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TOKYO, JAPAN

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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-09020

Subject: Submittal of requested information for HFE/HSI System Development Documentations

Reference: 1) Letter MHI Ref: UAP-HF-08298 from Y. Ogata (MHI) to U.S. NRC, "Submittal of requested information for HFE/HSI System Development Documentation List," dated December 15, 2008.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") submits to the U.S. Nuclear Regulatory Commission ("NRC") the enclosed Human Factor Engineering ("HFE") and the Human System Interface ("HSI") System Development Documents which were requested by the NRC for future QA inspection activities. These documents are to present the HFE bases used for the design of the US-APWR HSI and requested from the NRC at the ACRS/NRC meeting of the four I&C related Topical Reports on November 5, 2008:

As described in the MHI letter UAP-HF-08298 "Submittal of requested information for HFE/HSI System Development Documentation List", if the NRC requests more information to review, some of the document about the following information are to be submitted by the end of March 2009 according to the requirement of the NRC:

- Applicability of One-Person Operation (note: almost same as enclosures 6 and 7)
- Gross and Narrative Task Analysis Sheet
- Task Analysis (GOMS) Sheet
- Investigation on Evaluation Method for Human Error Probability
- Application of THERP Method to Computerized Main Control Boards
- THERP Analysis Sheet
- VDU Design Style Guide

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this letter. His contact information is provided below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
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Enclosures:

1. PWR Plant Critical Function Hierarchy Analysis
2. Operating Task Functional Analysis
3. Functional Assignment to Operator
4. Plant Automation System Function Summary
5. Selection of Event Scenario for Task Analysis
6. Task Analysis (GOMS) Summary Report
7. Human Reliability Analysis (THERP) Summary Report

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Enclosure 1

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1. PWR Plant Critical Function Hierarchy Analysis

January, 2009

1. Identification of functions

The purpose of the Advanced Main Control Boards (ACB) ultimate goal is the same as that of a predecessor plant. A predecessor PWR plant has two higher purpose, electricity generation (availability goal) and protection of radioactive release to the environment (safety goal).

In a predecessor plant, in order to achieve availability goal, there are four sub-goals;

- Bring the plant to each operational power stage (i.e., Cold shut down, Hot shut down and each output power stage)
- Control nuclear heat and steam supply according to electrical power demand
- Convert nuclear heat and steam supply to electrical power with practicable efficiency and availability
- Conduct refuelling

The essential functions necessary for achieving each sub-goal are as follows

- Bring the plant to each operational power stage and
- Control nuclear heat and steam supply
  - Generator power control
  - Turbine power control
  - Nuclear power control
  - Neutron flux distribution control
  - Reactor coolant inventory control
  - Core heat removal control
  - Heat sink control
  - Maintain reactor coolant system performance
- Convert nuclear heat and steam supply to electrical power
  - Steam generator control
  - Turbine speed control
- Conduct refuelling
  - Refuelling system control

For the safety goal, there are five physical barriers; fuel pellet, fuel clad, boundary of reactor coolant system, containment vessel and concrete building wall.

Operating procedures are intended to maintain the integrity of these barriers to achieve the safety goal under accident conditions.

Essential critical functions to support maintaining the barrier integrity are;

- Reactivity control
- Reactor coolant inventory control
- Reactor coolant system integrity control
- Core heat removal control
- Heat sink control
- Containment vessel integrity control

shows a hierarchical decomposition structure of essential function for availability goal and critical safety functions for safety goal. This hierarchical decomposition contains primary control equipments and instrumentations.

This decomposition is performed based on the existing operating plant functions and designs, safety analysis experience.

Plant safety and plant availability can be maintained under following design based accidents/malfunctions by alternative methods on Table 1-1 and 1-2;

Table 1-1 Alternative method under accidents/malfunctions (Plant safety)

Accident events / malfunctions	Alternative systems/ methods
LOCA Damage to all critical safety functions	ECCS
Main steam line break	ECCS
Feedwater line break	ECCS
Steam generator tube rupture	ECCS
Loss of all AC power	Diesel generator

Table 1-2 Alternative methods under accidents/malfunctions (Plant availability)

Failure of control system sensor to affect plant availability (Feedwater control system failure)	Important I&C system related power generation have a redundancy. Therefore, single failure does not affect the function.

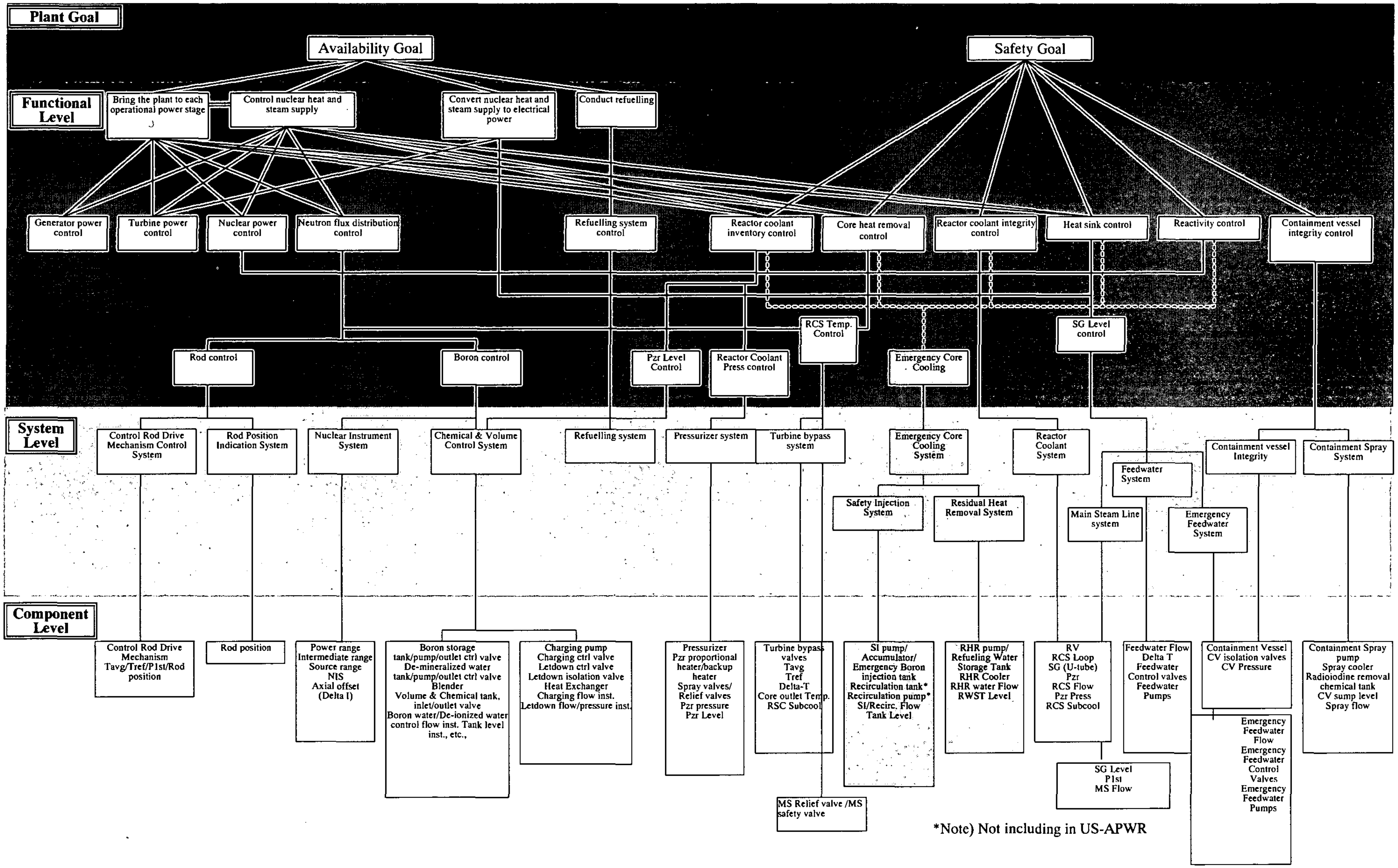

Figure 1-1 Hierarchical Architecture of PWR NPPs

Enclosure 2

UAP-HF-09020
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2. Operating Task Functional Analysis

January, 2009

1. Introduction

The typical Japanese PWR plant's critical functions are analyzed based on the safety importance. At first, the analysis was executed to developed knowledge-based operator guidance system, and the functions analyzed are basically safety related.
The plant function analysis for normal operations was added to diagnose initial or slight anomaly events to react to alarms, etc.

2. Monitoring/Operating Ranges at Main Control Room

The followings are realized by concentrating the local control/monitors to the main control room.

(1) Further concentration of plant's monitoring/operating functions
(2) Facilitated control of operators' movement (component personnel staying at main control room for longer time)
(3) Facilitated monitoring/control of systems (Information can be seen without going to local panels)
(4) Energy/cost saving (More cases can be dealt with centrally without going to the sites.)
(5) Reduced physical amounts (local panels abolished or reduced)

Concept for the plant monitoring/operating places tends to concentrate units at center so far. In perspective, further concentration or shift to complete concentration is expected to happen. Therefore, the policy shall be to concentrate, at center, the monitoring/operating functions by local panels in all systems.

Tables 2-1(1/3), (2/3) and (3/3) show the comparisons of monitoring/operating places between reference plant and new type main control room.

<Description of symbols in Table 2-1 (1/3), (2/3) and (3/3)>
Monitoring/operating places in the systems are classified as shown below.

A	:	Monitored/operated mainly at center.
A'	:	Monitored/operated at component room (primary component, secondary component).
B	:	Parallel-IN, switchover, isolation, etc. to sub-systems are executed at center after the operation of sub-systems is prepared by local panels (including line-up and pump oil system preparation).
C	:	Monitored/operated at local panels.

Table 2-1 (1/3) Plant system and monitoring/operating places

		Monitoring/operating place at reference plant		Monitoring/operating place at new main control room		Alarm display	
		Monitoring	Operation	Monitoring	Operation	Reference	Advanced
Conventional main control/ monitoring system	Reactor system	A	A	A	A	Displayed at window/CRT according to gravity classification in each system	Displayed at individual CRT
	Safety protection system	A	A	A	A		
	Turbine system	A	A	A	A		
	Generator system	A	A	A	A		
	On site power system	A	A	A	A		
	Transmission system	A	A	A	A		
	Heating, Ventilation, air conditioning system	A	A	A	A		
	Meteorological monitoring system	A	—	A	—		
Primary auxiliary system	CVCS, WDS	A'	A'	A	A	Displayed collectively at typical window/CRT	Displayed at individual CRT
	Drying/granulation system	A'	A'	A	A		
	Coagulated miscellaneous solid incineration system	A'	A'	A	A		
	SG blow-down	B	B	A	A		
	Post-accident sampling system	B	B	A	A		
	Chiller for air-conditioning	B	B	A	A		
	Auxiliary vibration monitoring system	B	—	A	—		
	Fuel handling system (transfer, inspection)	C	C	A	A		
	Instrument air system compressor	B	B	A	A		

Table 2-1 (2/3) Plant system and monitoring/operating places

		Monitoring/operating place at reference plant		Monitoring/operating place at new main control room		Alarm display	
		Monitoring	Operation	Monitoring	Operation	Reference	New type
Turbine generator auxiliary system	Condensate demineralizer	A'	A'	A	A	Basically central window, CRT is typical.	Displayed at individual CRT
	Station air system	C	C	A	A		
	Condenser Chorine detection system	C	C	A	A		
	Sampling system	B	C	A	A		
	Chemical feeder system	C	C	A	A		
	Demineralizer	A'	B	A	A		
	Raw water pre-treatment system	A'	B	A	A		
	Raw water system	A'	B	A	A		
	Reverse osmosis system	B	B	A	A		
	Chlorination equipment	B	B	A	A		
	Steam converter	A'	B	A	A		
	Auxiliary boiler	A'	B	A	A		
	Condenser tube cleaning system	C	C	A	A		
	Screen cleaning system	C	C	A	A		
	Cooling water intake cathodic protection system	C	C	A	A		
	Waste water treatment system (sump)	A'	B, C	A	A		

Table 2-1 (3/3) Plant system and monitoring/operating places

		Monitoring/operating place at reference plant		Monitoring/operating place at new main control room		Alarm display	
		Monitoring	Operation	Monitoring	Operation	Reference	New type
	Main turbine oil system	A, A'	A, A'	A	A	Central window and CRT are basically represented.	Display at individual CRT
	FWPT oil system	A, A'	A, A'	A	A		
	Fire-extinguishing water system	B	B	A	A		
	Each CO_2 fire extinguisher	C	C	A	A		
Electric system auxiliary system	Diesel generator system	B	B	A	A	Central window and CRT are basically represented	Display at individual CRT
	Generator stator cooling system	B	C	A	A		
	Generator seal oil system	B	C	A	A		
	On Site transformer cooling panel	C	C	A	A		
	Main transformer cooling panel	C	C	A	A		
	Emergency transformer cooling panel	C	C	A	A		
	GMCS cooling system	A'	A'	A	A		
	GIS	C	C	A	A		
	Insulator cleaning system	B	C	A	A		

2.4 Roles and Functions of Main Control Room

For the requirements to study the image patterns of main control room/main control panel, the work by operators was classified, and the roles and role sharing of main control room were clarified.

