2. Self-Study Guide Supplement

Appendix E: Expert Consensus Tables

Part2 Operating Experience Review (OER)

1. Purpose

The purpose of the US-APWR human factors engineering (HFE) operating experience review (OER) is to identify, analyze, and document HFE-related problems and issues so that the negative features are not repeated and the positive features are retained. The problems and issues were documented with a content and format conducive for inclusion in the HFE design analysis process.

2. Scope

The scope of this review includes human factors issues related to predecessor plant(s) or highly similar plants and plant systems. An OER process was conducted for the development of the standard Japanese HSI System. This report was updated and expanded for the US-APWR.

Findings of this US-APWR OER that are generically applicable to all nuclear applications are included in the standard US Basic HSI System, which was the basis of the US-APWR HSI System. Other findings, which were considered unique to specific plant applications, were evaluated specifically for the US-APWR only. The applicability of these plant specific findings to other nuclear facilities, that also adopt the US Basic HSI System, were evaluated for those facilities in the future and within the context of their plant specific OER program.

Recognized nuclear industry HFE issues and issues related to HFE technology were included in the review. Since the nuclear industry lacks significant experience with the modern HSI technology used in the US-APWR, the OER also encompassed the utilization of similar HSI technologies from other process industries. The OER shall be documented in this report.

All aspects of the OER shall be conducted as described in Reference 7-1, Section 18.2.

3. Methodology

The methodology for performing the HFE OER and documentation to support the HFE analyses are described in this section.

3.1 Data Acquisition

Operating experience related to system and human performance for systems similar to the US-APWR were obtained from the following data sources:

- Licensee event reports (LERs)
- Significant event reports (SERs)
- Significant operating experience reports (SOERs)
- Event Reports for Non-Nuclear and Nuclear Chemical facilities
- Event Reports for Transportation Industries
- Event Reports for Electrical Transmission Infrastructure

3.2 Data Review

A structured evaluation was conducted to determine the applicability of the operational data to each human factors issue identified in the tables below. Issues identified during the OER include human performance issues, problems, and sources of human error as well as design elements that support and enhance human performance. The OER identified potential human engineering deficiencies (HEDs) that could exist in the US-APWR HSI. HEDs that are currently addressed in the US-APWR HSI System are dispositioned with an explanation of the design elements that resolve the issue. HEDs that are not currently addressed in the US-APWR HSI System are entered into the issues tracking system to ensure evaluation and resolution during the OER HED evaluation process, described below.

Issues identified during the review are classified for their applicability. The review determined if the issue was generically applicable to the US Basic HSI System or applicable on a plant specific basis and whether it was already addressed in the current design. Some identified issues may include a combination of both generic Basic HSI features and plant specific HSI features.

The OER addressed related HFE technology utilized in the standard Japanese PWR HSI and the US-APWR HSI. For example:

- touch screen interfaces
- large-screen displays
- computerized procedures

HFE issues associated with the use of these technologies were reviewed, including HFE design aspects used in other industries.

The OER considered the following topic areas during the review, as listed below in Tables 1 and 2. These issues and their resolutions were included in a summary table as depicted in Appendix 8.1 “US-APWR OER Report Issues and Resolutions Table”.

Table 1 HFE Issues from the US-APWR DCD Section 18.2 (Extracted from Reference 7-1)

Issue/Scope	Human Factors Aspect Issue
Plant Operations	Normal plant evolutions (e.g., startup, full power, and shutdown)
	Instrument failures (e.g., safety-related system logic and control unit, fault tolerant controller (nuclear steam supply system), data network bus system, network bus controller, and break in data network line)
	HSI equipment and processing failure (e.g., loss of video display units, loss of data processing, or loss of large overview display)
	Transients (e.g., turbine trip, loss of offsite power, station blackout, loss of all feedwater, loss of service water, loss of power to selected buses or control room power supplies, and safety/relief valve transients)
	Accidents (e.g., main steam line break, positive reactivity addition, control rod insertion at power, control rod ejection, anticipated transients without scram, and various-sized loss-of-coolant accidents)
	Reactor shutdown and cooldown using remote shutdown system
HFE Design Topics	Alarm and annunciation
	Display
	Navigation
	Control and automation
	Information processing and job aids
	Real-time communications with plant personnel and other organizations
	Procedures, training, staffing/qualifications, and job design

Table 2 Automated/Advanced Systems Topics Extracted from NUREG/CR-6400 (Reference 7-2) (sheet 1 of 2)

