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.:	**312-8343**
SRP Section:	**SRP 19**
Application Section:	**19.1**
Date 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.

Table 1 Results of Pre-Initiator HFEs Assessment

HFE Name	Description	HEP	Remark
CSOPU1A-1015	OPERATOR FAILS TO OPEN V-1015 AFTER IN-SERVICE TEST FOR CSP 01A	9.90E-04	RIHA*)
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*)
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	OPERATOR ERROR: MISCALIBRATION OF LO PZR PR. CH.D	9.70E-04	
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*)
RPOPU-S-LT1123ABCD	OPERATOR ERROR: COMMON MISCALIBRATION OF LO SG2 LVL.	3.32E-05	RIHA*)
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*)
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

Table 2 Results of Post-Initiator HFEs Assessment

HFE Name	Description	HEP	Remark
AFOPH-S-ALT-LT	OPERATOR FAIL TO ALIGNE FOR SUPPLYING AN ALTERNATE SOURCE	9.10E-04	RIHA*)
AFOPV-S-AFAS-FW	OPERATOR FAILS TO RECOVER AFAS	5.90E-03	RIHA*)
CDOPH-S-ALIGN	OPERATOR FAILS TO START FOR PP01,02,03 BY HAND SWITCH	5.60E-04	RIHA*)
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*)
CVOPH-S-RCPSEAL	OPERATOR FAILS TO RECOVER RCP SEAL COOLING (CCW CONNTECT. OR AUX. CHG PUMP)	1.10E-02	RIHA*)
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*)
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*)
HR-RCSCD2	OPERATOR FAILS TO TAKE ACTION FOR SG COOLDOWN, RC DEPRESS	3.20E-03	RIHA*)
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*)
RCOPH-S-SDSE-FW	FAILURE OF SDS VALVES EARLY PHASE OPEN (1/4)	9.10E-03	RIHA*)
RCOPH-S-SDSL	FAILURE OF SDS VALVES (1/4) LATE PHASE OPEN	8.30E-03	RIHA*)
RPOPV-S-RTRIP	OPERATOR FAILS TO MANUALLY INITIATE REACTOR TRIP	1.20E-02	

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_{exe}	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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
1	Align CS pump PP01A Miniflow Heat Exchanger Isolation Manual Valve CS-V1015					1	
	Location: Local - Aux. Bldg.	EOM	20-7b	1	4.3e-04		
		EOC	20-13	1	1.3E-3		
					Total Step HEP		1.7e-03
2	Confirm the Valve Position					1	
	Location: Local - Aux. Bldg.	EOM	20-8a	1	1.3e-03		
		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		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	
$P_{exe\ (Median)}$	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	
$P_{exe\ (Median)}$	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 information is not available in DC phase. 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	
$P_{exe\ (Median)}$	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" 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	
$P_{exe\ (Median)}$	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" 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-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	
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	
$P_{exe\ (Median)}$	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" 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 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 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 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	
$P_{exe\ (Median)}$	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" 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-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 pressure transmitter 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	
$P_{exe\ (Median)}$	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" 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	

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	
$P_{exe\ (Median)}$	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_{exe}	Error Factor
Without Recovery	8.3e-06	
With Recovery	(8.3e-06, which is less than the minimum of 1.0e-05)	10

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" 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-LT1113A, 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 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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
1	Calibrate transmitter LT1113A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		EOC	20-10	9	1.3E-3		
					Total Step HEP		2.6e-03
2	Calibrate transmitter LT1113B by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		EOC	20-10	9	1.3E-3		
					Total Step HEP		2.6e-03
3	Calibrate transmitter LT1113C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		EOC	20-10	9	1.3E-3		
					Total Step HEP		2.6e-03
4	Calibrate signal converter LY1113A by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		EOC	20-10	9	1.3E-3		
					Total Step HEP		2.6e-03
5	Calibrate signal converter LY1113B by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		EOC	20-10	9	1.3E-3		
					Total Step HEP		2.6e-03
6	Calibrate signal converter LY1113C by technician						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		EOC	20-10	9	1.3E-3		
					Total Step HEP		2.6e-03
7	Checking by supervisor						
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03	1	
		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-03			**Total 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_{exe}	Error Factor
Without Recovery	8.3e-06	
With Recovery	(8.3e-06, which is less than the minimum of 1.0e-05)	10

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" 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-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 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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
1	Calibrate transmitter PDT 115A by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
2	Calibrate transmitter PDT115B by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
3	Calibrate transmitter PDT115C by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
4	Calibrate signal converter PDY115A by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
5	Calibrate signal converter PDY115B by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
6	Calibrate signal converter PDY115C by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
7	Checking by supervisor					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-22	1	1.6E-1		
						Total Step HEP	1.6e-01

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

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_{exe}	Error Factor
Without Recovery	8.3e-06	
With Recovery	(8.3e-06, which is less than the minimum of 1.0e-05)	10

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" 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 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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
1	Calibrate pressure transmitter PT-1013A by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
2	Calibrate pressure transmitter PT-1013B by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
3	Calibrate pressure transmitter PT-1013C by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
4	Calibrate pressure signal converter PY-1013A by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
5	Calibrate pressure signal converter PY-1013B by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
6	Calibrate pressure signal converter PY-1013C by technician					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		EOC	20-10	9	1.3E-3		
						Total Step HEP	2.6e-03
7	Checking by supervisor					1	
	Location: Local - Out of MCR	EOM	20-7b	2	1.3e-03		
		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 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_{exe}	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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
1	Align SI pump PP02A Miniflow Manual Valve SI-V218					1	
	Location: Local - Aux. Bldg.	EOM	20-7b	1	4.3e-04		
		EOC	20-13	1	1.3E-3		
						Total Step HEP	1.7e-03
2	Confirm the Valve Position					1	
	Location: Local - Aux. Bldg.	EOM	20-8a	1	1.3e-03		
		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		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	
$P_{exe\ (Median)}$	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_{cog}	P_{exe}	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.

Assigned Basic Events

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.

Dependencies (Related Human Interactions)

Key Assumptions

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

Timing Analysis	
T_{sw}	65.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	15.00 Minutes
Time available for recovery	45.00 Minutes
SPAR-H Available time (cognitive)	50.00 Minutes
SPAR-H Available time (execution) ratio	4.00
Minimum level of dependence for recovery	LD

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		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	h	neg.
Notes: If additional procedure is required, the high workload is assumed. This HFE is to connect alternate water source to the Auxiliary Feedwater Storage Tank (AFST), and thus the operator only performs an one-time check of a auxiliary feedwater storage tank level and doesn't need to check the tank level 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 modern control room are expected to be located in the front of the room. Pre-empty alarm is assumed for auxiliary feedwater source change, because the water capacity at Lo-Lo-Lo alarm is greater than 400,000 gal which is minimum capacity assuring to reach shutdown cooling condition and also greater than Condense Storage Tank (CST), which is an alternative auxiliary feedwater source. So, value of the Auxiliary Feedwater Storage Tank (AFWST) level is signaled by an annunciator.		
P_{cc}: Misread/miscommunicate data	a	neg.
Notes: 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_{cd}: Information misleading	a	neg.
Notes: It is assumed that all cues will be as stated when the operators follow the "Instruction" column of the EOGs.		
P_{ce}: Skip a step in procedure	g	6.0e-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 required to use an an additional alarm 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 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_{cf}: 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.		

