTMT) LARGE SECONDARY SIDE BREAK (MSIV UPSTREAM) LARGE SECONDARY SIDE BREAK (MSIV DOWNSTREAM) PLOESW PLOCCW TLOESW TLOESW TLOCCW Loss of IA Loss of 1A Loss of 1E 125DC VITAL BUS B Loss of 1E 125DC VITAL BUS A LOOP SBO GRID-SBO GRID-SBO GRID-LOOP POSRV CHALLENGE INDUCED SLOCA ATWS
3. Preceding operator error or success in sequence : Core Exit Thermocouples (CET) exceeds 1,200°F
4. Operator action success criterion : Operators should manually open the POSRVs and 3-way valves within 30 minutes after severe accident initiation (CET > 1,200 $^{\circ}$ F).
5. Definition : If the CET exceeds 1,200°F and RCS pressure is higher than 250 psig, the operator

must operate the POSRVs and the 3-way valves to depressurize the RCS pressure and to convert the release point of RCS inventory from IRWST to SG compartment (i.e., containment atmosphere). The success of this action provides the following benefits to maintain the containment integrity; 1) prevent from containment challenges due to HPME/DCH, 2) Make the in-vessel injection available due to RCS depressurization, and 3) eliminate the possibility of hydrogen accumulation inside the IRWST area.

This is a kind of operator action after core damage, however, the APR1400-DC SAMG is not available at this time. So, the SAMG of reference plants (SKN 3&4) was used to evaluate the HEP of this operator action.

#### Assigned Basic Events

Cues and Indications				
Initial Cue	CET Temperature			
Recovery Cue				
Cue Comments				
Degree of Clarity	Very Good			

Procedures and Training						
Cognitive Procedure	EOG-10, HR3 (Revision: 0)					
Cognitive Step Number	Continuing Action for HR # 4-b.1					
Cognitive Instruction	If representative CET temperature is increasing					
	uncontrollably, then implement appropriate procedure as					
	directed by TSC or PNSC.					
Execution Procedure	SAMG-xx (Revision: xx)					
Job Performance Measure						
Classroom Training	None					
Simulator Training	None					
Notes						
The procedure and training information is not available in DC phase. However, APR1400 EOG is						

used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	1	
Local Turbine Operator	2	0	

# Dependencies (Related Human Interactions)

#### Key Assumptions

It is assumed that the procedure for this HFE is described in the Control Room Guideline for Severe Accident, which is performed by MCR operators when FRG actions fails and CET is increasing uncontrollably.

#### Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	30.00 Minutes				
T <sub>delay</sub>	0.00 Minutes				
T <sub>1/2</sub>	5.00 Minutes				
T <sub>M</sub>	17.00 Minutes				
Time available for recovery	8.00 Minutes				
SPAR-H Available time	13.00 Minutes				
(cognitive)					
SPAR-H Available time	1.47				
(execution) ratio					
Minimum level of dependence	HD				
for recovery					
Notes					

Tsw is determined to be 30 minutes based on MAAP calculations. The MAAP calculations, presented in Appendix A of Level 2 PDS analysis notebook, shows that POSRVs opening within

30 minutes after CET > 1200°F successfully depressurize the RCS pressure to lower than 250 psig until RPV fails.

\* T0 = Accident occurrence

\* Tsw = 30 min (Time from severe accident initiation to opening POSRVs & 3way valves)

\* Td = 0 min

\* T1/2 = 5 min (SFSC and transfer to SAMG = 5 min)

\* Tm = 17 min (conservative assumed including POSRVs power recovery in local and opening POSRVs and 3way valves in the MCR.)