Issue/Scope	Human Factors Aspect Issue
Integration of information – Supervisory Control	Integrate information from multiple sources (displays/audio) – control room noise level
	Identification and establishment of facility operating modes as specified in Technical Specifications
	Coordinate actions of multiple operators
	Monitor/Manage multiple automatic sequences
	Multiple Alarms – Alarm “Avalanche”
	Alarm Prioritization – Multiple Prioritization Schemes
	Integration of equipment removed from service into automated sequences
Processing of Information	Overly complex interfaces
	Calculations
	Unit selection
	Parameter display and trending
	Loss of information – alarm failures
	Operator alarm selection – allocation to an interface
	Invalid data input awareness
Inadvertent Operation	Equipment operation, error of omission or commission
	Memorized actions – failure to perform
	Operation feedback – slow computer response

Table 2 Automated/Advanced Systems Topics Extracted from NUREG/CR-6400 (Reference 7-2) (sheet 2 of 2)

Issue/Scope	Human Factors Aspect Issue
Test and Maintenance	Identification of hardware/software faults
	Spurious alarms during testing
	Failure to receive bypassed alarms
	Inadvertent actuation of safety systems
	Control/status of equipment removed from service.
Procedures (Electronic or Paper)	Space/provision for explanatory information
	Non-linear information – sequential presentation
	Irrelevant information
	Cross-referencing between procedures
	Physical management of multiple procedures – multiple media (electronic and paper simultaneously)
	Maintaining the technical accuracy of procedures
Local Control Stations – Field Operations	Containment/ventilation integrity – hatch or damper configuration or operation
	Field valve position indicators/operators
	Field water level indicators - refueling
	Fuel handling equipment operations
	Field configuration of off-site power, portable power/air supply units
	Functional centralization of LCSs

3.3 Data Documentation

The evaluation data was recorded on the form contained in Appendix 8.1. Each operating experience item determined to be appropriate for HFE consideration was entered in the form. Those items that were considered to be already included in the US-APWR HSI System were dispositioned and closed out within the form. Those items not already addressed in the US-APWR HSI System were noted in the form and further documented by entering an HED in the HFE issues tracking system.

The HFE design aspects incorporated in the US-APWR design from previous or predecessor plant designs are clearly identified in the US-APWR operating experience review report. The HFE-related problem resolutions, including supporting analysis and corrective designs are provided. In addition, a discussion of positive HFE features that were identified, evaluated, and retained is provided.

The OER information source documents citations are summarized on a form contained in Appendix 8.2. The source document is listed, its unique source document identifier was recorded (from the form in Appendix 8.1), and a brief summary of background information or scenarios obtained from source document are recorded.

4. Records

The results from the HFE OER analysis are documented in this report. Issues identified during the HFE OER are currently being entered into the HFE issues tracking system. All documentation activities were conducted as described in Reference 8-3.

5. Responsibilities

5.1 OER Team

The OER Team has the following functions and responsibilities:

- Perform OER literature searches
- Develop the initial draft of the Issues and Resolutions Table (form in Appendix 8.1) and the OER Information Sources table (form in Appendix 8.2)
- Conduct evaluation of the tables
- Writes the OER report
- Disposition technical reviewer's comments.

5.2 HSI System Design Team Manager

The HSI system design team manager (DTM) organizes the OER team. The DTM is responsible for issuing the OER report.

5.3 Additional Guidance

Reference 7-1, Section 18.1 provides additional guidance on organizational requirements in the area of people, roles, responsibilities, and qualifications for work performed under this procedure.

6. Result

Table 3 and table 4 listed information sources for each OER. Table 3 is nuclear industries OER which contains NUREG/CR-6400 issues, recent issue extracted from INPO information and Japanese OER issues from JANTI (Japan Nuclear Technologies Institute) database. Table 4 is non-nuclear industries OER which contains Chemical Plants, Nuclear Processing, Marine Events, Railroad Events, Aircraft Events, Electrical Transmission, Pipeline Events and Japanese industries applied by Mitsubishi screen based HSI system.

Table 3 OER Information Sources (Nuclear Industries)