The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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. The operators are always trained and practiced about specified scenario to perform.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	X	X	-	-	-	N/A	LD	2.8e-02		1.7e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											1.7e-04
Notes											
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 Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Optimal
Notes		
The depletion of AFWST means the secondary heat removal is performed successfully. Therefore, plant response as expected is assumed. This operator action is required long time later from initiator. Therefore, it is assumed that sufficient operators are available for this action. Therefore, low workload is selected.		
Execution Complexity	Simple	

Execution Unrecovered							
Procedure: SYS-AF, Auxiliary Feedwater System		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-AF #XX	Align valves to provide AFW from RST/CST locally						
	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03	1	
		EOC	20-13	2	3.8E-3		
					Total Step HEP		5.1e-03
SYS-AF #XX-2	Check the AFWST and AFW flow						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-9	2	1.3E-3		
					Total 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-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

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

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_{cog}	P_{exe}	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.

Assigned Basic Events

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	

Dependencies (Related Human Interactions)

Key Assumptions

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

Timing Analysis	
T_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	1.00 Minutes
Time available for recovery	24.00 Minutes
SPAR-H Available time (cognitive)	29.00 Minutes
SPAR-H Available time (execution) ratio	25.00
Minimum level of dependence for recovery	MD

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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 AFAS manually and thus the operator only performs and one-time check of AFAS alarm and status of related components and variables. 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 modern control room are expected to be located in the front of the room. 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of AFAS automatically). Thus operators recover AFAS manually. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		

P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											4.6e-03
Notes											
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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
This HFE is to recover failed ESF 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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-01 #6-a.1-3)	IF SG level is less than or equal to AFAS setpoint, then ensuer AFAS is initiated.						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	3	1.3E-3		
					Total Step HEP		8.7e-03
EOG-07 #6	Replenish SG inventory in at least one SG by auxiliary feedwater						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	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-01 #6-a.1-3)		IF SG level is less than or equal to AFAS setpoint, then ensuer AFAS is initiated.	8.7e-03				1.3e-03
	EOG-07 #6	Replenish SG inventory in at least one SG by auxiliary feedwater		8.7e-03	MD	1.5e-01	
		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_{cog}	P_{exe}	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.

Assigned Basic Events

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	
Cognitive Procedure	APR-xx1 (Revision: 00)
Cognitive Step Number	xx
Cognitive Instruction	Verify Condenser Hotwell Makeup Valve operation
Execution Procedure	SYS-CD (Revision: 00)
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	
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_{sw}	180.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	15.00 Minutes
Time available for recovery	160.00 Minutes
SPAR-H Available time (cognitive)	165.00 Minutes
SPAR-H Available time (execution) ratio	11.67
Minimum level of dependence for recovery	ZD

Notes

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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 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. 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: In this HFE, low level values of hot 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.		
P_{ce}: Skip a step in procedure	g	6.0e-03
Notes: It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the 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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	X	-	-	-	-	N/A	ZD	6.0e-03		3.6e-05
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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 Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Optimal
Notes		
This operator action is required to maintain feedwater supply using start-up feedwater pump. In other 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 available for this action. Therefore, low workload is selected.		
Execution Complexity	Simple	

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

CSOPV-S-CSAS, Operator Fails to Actuate CSAS

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			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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	

Dependencies (Related Human Interactions)

Key Assumptions

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

Timing Analysis	
T_{sw}	150.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	10.00 Minutes
T_M	1.00 Minutes
Time available for recovery	139.00 Minutes
SPAR-H Available time (cognitive)	149.00 Minutes
SPAR-H Available time (execution) ratio	140.00
Minimum level of dependence for recovery	ZD

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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	a	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 CSAS manually and thus the operator only performs and one-time check of CSAS alarm and status of related components and variables. 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 modern control room are expected to be located in the front of the room.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of CSAS automatically). Thus operators recover CSAS manually. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_e	3.0e-03	X	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	X	X	-	-	N/A	ZD	8.0e-03		1.3e-04
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											1.5e-04
Notes											
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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-01 #8.2-1)	Ensure CSAS is initiated.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	3	1.3E-3		
					Total Step HEP		8.7e-03
EOG-01 #8.2-2)	Ensure at least on CSS train is delivering greater than or equal to minimum CS flowrate.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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-01 #8.2-1)		Ensure CSAS is initiated.	8.7e-03				7.6e-05
	EOG-01 #8.2-2)	Ensure at least on CSS train is delivering greater than or equal to minimum CS flowrate.		8.7e-03	ZD	8.7e-03	
		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_{cog}	P_{exe}	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.

Assigned Basic Events

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	

Dependencies (Related Human Interactions)

Key Assumptions

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

Timing Analysis	
T_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	1.00 Minutes
T_M	2.00 Minutes
Time available for recovery	27.00 Minutes
SPAR-H Available time (cognitive)	28.00 Minutes
SPAR-H Available time (execution) ratio	14.50
Minimum level of dependence for recovery	MD

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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 fails to initiate successfully (i.e. Fails to insert all CEA). Thus operator performs boration to control reactivity. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.

Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_e	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	X	-	-	-	N/A	-	5.0e-01		8.0e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											1.1e-02
Notes											
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 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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
The Reactor trip was not successful due to insert failure of one or more CEA. Therefore, plant response as unexpected is assumed.		
Execution Complexity	Simple	

Execution Unrecovered							
Procedure: EOG-01, SPTA		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-01 #1.c.1-1	Align VVs for CV PPs to take suction from BAST						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-01 #1.c.1-2	Maximize Charging Flow						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, RC-2 #2	Commence maximumboration using the CVCS to achieve adequate shutdown margin						
	Location: MCR	EOM	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-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.10.hra	1806336	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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

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 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.