(1) Classification of operator work

Operation procedure, etc. were mainly analyzed, and the work categories, outlined frequencies and the systems required along the work flow were investigated, so that the operator work might be classified.

Table 2-2 shows the work related to the operations performed at main control room.

(2) Results of basic role classification required for main control room/panel were studied.

a. Basic functions

Requirements related to the operating functions shown in Figure 2-3 (1/2) and (2/2) were extracted. Further by surveying these things from the plant as a whole, the roles of main control room were put in order as shown in Figure 2-4.

b. Requirements related to spaces in main control room

By focusing on the space as one of the elements realizing the basic functions, the requirements related to the spaces shown in Figure 2-5 (1/2) and (2/2) were extracted.

Table 2-2 Classification of Tasks related to operation

1	Transition of work	Relay work securely by using transition book, etc. in work shift.
2	Receiving power supply command	Perform operation/steps according to the power supply command received from the center.
3	Operation contact	Take cautions to prevent accident or calamity due to insufficient communication.
4	Operation records	Record and study necessary things to maintain efficient operation and prevent accidents.
5	Operating work by on-duty personnel	On-duty personnel shall work under the direction/supervision of on-duty section manager.
6	Security system & protective relays (control)	If any fault occurs in the system, investigate the condition, and issue work form if necessary.
7	Operation standard values & operation limit values	Ensure the operation standard values/limit values in every operation.
8	System operation (daily operation)	Operate the system deliberately and securely by identifying the operation and work condition so that quick actions can be taken.
9	System operation (associated with work & test run)	Perform work while operation/maintenance personnel are ensuring the operation/steps associated with work and its completion.
10	Operation monitoring	By monitoring the equipment and measurement controllers, make efforts to maintain the best condition at all times.
11	Patrol checks	Carry out patrol checks of the specified systems.
12	Periodical testing	Carry out periodical tests of equipment, measurement controllers and security system in operation.
13	Provisional testing	Carry out irregular or provisional tests and special tests.
14	Treatment in accident & other faults	Perform necessary restoration work or take actions to prevent expansion according to the detailed rules for operation in accidents.
15	Accident prevention	Carry out patrol checks and treatment to prevent accidents.
16	Safety control	Take every measure to prevent accidents.
17	Operation maintenance	Carry out daily checks, treatment, easy maintenance work and first-aid treatment.
18	Performance control, etc.	By identifying the performance of equipment, try to maintain safe and functional operation.
19	Radiation control	By heeding the indications on radiation monitor, try to find faults such as in radiation early.

Requirements related to operating

1) **Central power supply command receiving function (external communication function)**

Central power supply command can be received, and shall be responded in fault/accident.

2) **Paging / broadcast function**

Various operating communications shall be available.

3) **Clock function**

This function shall be used in various operation records and status assessment.

4) **On-site communication function**

Shift supervisor → Shift personnel
Shift supervisor → Control Room Supervisor
Shift supervisor → Repair/Maintenance Section Manager

5) **Operating function**

Various equipments shall be operated.

6) **Display function**

Displays shall be provided, by which to monitor the operating conditions, operation limit values and system condition.

Figure 2-3 (1/2) Basic requirements related to operating functions

7) Function to communicate with locals

Faults can be communicated in patrol checks.

8) Test function

Periodical tests can be carried out in parallel with normal operation.

9) Operating function by shift supervisor

Specified operations such as manual reactor trip can be performed.

10) Data recording function

Various plant data can be memorized and accumulated.

11) System isolation control function (outage)

Status control such as overall isolation and partial isolation shall be available.

12) Test function (outage)

Tests can be carried out in outage in parallel with operation in outage.

11) and 12) are functions related to outage.

Figure 2-3 (2/2) Basic requirements related to operating functions

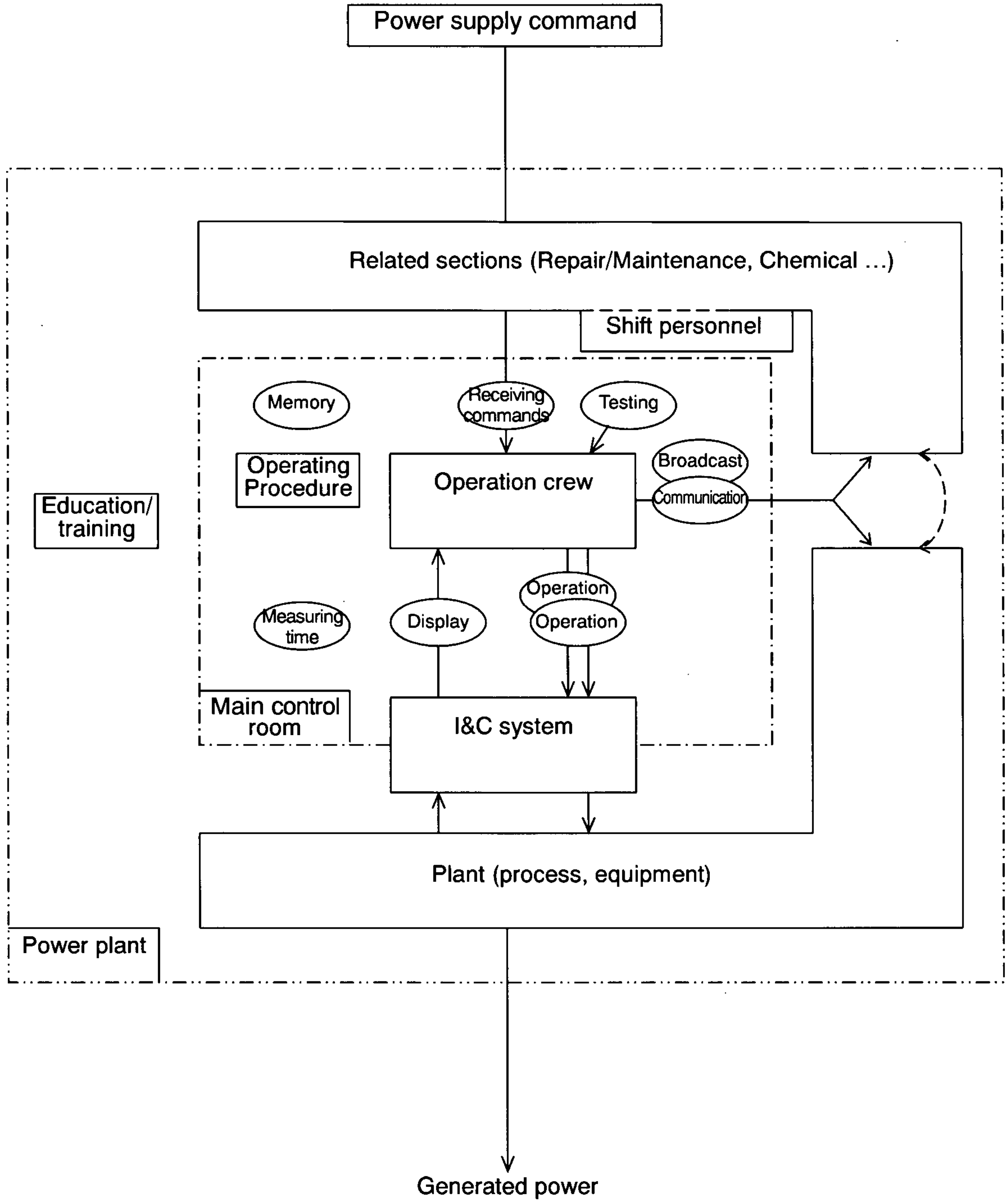

Figure 2-4 Role of the main control room

Requirements related to space

- **Space for transition meeting**

  Members of two work shifts shall hold meetings while spreading the operation logging and shift transition materials.

- **Space to prepare operating records and forms**

  Operation records and forms shall be filled in.

- **Space for operations**

  Under the instructions by the on-duty manager, sequences and methods can be checked in close communications, and operation and status shall be confirmed.

- **Space for operations in coordination with maintenance personnel**

  In limited cases, the maintenance personnel shall do the work. However, monitoring and operations can be performed in mutual reassurance.
  (Those associated with work or test run, to which periodical test and provisional test correspond.)

- **Space for operation monitoring**

  Operation can be monitored to maintain the best condition by monitoring the operating condition of system.

- **Space for reporting the result of patrol checks**

  Operating personnel can report to the shift supervisor.

- **Space for treatment in accident or other fault**

  Under the direction by the shift supervisor, the crew, as a whole, can carry out restoration work and take actions to prevent expansion.

Figure 2-5 (1/2) Requirement related to spaces in main control room

- Space for operations by manager on-duty

  Manual operations can be taken for the reactor trip, safety injection, emergency diesel generator malfunction, etc.

- Space within hearing of oral instructions, citation, name-calling by finger pointing

  These things shall be met, as items to prevent accidents.

- Space capable of storing various documents and forms

Figure 2-5 (2/2) Requirement related to spaces in main control room

2.5 Role Sharing of Operators and Machines

In this section, the role sharing of operators and machines was studied for the purpose of alleviating the burden on operators in the job or work performed by operators. If roles are to be set again, key points seem as shown below.

1) Operation monitoring work
   - Scope of automated operation
   - Scope of monitoring from MCR
   - Scope of application for operation assist system
2) Work related to plant control
   - Scope of mechanized control work

(1) Role sharing of operators and machines

Work classifications for operators at nuclear power plant were put in order in the previous section. Table 2-3 outlines this classification of work summarized in medium classes.

All operator work in this table has the real time elements. However, operation plan and system maintenance can also be carried out as off-line processing. Others should use plant data in real time, and should be closely connected to the plant computers.

Table 2-4 shows the settings of the roles of operators and machines in consideration of the personal and mechanical characteristics.

When taking a look at this table, operator's work mainly consists of monitoring and operating work. Detailed analysis of monitoring and operating work is as shown in Table 2-5. As the information processing and operation automation advances, operator's work shifts to the overall monitoring and control work of plant.