Source Document Citation	Source Document ID (X)	Brief Summary of background information/scenario obtained from source document
Unresolved safety issues-- NUREG/CR-6400	A-xx, B-xx,	These are extracted from NUREG/CR-6400. NUREG/CR-6400 described several unresolved safety issues.
Generic safety issues-- NUREG/CR-6400	GI-xx	These are extracted from NUREG/CR-6400. NUREG/CR-6400 described several generic safety issues.
Three Mile Island issues-- NUREG/CR-6400	1v,2x, etc.	Many issues were obtained from TMI-3 accident. These issues are described in NUREG-0737, and NUREG/CR-6400 quotes these issues.
Generic letter and information notices	Generic Letter-xx, Information Notices	These are extracted from NUREG/CR-6400.
NUREG-1275		The NRC analyzed and evaluated operational data (AEOD) to identify human factors and human performance issues. Results were summarized in NUREG-1275.
INPO information	INPO-xx, MR-xx, ORE-xx, LER-xx	INPO has a big database which includes troubles, failures, operational errors etc. of nuclear power stations. These issues were extracted from tens of thousands of events in the INPO database by key word “human error”. The extraction was performed from 1995 to 2008.
NUCIA database	xx-(utility name)-xx	Japan Nuclear Technologies Institute (JANTI) has a big database of operating experience of Japanese nuclear power plants. JANTI database are called NUCIA (Nuclear Information Archives), which includes thousands of events data and NUCIA includes troubles, failures, operational errors etc. of Japanese nuclear power stations. Everybody can access to the NUCIA database from internet, but described in Japanese. For OER consideration, issues were extracted by key word “human error” of PWR.

Note)
- Source Document Citation – Formal reference format

- Source Document ID (X) – Number assigned of the Source Document Citation in the "Item" column in Table 8.1

Brief Summary of background information/scenario obtained from source document – Summary description of scenario with emphasis on HFE aspects

Table 6 through table 10 shows the results of each OER. These tables consist of ;

Table 6	NUREG/CR-6400/Generic Letter/Information Notices
Table 7	INPO Database
Table 8	Japanese PWR
Table 9	Non nuclear facilities in U.S.
Table 10	Non nuclear facilities in Japan

Table 4 OER Information Sources (Non-nuclear industries)

Source Document Citation	Source Doc ID	Brief Summary of background information/scenario obtained from source document
Chemical Plants	**CP-**	
CSB Report 2003-13-I-LA	A	Honeywell Chemical Incidents, Baton Rouge, LA, July/August 2003
CSB Report 2004-11-I-CA	B	Sterigenics Ethylene Oxide Explosion, Ontario, CA, August 19, 2004.
CSB Report 2005-04-I-TX	C	BP America Refinery Explosion, Texas City, TX, March 23, 2005.
CSB Report 2006-01-I-TX	D	Formosa Plastics Propylene Explosion, Point Comfort, TX, October 06, 2005.

Nuclear Processing	**NP-**	
DNFSB Report, DWPF DCS, Reference 5.2-1	A	Human Factors Issues - DWPF DCS for inadvertent activation.
DNFSB Report, Pantex Fire Issues, Ref. 5.2-2	B	Pantex Fire Response Issues, Missed fire alarms.

Marine Events	**M-**	
NTSB Report MAR-97-01	A	Accident Report Grounding of the Panamanian Passenger Ship *ROYAL MAJESTY* on Rose and Crown Shoal near Nantucket, Massachusetts.
NTSB Report MAR-01-01	B	Marine Accident Report: Fire On Board Liberian Passenger Ship *Ecstasy*, Miami, Florida.
NTSB Report MAB-07-02	C	Grounding of the Hong Kong-Registered Container Ship *New Delhi Express* New York Harbor, Kill Van Kull Waterway,
NTSB Report MAR-08-01	D	Marine Accident Report: Heeling Accident on *M/V Crown Princess*, Atlantic Ocean Off Port Canaveral, Florida.

Railroad Events	**RR-**	
NTSB Report RAB-08-03	A	Railroad Accident Brief: Collision of Two Southeastern Pennsylvania Transportation Authority Trains, Abington, Pennsylvania.
NTSB Report	B	Railroad Accident Report: Collision of Massachusetts

Source Document Citation	Source Doc ID	Brief Summary of background information/scenario obtained from source document
RAR-08-01		Bay Transportation Authority Train 322 and Track Maintenance Equipment Near Woburn, Massachusetts.

Aircraft Events	AC -	
Aviation Safety Network(Flight Safety Foundation) http://aviationsafety.net/database/record.php?id=19880626-0	A	Air France Flight 296 Airbus A320 Airline Crash, Mulhouse-Habsheim Airport, France, June 26, 1988
Aviation Safety Network(Flight Safety Foundation) http://aviationsafety.net/database/record.php?id=19940323	B	Aeroflot Flight 593 Airbus A310-304 Airline Crash on March 23,1994
Ministry of Transport Japan, Aircraft Accident Investigation Commission (1996). China Airlines Airbus Industries A300B4-622R, B1816, Nagoya *Airport, April 26, 1994*. Report 96-5.	C	China Airlines Flight 140 Airbus A300 Airline Crash in Nagoya, Japan on April 26, 1994
"Final Report on the Investigation into the accident involving the Armavia A320 near Sochi Airport on 2 May 2006", Interstate Aviation Committee, Air Accident	D	Armavia Airlines Flight 967 Airbus A320 Airline Crash into the Black Sea off the coast of Sochi, Russia, May 2, 2006