Assigned Basic Events

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_{sw}	240.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	15.00 Minutes
Time available for recovery	220.00 Minutes
SPAR-H Available time (cognitive)	225.00 Minutes
SPAR-H Available time (execution) ratio	15.67
Minimum level of dependence for recovery	ZD

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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		

P_{cb}: Failure of Attention	h	neg.
Notes: If Additional procedure is required, the high workload is assumed. This HFE is to initiate IRWST make up through CVCS 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 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. Operator can know the low level of IRWST by IRWST low level alarm. It takes for long time to dry out IRWST after initiating event. Thus operator uses ARP and response immediately when IRWST low level alarm occurs.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: In this HFE, ARP and system operating procedure are considered to perform operator actions. The IRWST low level is used to determine the IRWST make up. It is assumed that the ARP and system operating procedure describes how the operator response when the indicated values are not satisfy the normal range level of IRWST.		
P_{ce}: Skip a step in procedure	g	6.0e-03
Notes: It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the 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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	X	-	-	-	-	N/A	LD	5.6e-02		3.4e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											3.4e-04
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	Local - Aux. Bldg.	Accessible
Stress	**Low**	
	Plant Response As Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Optimal
Notes		
The depletion of IRWST means safety injection and secondary heat removal is performed successfully. Therefore, plant response as expected is assumed. This operator action is required long time later from initiator. Therefore, it is assumed that 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		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-CV #xx-1	Align Valves in CVCS to transfer borated water of BAST to the IRWST/BAMP (in Local)					1	
	Location: Local - Aux. Bldg.	EOM	20-8a	1	1.3e-03		
		EOC	20-13	2	3.8E-3		
					Total Step HEP		5.1e-03
SYS-CV #xx-2	Align Valves in CVCS to transfer borated water of BAST to the IRWST/BAMP (in MCR)					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.7e-03
SYS-CV #xx-3	Start BAMPs					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.7e-03
SYS-CV #xx-4	Check Flow and IRWST level					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		1.7e-03
SYS-CV #XX-5	Throttle SI Flow					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	10	3.8E-3		
					Total Step HEP		4.2e-03
SYS-CV #XX-6	Verify SI Flow Rate					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total 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-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

	SYS-CV #xx-4	Check Flow and IRWST level		1.7e-03	LD	5.2e-02	
SYS-CV #XX-5		Throttle SI Flow	4.2e-03				2.2e-04
	SYS-CV #XX-6	Verify SI Flow Rate		1.7e-03	LD	5.2e-02	
		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.10.hra	1806336	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	5.00 Minutes
Time available for recovery	20.00 Minutes
SPAR-H Available time (cognitive)	25.00 Minutes
SPAR-H Available time (execution) ratio	5.00
Minimum level of dependence for recovery	MD
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**
P_{ca}: Availability of Information	a	neg.

Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	i	neg.
Notes: n 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. In this HFE, additional procedure is required too. This HFE is to initiate RCP seal injection and thus the operator only performs and one-time check the status of related components and the value of variables. 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 modern control room are expected to be located in the front of the room. 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: In this HFE, ARP and system operating procedure are considered to perform operator actions. The status of CV pump and charging flow are used to determine the need of Aux. charging. It is assumed that the ARP and system operating procedure describes how the operator response when the normal charging line is failed including CV pump fail or any problem with charging flow.		
P_{ce}: Skip a step in procedure	g	6.0e-03
Notes: It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the 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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	-	-	-	-	-	N/A	-	1.0e+00		6.0e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
This HFE is to recover failed RCP seal injection by charging pump. This operator action have to be performed under limited time condition to prevent undesired plant state.		
Execution Complexity	Simple	

Execution Unrecovered							
Procedure: SYS-CV, Chemical Volume and Control System		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
SYS-CV #x-1	Close Charging Line Isolation Valve						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-CV #x-2	Start Aux. Charging Pump						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-CV #x-3	Check Seal Injection Flow						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-9	2	1.3E-3		
					Total Step HEP		8.7e-03
APR-RC #x-1	Ensure RCP seal cooling						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
ARP-RC #x-2	Stop RCP manually						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
ARP-RC #x-3	Check RCP status						
	Location: MCR	EOM	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**
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_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	1.00 Minutes
T_{M}	5.00 Minutes
Time available for recovery	24.00 Minutes
SPAR-H Available time (cognitive)	25.00 Minutes
SPAR-H Available time (execution) ratio	5.80
Minimum level of dependence for recovery	MD

Notes

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

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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. In this HFE, additional procedure is required too. This HFE is to initiate AACTG and supply power to 4.16kV bus. 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of EDG). The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	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 Factors:	N/A
Notes		
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-01 #2-c.1-3)	Ensure Alternative AC (AAC) generator has started.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-09 #9.a	Ensure Alternative AC(AAC) generator operation					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		8.7e-03
SYS-DA #x	Connection of braker to C1E power bus					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-DA #xx	Verify providing of power source from AAC TG					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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-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 .10.hra	1806336	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	1.00 Minutes
T_M	5.00 Minutes
Time available for recovery	24.00 Minutes
SPAR-H Available time (cognitive)	25.00 Minutes
SPAR-H Available time (execution) ratio	5.80
Minimum level of dependence for recovery	MD
Notes	
This operator's action is similar to operator action, such as DAOPH-S-AACTG.	

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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. In this HFE, additional procedure is required, too. This HFE is to change power supply division after successful initiating of AACTG because the train related SW01AC is unavailable. 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	b	3.0e-03
Notes: In this HFE, the train which is supplied from switch gear by AACTG is unavailable and operator tries to change another train. This is not matched with cue states or parameter values as stated in EOG. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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	Dependency Level	Multiply HEP By	Override Value	Final Value
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-DA #x	Close braker of AAC TG power bus to SWGR B/D						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-DA #xx	Open braker of AAC TG power bus from SWGR A/C						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-DA #xxx	Verify providing of power source from AAC TG						
	Location: MCR	EOM	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
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_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	50.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	15.00 Minutes
T_M	2.00 Minutes
Time available for recovery	33.00 Minutes
SPAR-H Available time (cognitive)	48.00 Minutes
SPAR-H Available time (execution) ratio	17.50
Minimum level of dependence for recovery	LD
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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 start up FW pump 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	b	3.0e-03
Notes: The EOG describes about post trip SG level band. But, in this HFE, indicated SG level is not satisfied what EOG described. The EOG provides contingency actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: Misinterpret Instructions	b	3.0e-03
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 does not mention about using start FW pump directly. But it is assumed that operators have enough training opportunity for using start up FW pump.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_f	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											5.0e-03
Notes											
STA review is possible using RCS heat removal section in SFSC. And also, CPS provides the 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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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: EOG-03, Reactor Trip		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-03 #7.1	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	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-07 #6.1-2)	Operate start-up feedwater pump	STA will be specially trained in mitigating the consequences of abnormal events. Feedwater supply is a major event during almost accident. Therefore, SG level is not controlled, supervisor and STA will re-diagnose the event and enter to the EOG-07.				5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	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-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_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	160.00 Minutes
T_{delay}	45.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	2.00 Minutes
Time available for recovery	108.00 Minutes
SPAR-H Available time (cognitive)	113.00 Minutes
SPAR-H Available time (execution) ratio	55.00
Minimum level of dependence for recovery	ZD
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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	h	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. In this HFE, additional procedure is required too. This HFE is to initiate start up FW pump 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 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. This HFE is performed in the late phase after initiating event occurred. It means that it takes for long time to perform this HFE. Thus operator response related alarms with ARP.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: Value of cues and parameters for this HFE are described in the ARP and system operating procedure. It is assumed that cues and parameters are indicated on the MCR		
P_{ce}: Skip a step in procedure	g	6.0e-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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	-	X	-	-	-	N/A	-	5.0e-01		3.0e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											3.0e-03
Notes											
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 Expected:	No
	Workload:	N/A

	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
ARP-xx #xx-1	Start Start-Up Feedwater Pump						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-07 #6.1-2)	Operate start-up feedwater pump	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.				5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	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
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 .10.hra	1806336	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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 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	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_{sw}	210.00 Minutes
T_{delay}	15.00 Minutes
$T_{1/2}$	25.00 Minutes
T_M	20.00 Minutes
Time available for recovery	150.00 Minutes
SPAR-H Available time (cognitive)	175.00 Minutes
SPAR-H Available time (execution) ratio	8.50
Minimum level of dependence for recovery	ZD

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**
P_{ca}: Availability of Information	a	neg.

Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 perform RCS depressurization and to isolate damaged SG. 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: The EOG describes about RCS depressurization and isolation of damaged SG when SGTR occurs.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	3.0e-03	X	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	ZD	1.6e-02		2.6e-04
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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	**Moderate**	
	Plant Response As Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Negative
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							
Procedure: EOG-05, Steam Generator Tube Rupture Recovery Guideline		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
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.					2	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	10	3.8E-3		
					Total Step HEP		8.5e-03
EOG-05 #15.b or 15.1	Operate main or auxiliary pressurizer spary or operate the pressurizer gas vent valve.	Aux. spray valve is on-off control SOV.				2	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		3.5e-03
EOG-05 #15.c	Control charging flow or throttle SI flow as necessary.	SI MOV 616/626/636/646 is jog control type MOV.				2	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	10	3.8E-3		
					Total Step HEP		8.5e-03
EOG-05 #25	Maintain the isolated SG level within isolated SG level control band					2	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		3.5e-03
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.					2	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	10	3.8E-3		
					Total Step 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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	240.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	22.00 Minutes
T_M	20.00 Minutes
Time available for recovery	198.00 Minutes
SPAR-H Available time (cognitive)	220.00 Minutes
SPAR-H Available time (execution) ratio	10.90
Minimum level of dependence for recovery	ZD

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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 perform RCS depressurization and SG cooldown. 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: The EOG describes about RCS depressurization and SG cooldown when SGTR occurs.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	3.0e-03	X	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	ZD	1.6e-02		2.6e-04
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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								
Procedure: EOG-05, Steam Generator Tube Rupture Recovery Guideline		**Comment**					**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**			
			Table	**Item**				
EOG-05 #23	Perform controlled cooldown within maximum cooldown rate by TBV or ADV.	TBV and ADV are flow control valve.						
	Location: MCR	EOM	20-7b	1	4.3e-04		5	
		EOC	20-12	10	3.8E-3			
						Total Step HEP		2.1e-02
EOG-05 #25	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	
		EOC	20-12	4	1.3E-3			
						Total Step HEP		8.7e-03
EOG-05 #28-b	Throttle SI flow as necessary.	SI MOV 616/626/636/646 is jog control type MOV.						
	Location: MCR	EOM	20-7b	1	4.3e-04		5	
		EOC	20-12	10	3.8E-3			
						Total Step HEP		2.1e-02
EOG-05 #45	Verify RCS condition for SC operation							
	Location: MCR	EOM	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-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-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 .10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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 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_{sw}	240.00 Minutes
T_{delay}	17.00 Minutes
$T_{1/2}$	27.00 Minutes
T_M	5.00 Minutes
Time available for recovery	191.00 Minutes
SPAR-H Available time (cognitive)	218.00 Minutes
SPAR-H Available time (execution) ratio	39.20
Minimum level of dependence for recovery	ZD

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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 perform aggressive cooldown with MSADVs and thus the operator only performs and one-time check of maximum 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of SI). Thus operator performs aggressive cooldown with MSADVs The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		

P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_e	3.0e-03	X	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	ZD	1.6e-02		2.6e-04
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											2.8e-04
Notes											
STA review is possible through SFSC for Pcd and Pcg. And also, 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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-10, IC-2 #3.a	Perform rapid cooldown within maximum cooldown rate						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	10	3.8E-3		
					Total Step 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.				5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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				1.2e-03
	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 .10.hra	1806336	07/24/13	07/16/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	40.00 Minutes
T_{delay}	2.00 Minutes
$T_{1/2}$	27.00 Minutes
T_M	5.00 Minutes
Time available for recovery	6.00 Minutes
SPAR-H Available time (cognitive)	33.00 Minutes
SPAR-H Available time (execution) ratio	2.20
Minimum level of dependence for recovery	HD

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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 perform aggressive cooldown with MSADVs and thus the operator only performs and one-time check of maximum 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of SI). Thus operator performs aggressive cooldown with MSADVs The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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.		

The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	HD	5.0e-01		1.5e-03
Pc_e	3.0e-03	-	-	-	-	-	N/A	-	1.0e+00		3.0e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	HD	5.1e-01		8.2e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											1.3e-02
Notes											
STA review is possible through SFSC, so STA review is applicable to Pcd and 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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-10, IC-2 #3.a	Perform rapid cooldown within maximum cooldown rate						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	10	3.8E-3		
					Total Step 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.				5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	60.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	5.00 Minutes
Time available for recovery	50.00 Minutes
SPAR-H Available time (cognitive)	55.00 Minutes
SPAR-H Available time (execution) ratio	11.00
Minimum level of dependence for recovery	LD

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)

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 open ADVs and thus the operator only performs and one-time check of SG pressure and status of related components and variables. 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 modern control room are expected to be located in the front of the room. 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. High SG pressure). Thus operator controls SG pressure with ADVs. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	LD	5.3e-02		1.6e-04
Pc_e	3.0e-03	X	-	-	-	-	N/A	LD	5.3e-02		1.6e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	LD	6.5e-02		1.0e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											1.3e-03
Notes											
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 also can 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	MCR	Accessible
Stress	**Low**	
	Plant Response As Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Optimal
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		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-01 #6-c.3-2)	To maintain SG pressure within post trip SG pressure control band, operate ADVs.					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	10	3.8E-3		
					Total 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 #6-c.3-2)		To maintain SG pressure within post trip SG 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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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.

Assigned Basic Events

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_{sw}	60.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	40.00 Minutes
Time available for recovery	15.00 Minutes
SPAR-H Available time (cognitive)	20.00 Minutes
SPAR-H Available time (execution) ratio	1.38
Minimum level of dependence for recovery	HD

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 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:	7.5e-03			
Notes/Assumptions:				

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 Expected:	Yes
	Workload:	High
	Performance Shaping Factors:	Negative
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. 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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-09 #6	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	
	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03		
		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 #6		Operate SG ADVs to maintain RCS Tavg within post-trip RCS Tavg control band.	1.3e-02				1.3e-02
		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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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.