Table 2-3 Classification and outline of operation work

Classification		Outline
1	Operation plan	The operation plan in normal operation like plant start-up and shutdown is drawn up based on power supply commands, and adjustments are made, if required, with the central power supply command center.
2	Operating steps	Power plant is operated while meeting the operation limit values and standard values based on the operation plan. If any fault occurs in plant or if any accident occurs, necessary actions are taken. Components are replaced and tested periodically.
3	Operation monitoring	The operating condition of plant and equipment are monitored by using the monitoring instruments (such as CRT) on main control panel. Moreover, any faults in the system are also monitored by patrol check at sites.
4	Collection of actual operation data	By collecting the actual data of plant operation periodically, information required in operation control and repair/maintenance control is supplied. The plant condition and component systems are analyzed and evaluated.
5	System maintenance	Treatments for repair/maintenance work (preparation of tags and forms) are carried out as necessary while conducting the primary maintenance work by checking the systems and equipment.
6	Preparation of daily logs/reports	Daily logs and fault/accident reports are prepared and supplementary work like the control of fixtures and tools are carried out. Shift transition is also performed.
7	Radiation control	By checking the radiation monitor, any fault in radiation is checked for. Related sections are contacted if necessary.

Table 2-4 Role-sharing of operators and machines

Classification	Machine	Personnel
Operation plan	Schedule calculation → Output	Planning → Data setting → Evaluation
Operating steps	Provision of guidance Steady operation	Preparations for start-up System isolation/release Periodical test operations Periodical switchover of components
Operation monitoring	Collection, processing and provision of information Equipment diagnosis Provision of guidance	Overall monitoring Check and patrol
Collection of actual operation data	Collection and processing of information Recording Storage	Evaluation and analysis —— (technical)
System maintenance	Processing, output and storage of information Preparation of tags and forms	Data collection, data input Repair work —— (repair)
Preparation of daily logs and reports	Collection, processing and recording of information	Evaluation, analysis — (repair) (technical) (chemical) (Radiation control)
Radiation control	Collection, processing and recording of information	Sampling, data setting, analysis, evaluation — (Radiation control)

Table 2-5 Operator's roles and reduction of workload by machines in plant operations

Operator's role		Reduction of work burden by machines		
Role	Work	Monitoring system	Operation guide	Automation
Monitoring	Collection of plant information	S	S	S
	Reading of plant information	S	S	S
	Memory of plant information	S	S	S
Situation evaluation and judgment	Combination of plant information	S	S	S
	Reading of changes in plant information	S	S	S
	Correlation of plant information with own knowledge		S	S
	Output of correlated results		S	S
	Selection of targets to operate		S	A
	Determination of operating amounts/timing			A
Operation	Execution of control/operations			A
	Reporting to manager on-duty, etc.			
	Confirmation of control/operations			

HSI improvement research and developments

1. Arrangement of panel devices, Identification of devices ------ (Monitoring system)
   Introduction of CRT displays
2. Introduction of operator support system ------ (Operation guide)
3. Automation of operation ------ (Automation)

S: Support, A: Automated

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Enclosure 3

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3. Functional Assignment to Operator

January, 2009

1. Function assignments

1.1 Task analysis results

As described in enclosure 2, sub-functions which are necessary for plant safety and achievement goal, are identified. These sub-functions include essential functions as well as alternative functions for the higher level functions.

Table 3-1 shows evaluation criteria, plant parameters and control functions for each system.

Table 3-1 Evaluation criteria, plant parameters and control functions

Sub-functions	Logical requirement	Control actions/Parameters	Criteria for evaluating the result of control actions	Parameters necessary for evaluation	Evaluation criteria/ criteria for choosing alternatives
Generator power control	Controlling generator power due to electric power demand	Power factor Stator current	Stator current is controlled to produce stable electric power	Power factor Stator current	-
Turbine power control	Controlling turbine Inlet steam from SG according to turbine load limiter demand	Steam governor valve Steam governor valve gate Steam line flow	Turbine power load is controlled by steam governor.	Turbine load, Steam governor valve gate	-
Rod control	Rod control controlling primary power (Tavg and reactor power) to adjust it to a secondary power target (Tref and P1st).	Inserting/withdrawing control rods with CRDM Control Rod position to match a secondary power.	A primary power is controlled depending on a secondary power variation.	Rod position indication/ Tavg, P1st, Tref, NIS	Controlling a Reactivity/ Nuclear power/ RCS temperature/ Axial Offset
Boron control	Boron control contributes reactivity control. Boron control also affects reactor power with rod control. Boron control mitigates axial offset deviation caused by emergency load drop using rod control function.	Boration / Dilution Current boron density (sampling) Target boron density Current and total Mixing flow	Reactor coolant boron density is trending to the target boron density. Mitigating axial offset deviation at emergency load reduction.	Boron density Delta I (axial offset instrumentation)	Controlling a Reactivity/ Nuclear power/ RCS temperature/Axial Offset
Pzr Level Control	Controlling RCS inventory.	Charging flow Charging pump Backup heaters Letdown isolation valves	Pressurizer level is trending to Pressurizer level setpoint (Lref) which are programmed by reactor coolant temperature (Tavg).	Pzr level Pzr setpoint (Lref) Charging flow Tavg	Controlling a RCS inventory
Reactor Coolant Press control	Controlling RCS inventory.	Pressurizer heaters switching Spray valves/ relief valves open/close Pressurizer pressure Pressurizer level	Pressurizer pressure is controlled to keep pre-defined set point	Pressurizer pressure	Controlling a RCS inventory
Turbine bypass control	RCS temperature control for rapid power load reduction and keeping hot	Tavg, Tref, Main Steam line header pressure, Turbine bypass valves	Tavg is controlled to match Tref or hot shut down standby state Tavg	Tavg	Controlling a RCS temperature

Table 3-1 Evaluation criteria, plant parameters and control functions

Sub-functions	Logical requirement	Control actions/Parameters	Criteria for evaluating the result of control actions	Parameters necessary for evaluation	Evaluation criteria/ criteria for choosing alternatives
	shut down standby state.		temperature by steam dumping via turbine bypass valves.		
Reactor Coolant System	RCS integrity control	RCP,RCS Flow, Pressurizer (Pzr Pressure/level), RCS Subcool, RCS temperature, RCS pressure	No leak from RCS inventory	RCS pressure, Pzr pressure/level, RCS subcool	RCS integrity control
Emergency Core Cooling	Alternative method for keeping critical safety functions	SI pump actuation, RHR actuation, Pressurizer pressure/level, RCS pressure/temperature, RCS Subcool,	Satisfy each critical safety function	Critical safety parameters	

All of the high-level functions necessary to achieve safe operation are extracted Japanese NPPs' safety analyses, PRAs and Emergency Operating Procedures (EOPs).

Those functions are summarized two major operator actions as follows;

- For all shutdowns, decay heat must be removed through the steam generators to maintain a stable hot standby condition;
- Higher level critical safety function and heat sink function cover this function.
- For all shutdowns from power, if a hot standby condition is maintained for an extended time, operator action may be required to add boric acid through the chemical and volume control system (CVCS) or ECCS with emergency letdown to compensate for xenon decay, which could otherwise reduce shutdown margin.
- Higher level critical safety function, reactivity control covers this function.

Those functions also identified the operator actions required to mitigate accidents as follows;

- In the non-LOCA events, operator actions are credited as inadvertent dilution of boron concentration in the RCS, CVCS malfunction that increases RCS inventory, and steam generator tube failure. Higher critical safety functions against these credit human actions also are included as reactivity control, reactor coolant inventory control, and heat sink/core heat removal/reactor coolant inventory control respectively.
- In the radiological consequence events, operator actions are credited as RCCA ejection and failure of small lines carrying primary coolant outside containment. In addition, operator actions are credited to prevent boric acid precipitation to assure post-LOCA long term cooling. Higher critical safety functions against these credit human actions also are included as reactivity control, reactor coolant inventory control, and core heat removal/reactor coolant inventory control/Containment vessel integrity control respectively.

These critical actions assessed in existing safety analyses are covered by previous plant functions.

In the PRA assumptions, following Important Human Actions in prospect of Mitigating Accidents;

1) At Power Operation

Prevention of Core Damage (Level 1)
Establish Alternate CCWS Utilizing the Non-essential Chilled Water System
Establish Alternate CCWS Utilizing Fire Protection Water Supply System
Start the Standby Charging Injection Pump B
Open AFW pump discharge tie line Tie-line Valves
Changeover AFW water source
Calibration of AFW pit A Water Level Sensor
Calibration of AFW pit B Water Level Sensor

Connect the Alternate ac Power Source to Class 1E Bus
Feed and Bleed Operation (Under non-LOCA events)
Feed and Bleed Operation (Under LOCA events)
Main Feed Water System Recovery
Close Main Steam Isolation Valve NMS-AOV-515A
Establish Alternate Containment Cooling by Containment Fan Cooler Unit
Alternate Core Cooling Operation (Under actuation of Containment Spray Signal)

Prevention of Large Release (Level 2)
RCS Depressurization
High Head Injection System Control
Closing the Turbine bypass Manual Valve (at SGTR)
RCS Depressurization by Secondary Side Cooling (at SGTR)
RCS Depressurizing (SGTR)
Firewater Injection to Spray Header
Transfer to RHR Operation Mode (SGTR)
Calibration of C/V Pressure Sensors

They are covered by core heat removal, core integrity, containment vessel integrity and heat sink control. Supporting system (i.e., Alternate systems of CCWS supported by Chilled water system and water supply system, and Containment cooler) are also used alternate method of supporting above critical functions. These supporting systems are also included as functional requirement assessment.

2) Low-power and Shutdown Operation

Prevention of Core Damage (Level 1)
Establish the Alternate CCWS utilizing Fire Protection Water Supply System
Establish Charging Injection System
RCS Water Level Recovery
Establish Charging Injection System and Recover RCS Water Level
Connect the Alternate ac Power Source to Class 1E Bus
Start Standby Safety Injection Pump
Isolate the Leakage from RHR
Isolate the Drain Line
Start RHR Standby Pump
Alignment of the Manual Valve of Serial System
Start Auxiliary Feed Water Pump for Decay Heat Removal

3) Mitigation of FP Large Release (Level 2)

Operation to Control RCS Water Level
(1) Isolate charging injection system
(2) Start to RCS water drain by opening drain valve
(3) Stop draining with monitoring pressurizer water level
(4) Service the reactor cavity water level indicator and RCS water level indicator
(5) Calibrate the reactor cavity water level indicator and RCS water level indicator

(6) Restart to drain RCS water
(7) Service the RCS temporary water level indicator
(8) De-block the water level alarm
(9) Confirm that the water level high alarm is reset
(10) Maintain the mid-loop water level by drain valve
(10a) Monitor the water level by temporary indicator
(10b) Respond to water level alarm
(10c) Operate the drain valve
(10d) Monitor the water level by RCS water level indicator

4) Control of the RHR Valves

They are covered by core heat removal, core integrity, containment vessel integrity and heat sink control. Supporting system (i.e., Alternate systems of CCWS supported by Fire Protection Water Supply System, and Drain Line) are also used alternate method of supporting above critical functions. These supporting systems are also included as functional requirement assessment.