Source Document Citation	Source Doc ID	Brief Summary of background information/scenario obtained from source document
Investigation Commission, Moscow, 2006		

Chemical Plants	**CP-**	
CSB Report 2003-13-I-La	A	Honeywell Chemical Incidents, Baton Rouge, LA, July/August 2003
CSB Report 2004-11-I-CA	B	Sterigenics Ethylene Oxide Explosion, Ontario, CA, August 19, 2004.
CSB Report 2005-04-I-TX	C	BP America Refinery Explosion, Texas City, TX, March 23, 2005.
CSB Report 2006-01-I-TX	D	Formosa Plastics Propylene Explosion, Point Comfort, TX, October 06, 2005.

Electrical Transmission	**ET-**	
U.S.-Can Task Force Report, Reference 5.2-3	A	Electrical System Blackout in the U.S. and Canada, August 14, 2003.

Pipeline Events	**PL-**	
NTSB Report PAB-99-03	A	Hazardous Liquid Petroleum Products Overpressure Rupture, Murfreesboro, Tennessee.
NTSB Report PAB-01-01	B	Hazardous Liquid Petroleum Products Pipeline Rupture, Colonial Pipeline Company, Knoxville, Tennessee.
NTSB Report PAB-01-02	C	Hazardous Liquid Pipe Failure and Leak, Marathon Ashland Pipe Line, LLC Winchester, Kentucky.
NTSB Report PAB-01-03	D	Hazardous Liquid Pipe Failure and Leak, Explorer Pipeline Company, Greenville, Texas.
NTSB Report PAR-02-01	E	Pipeline Accident Report: Rupture of Piney Point Oil Pipeline and Release of Fuel Oil Near Chalk Point, Maryland.
NTSB Report PAR-02-02	F	Pipeline Accident Report: Pipeline Rupture and Release of Gasoline, Olympic Pipeline Company, Bellingham, Washington.
NTSB Report PAR-04-02	G	Pipeline Accident Report: Storage Tank Explosion and Fire in Glenpool, Oklahoma.

Source Document Citation	Source Doc ID	Brief Summary of background information/scenario obtained from source document
NTSB Report PAB-07-02	H	Pipeline Accident Brief: Anhydrous Ammonia Pipeline Rupture Near Kingman, Kansas.
NTSB Report SS-05-02	I	Supervisory Control and Data Acquisition (SCADA) in Liquid Pipelines

Japanese industries		
Japanese industries applied by Mitsubishi System	-	Thermal power station and Manufacturing factories

Note)
- Source Document Citation – Formal reference format
- Source Document ID (X) – Number assigned of the Source Document Citation in the "Item" column in Table 8.1
- Brief Summary of background information/scenario obtained from source document – Summary description of scenario with emphasis on HFE aspects

Table 6 through table 10 consists of the same format as shown in table 5.
Contents of each table are as follows;

- No. - Sequential Row Number
- Item – Item number link to information source, X-YY, where X=source document, and YY= item in source document.
- Issue/Scope – General HFE categorization from Section 4.2
- Human Factors Aspect Issue – Brief description of the HFE issue from Section 4.2.
- Human Factors Issue Addressed by US-APWR - Brief description of the HFE issue potentially impacting the US-APWR Specific Design as determined by the OER Team.

Table 5 Example of OER issues and resolution list

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 1 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 2 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 3 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 4 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 5 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 6 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 7 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 8 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 9 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 10 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 11 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 12 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 13 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 14 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 15 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 16 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 17 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 18 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 19 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 20 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 21 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 22 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 23 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 24 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 25 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 26 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 27 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 28 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 29 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 30 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 31 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 32 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 33 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 34 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 35 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 36 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 37 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 38 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 39 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 40 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 41 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 42 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 43 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 44 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 45 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 46 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 47 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 48 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 49 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 50 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 51 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 52 of 64)

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Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 54 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 55 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 56 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 57 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 58 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 59 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 60 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 61 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 62 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 63 of 64)

Table 6 Operating Experience Review for US-APWR (Issues obtained from NUREG/CR-6400) (Sheet 64 of 64)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 1 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 2 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 3 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 4 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 5 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 6 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 7 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 8 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 9 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 10 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 11 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 12 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 13 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 14 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 15 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 16 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 17 of 27)

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Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 19 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 20 of 27)

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Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 23 of 27)