Assigned Basic Events

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_{sw}	30.00 Minutes
T_{delay}	6.00 Minutes
$T_{1/2}$	3.00 Minutes
T_M	15.00 Minutes
Time available for recovery	6.00 Minutes
SPAR-H Available time (cognitive)	9.00 Minutes
SPAR-H Available time (execution) ratio	1.40
Minimum level of dependence for recovery	HD
Notes	
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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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: ,		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-AP #xx	Open 1E 4.16KV bus breaker from UAT manually					5	
	Location: Local - SWGR Room	EOM	20-8a	1	1.3e-03		
		EOC	20-13	2	3.8E-3		
					Total Step 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.10.hra	1806336	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	60.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	28.00 Minutes
T_M	15.00 Minutes
Time available for recovery	17.00 Minutes
SPAR-H Available time (cognitive)	45.00 Minutes
SPAR-H Available time (execution) ratio	2.13
Minimum level of dependence for recovery	MD

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) ~ 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
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 open POSRVs manually and thus the operator only performs and one-time check of SG level and status of related components and variables. 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 modern control room are expected to be located in the front of the room. 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of RCS heat removal by secondary side). Thus operators recover RCS heat removal with POSRVs. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	a	1.0e-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. For this operator action, related procedure step is hold point step and has graphically distinct. 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_{cf}: 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.		

The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	1.0e-03	-	-	-	-	-	N/A	-	1.0e+00		1.0e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											4.1e-03
Notes											
STA review is possible through RCS heat removal section of SFSC.											

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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
This HFE is to recover RCS heat removal after the failure of RCS heat removal 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		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-10, HR-3, #2-d.1	Ensure electrical pwer is available to motor operated pilot valves.					5	
	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03		
		EOC	20-12	8a	2.7E-4		
					Total Step HEP		7.9e-03
EOG-10, HR-3, #7-1	Confirm POSRV open status - POSRV leakage alarm and associated POSRV discharge line temperature					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #7-2	Manually open ALL motor operated pilot valves.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #9	If pressurizer pressure is less than or equal to low pressurizer pressure SIAS setpoint, then ensure SIAS is actuated.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	3	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #10-b	Verify SI flow of each pump is greater than SI flow delivery curve.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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, 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 .10.hra	1806336	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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 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_{sw}	240.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	31.00 Minutes
T_M	15.00 Minutes
Time available for recovery	194.00 Minutes
SPAR-H Available time (cognitive)	225.00 Minutes
SPAR-H Available time (execution) ratio	13.93
Minimum level of dependence for recovery	ZD

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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the		

main control room.		
P_{cb}: Failure of Attention	a	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 open POSRVs manually and thus the operator only performs and one-time check of SG level and status of related components and variables. 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 modern control room are expected to be located in the front of the room.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of RCS heat removal by secondary side). Thus operators recover RCS heat removal with POSRVs. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	a	1.0e-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. For this operator action, related procedure step is hold point step and has graphically distinct.		
P_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	1.0e-03	X	-	-	-	-	N/A	MD	1.4e-01		1.4e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											3.2e-03
Notes											
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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
This HFE is to recover RCS heat removal after the failure of RCS heat removal 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		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-10, HR-3, #2-d.1	Ensure electrical pwer is available to motor operated pilot valves.					5	
	Location: Local (Outside MCR)	EOM	20-8a	1	1.3e-03		
		EOC	20-12	8a	2.7E-4		
					Total Step HEP		7.9e-03
EOG-10, HR-3, #7-1	Confirm POSRV open status - POSRV leakage alarm and associated POSRV discharge line temperature					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #7-2	Manually open ALL motor operated pilot valves.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #8	Verify the motor operated pilot valves are fully opened.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #9	If pressurizer pressure is less than or equal to low pressurizer pressure SIAS setpoint, then ensure SIAS is actuated.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	3	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, HR-3, #10-b	Verify SI flow of each pump is greater than SI flow delivery curve.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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, 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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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

	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.

Timing Analysis	
T_{sw}	74.00 Seconds
T_{delay}	30.70 Seconds
$T_{1/2}$	0.00 Seconds
T_M	15.00 Seconds
Time available for recovery	0.47 Minutes
SPAR-H Available time (cognitive)	0.47 Minutes
SPAR-H Available time (execution) ratio	2.89
Minimum level of dependence for recovery	HD
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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 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. 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of reactor trip automatically). Thus operators recover reactor trip manually. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: Misinterpret decision logic	g	1.0e-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. But this operator action is considered and performed at the first step of EOG-01. Thus it does not include NOT statement. The operators are always trained and practiced about specified scenario to perform.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_e	3.0e-03	X	X	-	-	-	N/A	HD	2.5e-01		7.5e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.0e-02	-	X	-	-	-	N/A	-	5.0e-01		5.0e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											7.3e-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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-01 #1.a.1	Trip Rx manually						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-01 #1.b	Check Power Rate						
	Location: MCR	EOM	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-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

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

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_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	180.00 Minutes
T_{delay}	120.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	10.00 Minutes
Time available for recovery	45.00 Minutes
SPAR-H Available time (cognitive)	50.00 Minutes
SPAR-H Available time (execution) ratio	5.50
Minimum level of dependence for recovery	LD
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 boron precipitation. APR1400 SSAR section 6.3.3.4.4 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
* Tsw = 180 (Assumption)
* Td = 120 (elapse time from LOCA to perform EOG-04 step #4)
* T1/2 = 5 (Re-visitation to EOG-04 step #4 after elapse time of 2 hours)
* Tm = 10 (conservative time to align SI flow path and verify)

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	a	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 align valves of hot leg and DVI injection manually 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 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.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	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_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: Misinterpret decision logic	g	1.0e-02
Notes: This action is performed 2 hour after DA procedure. Therefore, only the LOCA EOG step #38 is considered for this tree. The operators are always trained and practiced about specified scenario to perform.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(without recovery credited)		1.3e-02
Notes		
Equipment Accessibility	MCR: Accessible	

Cognitive Recovery											
	Initial HEP	**Self Review**	**Extra Crew**	**STA Review**	**Shift Change**	**ERF Review**	**Recovery Matrix**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	3.0e-03	X	X	-	-	-	N/A	LD	2.6e-02		7.8e-05
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.0e-02	-	X	X	-	X	N/A	LD	1.8e-03		1.8e-05
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											9.6e-05
Notes											
STA review is possible through SFSC regarding RCS. 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	**Low**	
	Plant Response As Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Optimal
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		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-04 #38.a	Establish simulaneous hot leg and direct vessel injection					1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	10	3.8E-3		
					Total Step HEP		4.2e-03
EOG-04, SFSC	STA supervise "Establish simulaneous hot leg and direct vessel injection"	STA will be specially trained in mitigating the consequences of abnormal events. Hot leg injection is a major event during LOCA sequence. Therefore recovery by STA is possible.				1	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	2	1.3E-3		
					Total 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**
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