1.2 Assignment Criteria

1) Criteria for function assignment to human or machine
Following criteria in table 3-2 has been applied for assignment to human or machine;

Table 3-2 Criteria for function assignment to human or machine

Characteristics	Assignment	
	Human	Machine
Load	Moderate	High or Very Low
Time margins	Large	Small or very large
Rate	Moderate	High or Very Low
Complexity of action logic	Simple	Complicated
Types and complexities of decision-making	Ill-structured	Well-structured

2) Criteria for function assignment for remote or local manual controls
Criteria for function assignment for remote or local manual controls are primary upon the following characteristic measures;

- time factors;
- impacts resulting from the loss of functions and associated time factor
- Operating experiences
- Costs

Critical operator actions required to mitigate accidents, as described section X, are basically conducted by remote controls except for necessary local operation, such as power energizing operation of components.

3) Criteria for function assignment for operator support system (OSS)

Criteria for function assignment for operator support system (OSS) are based on following characteristic measures (Reference A);

- Complicity of decision-making with time margins;
- Importance of decision-making to the plant safety and availability;
- Necessity for enhancement of operator's potential capabilities in decision-making activity diagnostic monitoring and high-level mental processing.

Safety Parameter display including primary parameters for critical safety function monitoring (i.e., Pressurizer level, SG level, RCS temperature, etc.) and power production availability, integrated information display and guidance display (i.e., task displays) for conducting complicating tasks are integrated and provided in MCR system.

1.3 Assignment implementation

Using assignment criteria as described in 1.2, controllers and parameters necessary for controlling each plant control function in table 3-1 and supporting systems in PRA assessment described in 1.1 are assigned to automatic/manuals and remote (MCR) /locals in table 3-3.

Table 3-3 plant parameters and control Assignment

Sub-functions	Controllers/Parameters extracting from table 3-1 assessment	Assignment of automatic/manuals	Assignment of remote (MCR) /locals
Generator power control	Power factor	N/A	Remote (MCR)
	Stator current	N/A	Remote (MCR)
	Generator Load Control	Automatic	Remote (MCR)
Turbine power control	Steam governor valve	Automatic	Remote (MCR)
	Steam line flow	N/A	Remote (MCR)
	Turbine load	N/A	Remote (MCR)
Rod control	Rod Control	Automatic	Remote (MCR)
	Rod position indication	N/A	Remote (MCR)
	Tavg	N/A	Remote (MCR)
	P1st	N/A	Remote (MCR)
	Tref	N/A	Remote (MCR)
	NIS	N/A	Remote (MCR)
Boron control	Boration / Dilution Control	Semi-Automatic (Need to put input setpoint and start for operator's confirmation)	Remote (MCR)
	Current boron density (sampling)	N/A	Remote (MCR)
	Target boron density	N/A	Remote (MCR)
	Current and total Mixing flow	N/A	Remote (MCR)
	Boron density	N/A	Remote (MCR)
	Delta I (axial offset instrumentation)	N/A	Remote (MCR)
Pzr Level Control	Charging flow Controller	Automatic	Remote (MCR)
	Charging pump	Manual (Less frequent, Simple operation action (Start/Stop))	Remote (MCR)
	Backup heaters	Manual (Less frequent, Simple operation action (Start/Stop))	Remote (MCR)
	Letdown isolation valves	Automatic (automatic isolation by interlock signal)	Remote (MCR)
	Pzr level	N/A	Remote (MCR)
	Pzr setpoint (Lref)	N/A	Remote (MCR)
	Charging flow	N/A	Remote (MCR)
	Tavg	N/A	Remote (MCR)
Reactor Coolant Press control	Pressurizer heaters	Automatic	Remote (MCR)
	Spray valves	Automatic	Remote (MCR)
	relief valves	Manual (Less frequent, Simple operation action (Open/Close))	Remote (MCR)
	Pressurizer pressure	N/A	Remote (MCR)
	Pressurizer level	N/A	Remote (MCR)
Turbine bypass control	Tavg	N/A	Remote (MCR)
	Tref	N/A	Remote (MCR)
	Main Steam line header pressure	N/A	Remote (MCR)
	Turbine bypass valves	Automatic	Remote (MCR)
Reactor Coolant System	RCP	Manual (Less frequent, Simple operation action (Start/Stop))	Remote (MCR)
	RCS Flow	N/A	Remote (MCR)
	Pressurizer (Pzr Pressure/level)	N/A	Remote (MCR)

Sub-functions	Controllers/Parameters extracting from table 3-1 assessment	Assignment of automatic/manuals	Assignment of remote (MCR) /locals
	RCS Subcool	N/A	Remote (MCR)
	RCS temperature	N/A	Remote (MCR)
	RCS pressure	N/A	Remote (MCR)
Emergency Core Cooling	SI pump actuation	Manual (Less frequent, Simple operation action (Start/Stop))	Remote (MCR)
	RHR actuation	Manual (Less frequent, Simple operation action (Start/Stop))	Remote (MCR)
	Pressurizer pressure/level	N/A	Remote (MCR)
	RCS pressure	N/A	Remote (MCR)
	RCS temperature	N/A	Remote (MCR)
	RCS Subcool	N/A	Remote (MCR)

Enclosure 4

UAP-HF-09020
Docket No. 52-021

4. Plant Automation System Function Summary

January, 2009

The plant automation system functions for Japanese PWR/APWR plants are selected to reduce operators' physical/mental workload and potential human errors from following view of points:

A. Potential operations that need long time continuous operation/monitoring
B. Operations that need to be performed in a narrow time window
C. Complicated or adjustment or control operation

In Japanese plant design, automation systems have been introduced for above objects (see Table 4-1).

Adoption of automation is judged by the degree of contribution to the operability and economic impacts (economical efficiency) to a reduction of incidence / incorrect operation prevention of an operation member are taken into consideration, and introduction is judged.

In order to introduce computerized (i.e., advanced) main control boards, and apply single-operator operation, the extension of the automations are conducted as described in this report.

In the development phase of the Advanced Control Boards (ACB), the analyses on the story boards (i.e., OSD: Operation Sequence Diagram) have been conducted.

As a result, the following items are evaluated from the existing PWR plants and APWR to be candidates for implementing with the advanced main control boards:

a) Automated control of auxiliary feedwater flow rate

In case of tangent or accident with reactor trip or ECCS actuation, auxiliary feed water system provides feed water to the steam generators.

As the auxiliary feed water flow rates are controlled manually. The frequency of the operator to monitor and modulate is quite high.

In addition, the control actions for the auxiliary feed water flow should be done to multiple loops and just after the reactor trip.

The automated control of auxiliary feedwater flow rate will reduce operator's workload adequately.

(Selected as the type A, B and C)

b) Automated cooldown operation in case of SGTR

In case of SGTR, the primary side (i.e., reactor coolant) is cool-downed by opening the main steam relief valves (MSRVs) rapidly to be full-opened.

When the RCS is cooled to the target temperature (no-load temperature minus 86 deg °F (30 deg °C)), the cool down rate is moderated by manual control of the MSRVs.

It is necessary to control three MSRVs of unbroken SGs in a short time.

The automated cooldown operation in case of SGTR will reduce operator's workload adequately.

(Selected as the type A, B and C)

c) Automated isolation of steam generator in case of secondary side break accidents.

In case of SGTR, FWLB or MSLB, the broken steam generator should be isolated secondary side immediately. In the particular case of SGTR, operator has to isolated many (more than 5) valves, such as the main steam isolate valve, the auxiliary feed water isolate valve, etc.

The automated isolation of steam generator is planned to be applied to APWR in case of MSLB, but not in case of SGTR at present state.

The automated isolation of steam generator in case of SGTR will reduce operator's workload adequately.

(Selected as the type A, B and C)

d) Automated restoration of on-site electrical system

Restoration of on-site electrical system operation (i.e., feed electrical power to house service grids) is needed at the time of the plant restoration after B.O. (Black Out) and safety injection, and in that case the synchronous insertion of the breaker at the time of power supply restoration is carried out, synchronous adjustment operation needs a certain amount of skill.

The automate restoration of on-site electrical system will reduce operator's workload adequately.

(Selected as the type C)

e) Automated load of adjustment of main generator power

The operation of the generator at the time of load interception (the next dynamo frequency adjustment, adjustment of governor control, etc. are needed at the time of insertion.

Moreover, the surveillance accompanying the tangent state of a plant is also needed.

Automated load of adjustment of main generator power will reduce operator's workload adequately.

(Selected as the type C)

f) Automation of the nuclear reactor control system (control rod control system) at the time of the low load at the time plant startup/shutdown

It is necessary to control a nuclear reactor side by manual control of reactor control rods operation, both operation of a nuclear reactor and operation of a turbine generator taking cooperation at the time of the low output at the time of plant start-up/stop (under 15% power).

If automation of the nuclear reactor control system at the time of the low load at the time of plant start-up/stop (control rod control system) is realized, it will become useful combined with turbine automatic speed-up and a load rise and reduce incidence of the surveillance operation work of an operation member conjointly.

(Selected as the type A, B and C)

g) Automatic startup of additional a condense water pump and a condense water booster pump at the time of plant start-up

It is necessary to carry out additional start-up of a condense water pump and a condense water booster pump from one-pump operation by after 25% load at two-pumps operation. In the time of plant start-up, there are many pumps which operate automatically in each load, and surveillance operation should be carried out congressionally.

Automated startup of additional a condense water pump and a condense water booster pump will reduce operator's workload adequately.

(Selected as the type C)

h) The change of the secondary system heater at the time of plant start-up, and MSH (main steam heater) drain recovery

From operations other than the storyboard set up by this development research, the automation item which leads to an operation reduction of incidence was extracted from the viewpoint of above-mentioned selection type A to C.

As for the heater drain and a MSH drain system, drain change operation is required after turbine ventilation system cleanup.

Conventionally, it corresponds by remote (MCR) manual operation or remote manual operation, and a discharge place needs cooperation operation of each valve at the change of condenser and a blow system outside, and operation will be complicated and will be restrained by surveillance operation to load 3.0% after turbine ventilation in a plant.

If automation of a secondary system heater and the MSH drain recovery change is realized, it will become the reduction of incidence of the surveillance operation work of an operator.

The change of the secondary system heater at the time of plant start-up, and MSH drain recovery will reduce operator's workload adequately.

(Selected as the type A and C)

The candidates of automations for the advanced main control boards are summarized in Table 4-2.

Table 4-1 Comparison of Plant Automation between Japanese Conventional/Latest PWRs, and APWR

operating mode		Conventional PWRs	Latest PWRs	APWR
full power base load		auto	***Available to be auto***	***auto***
LF, AFC/GF		manual	manual	auto
plant startup & shutdown				
	Low power (less than 15%PWR)	– rod control :manual – startup FW control :manual – FW control valve transfer :auto	– rod control :manual – startup FW control :auto – FW control valve transfer :***auto***	– rod control :auto – startup FW control :***auto*** – FW control valve transfer ***:auto***
	reactor startup & shutdown	manual	manual	manual
	heatup & cooldown	manual	auto	***auto***
	turbine plant startup	– main turbine startup :manual – MSH control :auto – FWPT startup :manual	– main turbine startup :auto – MSH control :***auto*** – FWPT startup :auto	– main turbine startup ***:auto*** – MSH control :***auto*** – FWPT startup ***:auto***
Auxiliary system		auto	***auto***	***auto***

Table 4-2 Candidates of Automations for the Advanced Main Control Boards

Established/Experienced Automation Technologies
- CSD to HSD RCS heat up - HSD to CSD RCS cool down - Condenser vacuum establishment/fading - SG makeup feed water control - Main turbine turning/speed-up/Insertion/load up - FWPT warming and speed up - MSH (Main Steam Heater) purging/warming - Control of hi-pressure steam extraction - Automatic exchange between main feedwater control valve and bypass valve - Warming of steam converters - Local control of CVCS/WDS system - Secondary side utilities (demineralizer /condemineralizer/auxiliary boiler, etc.) controls - Automatic back up of MFWP, FWBP, CBP, CP, etc. - Control of FWP NPSH - Automatic recirculation line up for ECCS
Possible/Applicable Automation Technologies
- Automatic reactor power control at low power stage - Automatic connection/disconnection of additional FWP - Condenser cleanup - Main steam pipe warming - Secondary side heaters, MSH drain recycle system exchange - Automatic isolation of the broken SG incase of SGTR or secondary side break

Enclosure 5

UAP-HF-09020
Docket No. 52-021

5. Selection of Event Scenario for Task Analysis

January, 2009

1. Introduction

The event scenarios for task analysis are selected from following view of points:
- Human error rate (HEP) (i.e., risk for plant safety)
- Operators' work load
- Verification of the control board

Above mentioned points, the HEP and the workload are recognized to be highly dependant, and in this report the task analysis scenarios are extracted and evaluated from the evaluation of operator sequence (i.e., workload cause) analyses.