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Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 25 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 26 of 27)

Table 7 Operating Experience Review for US-APWR (Issues obtained from INPO database 1994 ~ 2008) (Sheet 27 of 27)

Table 8 Operating Experience Review for US-APWR (Issues obtained from NUCIA) (Sheet 1 of 6)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
1	1983-Kansai-T022	Miss operation in periodic test Reactor trip during over speed test for turbine governor control system	The plant was disconnected from grid at 9:00 on November 1for the 4th periodic inspection and over speed test for turbine governor control system was performed. The turbine and reactor was automatically tripped when the over speed test for governor controlled system was performed (the reactor power was 5 % and number of turbine revolutions 1800 rpm) at 9:32 on the same day. (Cause of Occurred Event) During the over speed test for governor controlled system, the test was conducted on manual control because turbine speed up was inoperable on automatic operation. As a result of plenty of steam flow by manual operation, because of too fast to speed up, turbine first stage pressure was increased and exceeded 10% of full power, therefore the permissive P-7 signal was initiated then trip condition for turbine over speed was allowed, finally reactor trip occurred. The cause of inoperable condition of automatic operation is unidentified.	Basic HSI system No additional features. US-APWR HED – The restriction on manual turbine speed-up will be described in the operating procedure and training material.
2	1992-JAPC-T005	Miss operation in drain valve change Power reduction due to decrease of condenser vacuum	During tuning operation, the power is 136MWe, at 10:15 November 11, 1992, “unit 2 low condenser vacuum” annunciator was initiated. The operator confirmed that the vacuum of condenser was decreasing, unit was disconnected from grid at 10:19. (Cause of Occurred Event) Steam line drain valve was changed one group to another group by daily drain valve changing operation, and after changing operation, turbine grand seal steam isolation valve (6S1107) was	Basic HSI system To prevent operational error, the Basic HSI system provides the following enhancements over conventional control panels. - Appropriate component arrangements on the mimic display – The use of mimics on the Operational VDUs are expected to minimize this type of component selection error, since the operators can see the orientation of the component within the piping system, before they select the component for control. Conventional control panels have very limited use of piping mimics due to unavailability of space on the control panels. - English description labeling on the control switch pop-up – To identify each switch, name labeling with component ID tags are placed. Due to space constraints, conventional control panels typically label switches only with component ID tags. While ID

Table 8 Operating Experience Review for US-APWR (Issues obtained from NUCIA) (Sheet 2 of 6)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
			closed instead of the drain valve (6S1117) that was required to be closed. The number of these two valves is similar and maintenance people confused. Therefore, steam for turbine grand seal was isolated and loss of function of turbine grand seal resulted in decreasing the vacuum of condenser.	tags are used on Operational VDU mimic displays, the Basic HSI System also displays component English descriptions with ID on the pop-up control switch face plate. - Label touch (make to two actions) before operating（same as action to INPO PS 3812）- Since the pop-up switch label , which includes ID tags and English description, must be touched by the operator, prior to taking any control action, to enable the control switch functions, it is very likely that if a component selection error occurs at the mimic display, that error will be self-detected by the operator when the pop-up is enabled. <u>US-APWR</u> No additional features.
3	1984-Kansai-T002	Procedure Power reduction due to decrease of condenser vacuum	During tuning operation, the power of Takahama unit 3 is 15% of full power, at 20:00 May 9, 1984, power decreased form 15% to 11.8% due to low condenser vacuum at 13:56 May 19th. The vacuum of condenser decreased 744 mmHg to 714mmHg.. (Cause of Occurred Event) At restoration from clean up of condensate pump B strainer maintenance in previous outage, condensate pump B strainer blow valve CW-203B must be full close position, but this valve was not tightened enough. Therefore, when the condensate pump balance valve CW-381B was opened, air blow into the condenser and vacuum became decrease. The reason of less tightness of valve is that procedure for the valve maintenance was not written properly.	<u>Basic HSI system</u> No additional features. <u>US-APWR</u> HED – Maintenance procedures and related training will emphasize correct valve tightening for local condenser vacuum valves.
4	1986-Kansai-T011	Miss operation in turbine start up Reactor trip during turbine speed up	On August 22, 1986, Takahama unit 2 was in tuning operation after the periodic inspection and started the turbine speed up, the turbine speed became faster very quickly, operator decided to shutdown reactor manually.	<u>Basic HSI system</u> No additional features. <u>US-APWR</u> HED – Manual setting of the load limiter will be described in the operating procedure and training material.