Sigma Table						
Plant Type	Response	LB	Sigma	UB		
	Туре					
BWR	CP1	0.4	0.7	1		
	CP2	0.2	0.58	0.96		
	CP3	0.59	0.75	0.91		
PWR	CP1	0.26	0.57	0.88		
	CP2	0.07	0.38	0.69		
	CP3		0.77			
Sigma:	7.7e-01					
HEP:	1.1e-01					
Notes/Assumpt	ions:					

Execution Performance Shaping Factors						
Environment	Lighting	Emergency				
	Heat	Hot / Humid				
	Radiation	Green				
	Atmosphere	Normal				
Equipment Accessibility	Local - Aux. Bldg.	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
Notes						
It is assumed that plant response is not expected, because this event is for Level 2 PRA.						
Execution Complexity Simple						

	Execution Unrecovered						
Procedure: SAMG-xx, Severe Accident Mitigation Guideline			Comment				
Stop No.	Instruction/Comment	Error	THERP		HED	Stress Factor	Over Ride
otop No.		Туре	Table	Item			
	Recover power to POSRVs						
SAMC VV #	Location: Elec. Equip. Room	EOM	20-8a	1	1.3e-03	5	
x-1		EOC	20-12	8a	2.7E-4		
	Total Step HEP						
	Open POSRVs manually						
SAMG-XX #	Location: MCR	EOM	20-7	1	1.3e-03	5	
x-3		EOC	20-12	4	1.3E-3		
				•	Total S	tep HEP	1.3e-02
	Open 3-way valve						
SAMG-xx #	Location: MCR	EOM	20-7	1	1.3e-03	5	
x-5		EOC	20-12	4	1.3E-3		
					Total S	tep HEP	1.3e-02

	Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step		
SAMG-xx , # x-1		Recover power to POSRVs	7.9e-03				7.9e-03		
SAMG-xx , # x-3		Open POSRVs manually	1.3e-02				1.3e-02		
SAMG-xx , # x-5		Open 3-way valve	1.3e-02				1.3e-02		
	Total Unrecovered: 3.4e-02 Total Recovered: 3.4e-02								

# HR-OPH-ERVC, Operator Fails to Rx Cavity Injection

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	HCR/ORE	THERP	HCR/ORE+THE RP				
Without Recovery	1.5e-01	7.8e-02					
With Recovery	1.5e-01	7.8e-02	2.2e-01	1			

Identification and Definition
1. Initial Conditions : After core damage, at full power operation
2. Initiating Events:
Large LOCA Medium LOCA SLOCA GTRN Loss of FW Loss of CV MAIN FEED WATER LINE BREAK (INSIDE CTMT) LARGE SECONDARY SIDE BREAK (MSIV UPSTREAM) LARGE SECONDARY SIDE BREAK (MSIV DOWNSTREAM) PLOESW PLOCCW TLOESW TLOCCW
Loss of 1E 125DC VITAL BUS B POSRV CHALLENGE INDUCED SLOCA
3. Preceding operator error or success in sequence : Core Exit Thermocouples (CET) exceeds 1,200°F
4. Operator action success criterion : Operators should manually operate the ERVC system within 30 minutes after sever accident initiation (CET > $1,200^{\circ}F$ )
5. Definition : In the APR1400-DC, the reactor cavity can be filled with water in two separate operations. One is the passive flooding by manual opening cavity flooding valves, and the other is active flooding by operating External Reactor Vessel Cooling (ERVC) system. Passive flooding is related to the operator action of "IWOPH-S-CFS", and active flooding is related to this operator action of "HR-OPH-ERVC". The ERVC system consists of 1 SCP train and 2 BAMP trains. The SCP train operates to initially inject water into cavity. The BAMP trains operate to maintain the cavity water level after SCP injection. If the cavity is flooded by ERVC system, the cavity is flooded with water up to 13.2m to submerge approximately a half of RPV for ex-vessel cooling. However,

in the baseline model of Level 2 PRA, the ERVC system is not credited for the severe-accident mitigation features due to uncertainty surrounding the phenomena of in-vessel retention by ex-vessel cooling. Therefore, this operator action is only considered for sensitivity analysis for Level 2 PRA.

## **Assigned Basic Events**

Cues and Indications			
Initial Cue	CET Temperature		
Recovery Cue			
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training						
Cognitive Procedure	EOG-10, HR3 (Revision: 0)					
Cognitive Step Number Continuing Action for HR # 4-b.1						
Cognitive Instruction If representative CET temperature is increasing						
	uncontrollably, then implement appropriate procedure as					
	directed by TSC or PNSC.					
Execution Procedure	SAMG-xx (Revision: xx)					
Job Performance Measure						
Classroom Training	None					
Simulator Training	None					
Notes						

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	1	
Local Turbine Operator	2	0	

### Dependencies (Related Human Interactions)

#### Key Assumptions

It is assumed that the procedure for this HFE is described in the Control Room Guideline for Severe Accident, which is performed by MCR operators when FRG actions fails and CET is increasing uncontrollably.