2. Procedures/Scenarios for Analysis

In order to limit workloads during the single-operator operation below the target workload, it will be necessary to extract operational responses of the conventional two-operator operation that would overlap in a short period of time and discuss measures for reducing the corresponding workloads, including the introduction of automated operation modes.

(1) Extract operation modes that require responses of both the primary system operator and the secondary system operator.

(2) Carry out operational task analyses (see Attachment 1) on the operation modes extracted in (1) above to identify operational responses of the primary system operator and the secondary system operator that would overlap in a short period of time (i.e., operational responses of the primary system operator and the secondary/electrical system operator that would be required within ten minutes).

(3) Discuss load reducing measures with respect to the operational responses identified in (2) above. The following may be examined as possible load reducing measures:

- Automated operation mode and monitoring; and
- Concentrated display (workload reduction associated with screen-requesting scheme).

(4) Carry out workload evaluations on the operational responses identified in (2) above to confirm that the targets discussed in Section 1 are attained.

In the following sections, discussions will be conducted in accordance with the above procedure with respect to the plant start-up/shutdown operation and the operation during abnormal conditions.

2.1 Start-up/Shutdown

Figure 5-1 shows plant start-up/shutdown sequences, and Table 5-1 shows the result of operational task analysis covering from HSD to 100% power.

- During the periods before criticality operation is engaged and after the reactor is taken off-line, operational responses of the primary system operator and the secondary system operator do not overlap.

- During the period of low power operation (up to 15%), operational responses of the primary system operator and the secondary system operator overlap, conventionally requiring intermittent operational responses in both the primary system and the secondary system (intermittent operation of the control rods for the primary system, and intermittent monitoring of the turbine for the secondary system). However, for the APWR plant, we are planning to automate these operational responses so that only key points in the course of operation would be monitored. Therefore, the operational responses would not overlap. It should be noted that the overlapping of operational responses could be resolved by automating either one, not both, of these operational responses.

- At 15% and beyond, the reactor output automatically follows the generator output, and, hence, operational responses of the primary system operator are barely required.

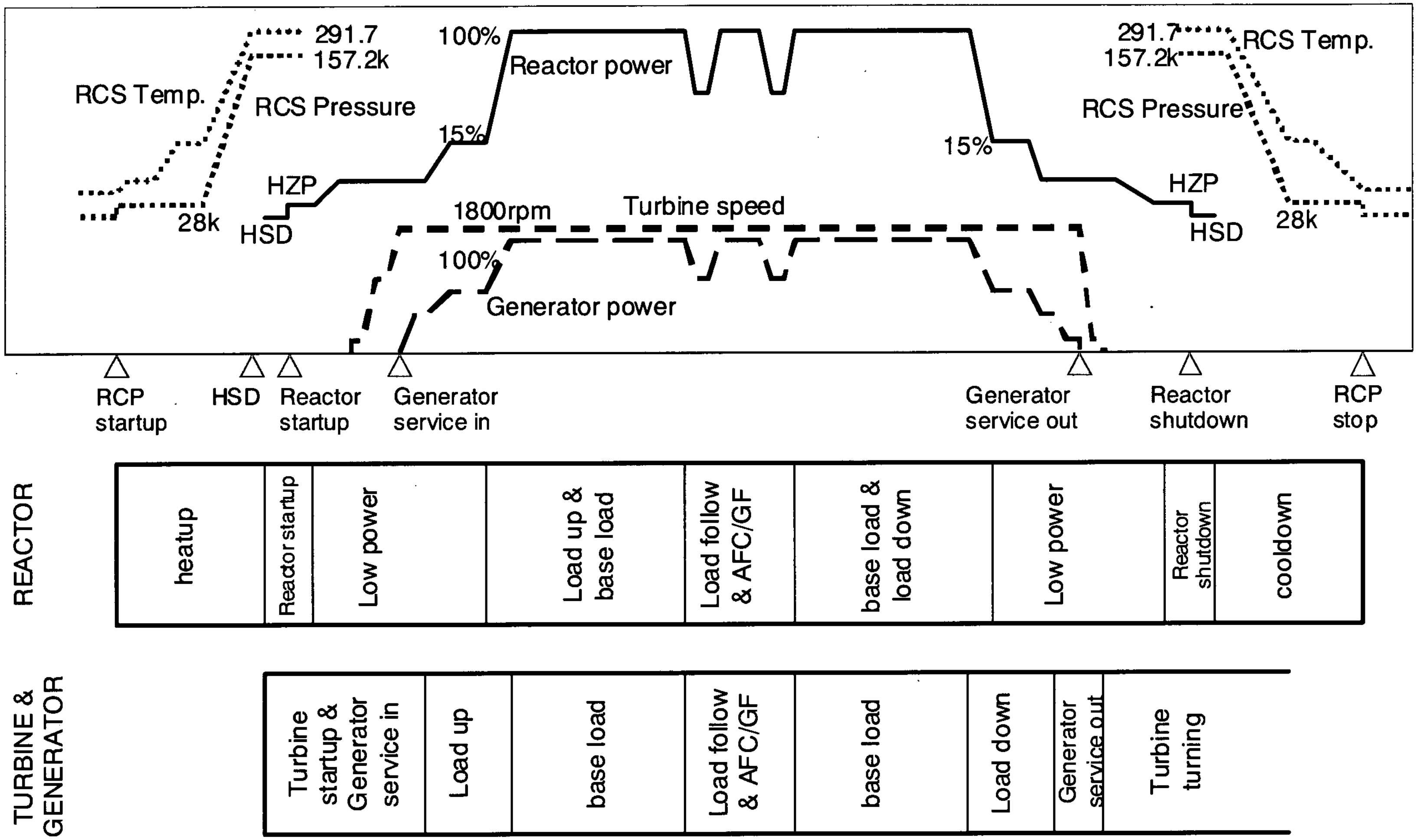


Figure 5-1 Plant Start-up/Shutdown Sequences

Table 5-1 Operator Tasks during Plant Start-up/Shutdown (CSD - HFP)

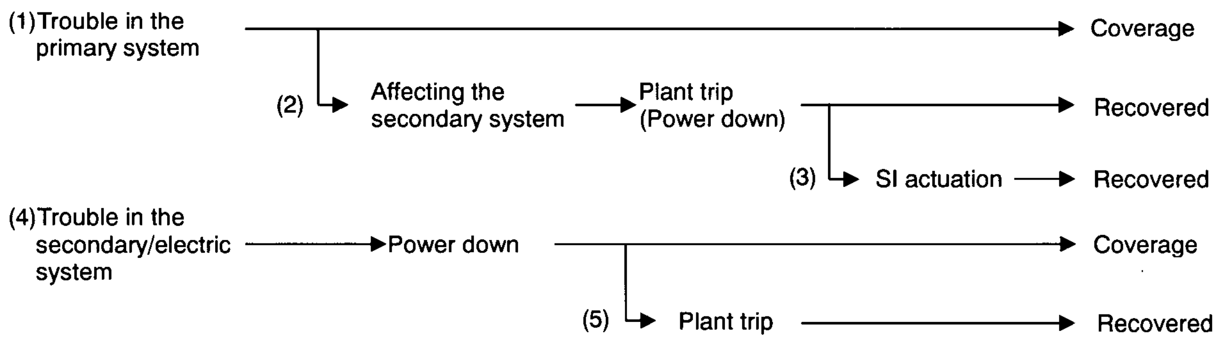
No.	Reactor operator	Secondary side Operator	Communication			Monitor		Judge	Operation		Multi Monitoring		Multi Operation		Parallel tasks	Required time				No.	Reactor operator	Secondary side Operator
			Sr	Ss	P	R	V	J	C	T"	2	>3	2	>3		<1 Min	<10 min	<1 hr	>1 hr			
1	Check before Start-up		11	11	2	21	21	0	0	0	0	0	0	0					X	-		
2	Prepare for charging/letdown		15	12	0	16	129	0	101	7	2	0	1	0					X	-		
3	Start charging/letdown		0	0	0	1	26	0	7	11	4	3	1	0				X		24	Stop charging/letdown	
4	Prepare for heat-up		0	0	0	3	15	0	12	0	0	0	0	0				X		-		
5	Reset reactor trip breaker		2	2	0	7	21	0	9	0	1	1	0	0				X		23	Insert shutdown bank control rods	
6	Start RCP		3	3	0	8	68	0	13	3	1	1	1	0				X		22	Stop RCPs	
7	RCS sampling		1	1	0	0	0	0	0	0	0	0	0	0		X				-		
8	RCS Heat-up (Auto)		0	0	0	1	4	0	3	0	0	1	0	0		X				21	RCS Cooldown (Auto)	
9	Extraction of O_2 gas from RCS		3	4	0	2	8	0	4	0	0	0	0	0						-		
10	Restart RCS heat-up (Auto)		1	1	0	2	9	0	6	0	0	1	0	0					X	20	Restart RCS Cooldown (Auto)	
11	Create vapor phase in the pressurizer		0	0	0	1	3	0	1	0	0	0	0	0	●11		X			19	Break vapor phase in the pressurizer	
12	VCT N2→H2 gas exchange		9	3	0	2	12	0	4	1	1	0	0	0					X	18	VCT H2→N2 gas exchange	
13	RHRS isolation		1	1	0	5	28	0	12	6	1	0	0	0				X		17	RHRS service in (Auto)	
14	RCS Heat-up and pressurize (Auto)		0	0	0	9	17	0	7	4	0	1	0	0	●14				X	16	RCS cooldown/ depressurize	
15		MD-FWP warming	8	4	0	9	21	0	2	1	5	0	0	0	▼				X			
16		Aux. FWP stand by	0	0	0	1	4	0	3	0	0	0	0	0		X				-		
17		MS line warming	2	1	0	1	26	0	16	8	0	1	0	1				X		-		
18	TBBY control mode change to 'Pressure'		0	0	0	1	10	0	4	5	0	1	0	0		X				-		
19	Prepare for reactor critical operation		0	1	0	2	12	0	1	0	0	0	0	0	▼				X	-		
20	Adjustment of Boron density		1	2	0	2	8	0	6	0	0	0	0	0			X			15	Adjustment of Boron density	
21	Reactor critical operation		0	1	0	2	10	0	5	0	3	0	0	0			X			14	Shutdown Reactor	
22		Start up steam converter	2	2	0	0	0	0	0	0	0	1	0	0				X		13		Stop steam converter
23		1st TD-FWP start up	0	0	13	16	38	1	6	1	1	10	0	0					X	12		Stop TD-FWP
24		FW makeup vlv. →bypass valve.	0	0	0	1	14	0	2	8	0	1	4	0					X	11		FW bypass valve → makeup valve
25	Reactor power-up (Auto)	Prepare for Turbine start up	0	0	5	25	50	0	23	3	2	8	1	0	●25	X				-		
26		Prepare for Generator start up	2	2	0	2	20	0	15	0	0	1	0	0					X	-		
27		Turbine start up (Auto)	0	0	4	12	23	1	6	0	2	5	0	0	●27				X	1	Reactor power-down (Auto)	Load down (Auto)
28		Generator line-up	3	2	1	11	25	0	9	2	1	1	0	0					X	10		Generator line-off
29		Gen. Power to 10%	0	0	0	3	3	0	0	0	0	1	0	0				X		9		Gen. Power to 10%
30		Gen. Power to 15% (FW bypass valve → main valve.)	1	1	0	9	18	3	7	2	0	1	0	0	▼			X		8		Gen. Power to 15% (FW main valve → bypass valve.)
31	TBBY control mode change to 'Tavg'		0	0	0	7	11	0	2	0	1	0	0	0		X				6	TBBY control mode change to 'Pressure'	
32		Line up on-site electrical grids	0	0	0	1	3	0	1	0	1	0	0	0		X				7		Line up on-site electrical grids
33		Gen. Power to 20%	1	1	0	14	21	0	3	0	0	0	0	0				X		5		Gen. Power to 20%
34		Gen. Power to 35%	2	2	0	3	3	0	0	0	0	0	0	0				X		4		Gen. Power to 35%
35		Gen. Power to 50%	1	1	1	7	7	0	0	0	0	1	0	0	▼			X		3		Gen. Power to 50%
36		Gen. Power to 90% - 100%	2	3	2	8	7	0	0	0	0	0	0	0				X		2		Gen. Power to 90% - 100%