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

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_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	240.00 Minutes
T_{delay}	136.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	30.00 Minutes
Time available for recovery	69.00 Minutes
SPAR-H Available time (cognitive)	74.00 Minutes
SPAR-H Available time (execution) ratio	3.30
Minimum level of dependence for recovery	ZD

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
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	m	1.5e-02
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. Operator have to monitor the depressurization of RCS. 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of SIP operation). Thus operators performs aggressive cooldown and use SCS. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(without recovery credited)		3.7e-02
Notes		
Equipment Accessibility	MCR: Accessible	

Cognitive Recovery											
	Initial HEP	**Self Review**	**Extra Crew**	**STA Review**	**Shift Change**	**ERF Review**	**Recovery Matrix**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	1.5e-02	-	-	X	-	-	N/A	ZD	1.5e-02		2.3e-04
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_e	3.0e-03	X	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	ZD	1.6e-02		2.6e-04
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											5.1e-04
Notes											
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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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: EOG-10, IC-2, Functional Recovery Guideline - RCS Inventory Control, Safety Injection		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-10,IC-2 #9.2.4-1	SCS Valves align (in MCR)	Jog control type MOV					
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	10	3.8E-3		
					Total Step HEP		2.1e-02
EOG-10,IC-2 #9.2.4-3	SCS Pump Start						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10,IC2 #10	Check and Write the Safety Function Status						
	Location: MCR	EOM	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 #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,IC-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_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	150.00 Minutes
T_{delay}	70.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	2.00 Minutes
Time available for recovery	73.00 Minutes
SPAR-H Available time (cognitive)	78.00 Minutes
SPAR-H Available time (execution) ratio	37.50
Minimum level of dependence for recovery	ZD
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 * Tsw = 150 min (based on MAAP Analysis) * Td = 70 min (based on MAAP Analysis) * T1/2 = 5 min (step location assumption for IRWST cooling within 20 procedure steps after F&B completion) * Tm = 2 min (time for pump start and valve alignment)	

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the		

main control room.		
P_{cb}: Failure of Attention	h	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 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: The step of procedure for this action is not available now. But it is assumed that related steps may be added and well described in the related procedure.		
P_{ce}: Skip a step in procedure	g	6.0e-03
Notes: It's assumed that it's always transparent for operators to proceed the relevant instruction or stand-alone numbered step on the 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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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 system operating procedure describes clearly related actions. The operators are always trained and practiced about specified scenario to perform.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	X	-	-	-	-	N/A	ZD	6.0e-03		3.6e-05
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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	MCR	Accessible
Stress	**High**	
	Plant Response As Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-xx, #xx-1	Align Valves (in MCR)						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	10	3.8E-3		
					Total Step HEP		2.1e-02
SYS-xx, #xx-2	Start SDC PP						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-xx, #xx-3	Check SDC flow and IRWST Temp						
	Location: MCR	EOM	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
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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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 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_{sw}	240.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	20.00 Minutes
T_M	30.00 Minutes
Time available for recovery	190.00 Minutes
SPAR-H Available time (cognitive)	210.00 Minutes
SPAR-H Available time (execution) ratio	7.33
Minimum level of dependence for recovery	ZD
Notes	
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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	a	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 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. 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.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	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_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: Misinterpret decision logic	i	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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		

Pc_e	3.0e-03	X	-	-	-	-	N/A	ZD	3.0e-03		9.0e-06
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	3.0e-04	-	-	X	-	-	N/A	ZD	3.0e-04		9.0e-08
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
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 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 Expected:	Yes
	Workload:	Low
	Performance Shaping Factors:	Optimal
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 Unrecovered							
Procedure: SYS-SDC, Shutdown Cooling System		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-SDC #xx-1	Align Valves (in MCR)						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-12	10	3.8E-3		
					Total 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 Step HEP		1.7e-03
SYS-SDC #xx-3	Check SDC flow and RCS Temp						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-9	2	1.3E-3		
					Total Step HEP		1.7e-03
SYS-SDC #XX-4	Throttle SI Flow						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-12	10	3.8E-3		
					Total Step HEP		4.2e-03
SYS-SDC #XX-5	Verify SI Flow Rate						
	Location: MCR	EOM	20-7b	1	4.3e-04	1	
		EOC	20-9	2	1.3E-3		
					Total 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-SDC #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-SDC #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-SDC #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_{cog}	P_{exe}	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.

Assigned Basic Events

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	Establish CS Flow
Execution Procedure	SYS-CS (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	
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_{sw}	240.00 Minutes
T_{delay}	17.00 Minutes
$T_{1/2}$	20.00 Minutes
T_M	30.00 Minutes
Time available for recovery	173.00 Minutes
SPAR-H Available time (cognitive)	193.00 Minutes
SPAR-H Available time (execution) ratio	6.77
Minimum level of dependence for recovery	ZD

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)

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: Failure of Attention	h	neg.
Notes: If additional procedure is required, the high workload is assumed. This HFE is to align valves and initiate SC pump and thus the operator only performs and one-time check of CS flow and the status of related components and variables. 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 modern control room are expected to be located in the front of the room. This HFE is performed in the late phase after initiating event occurred. It means that it takes for long time to perform this HFE. Thus operator response related alarms with ARP.		
P_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: Value of cues and parameters for this HFE are described in the ARP and system operating procedure. It is assumed that cues and parameters are indicated on the MCR		
P_{ce}: Skip a step in procedure	g	6.0e-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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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.		
P_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	6.0e-03	X	-	-	-	-	N/A	ZD	6.0e-03		3.6e-05
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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	MCR	Accessible
Stress	**High**	
	Plant Response As Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-CS #xx-1	Align Valves (in MCR)						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-CS #xx-2	Start SDC PP						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-CS #xx-3	Check CS flow and Containment Pressure						
	Location: MCR	EOM	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
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_{cog}	P_{exe}	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.

Assigned Basic Events

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	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.	

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_{sw}	20.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	3.00 Minutes
T_M	1.00 Minutes
Time available for recovery	16.00 Minutes
SPAR-H Available time (cognitive)	19.00 Minutes
SPAR-H Available time (execution) ratio	17.00
Minimum level of dependence for recovery	MD

Notes

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_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 SIAS manually and thus the operator only performs and one-time check of SIAS alarm and status of related components and variables. 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 modern control room are expected to be located in the front of the room. 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_{cc}: Misread/miscommunicate data	a	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_{cd}: 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 does not respond automatically(i.e. Failure of SIAS automatically). Thus operators recover SIAS manually. The EOG provides contingeny actions which are instructions on how to proceed if the cue states are not as stated.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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.		

The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_e	3.0e-03	-	X	-	-	-	N/A	-	5.0e-01		1.5e-03
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
This HFE is to recover ESF actuation signal. This operator action have to be performed under under limited time condition to prevent undesired plant state.		
Execution Complexity	Simple	

Execution Unrecovered							
Procedure: EOG-01, SPTA		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-01 #4.3	Ensure SIAS is initiated					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	3	1.3E-3		
					Total Step HEP		8.7e-03
EOG-04 #4.a	Verify and Ensure SIAS Actuation					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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-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
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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.