Table 8 Operating Experience Review for US-APWR (Issues obtained from NUCIA) (Sheet 3 of 6)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
			(Cause of Occurred Event) When the turbine revolution was increasing faster, operator set load limiter as too high setpoint, therefore the turbine revolution became faster very quickly. This was due to miss operation by the operator.	
5	1992-JAPC-T008	Miss operation in diesel generator periodic test Trouble due to the emergency diesel generator	On February 8, 1993, Tsuruga unit 2 was in full power operation, when diesel generator was connected to network in periodic inspection, “B-DG trip” annunciator was initiated and diesel generator was tripped. The operator confirmed that deferential relay 87EG for 2nd phase and 3rd phase were actuated. (Cause of Occurred Event) The reason of diesel generator trip was misconnection to network. The diesel generator was connected to network when phase difference was more than 25 degree, then the deferential relays 87EG were actuated. Procedure did not described that allowable phase difference and procedure for connection to network. Also the allowable phase difference was not illustrated in the synchroscope.	Basic HSI system HED – Due to the data communication delays in a digital HSI system, this issue cannot be resolved through procedures and training. The Basic HSI System documentation shall define that electric connections that require bus synchronization shall be automated due to manual operation difficulty under digital control. US-APWR No additional features.
6	1990-Tyugoku-T003	Miss operation in plant start up Reactor trip during reactor speed up	On December 4, 1990, Shimane unit 2 was increasing power. At 01:02, reactor power was 6% of full power and reactor pressure was 60 Kg/cm^2, “A-Main steam line isolation” and ” B-Main steam line isolation” annunciator were initiated, then these main steam line isolation valves were closed and reactor was automatically scrammed. (Cause of Occurred Event) Operator had to change mode of reactor to “operation” at reactor pressure was65	Basic HSI system No additional features. US-APWR US-APWR PSMS (RPS/ESFAS) has following trip/bypass management logic. That function reduce operator’s erroneous actuations. For each bypass interlock that must be manually initiated, to prevent inadvertent RPS/ESFAS actuation, there are prompting alarms. For each bypass interlock that must be manually removed, to restore RPS/ESFAS actuation operability, there are prompting alarms and permissive interlocks that prevent the bypass interlock

Table 8 Operating Experience Review for US-APWR (Issues obtained from NUCIA) (Sheet 4 of 6)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
			Kg/cm^2, but the operator changed mode at reactor pressure was 60 Kg/cm^2, therefore the main steam isolation condition was established and the reactor was scrammed automatically. This was due to miss operation by the operator.	from being removed prematurely.
7	1991-Kansai-T011	Miss operation in turbine protection system test Reactor trip during turbine protection system test by turbine trip	On February 2, 1992, Takahama unit 1 was in full power operation. At 10:07, periodic test was performed for turbine protection system, turbine was stopped automatically and consequently reactor was tripped. (Cause of Occurred Event) Restoration of turbine protection system from the test mode, maintenance people returned a test lever to normal position before returned a reset lever. Therefore, oil pressure for turbine stop system decreased and the turbine stopped automatically. This was due to miss operation by the maintenance people.	Basic HSI system HED - This was due to maintenance personnel error during periodic testing. The Procedure Writer's Guide shall require CAUTION statements for manual actions that can lead to inadvertent plant trips, if performed incorrectly. The Procedure Writer's Guide shall emphasis restoration of normal operation from the test mode. The Training Developer's Guide shall emphasize the training material for CAUTION conditions and restoration conditions. US-APWR Restoration of the normal mode from the test mode will be clearly described in procedures and training material, in accordance with the Basic HSI System guidance documents. HED - The plant specific turbine control system design shall be reviewed to indentify the potential for these maintenance errors. The designers of the turbine control system shall be encouraged to include interlocks and alarms to reduce this error potential.
8	1977-Tokyo-T008	Maintenance error in tuning operation Reactor scram due to maintenance	On March 29, 1978, Fukushima Daiichi unit 2 was increasing power. At 11:00, " Reactor HI/LO Level" annunciator was initiated, operator confirmed level meter, the indication of the level meter was out of range. After this, " Reactor Vessel LO Level Trip" annunciator was initiated and reactor was scrammed automatically. (Cause of Occurred Event) Before scram occurred, maintenance people were checking the reactor vessel level meter dPI-93 and dPI-65. At this time, maintenance people opened equalizing valve for the level meter without closure the isolation valve of that level meter. So high pressure was	Basic HSI System HED - This was due to maintenance personnel error during periodic testing. The Procedure Writer's Guide shall require CAUTION statements for manual actions that can lead to inadvertent plant trips, if performed incorrectly. The Training Developer's Guide shall emphasize the training material for CAUTION conditions. US-APWR This condition would not occur in the US-APWR because NSSS control systems use the Signal Selector Algorithm (SSA). The SSA prevents the control system from taking erroneous actions due to a single sensor failure/deviation. For redundant sensors, each sensor has separate isolation valves.