# Operator Interview Insights

Operator interview is not available in DC phase.

Timing Analysis				
T <sub>sw</sub> 30.00 Minutes				
T <sub>delay</sub> 0.00 Minutes				

T <sub>1/2</sub>	5.00 Minutes			
T <sub>M</sub>	19.00 Minutes			
Time available for recovery	6.00 Minutes			
SPAR-H Available time	11.00 Minutes			
(cognitive)				
SPAR-H Available time	1.32			
(execution) ratio				
Minimum level of dependence	HD			
for recovery				
Natas				

Notes

The earlier the cavity is flooded by ERVC, the more effectiveness of the in-vessel retention by external cooling is expected. In this analysis, it is assumed to be a successful operation that operators operate ERVC system within 30 minutes after accident initiation. Thus, Tsw for this action is determined to be 30 minutes.

\* T0 = Accident occurrence

\* Tsw = 30 min (Time from severe accident initiation to operating ERVC system)

\* Td = 0 min

\* T1/2 = 5 min (SFSC and transfer to SAMG = 5 min)

\* Tm = 19 min (It is assumed that 19 minute will be used as recovery time including local valve align.)

	Sigma Table					
Plant Type	Response	LB	Sigma	UB		
	Туре					
BWR	CP1	0.4	0.7	1		
	CP2	0.2	0.58	0.96		
	CP3	0.59	0.75	0.91		
PWR	CP1	0.26	0.57	0.88		
	CP2	0.07	0.38	0.69		
	CP3		0.77			
Sigma:	7.7e-01					
HEP:	1.5e-01					
Notes/Assumpt	ions:					

Execution Performance Shaping Factors					
Environment	Lighting	Emergency			
	Heat	Hot / Humid			
	Radiation Green				
	Atmosphere	Normal			
Equipment Accessibility	MCR	Accessible			
Stress	High				
	Plant Response As	No			
	Expected:				
	Workload:	N/A			
	Performance Shaping	N/A			
	Factors:				
	Notes				
It is assumed that plant response is not expected, because this event is for Level 2 PRA.					
Execution Complexity Simple					

	Execution Unreco	vered					
Procedure: SAMG-xx, Severe Accident Mitigation Guideline			Comment				
Sten No	Instruction/Comment	Error	THE	RP	HEP	Stress Factor	Over Ride
		Туре	Table	Item			
	Align SCS valves for Rx cavity injection				•		
SAMG-XX #	Location: MCR	EOM	20-7	1	1.3e-03	5	
x-1		EOC	20-12	4	1.3E-3		
					Total S	Step HEP	1.3e-02
	Start SCP pump for Rx cavity injection						
SAMG-xx #	Location: MCR	EOM	20-7	1	1.3e-03	5	
x-2		EOC	20-12	4	1.3E-3		
					Total S	Step HEP	1.3e-02
	Align CVCS valves for Rx cavity injection (MCR)					5	
SAMG-xx, #	Location: MCR	EOM	20-7	1	1.3e-03		
x-3		EOC	20-12	4	1.3E-3		
					HEP         HEP           Item         1           1         1.3e-03         5           4         1.3E-3         5           1         1.3e-03         5           4         1.3E-3         5           1         1.3e-03         5           4         1.3E-3         5           1         1.3e-03         5           2         3.8E-3         5           1         1.3e-03         5           2         3.8E-3         5           1         1.3e-03         5           1         1	1.3e-02	
	Align CVCS valves for Rx cavity injection (Local)						
SAMG-xx, #	Location: Local - Out of MCR	EOM	20-7	1	1.3e-03	5	
x-4		EOC	20-13	2	3.8E-3		
					Total S	Step HEP	2.6e-02
	Start BAMP for Rx cavity injection						
SAMG-xx, #	Location: MCR	EOM	20-7	1	1.3e-03	5	
x-5		EOC	20-12	4	1.3E-3		
					Total S	Step HEP	1.3e-02