Assigned Basic Events

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	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_{sw}	20.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	2.00 Minutes
Time available for recovery	13.00 Minutes
SPAR-H Available time (cognitive)	18.00 Minutes
SPAR-H Available time (execution) ratio	7.50
Minimum level of dependence for recovery	HD
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 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:	1.2e-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	MCR	Accessible
Stress	**High**	
	Plant Response As Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-HV #xx-0	Ensure EDG Room HVAC.						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-HV #xx-1	Verify the EDG room temperature.						
	Location: MCR	EOM	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
SYS-HV #xx-0		Ensure EDG Room HVAC.	8.7e-03				4.4e-03
	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.10.hra	1806336	07/24/13	07/23/13
	Name			**Date**
Analyst	Namcheol Kim			04-26-2013
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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.

Assigned Basic Events

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_{sw}	20.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	2.00 Minutes
Time available for recovery	13.00 Minutes
SPAR-H Available time (cognitive)	18.00 Minutes
SPAR-H Available time (execution) ratio	7.50
Minimum level of dependence for recovery	HD
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 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:	1.2e-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	MCR	Accessible
Stress	**High**	
	Plant Response As Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SYS-WO #xx-0	Start ECW Pump and/or Chiller						
	Location: MCR	EOM	20-7b	1	4.3e-04	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
SYS-WO #xx-1	Verify the essential chilled water flow						
	Location: MCR	EOM	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
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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	60.00 Minutes
T_{delay}	2.00 Minutes
$T_{1/2}$	20.00 Minutes
T_M	1.00 Minutes
Time available for recovery	37.00 Minutes
SPAR-H Available time (cognitive)	57.00 Minutes
SPAR-H Available time (execution) ratio	38.00
Minimum level of dependence for recovery	LD

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**
P_{ca}: Availability of Information	a	neg.

Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: It is assumed that all cues will be as stated when the operators follow the "Instruction" column of the EOGs.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	3.0e-03	X	-	-	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
It is assumed that plant response is not expected, because this event is for Level 2 PRA.		
Execution Complexity	Simple	

Execution Unrecovered							
Procedure: EOG-10, CI-1, Functional Recovery Guideline - Containment Isolation		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-10, CI-1 # 1-a	Ensure CIAS is initiated.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	3	1.3E-3		
					Total Step HEP		8.7e-03
EOG-10, CI-1 # 1-b	Ensure all containment isloation valves receiving CIAS are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-9	3	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, CI-1 # 1-a		Ensure CIAS is initiated.	8.7e-03				5.1e-04
	EOG-10, CI-1 # 1-b	Ensure all containment isloation valves receiving CIAS are closed.		8.7e-03	LD	5.8e-02	
		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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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.

Assigned Basic Events

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_{sw}	60.00 Minutes
T_{delay}	2.00 Minutes
$T_{1/2}$	20.00 Minutes
T_M	20.00 Minutes
Time available for recovery	18.00 Minutes
SPAR-H Available time (cognitive)	38.00 Minutes
SPAR-H Available time (execution) ratio	1.90
Minimum level of dependence for recovery	MD
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 credit is given for this operator action in the Level 2 PRA. * 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 = 20 min (It is assumed that 20 minute will be used as recovery time including local operation.)

Cognitive Analysis		
Pc Failure Mechanism	**Branch**	**HEP**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	c	1.0e-02
Notes: This operator action is required after failure of recovery for CIAS in the MCR. The EOG does not describe that this action is performed at local after failure of recovery CIAS in the MCR. Thus, "no" is selected at the all cues as stated branch and warning of differences branch. Additional information for training programs describes that the radiation should be checked when isolation is preformed in local. And the resource tree includes the path for local manual operation.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: Misinterpret Instructions	b	3.0e-03
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 does not present about local operation for the failure of CIAS recovery in the MCR. But it is assumed that the operator has enough training for this action.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(without recovery credited)		3.2e-02
Notes		
Equipment Accessibility	MCR: Accessible	

Cognitive Recovery											
	Initial HEP	**Self Review**	**Extra Crew**	**STA Review**	**Shift Change**	**ERF Review**	**Recovery Matrix**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	1.0e-02	-	-	X	-	-	N/A	MD	1.5e-01		1.5e-03
Pc_e	3.0e-03	X	-	-	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_f	3.0e-03	-	-	X	-	-	N/A	MD	1.5e-01		4.5e-04
Pc_g	1.6e-02	-	-	X	-	-	N/A	MD	1.6e-01		2.6e-03
Pc_h	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Final Pc (with recovery credited)											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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A

Notes	
It is assumed that no plant response as expected, because this event is for Level 2 PRA.	
Execution Complexity	Simple

Execution Unrecovered							
Procedure: EOG-10, CI-1, Functional Recovery Guideline - Containment Isolation		Comment				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
EOG-10, CI-1 Cont. Act. #2.c	The feasibility of isolating containemtn peenetration(s) by alternate means.						
	Location: Local - Aux. Bldg.	EOM	20-7b	1	4.3e-04	5	
		EOC	20-13	2	3.8E-3		
					Total Step 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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	**P_{exe}**	**Total HEP**	**Error Factor**
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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 DOWNSTREAM)
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-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℉

4. Operator action success criterion : Operators should manually open the 3-way valves within 30 minutes after severe accident initiation (CET > 1,200 ℉).

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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	2.00 Minutes
Time available for recovery	23.00 Minutes
SPAR-H Available time (cognitive)	28.00 Minutes
SPAR-H Available time (execution) ratio	12.50
Minimum level of dependence for recovery	MD
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/Assumptions:				

Execution Performance Shaping Factors		
Environment	Lighting	Emergency
	Heat	Hot / Humid
	Radiation	Green
	Atmosphere	Normal
Equipment Accessibility	MCR	Accessible
Stress	**High**	
	Plant Response As Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SAMG-xx, # x-5	Open 3-way valve						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.3e-02
SAMG-xx, # x-6	verify flow						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-9	2	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
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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	**P_{exe}**	**Total HEP**	**Error Factor**
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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
TLOCCW
Loss of IA
Loss of 1E 125DC VITAL BUS B
Loss of 1E 125DC VITAL BUS A
LOOP
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℉

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 ℉).