Table 8 Operating Experience Review for US-APWR (Issues obtained from NUCIA) (Sheet 5 of 6)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
			added to high pressure portion of vessel level meter of feedwater control system. This resulted in decreasing the feedwater flow rapidly and reactor vessel level decreasing. Finally, the reactor scrammed due to low vessel level.	
9	1978-Kansai-T006	Miss operation in cycling operation Reactor trip due to improper operation	Mihama unit 1 was connected to grid and was operated in the cycling operation 11:06 AM December 6, 1978. Power of plant was 17MW, operator intended to stabilize the plant power, steam generator water level and try to change operation mode from governor control mode to load limit control mode. After the connection to grid, steam flow from steam generator was higher than designed value, so average temperature of reactor coolant (Tavg) was decreasing and water level of steam generator was decreasing. At 11:06, the operator could not recover the steam generator water level, “B-Steam Generator Water Level low-low” annunciator was initiated and reactor tripped automatically by this signal. (Cause of Occurred Event) From the investigation, followings were cleared. This occurrence was due to improper operation by the operator. a) Withdrawal of control rod for recovery of Tavg was too much. b) Therefore, Tavg increased higher resulted in open of steam dump valves. c) The steam flow from steam generator increased. d) Operator’s recovery action for steam generator water level was not enough to increase the water level. e) Finally, the steam generator water	<u>Basic HSI system</u> Operator awareness of key parameter deviation, including Tavg and Steam Generator Level, is enhanced by including trend indications on the LDP. In addition, the Style Guide requires a trend display of the controlled parameter and the reference setpoint on the same screen with the controls. For example, for Tavg control the deviation trend of Tavg and Tref would be displayed on the control rod control screen with the setting of the operation speed of the control rod value. <u>US-APWR</u> HED - Procedures and training shall clearly define the process of changing from governor control to load limit control.

Table 8 Operating Experience Review for US-APWR (Issues obtained from NUCIA) (Sheet 6 of 6)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
			level decreased and reached to reactor trip setpoint.	
10	1979- Kansai-T009	Error in periodic sampling Gas release include radioactive material	Periodic sampling from gas portion of volume control tank was performed in Ohi unit 1 about 14:00 September 29, 1978. After sampling, drain valve was opened to discharge the drain of sampling tube. In this action, the gas of volume control tank was discharged and flow into hold up tank through drain line. The gas included radioactive material and was discharged to atmosphere from plant vent through auxiliary ventilation duct and hold up tank. (Cause of Occurred Event) The reason of this occurrence was that open time of drain valve for sampling was too long and improper pipe connection of drain line.	Basic HSI system HED - This was due to maintenance personnel error during periodic sampling. The Procedure Writer's Guide shall require CAUTION statements for manual actions that can lead to inadvertent radiation exposure, if performed incorrectly. The Training Developer's Guide shall emphasize the training material for CAUTION conditions. US-APWR The maintenance procedures and training will provide thorough instruction related to periodic process sampling, in accordance with the Basic HSI System guidance documents.

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 1 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 2 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 3 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 4 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 5 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 6 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 7 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 8 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 9 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 10 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 11 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 12 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 13 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 14 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 15 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 16 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 17 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 18 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 19 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 20 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 21 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 22 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 23 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 24 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 25 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 26 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 27 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 28 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 29 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 30 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 31 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 32 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 33 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 34 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 35 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 36 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 37 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 38 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 39 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 40 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 41 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 42 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 43 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 44 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 45 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 46 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 47 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 48 of 49)

Table 9 Operating Experience Review for US-APWR (Issues obtained from non nuclear industries in U.S.) (Sheet 49 of 49)

Table 10 Operating Experience Review for US-APWR (Issues obtained from other industries (Mitsubishi system) in Japan)