Execution Recovered								
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
SAMG-xx , # x-1		Align SCS valves for Rx cavity injection	1.3e-02				1.3e-02	
SAMG-xx , # x-2		Start SCP pump for Rx cavity injection	1.3e-02				1.3e-02	
SAMG-xx , # x-3		Align CVCS valves for Rx cavity injection (MCR)	1.3e-02				1.3e-02	
SAMG-xx , # x-4		Align CVCS valves for Rx cavity injection (Local)	2.6e-02				2.6e-02	
SAMG-xx , # x-5		Start BAMP for Rx cavity injection	1.3e-02				1.3e-02	
	•	Total Unrecovered:	7.8e-02			Total Recovered:	7.8e-02	

# HR-SGTR-ISOL, Operator Fails to Isolate the Ruptured SG

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary							
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor			
Method	CBDTM	THERP	CBDTM+THERP				
Without Recovery	1.9e-02	5.2e-02					
With Recovery	1.2e-03	3.0e-03	4.2e-03	5			

# Identification and Definition

1. Initial Conditions : Before core damage, at full power operation

2. Initiating Events:

SGTR LARGE SECONDARY SIDE BREAK (MSIV UPSTREAM) LARGE SECONDARY SIDE BREAK (MSIV DOWNSTREAM)

3. Preceding operator error or success in sequence : SGTR (or PI-SGTR) event initiation

4. Operator action success criterion : In the SGTR(or PI-SGTR) event, operators should manually isolate the tube-ruptured SG prior to core damage.

5. Definition : If the SGTR occurs, the operator must isolate the ruptured SG to prevent resulting in release into environment via ruptured SG. The emergency operating procedure of "EOG-05, Step 12" describes that all the following leak paths from ruptured SG to environment should be isolated; 1) MSIVs, 2) MSSVs, 3) MS-ADVs, 4) MFIVs, 5) Auxiliary feedwater isolation valves, 6) The isolation valves in steam supply line to turbine driven AF pumps, and 7) SG blowdown isolation valves. This considers the operator action in MCR, not a local operator action. If the MSSV is stuck open, the MSSV is forced to be closed by local operator action, so called gagging the MSSVs. Conservatively, no credit is given for gagging the stuck-open MSSVs in this analysis.

#### Assigned Basic Events

	Cues and Indications
Initial Cue	S/G Level
Recovery Cue	
Cue Comments	
Degree of Clarity	Very Good

Procedures and Training					
Cognitive Procedure	EOG-02 (Revision: 00)				
Cognitive Step Number	All				

Cognitive Instruction	Perform Accident Diagnosis			
	Enter into EOG-05 SGTR			
Execution Procedure	EOG-05 (Revision: 00)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.				

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	0	
Turbine Operator	1	1	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## **Dependencies (Related Human Interactions)**

### **Key Assumptions**

<u> </u>	norotor	Intonviouv	Incideta
U	perator	interview	insignts

Operator interview is not available in DC phase.

Timing Analysis					
T <sub>sw</sub>	150.00 Minutes				
T <sub>delay</sub>	15.00 Minutes				
T <sub>1/2</sub>	40.00 Minutes				
Τ <sub>M</sub>	20.00 Minutes				
Time available for recovery	75.00 Minutes				
SPAR-H Available time	115.00 Minutes				
(cognitive)					
SPAR-H Available time	4.75				
(execution) ratio					
Minimum level of dependence	ZD				
for recovery					
Notos					

#### Notes

Tsw is determined to be 2.5 hours based on MAAP calculation for SGTR event. Following the MAAP calculations for SGTR event, in which there is no SI injection and no secondary heat removal, it takes approximately 2.5 hours to occur core damage after accident initiation. The MAAP calculation is presented in Table 5-7 of Success Criteria notebook.