Note:
Sr: Receive of Verbal Report/Order, Ss: Send Verbal Report /Order, P: Operation of Paging/ext. phones, R: Request of VDU display, V: Monitor CRT display, J: Judgment, C: ON/OFF operation by VDU, T: Control operation by VDU

2.2 Operation during Abnormal Conditions

2.2.1 Extraction of Overlapping Modes

Abnormal events could roughly be classified as follows:



(a) Abnormal events (1) and (4) in the primary system and the secondary/electrical system, respectively, not leading to the plant trip, would basically converge to a settlement within the system. Therefore, operational responses of the primary system operator and the secondary/electrical system operator do not overlap.

However, events accompanying load reduction may affect the entire plant, and operational responses of the primary system operator and the secondary/electrical system operator may overlap.

Therefore, as to events (1) and (4) not leading to the plant trip, the single-operator operation is possible, provided that the targets be attained with respect to an operator workload during the load reduction.

(b) Of events (2) leading to the plant trip due to trouble in the primary system, the SG tube leakage is the only event in which operational responses involve the secondary system except for responding to the plant trip (power down). Furthermore, operational responses in the secondary system to the power down and the plant trip are limited to confirmatory actions after the power down operation and the plant trip, irrespective of what the event in the primary system is.

On the other hand, in events (5) leading to the plant trip due to trouble in the secondary system and/or the generator, operational responses in the secondary system after the plant trip include, other than the post-trip confirmatory actions, the investigation into the cause of the trouble, which require no urgent attention, however.

It should be noted that, in an event leading to the plant trip due to the loss of power, operational responses of the primary system operator and the secondary/electrical system operator overlap.

Therefore, as to events (2) and (5) leading to the plant trip, the single-operator operation is possible, provided that the targets be attained with respect to the operator workload during the SG tube leakage, the plant trip and the loss of power.

(c) Of events (3) leading to the SI activation due to trouble in the primary system, the SG tube leakage is the only event in which operational responses involve the secondary system except for responding to the plant trip (power down) and the SI activation and for performing recovery actions.

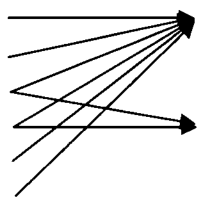
Operational responses in the secondary system after the plant trip and the SI activation are limited to confirming the plant trip and the SI activation and performing recovery actions, irrespective of what the event in the primary system is.

Therefore, as to events (3), the single-operator operation is possible, provided that the targets be attained with respect to the operator workload during the SG tube leakage.

Following the above discussion, abnormal events that need to be examined were extracted as shown below. These events were examined in the operational task analysis, and operational responses of the primary system operator and the secondary system operator that were required within a short period of time (< 10 minutes) were extracted.

<u>Abnormal events to be examined</u>

- •Load reduction (a)
- •Plant trip (b)
- •Blackout (b)[*1]
- •Small LOCA (c)[*2]
- •SG tube rupture (b)(c)
- •Malfunction of feedwater control valve. (a)[*3]
- •Total loss of AC power (b)[*1]



<u>Overlapping items</u>

Confirmatory actions during plant trip

Confirmatory actions during SI

*1: Since loss-of-power events do not significantly differ in the responding actions among themselves, task analyses shall be conducted on these two representative cases.

*2: Although "SG tube rupture" would suffice for (c), another case shall be examined in the operational task analysis to confirm that there are no overlapping items.

*3: Although "load reduction" would suffice for (a), since it represents an abnormal event on the border of the primary and secondary systems, the operational task analysis shall be conducted to be sure.

It should be noted that SG level adjustment, temperature reduction operation, and pressure reduction operation following the reset of safety injection during SGTR are carried out intermittently (for a few times). It should also be noted that recovery actions such as establishing a vacuum would require no urgent attention but could be dealt with sequential responses. Accordingly, these shall not be considered to be the overlapping items.

Table 5-2 Operator Tasks during Abnormal/Accidental Conditions (1 of 2)

Event	No.	Reactor operator	Secondary side Operator	Communication			Monitor		Judge	Operation		Multi Monitoring		Multi Operation		Parallel tasks	Required time			
				Sr	Ss	P	R	V	J	C	T"	2	>3	2	>3		<1 min	<10 min	<1 hr	>1 hr
Load Reduction	1		Acknowledge abnormal conditions	2	2	0	3	9	0	0	2	1	2	0	0		X			
	2	Recovery operation	Recovery operation	3	4	2	11	25	0	1	4	2	5	0	0				X	
Plant Trip	1	Monitor and Operation after Trip	Monitor and Operation after Trip	4	3	1	30	61	4	11	3	5	4	0	0			X		
	2	Recovery operation	Recovery operation	4	1	4	13	31	2	14	3	5	10	0	1				X	
Main feed water control valve close abnormity	1	Acknowledge abnormal conditions		1	2	0	5	15	1	6	2	0	1	0	0			X		
	2	Monitor and Operation after Trip	Monitor and Operation after Trip	4	3	1	30	61	4	11	3	5	4	0	0			X		
	3	Recovery operation	Recovery operation	4	1	4	13	31	2	14	3	5	10	0	1				X	
SGTR	1	Acknowledge abnormal conditions		3	4	0	2	8	0	4	0	0	0	0	0			X		
	2	Acknowledge process monitors High		1	0	0	4	9	0	3	0	1	2	0	0			X		
	3	Start additional charging pump		1	1	0	2	6	1	8	0	2	1	0	0		X			
	4		Unit power down	1	1	0	2	5	0	3	0	0	2	0	0			X		
	5	Monitor and Operation after Trip	Monitor and Operation after Trip	4	3	1	30	61	4	11	3	5	4	0	0			X		
	6	Monitor and Operation after ECCS activation	Monitor and Operation after ECCS activation	2	3	0	18	18	0	0	0	0	8	0	0			X		
	7	Isolate the broken SG		1	0	0	6	12	0	6	0	0	0	0	0	●		X		
	8	RCS cool down		0	0	0	1	4	1	0	3	0	1	0	1	●			X	
	9	RCS depressurize		0	0	0	1	4	1	3	0	0	2	0	0	●			X	
	10	Reset SI signal		2	1	0	6	10	1	0	3	0	2	0	0		X			
	11	Stop activated ECCS components		1	0	0	7	16	0	9	0	0	0	0	0		X			
	12	Recovery of charging/letdown system		0	1	0	3	18	1	16	1	1	1	0	0		X			
	13		Recovery of on-site electrical power system	2	0	1	1	5	0	6	0	1	0	0	0	▼	X			
	14	Restart RCPs		2	1	1	3	15	0	12	0	1	1	0	0		X			
	15	Prepare for reactor critical operation	Establish vacuum of the condenser	0	0	0	4	14	0	10	0	0	0	0	0		X			
	16	Use of TBBY valves		0	0	0	1	13	0	1	9	1	1	0	1	▼ ▼		X		
	17	To CSD operation		-	-	-	-	-	-	-	-	-	-	-	-					
Heat sink control	1	Recovery operation of SG water level		5	5	0	10	25	6	13	2	0	4	0	0				X	
	2	Feed and Breed operation		2	2	0	9	14	2	5	0	1	2	0	0				X	
Loss of All AC Electrical Power	1	Acknowledge abnormal conditions		1	2	0	0	2	0	0	0	0	1	0	0			X		
	2	Acknowledge process monitors High		4	3	1	30	61	4	11	3	5	4	0	0			X		
	3	Start additional charging pump		3	3	0	5	8	2	4	0	0	0	0	0			X		
	4		Unit power down	4	min 8	min 7	18	32	1	14	0	1	3	0	0				X	
	5	Monitor and Operation after Trip	Monitor and Operation after Trip	0	1	1	5	8	1	3	0	0	0	0	0				X	
	6	Monitor and Operation after ECCS activation	Monitor and Operation after ECCS activation	2	2	2	8	24	1	12	4	0	1	0	0				X	
	7	Isolate the broken SG		2	3	2	6	21	1	11	4	0	1	0	0				X	

Table 5-2 Operator Tasks during Abnormal/Accidental Conditions (2 of 2)

Event	No.	Reactor operator	Secondary side Operator	Communication			Monitor		Judge	Operation		Multi Monitoring		Multi Operation		Parallel tasks	Required time			
				Sr	Ss	P	R	V	J	C	T"	2	>3	2	>3		<1 min	<10 min	<1 hr	>1 hr
Loss of Off-Site Power	1		Acknowledge abnormal conditions	1	2	0	0	2	0	0	0	0	1	0	0			X		
	2	Monitor and Operation after Trip	Monitor and Operation after Trip	4	3	1	30	61	4	11	3	5	4	0	0			X		
	3		Acknowledge EDGs start-up	0	0	0	4	18	0	1	0	2	3	0	0					
	4	Monitor and control SG water level	Monitor and Operation after ECCS activation	0	0	0	4	13	0	1	3	1	2	0	1	●		X		
	5	Restart of charging/letdown system		0	0	0	1	2	0	1	0	1	1	0	0	│		X		
	6		Start of turbine axis cooling water pump	0	0	0	2	9	0	1	0	1	0	0	0	│				
	7	Awake auto startup block		0	1	0	1	4	0	1	0	0	0	0	0	│				
	8	Reset BO sequence signal		1	0	0	3	6	0	3	0	0	0	0	0	│				
	9		Exchange generator oil pumps	1	0	1	0	0	0	0	0	0	0	0	0	│				
	10	Monitor and control SG pressure		1	0	1	3	6	0	1	1	0	1	0	1	│				
	11		Restart battery charger (Local)	0	0	0	0	0	0	0	0	0	0	0	0	│				
	12		Generator H2 gas/Turbine oil control	1	0	0	4	0	1	3	0	0	0	0	0	│				
	13	Stop BTRS and evaporators		2	0	2	0	0	0	0	0	0	0	0	0	│				
	14		Recovery of off-site electrical power system	3	0	2	10	15	0	17	1	1	1	0	0	│			X	
	15		Recovery of on-site electrical power system	2	0	1	1	5	0	6	0	1	0	0	0	│			X	
	16	Restart RCPs		2	1	1	3	15	0	12	0	1	1	0	0	│	X			
	17		Establish vacuum of the condenser	0	0	0	4	14	0	10	0	0	0	0	0	│	X			
	18	Use of TBBY valves		0	0	0	1	13	0	1	9	1	1	0	1	▼		X		
SBLOCA	1	Acknowledge abnormal conditions		1	1	0	0	0	0	0	0	1	2	0	0			X		
	2	Start additional charging pump		1	1	0	2	6	1	8	0	0	2	1	0			X		
	3		Unit power down	1	1	0	2	5	0	3	0	0	1	0	0			X		
	4	Monitor and Operation after Trip	Monitor and Operation after Trip	4	3	1	30	61	4	11	3	5	4	0	0			X		
	5	Monitor and Operation after ECCS activation	Monitor and Operation after ECCS activation	2	3	0	18	18	0	0	0	0	8	0	0			X		
	6	Monitor and control SG water level		0	0	0	4	13	0	1	3	0	1	0	1	●				X
	7	Reset SI signal		2	1	0	6	10	1	0	3	0	2	0	0	│		X		
	8	Stop activated ECCS components		1	0	0	7	16	0	9	0	0	0	0	0	│		X		
	9		Recover on-site electrical power system (Stop EDGs)	2	0	1	1	5	0	6	0	1	0	0	0	│		X		
	10	Recovery of charging/letdown system		0	1	0	3	18	1	16	1	1	1	0	0	│		X		
	11		Establish vacuum of the condenser	0	0	0	4	14	0	10	0	0	0	0	0	▼		X		
	12	Use of TBBY valves		0	0	0	1	13	0	1	9	1	1	0	0					X