No.	Item	Issue/Scope	Human Factors Aspect Issue	Human Factors Issue addressed by Basic HSI System or US-APWR
1		Improvements Regarding the Choice of the Type of Touch Panel Operation Device	There are following three types of touch panel operation devices that can be used in a control panel for monitoring and controlling a fossil fired power plant or for similar purposes in other industries. - Infrared type - Ultrasonic type - Resistive touch type These three touch screen features are summarized in attached table 4a. One of them is the infrared type, which was mainly used in many applications since its capability to withstand contamination by water droplets or the like was highly valued. However, the infrared type had a parallax problem where the touched location and the sensed location did not coincide, thereby degrading the operability.	Basic HSI System Considering the fact that the control panel itself will be placed in a relatively environmentally favorable location such as the main control room, we have come to a conclusion that we do not have to take contamination such as water droplets into consideration. Accordingly, the ultrasonic type touch panel, which has superior performance in terms of the resolution for position detection and the operability, has been chosen. The above ultrasonic touching technology is applicable to both of Operational VDUs and Safety VDUs US-APWR No additional feature
2		Improvement in User Interface Associated with Software Control	Operation with a pointing device roughly comprises the pointing operation (locating the pointer and placing the pointer at the target) and the ON/OFF operation (executing a click/touch on the target). In the touch panel operation, determination of pointer location is not required so that the target location can be achieved immediately and, then, he or she touches the target for the ON/OFF operation. On the other hand, in the mouse operation, an operator first has to locate the mouse pointer so it can be moved in the correct direction to achieve the target location, and, then, he or she clicks the mouse buttons for the ON/OFF operation. Therefore, the mouse operation entails a somewhat higher task burden. Both methods entail a risk that an operator would inadvertently operate the panel in an unintended manner.	Basic HSI System In order to prevent such inadvertent operation, the HSI system accepts operation signal only after enabling the control face-plate by touching the labeling area. This enabling action helps to ensure the component is the one the operator intends to operate. US-APWR No additional feature

Table 11 Summary of Touch Screen features

	Infrared	Ultrasonic	Resistive film
Screen Transparency	Very Good (No shielding)	Very Good (No optical shielding since the sensing unit is made of glass)	Acceptable (Not 100% transparent since the sensing unit is made of a transparent electrode film)
Resolution	Good (Approx. 3 mm)	Very Good	Very Good
Durability	Very Good	Very Good	Acceptable
Parallax	Poor (Parallax Exist)	Very Good (No Parallax)	Very Good (No Parallax)
Other features	Resistant to contamination by water/oil droplets or the like, but sensitive to ambient light.	Susceptible to contamination by water/oil droplets or the like.	Resistant to contamination by water/oil droplets or the like. One can operate the panel with a pen or a gloved finger.

7. OER for the Japanese HSI System

This section describes the OER process and information sources used for the design of the Japanese HSI System

1. OER Process for the Japanese HSI System
   OER issues are collected and tracked in the OER database. The OER evaluation team periodically collects OER from Japan and around the world and provides information to the engineering/design organization for their review, according to the QA process. The engineering/design organization reviews each OER issue against the current design and documents their assessment regarding the features of the current design that address the OER issue, or changes that should be made to the current design to address the OER issue. The OER evaluation by the engineering/design team is in accordance with the QA process. Upon concurrence with the engineering/design organization evaluation, the OER evaluation team updates the evaluation results from the engineering/design organization within the OER database.
   When a new plant construction or operating plant updating project is established, the engineering/design department reports, to the project department, their plan to resolve any issues within the OER database that are not accommodated within the current design. The plan for OER resolution for each project is in accordance with the QA process.

2. OER information sources for the Japanese HSI System
   The original OER for the Japanese HSI system was conducted from the following information sources:
   - NUREG/CR-6400
   - INPO Database
   - NUCIA database
     Japan Nuclear Technologies Institute (JANTI) databases are called NUCIA (Nuclear Information Archives). NUCIA includes data from thousands of events, including failures, operational errors etc. from Japanese nuclear power stations. For HFE OER consideration, issues are extracted by key word “human error” of PWR.

   For the Japanese HSI system, new entries in the NUCIA databases are collected and evaluated as described in item 1, above.

   The significant events from these sources, that influenced the design of the Japanese HSI System, are included in Tables 6, 7 and 8. In these tables, these events are reevaluated, specifically for the US Basic HSI System and the US-APWR.

8. Summary

OER result revealed three categories of issues:

1. Issues that are already adequately covered by the current Basic HSI System or the application of that HSI system to the US-APWR

2. Issues that are already covered by HEDs that were previously generated during the Phase 1a V&V report (Part 1 report)

3. Issues that have not been previously addressed and require new HEDs.

Table 12 shows the summary of new HEDs addressed in the OER.

Table12 New HEDs generated through the Operating Experience Review

9. References

9-1. Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP DC018, Rev. 1, August 2008.
9-2. Higgins, J. and Nasta, K., HFE Insights For Advanced Reactors Based Upon Operating Experience, NUREG/CR-6400, December, 1996.
9-3. Quality Assurance Program (QAP) Description for Design Certification of the US-APWR, PQD-HD-19005, Rev. 2, Part II, Document Control, Section VI.