\* T0 = Accident occurrence

\* Tsw = 60 min (Time from alarm/signal to core damage)

\* Td = 15 min ( $\hat{R}x$  trip)

\* T1/2 = 40 min (SPTA EOG (9 min) + DA EOG (6 min) + STGR EOG execution time (25 min, conservative assumption) )

\* Tm = 20 min (conservative assumption for ruptured SG isolation)

Cognitive Analysis								
Pc Failure Mechanism	Branch	HEP						
<b>P</b> <sub>ca</sub> : Availability of Information	а	neg.						
Notes: Operator can access to all informa	ation and required indication	to operate a plant in the						
P.: Failure of Attention	i	nea						
Notes: In general within 2 hours from ac	cident initiation, work load is	assumed to be high for						
CBDTM unless the work load relevant to a specific HFE cannot be judged appropriately.								
This HFE is to isolate ruptured SG and the status of related components and vari continuously.	This HFE is to isolate ruptured SG and thus the operator only performs and one-time check the status of related components and variables. It is not necessary to check them continuously.							
It's assumed that the indicator to be check MCR because all of the controls in the mo- front of the room.	ked is always displayed on t odern control room are expe	the front panel of the acted to be located in the						
It is assumed that operators concentrate or reactor trip. Thus operators can not response in the EOG step.	on EOG and performs EOG and to alarms until related pa	-driven actions after arameter are mentioned						
P <sub>cc</sub> : Misread/miscommunicate data	а	neg.						
Notes: It is assumed that required indicat labeling and others is always located easi	or on the control board such ily.	n as layout, demarcation,						
With the advanced digital I&C interface in unless there are scenario specific conside justification for the deviation will be provid It is assumed that formal communications transferred between operators.	the MCR, the indication is a erations to warrant otherwise led. will always be used when t	assumed to be "good" e, in which case, the specified value is						
P <sub>cd</sub> : Information misleading	а	neg.						
<b>Notes:</b> It is assumed that all cues will be a column of the EOGs.	as stated when the operato	rs follow the "Instruction"						
P <sub>ce</sub> : Skip a step in procedure	С	3.0e-03						
<b>Notes:</b> It's assumed that it's always trans instruction or stand-alone numbered step	parent for operators to proc on the EOGs.	eed the relevant						
The MCR operator is not required to use a "single" branch is selected for this HFE.	an an additional procedure in	n addition to the EOG, so						
Only if there are special or distinct marks are provided in the procedure, "YES" branch in the "Graphically Distinct" should be selected.								
The use of placekeeping aids is always as computerized procedure system (CPS) so completion of a step as the procedural ite from this assumption are possible, justification	ssumed to be used due to the offware, i.e., the operator wins are addressed. Scena ation for the choice made w	he nature of the Il be required to confirm rios for which deviations ill be provided.						
P <sub>cf</sub> : Misinterpret Instructions	а	neg.						
<b>Notes:</b> It is generally assumed that the war ambiguous for the Misinterpret Instruction	ording of the procedures will decision tree, pcf, of the C	ll be standard versus BDTM.						
The step present all information required to	to identify the actions direct	ed and their obiects.						
P <sub>cg</sub> : Misinterpret decision logic	a	1.6e-02						

**Notes:** If diagnosis is performed just after EOG-01 completion, select sequence (a) or (b) because "NOT, AND, OR, BOTH AND and OR" are present through EOG01 and EOG02. Otherwise, "No" branch should be selected on the "NOT Statement" branch.

The operators are always trained and practiced about specified scenario to perform.						
P <sub>ch</sub> : Deliberate violation a neg.						
Notes: The operators are always assumed to believe in the adequacy of instruction						
presented.						
Initial P <sub>c</sub> (without recovery credited) 1.9e-02						
Notes						
Equipment Accessibility	MCR: Accessible					

	Cognitive Recovery										
	Initial HEP	Self Review	Extra Crew	STA Review	Shift Change	ERF Review	Recovery Matrix	Depende ncy Level	Multiply HEP By	Override Value	Final Value
Pca	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcb	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcc	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcd	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pce	3.0e-03	Х	-	-	-	-	N/A	LD	5.3e-02		1.6e-04
Pc <sub>f</sub>	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pcq	1.6e-02	-	-	Х	-	-	N/A	LD	6.5e-02		1.0e-03
Pch	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)									1.2e-03		
	Notes										