Enclosure 6

UAP-HF-09020
Docket No. 52-021

6. Task Analysis (GOMS) Summary Report

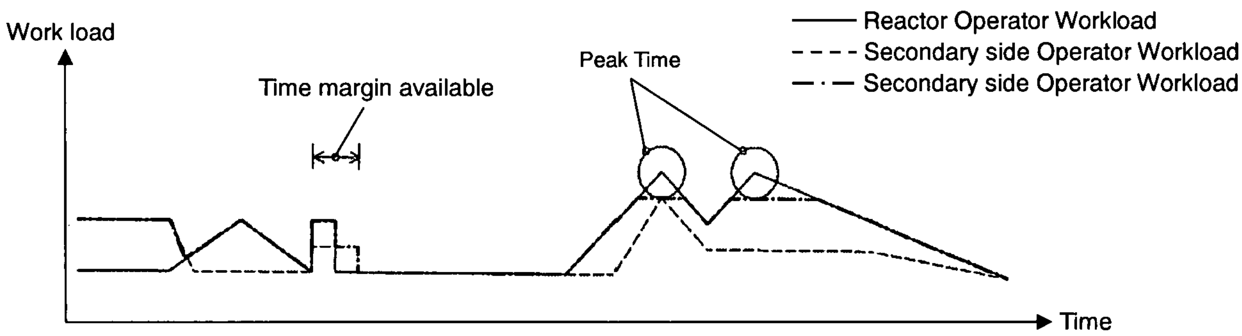
January, 2009

1. Purpose

In order to make the single-operator operation possible, it will be necessary to at least limit a workload of an operator per unit time to that which a single operator can take on. It is reasonable to assume that a workload a single operator can take on would be a workload of either the primary system operator or the secondary system operator of a conventional plant. Therefore, if an operator workload can be made equal to or less than the workload for either the primary system operator or the secondary system operator, whichever is heavier (see figure below), then it can be said that the single-operator operation is possible.

Furthermore, in an attempt of achieving a human-friendly plant, it will be attempted that the peak workload be less heavy than the peak workload for either the primary system operator or the secondary system operator, whichever is heavier.

However, even in the case where two operators appear to be responding to situations simultaneously during the two-operator operation, if there is sufficient time such that the two courses of action need not be performed simultaneously, or, in other words, if the sequential responses may be allowed, then the workload shall be evaluated with an assumption that situations are dealt with in a sequential manner (see the portion indicated by "↔" in the figure below).



2. Preconditions

The following automated operation modes proposed for APWR shall be assumed in the workload evaluation:

- Heat-up and cool-down of the primary system;
- Low-power operation (15% output or less);
- SG feedwater valve switching;
- Automated speed-up, engagement with the generator, and load-up of the main turbine;
- Automated speed-up of FWPT.

3. Workload evaluation for Single-Operator Operation

3.1 Load Reduction Measures

The following load reducing measure shall be implemented for these overlapping items.

- Since each event involves a number of monitoring items, conduct automated check sequences, the result of which shall be presented through the representative display, thereby reducing the workload.
- Since there are a number of screen-requests, concentrate monitoring items on a single screen, thereby reducing the workload.

3.2 Workload Evaluation

In order to confirm the degree of attainment of the targets, the workload evaluation was conducted for the cases of two-operator operation (advanced main control board) and of single-operator operation (advanced main control board).

(1) Evaluation Method

A flow of (perception in mind) → (recognition) → (motion (action command)) shall be converted into process time based on the human information processing model and used as workload indicators. The evaluation method is shown in Attachment A.

(2) Modes to be evaluated

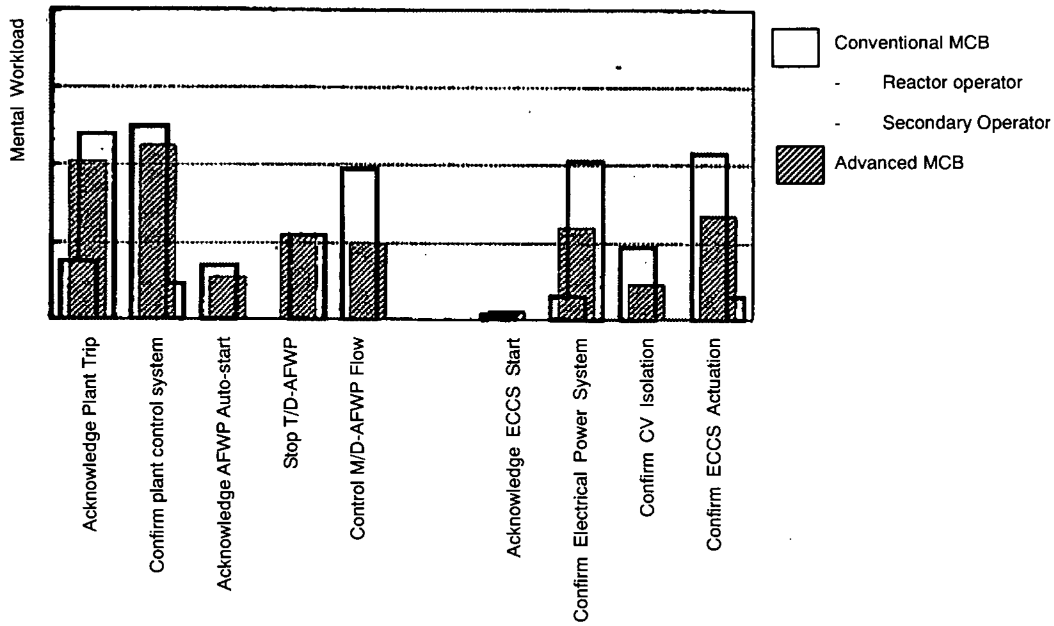
The following operational responses that the primary system operator and the secondary system operator would overlap within a short period of time shall be evaluated:

- Confirmations during the plant trip; and
- Confirmations during SI.

(3) Result of Evaluation

With respect to the above-mentioned operational modes, workloads were evaluated for the cases of advanced main control board operated by two operators and of advanced main control board operated by a single operator. The results of evaluation were then compared to one another.

The results of evaluation are shown in Table 6-3 and the graph below. In either case, the workload of the single operator on the new control board is less than the workload associated with the conventional control board for either the primary system operator or the secondary system operator, whichever is heavier, thereby attaining the targets with respect to the workload.



Furthermore, similar evaluations were conducted for "confirmatory actions during BO", "event discrimination during LOCA" and "temperature/pressure reducing operations during SGTR", which were considered to involve relatively high workloads. From the result of these evaluations, it was confirmed that the workload for the single operator of the new control board is entirely less than the workload associated with the conventional control board for either the primary system operator or the secondary system operator, whichever is heavier.