5. Definition : If the CET exceeds 1,200℉ 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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	17.00 Minutes
Time available for recovery	8.00 Minutes
SPAR-H Available time (cognitive)	13.00 Minutes
SPAR-H Available time (execution) ratio	1.47
Minimum level of dependence for recovery	HD
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℉ 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 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:	1.1e-01			
Notes/Assumptions:				

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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SAMG-xx, # x-1	Recover power to POSRVs						
	Location: Elec. Equip. Room	EOM	20-8a	1	1.3e-03	5	
		EOC	20-12	8a	2.7E-4		
					Total Step HEP		7.9e-03
SAMG-xx, # x-3	Open POSRVs manually						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.3e-02
SAMG-xx, # x-5	Open 3-way valve						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	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
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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	Total HEP	Error Factor
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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 IA
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°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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes

$T_{1/2}$	5.00 Minutes
T_M	19.00 Minutes
Time available for recovery	6.00 Minutes
SPAR-H Available time (cognitive)	11.00 Minutes
SPAR-H Available time (execution) ratio	1.32
Minimum level of dependence for recovery	HD
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 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:	1.5e-01			
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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SAMG-xx, # x-1	Align SCS valves for Rx cavity injection						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.3e-02
SAMG-xx, # x-2	Start SCP pump for Rx cavity injection						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.3e-02
SAMG-xx, # x-3	Align CVCS valves for Rx cavity injection (MCR)						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	1.3E-3		
					Total Step HEP		1.3e-02
SAMG-xx, # x-4	Align CVCS valves for Rx cavity injection (Local)						
	Location: Local - Out of MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-13	2	3.8E-3		
					Total Step HEP		2.6e-02
SAMG-xx, # x-5	Start BAMP for Rx cavity injection						
	Location: MCR	EOM	20-7	1	1.3e-03	5	
		EOC	20-12	4	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
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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	P_{exe}	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

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

Timing Analysis	
T_{sw}	150.00 Minutes
T_{delay}	15.00 Minutes
$T_{1/2}$	40.00 Minutes
T_M	20.00 Minutes
Time available for recovery	75.00 Minutes
SPAR-H Available time (cognitive)	115.00 Minutes
SPAR-H Available time (execution) ratio	4.75
Minimum level of dependence for recovery	ZD
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 (Rx 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**
P_{ca}: Availability of Information	a	neg.
Notes: Operator can access to all information and required indication to operate a plant in the main control room.		
P_{cb}: 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 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 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 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_{cc}: Misread/miscommunicate data	a	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_{cd}: Information misleading	a	neg.
Notes: It is assumed that all cues will be as stated when the operators follow the "Instruction" column of the EOGs.		
P_{ce}: Skip a step in procedure	c	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 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_{cf}: 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. The step present all information required to identify the actions directed and their objects.		
P_{cg}: 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_{ch}: Deliberate violation	a	neg.
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_c(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**	**Dependency Level**	**Multiply HEP By**	**Override Value**	**Final Value**
Pc_a	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_b	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_c	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_d	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_e	3.0e-03	X	-	-	-	-	N/A	LD	5.3e-02		1.6e-04
Pc_f	neg.	-	-	-	-	-	N/A	-	1.0e+00		
Pc_g	1.6e-02	-	-	X	-	-	N/A	LD	6.5e-02		1.0e-03
Pc_h	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 Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
Notes		
It is assumed that no plant response as expected, because this event is for Level 2 PRA.		
Execution Complexity	Simple	

Execution Unrecovered							
Procedure: EOG-05, Steam Generator Tube Rupture Recovery Guideline		**Comment**				**Stress Factor**	**Over Ride**
Step No.	**Instruction/Comment**	**Error Type**	**THERP**		**HEP**		
			Table	**Item**			
EOG-05, # 11-a	Ensure MSIVs are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-05, # 11-e	Ensure MFIVs are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-05, # 11-f	Close AFW isolation valves are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-05, # 11-g	Close AFW trubine steam isolation valves are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-05, # 11-h	Ensure SG sampling isolation valves are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-05, # 11-i	Ensure SG blowdown isolation valves are closed.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		EOC	20-12	4	1.3E-3		
					Total Step HEP		8.7e-03
EOG-5, # 12	Verify the most affected SG is isloated by observing SG activity levesl, secondary system radiation levels and SG levels.					5	
	Location: MCR	EOM	20-7b	1	4.3e-04		
		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-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 Level 2	APR1400_DC_HRA-M03-L2.HRA	921600	07/24/13	07/24/13
	Name			**Date**
Analyst	Namcheol Kim			
Reviewer	Kisu Kim			

HEP Summary				
	P_{cog}	**P_{exe}**	**Total HEP**	**Error Factor**
Method	HCR/ORE	THERP	HCR/ORE+THERP	
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: (All the Initiating Events except for ISLOCA) Large LOCA Medium LOCA SLOCA SGTR Reactor Vessel Rupture 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 IA Loss of 1E 125DC VITAL BUS B Loss of 1E 125DC VITAL BUS A LOOP 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 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, 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_{sw}	30.00 Minutes
T_{delay}	0.00 Minutes
$T_{1/2}$	5.00 Minutes
T_M	2.00 Minutes
Time available for recovery	23.00 Minutes
SPAR-H Available time (cognitive)	28.00 Minutes
SPAR-H Available time (execution) ratio	12.50
Minimum level of dependence for recovery	MD
Notes	
In general, it takes at least one hours to actually occur the reactor vessel breach after severe accident initiation (CET > 1,200°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 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/Assumptions:				

Execution Performance Shaping Factors		
Environment	Lighting	Emergency
	Heat	Hot / Humid
	Radiation	Green
	Atmosphere	Normal
Equipment Accessibility	MCR	Accessible
Stress	**High**	
	Plant Response As Expected:	No
	Workload:	N/A
	Performance Shaping Factors:	N/A
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				Stress Factor	Over Ride
Step No.	Instruction/Comment	Error Type	THERP		HEP		
			Table	Item			
SAMG-xx1	Open CFS valves					5	
	Location: MCR	EOM	20-7	1	1.3e-03		
		EOC	20-12	3	1.3E-3		
					Total Step HEP		1.3e-02
SAMG-xx2	verify CFS operation					5	
	Location: MCR	EOM	20-7	1	1.3e-03		
		EOC	20-9	2	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
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

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Table 19.1-25

Level 1 Internal Events Key Operator Actions by FV (CDF)

Rank	Operator Action	Description	FV
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	~~WOOPH-S-1AB2AB~~	OPERATORS FAIL TO START ECW PUMPS MANUALLY	1.9%
6	CVOPH-S-RCPSEAL	OPERATORS FAIL TO RECOVER RCP SEAL COOLING	1.7%
7	HR-RCSCD2	OPERATORS FAIL TO TAKE ACTION FOR SG COOLDOWN & RCS DEPRESS AFTER OVERFILL	1.5%
8	HR-RCSCD1-ISOL	OPERATORS FAIL TO TAKE ACTION FOR SG COOLDOWN & RCS DEPRESS PRIOR TO OVERFILL	1.5%
9	AFOPH-S-ALT-LT	OPERATOR FAIL TO ALIGNE FOR SUPPLYING AN ALTERNATE SOURCE	0.8%
10	RCOPH-S-SDSL	OPERATORS FAIL TO OPEN SDS VALVES DURING LATE PHASE	0.8%

WOOPV-S-1AB2AB