Execution Performance Shaping Factors						
Environment	Lighting	Normal				
	Heat	Normal				
	Radiation	Background				
	Atmosphere	Normal				
Equipment Accessibility	MCR	Accessible				
Stress	High					
	Plant Response As	No				
	Expected:					
	Workload:	N/A				
	Performance Shaping	N/A				
	Factors:					
	Notes					
It is assumed that no plant response as expected, because this event is for Level 2 PRA.						
Execution Complexity Simple						

	Execution Unrecovered										
Р	rocedure: EOG-05, Steam Generator Tube Rupture Recovery Guideline		Com	ment							
Char Na	In struction / Commont	Error	THE	THERP		Stress Factor	Over Ride				
Step No.		Туре	Table	Item	HEP						
	Ensure MSIVs are closed.										
EOG-05. #	Location: MCR	EOM	20-7b	1	4.3e-04	5					
11-a		EOC	20-12	4	1.3E-3						
	Total Step HEP										
	Ensure MFIVs are closed.										
EOG-05. #	Location: MCR	EOM	20-7b	1	4.3e-04	5					
11-e		EOC	20-12	4	1.3E-3						
				•	Total S	Step HEP	8.7e-03				
	Close AFW isolation valves are closed.										
EOG-05. #	Location: MCR	EOM	20-7b	1	4.3e-04	5					
11-f		EOC	20-12	4	1.3E-3						
	Total Step HEP										
	Close AFW trubine steam isolation valves are closed.										
EOG-05, #	Location: MCR	EOM	20-7b	1	4.3e-04	5					
11-g		EOC	20-12	4	1.3E-3						
	Total Step HEP										
	Ensure SG sampling isolation valves are closed.										
EOG-05. #	Location: MCR	EOM	20-7b	1	4.3e-04	5					
11-h		EOC	20-12	4	1.3E-3						
		Total Step HEP									
	Ensure SG blowdown isolation valves are closed.										
EOG-05. #	Location: MCR	EOM	20-7b	1	4.3e-04	5					
11-i		EOC	20-12	4	1.3E-3						
	Total Step HEP										
	Verify the most affected SG is isloated by observing SG activity levesl, secondary										
	Location: MCR	EOM	20-7b	1	4.3e-04	5					
EOG-5, # 12		EOC	20-9	2	1.3E-3						
	Total Stan HED										
							0000				
1											

	Execution Recovered							
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step	
EOG-05, # 11-a		Ensure MSIVs are closed.	8.7e-03				5.1e-04	
	EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.		8.7e-03	LD	5.8e-02		
EOG-05, # 11-e		Ensure MFIVs are closed.	8.7e-03				5.1e-04	
	EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.		8.7e-03	LD	5.8e-02		
EOG-05, # 11-f		Close AFW isolation valves are closed.	8.7e-03				5.1e-04	
	EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.		8.7e-03	LD	5.8e-02		
EOG-05, # 11-g		Close AFW trubine steam isolation valves are closed.	8.7e-03				5.1e-04	
	EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.		8.7e-03	LD	5.8e-02		
EOG-05, # 11-h		Ensure SG sampling isolation valves are closed.	8.7e-03				5.1e-04	
	EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.		8.7e-03	LD	5.8e-02		
EOG-05, # 11-i		Ensure SG blowdown isolation valves are closed.	8.7e-03				5.1e-04	
	EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.		8.7e-03	LD	5.8e-02		
		Total Unrecovered:	5.2e-02			Total Recovered:	3.0e-03	

# IWOPH-S-CFS, Operator Fails to Open CFS Valves

Plant	Data File	File Size	File Date	Record Date
APR1400-DC	APR1400_DC_HRA-M0	921600	07/24/13	07/24/13
Level 2	3-L2.HRA			
	Name			Date
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

		HEP Summary		
	P <sub>cog</sub>	P <sub>exe</sub>	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THE RP	
Without Recovery	1.3e-02	1.3e-02		
With Recovery	1.3e-02	2.0e-03	1.5e-02	5