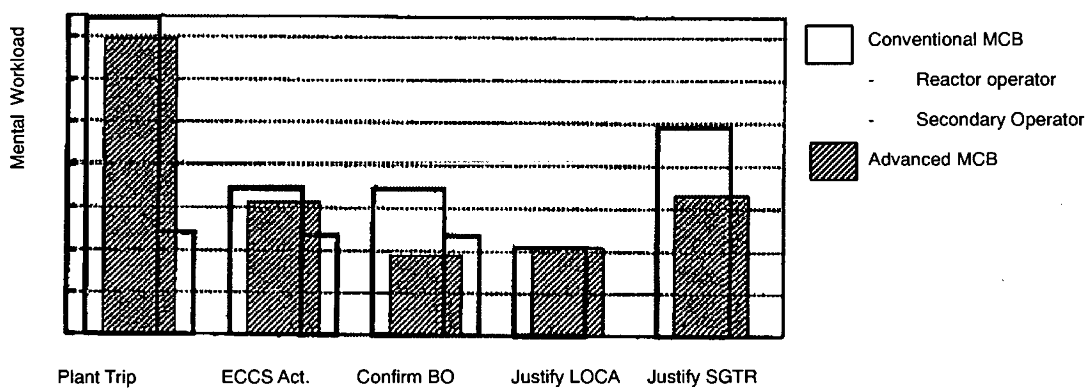


Table 6-3 Results of Workload Evaluation

Event	Step		Conventional MCB				ACB		Reduction Ratio (%)
			RO1		RO2				
			Mental Workload	Time (sec)	Mental Workload	Time (sec)	Mental Workload	Time (sec)	
Ack. Plant Trip	1	Confirm Reactor Trip Confirm Turbine Trip Confirm Generator trip	57tp+127tc+12tm	15	126tp+308tc+31tm	36	107tp+268tc+32tm	32	22
	2	Confirm plant control System	195tp+409tc+31tm	50	-	-	160tp+320tc+17tm	39	22
	3	Confirm AFWR auto start-up	45tp+124tc+13tm	14	-	-	35tp+99tc+8tm	11	21
	4	Stop TD-AFWP	72tp+187tc+27tm	22	-	-	71tp+187tc+25tm	22	0
	5	Control MD-AFWR Flow	144tp+314tc+40tm	39	-	-	64tp+180tc+13tm	20	48
	Sum		513tp+1161tc+123tm	140	126tp+308tc+31tm	36	488tp+1192tc+115tm	124	30
Ack. ECCS	1	Acknowledge ECCS start-up	5tp+10tc+2tm	1	-	-	6tp+13tc+2tm	2	-100
	2	Confirm electrical power system	23tp+55tc+3tm	6	147tp+357tc+15tm	41	79tp+222tc+12tm	24	49
	3	Confirm CV Isolation	18tp+44tc+5tm	5	-	-	16tp+42tc+4tm	5	0
		Confirm MCR/CVV Isolation	47tp+114tc+12tm	14	-	-	14tp+35tc+2tm	4	71
	4	Confirm SI sequence act.	12tp+30tc+4tm	5	-	-	8tp+21tc+2tm	2	60
		Confirm FW Isolation.	-	-	23tp+55tc+5tm	6	8tp+21tc+2tm	2	67
		Confirm MS Isolation	8tp+21tc+2tm	2	-	-	8tp+21tc+2tm	2	0
		Confirm CV spray act.	8tp+21tc+2tm	2	-	-	14tp+35tc+2tm	4	-100
		Confirm ECCS activation	111tp+303tc+26tm	34	-	-	54tp+150tc+16tm	17	50
	Sum		232tp+598tc+56tm	69	170tp+412tc+20tm	47	207tp+556tc+43tm	62	47
Ack. BO	1	Acknowledge on-site power off	-	-	140tp+319tc+17tm	38	54tp+130tc+4tm	15	61
	2	Confirm EDGs start-up	-	-	49tp+111tc+5tm	13	30tp+80tc+8tm	9	31
	3	Confirm auto-tripped components	-	-	52tp+126tc+9tm	15	22tp+51tc+2tm	6	60
	4	Confirm BO sequence start	9tp+23tc+4tm	3	-	-	8tp+21tc+2tm	2	33
	5	Reset BO Sequence	9tp+24tc+2tm	3	-	-	7tp+72tc+7tm	6	-100
		Sum	18tp+47tc+6tm	6	241tp+556tc+31tm	66	121tp+354tc+23tm	38	47
Justify Event	1	Confirm plant status after ECCS act.	115tp+274tc+4tm	31	-	-	115tp+273tc+3tm	31	0
	2	Event justification as LOCA	34tp+101tc+3tm	11	-	-	40tp+103tc+3tm	11	0
	Sum		154tp+375tc+7tm	42	-	-	155tp+376tc+6tm	42	0
Cooldown /Depress	4	RCS cool down	117tp+319tc+24tm	36	-	-	102tp+294tc+22tm	32	11
	5	RCS depressurize	97tp+218tc+18tm	26	-	-	76tp+215tc+15tm	24	8
	6	Adjust cool-down rate	112tp+319tc+36tm	36	-	-	30tp+97tc+4tm	10	72
	Sum		326tp+856tc+78tm	98	-	-	208tp+606tc+41tm	66	32

4. Evaluation of Maximum Workload

By implementing the load reducing measures of Section 3.2, the peak workload during the single-operator operation becomes less than the workload associated with the conventional control board for either the primary system operator or the secondary system operator, whichever is heavier. Consequently, it can be said that the single-operator operation is possible in terms of the workload.

5. Conclusions

In order to introduce the single-operator operation, the following measures need to be implemented with respect to the workload:

(1) Introduce automated check sequences, utilizing representative displays, to deal with the confirmatory actions during the plant trip and the SI activation; and

(2) Extensively consider the concentration of monitoring information on a single screen when designing the screen.

Detailed screen designs used in this evaluation are those of design specifications developed for the advanced main control board, including above (1) and (2). However, when preparing the screen design for Japanese PWR/APWR, further reduction of workloads will be pursued. Therefore, it is concluded that a single operator will sufficiently be able to respond to situations.

Attachment A

The Model Human Processor

The processing within man's brain is modeled, and it divides into a simple system, and enables it to compute processing time as a fixed quantity evaluation value of a processing burden in Card's and others Model Human Processor.
In this model, human was considered to be a kind of information processing system, and in giving a stimulus and taking action about it from the exterior, it assumes that it is what is generally performing the next processing.
The conceptual architecture of model human processor is shown in Figure 1.

- Perceptual processor
  Gather information by sense organs (an eye, an ear, a nose, skin, etc.), and memorize the stimulus from the informational input processing (consciousness processor) outside in a brain.
  Processing time: tp=100msec (experiment result)
- Cognitive processor
  Analyze and judge using the information memory from man's sense organ and the accumulated memory (knowledge).
  Processing time: tc=70msec (experiment result)
- Motor processor
  A command is transmitted to the movement systems (a hand, leg, etc.) relevant to the action performed based on a processing (movement processor) judgment result of operation, and final operation is carried out.
  Processing time: tm=70msec (experiment result)

Moreover, Card and others divides roughly about the work which man does, and supposes that it will be classified into "four work" of simple reaction, physical collation, and name collation and category collation.
The processing time of the processor extended in order to evaluate advanced main control board as these "four work" is shown in Table A-1.

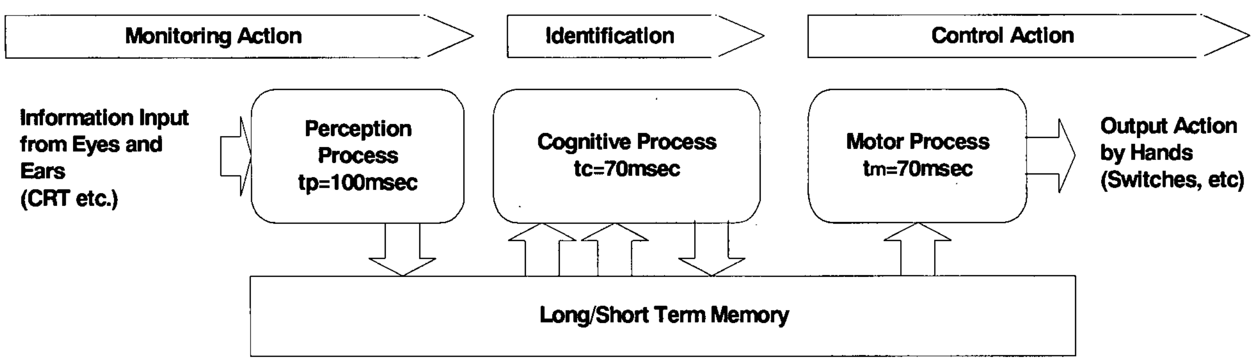


Figure 1 Architecture of the model human processor

Table A-1 Number of times of processing of perceptual, cognition and motor processor

Work item	Abbreviation	Explanation	The number of times of processor processing		
			tp	tc	tm
1) Simple reaction	sr	Work of "cognitive processor" represented by the action of "pushing a button if some are displayed on a VDU screen" does not move only once for of reaction determination	1	1	1
2) Physical matches	pm	Work of "cognitive processor" represented by the action of "pushing a button if the 2nd sign is the same type as the 1st sign when two signs are displayed on a VDU screen by something in order" makes collation and a reaction decision	1	2	1
3) Name matches	nm	Work of "cognitive processor" represented by the action of "pushing a button if the 2nd sign is the same name as the 1st sign when two signs are displayed on a VDU screen by something in order" makes a character check, collation, and a reaction decision	1	3	1
4) Class matches	cm	Work " cognitive processor" represented by the action of "pushing a button if the 1st sign belongs to the class with the 2nd same sign when two signs are displayed on a VDU screen by something in order" makes a character check, a classification, collation, and a reaction decision	1	4	1
Followings are extended items for main control board evaluation					
5) Simple reaction without perception	mo	Work similar to item 1) "simple reaction" which only movement of "it thinking that a button will be pushed and pushing a button" which does not include the consciousness reaction of "if some are displayed on VDU"	0	1	1
6) Simple reaction without motor	sr*	Work similar to item 1) "simple reaction" without movement of "pushing a button"	1	0	0
7) Physical matches without motor	pm*	Work similar to item 2) "physical matches" without movement of "pushing a button"	1	1	0
8) Name matches without motor	nm*	Work similar to item 3) "name matches" without movement of "pushing a button"	1	2	0
9) Class matches without motor	cm*	Work similar to item 4) "class matches" without movement of "pushing a button"	1	3	0
10) Memory reference	mr	Work which refers to long-term memory, such as "remembering the following operation item as something in the light of the operation point in the head."	0	1	0

Enclosure 7

UAP-HF-09020
Docket No. 52-021

7. Human Reliability Analysis (THERP) Summary Report

January, 2009

1. Introduction

This report discusses the operational structure upon introducing the computerized main control board to Japanese PWR/APWR. This advanced control board, which was developed as a soft-operation type control board with improved operability, is capable of being operated by a single operator. This report discusses "human error rate for the case of single-operator operation".

2. Purpose

Probability of occurrence of operational human errors that may affect the plant safety when the advanced control board is being operated by a single operator must be the same as when a conventional control board is being operated by two operators.
In this report, the human error rate in the case of single-operator operation with the advanced control board was evaluated by comparing it to that of the two-operator operation with the conventional control board.
It should be noted that, instead of human error ratios per one operator, human error ratios of an entire operating crew were evaluated from a standpoint of the safety for an entire system.

3. Preconditions

The following assumptions were made as prerequisites when evaluating human error ratios.

3.1 Role Assignment

- Two-operator operation: Operational responsibilities are clearly defined and assigned to the two operators, and each operator is expected to respond within the scope of his/her responsibility. The shift supervisor provides them with instructions and follows up on their actions. The fact that there are two operators shall not be taken as a basis that one can always follow up on another.
- Single-operator operation: Although operational responsibilities include those of two operators in a conventional setting, he/she is expected to respond within the scope of his/her responsibility. The shift supervisor provides him/her with instructions and follows up on his/her actions.

3.2 Control Board Design

Board configuration, screen hierarchy, etc. are suited for a single operator in the case of the single-operator operation with the advanced control board or for two operators in the case of the two-operator operation with the conventional control board.

3.3 Skill Level

For the single-operator operation, an operator has received sufficient training so that he/she is capable of responding to situations during the single-operator operation. Similarly, for the two-operator operation, operators have received sufficient training so that they are capable of responding to situations during the two-operator operation. In either case, the workload must be such that each operator to be able to respond to situations.

4. Evaluation

As shown in Table 7-1, the two-operator operation with the conventional control board and the single-operator operation with the advanced control board do not differ significantly in terms of the number of operation items and the human error rate associated with such operation items. Therefore, the human error rate for these two operation styles does not present any significant difference as a whole.

Table 7-1 Result of Evaluation of Human Error Ratios

Critical sequence				Human error rate		Reduction rate (%)
				Reference plant	Advanced main control board	
Monitoring-dominated sequence	Abnormal condition	Reactor trip	Checking reactor trip	0.08395	0.07815	6.9
		B.O.	Checking black out	0.06425	0.03851	40.1
		LOCA	Terminating safety injection	0.06460	0.06460	0.0
		SGTR	Checking during safety injection	0.13623	0.12505	8.2
			Discriminating events (investigation into the cause of safety injection initiation)	0.19651	0.14351	27.0
			Terminating safety injection	0.01320	0.01320	0.0
Overall evaluation of monitoring-dominated sequence						17.1
Operation-dominated sequence	Abnormal condition	SGTR	Removing heat in the primary system	0.23550	0.12351	47.6
			Depressurizing the primary system	0.08638	0.07613	11.9
			Identifying and isolating failed steam generator	0.03255	0.01516	53.4
Overall evaluation of operation-dominated sequence for abnormal condition						39.4
Overall evaluation of sequence for abnormal condition						25.8
	Normal condition	Start-up	Resetting turbine ~ engaging generator	0.07602	0.07028	7.6
			Loading up (toward15% load)	0.10948	0.06775	38.1
			Loading up (toward 100% load)	0.10160	0.09743	4.1
Overall evaluation of sequence for normal condition						18.0
Overall evaluation of operation-dominated sequence						29.8
Overall evaluation						23.9

5. Conclusion

By providing an environment suitable for the single-operator operation when designing and implementing it as shown below, there will be no significant difference in the human error rate between the two-operator operation with the conventional control board and the single-operator operation with the advanced control board so that the plant safety will not be affected.

- When designing board configuration and screen hierarchy, the single-operator operation is taken into consideration.
- Introducing automated check sequences (OK monitors, etc.) for confirmatory actions during the plant trip and the ECCS activation.
- Concentrating monitoring items on a single screen.
- Sufficient training for the single-operator operation is to be provided to an operator.