Identification and Definition
1. Initial Conditions : After core damage, at full power operation
2. Initiating Events:
<ul> <li>(All the Initiating Events.</li> <li>(All the Initiating Events except for ISLOCA) <ul> <li>Large LOCA</li> <li>Medium LOCA</li> <li>SLOCA</li> <li>SGTR</li> <li>Reactor Vessel Rupture</li> <li>GTRN</li> <li>Loss of FW</li> <li>Loss of CV</li> <li>MAIN FEED WATER LINE BREAK (INSIDE CTMT)</li> <li>LARGE SECONDARY SIDE BREAK (MSIV UPSTREAM)</li> <li>LARGE SECONDARY SIDE BREAK (MSIV DOWNSTREAM)</li> <li>PLOESW</li> <li>PLOCCW</li> <li>TLOCCW</li> <li>Loss of 1E 125DC VITAL BUS B</li> <li>Loss of 1E 125DC VITAL BUS A</li> <li>LOOP</li> <li>SBO</li> <li>GRID-SBO</li> <li>GRID-SBO</li> <li>GRID-LOOP</li> <li>POSRV CHALLENGE INDUCED SLOCA</li> <li>ATWS</li> </ul></li></ul>
3. Preceding operator error or success in sequence : Core Exit Thermocouples (CET) exceeds 1,200 $^\circ\text{F}$

4. Operator action success criterion : Operators should manually open the cavity flooding isolation valves prior to reactor vessel breach

5. Definition : If the CET exceeds 1,200°F, the operator must open the cavity flooding isolation valves prior to reactor vessel breach. The success of this action makes the ex-vessel core debris be cooled with water after reactor vessel breach, so it limits the molten corium concrete interaction (MCCI) and prevents from the basemat melt-through. This is a kind of operator action after core damage, however, the APR1400-DC SAMG is not available at this time. So, the SAMG of reference plant was used to evaluate the HEP of this operator action.

### Assigned Basic Events

Cues and Indications			
Initial Cue	CET Temperature		
Recovery Cue			
Cue Comments			
Degree of Clarity	Very Good		

Procedures and Training				
Cognitive Procedure	EOG-10, HR3 (Revision: 0)			
Cognitive Step Number Continuing Action for HR # 4-b.1				
Cognitive Instruction	If representative CET temperature is increasing			
	uncontrollably, then implement appropriate procedure as			
	directed by TSC or PNSC.			
Execution Procedure	SAMG-xx (Revision: xx)			
Job Performance Measure				
Classroom Training	None			
Simulator Training	None			
Notes				
The procedure and training information is not available in DC phase. However, APP1400 EOC is				

The procedure and training information is not available in DC phase. However, APR1400 EOG is used and training is assumed for this operator action.

Crew Member	Total Available	Required for Execution	Notes
Shift Supervisor	1	0	
STA	1	0	
Reactor Operator	1	1	
Turbine Operator	1	0	
Electrical Operator	1	0	
Local Reactor Operator	2	0	
Local Turbine Operator	2	0	

## **Dependencies (Related Human Interactions)**

#### Key Assumptions

It is assumed that the procedure for this HFE is described in the Control Room Guideline for Severe Accident, which is performed by MCR operators when FRG actions fails and CET is increasing uncontrollably.

Operator Interview Insights
Operator interview is not available in DC phase.

Timing Analysis			
T <sub>sw</sub>	30.00 Minutes		
T <sub>delay</sub>	0.00 Minutes		
T <sub>1/2</sub>	5.00 Minutes		
T <sub>M</sub>	2.00 Minutes		
Time available for recovery	23.00 Minutes		
SPAR-H Available time	28.00 Minutes		
(cognitive)			
SPAR-H Available time	12.50		
(execution) ratio			
Minimum level of dependence	MD		
for recovery			
Notes			

In general, it takes at least one hours to actually occur the reactor vessel breach after severe accident initiation (CET >  $1,200^{\circ}F$ ). And, following the design of cavity flooding system (CFS), it takes 20 minutes to fill the reactor cavity by one train of CFS, or takes 40 minutes to fill the reactor cavity by two trains of CFS. Therefore, Tsw for this action is conservatively determined to be 30 minutes.

\* T0 = Accident occurrence

\* Tsw = 30 min (Time from severe accident initiation to opening CFS valves)

\* Td = 0 min

\* T1/2 = 5 min (SFSC and transfer to SAMG = 5 min)

\* Tm = 2 min (It is assumed that 2 minute will be used to open CFS valves in the MCR.)

	Sigma Table				
Plant Type	Response	LB	Sigma	UB	
	туре				
BWR	CP1	0.4	0.7	1	
	CP2	0.2	0.58	0.96	
	CP3	0.59	0.75	0.91	
PWR	CP1	0.26	0.57	0.88	
	CP2	0.07	0.38	0.69	
	CP3		0.77		
Sigma:	7.7e-01				
HEP:	1.3e-02				
Notes/Assumptions:					

Execution Performance Shaping Factors				
Environment	Lighting	Emergency		
	Heat	Hot / Humid		
	Radiation	Green		
	Atmosphere	Normal		
Equipment Accessibility	MCR	Accessible		
Stress	High			
	Plant Response As	No		
	Expected:			
	Workload:	N/A		
	Performance Shaping	N/A		
	Factors:			
	Notes			
It is assumed that plant response is not expected, because this event is for Level 2 PRA.				
Execution Complexity Simple				

Execution Unrecovered							
	Procedure: SAMG-xx, Severe Accident Mitigation Guideline			Comment			
Stop No.	Instruction/Comment	Error	THERP		HEP	Stress Factor	Over Ride
		Туре	Table	Item			
	Open CFS valves						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
SAMG-xx1		EOC	20-12	3	1.3E-3		
SAMG-xx1		Total Step HEP					1.3e-02
	verify CFS operation						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
SAMG-xx2		EOC	20-9	2	1.3E-3		
					Total S	tep HEP	1.3e-02

Execution Recovered										
Critical Step No.	Recovery Step No.	Action	HEP (Crit)	HEP (Rec)	Dep.	Cond. HEP (Rec)	Total for Step			
SAMG-xx 1		Open CFS valves	1.3e-02				2.0e-03			
	SAMG-xx2	verify CFS operation		1.3e-02	MD	1.5e-01				
		Total Unrecovered:	1.3e-02			Total Recovered:	2.0e-03			

Attachment 3 (1/1)

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# Table 19.1-25

# Level 1 Internal Events Key Operator Actions by FV (CDF)

Rank	(	Operator Action	Description		
1	RCOPH-S-SDSE-FW		FAILURE OF POSRVS EARLY PHASE OPEN	12.8%	
2	PFOPH-S-UATBKR- LOCAL		OPERATOR FAILS TO RECOVER PCB FOR 1E 4.16kV SW01A,B,C,D AT LOCAL4.16kV	4.2%	
3	AFOPV-S-AFAS-FW		OPERATORS FAIL TO RECOVER AFAS	3.0%	
4	FWOPH-S-ERY		OPERATORS FAIL TO ALIGN STARTUP FEEDWATER PUMP PP07 (EARLY PHASE)	2.5%	
5	wop	PH-S-1AB2AB	OPERATORS FAIL TO START ECW PUMPS MANUALLY	1.9%	
6	CVOI	PH-S-RCPSEAL	OPERATORS FAIL TO RECOVER RCP SEAL COOLING	1.7%	
7	HR-R	CSCD2	OPERATORS FAIL TO TAKE ACTION FOR SG COOLDOWN & RCS DEPRESS AFTER OVERFILL	1.5%	
8	HR-R	CSCD1-ISOL	OPERATORS FAIL TO TAKE ACTION FOR SG COOLDOWN & RCS DEPRESS PRIOR TO OVERFILL	1.5%	
9	AFOP	PH-S-ALT-LT	OPERATOR FAIL TO ALIGNE FOR SUPPLYING AN ALTERNATE SOURCE	0.8%	
10	RCOI	H-S-SDSL	OPERATORS FAIL TO OPEN SDS VALVES DURING LATE PHASE	0.8%	

WOOPV-S-1AB2AB