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18.0 INTRODUCTION

This chapter addresses human factors engineering (HFE) at Yonggwang Nuclear Power Plant, Units 3 & 4 (YGN 3&4). From an overall plant design perspective, YGN 3&4 is not to be a duplicate of an existing plant. This design is developed within the constraints of meeting current licensing regulations, improving plant design, and incorporating the utility's preferences.

This uniqueness also pertains to the YGN 3&4 main control room (MCR) design, although several plant designs have been used for reference. The MCR design has continued to follow the guidance of the Standard Review Plan (SRP) NUREG-0800, Chapter 18. Specifically, the portion of Chapter 18, which was written for "applicants just starting the control room design process" is being followed. This means that a utility, who has not developed a Control Room design or is in the very early stages of a control room design, should be utilizing accepted human factors engineering principles during the design process. Therefore, it is not specifically required that a detailed control room design review (DCRDR) as defined in Supplement 1 to NUREG-0737 be performed.

The acceptance criteria for initial licensing applicants are based on meeting the relevant requirements of General Design Criterion 19 (GDC-19), as it relates to the MCR being designed with appropriate human factors engineering design principles to assure that the operator-machine interfaces of the main control room are adequate to support safe operations of the plant.

18.0.1 General Design Criteria 19 : Control Room

The following information is provided from 10 CFR Part 50, Appendix A, GDC-19.

a. A control room is provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions, including loss-of-coolant accidents.

b. Equipment at appropriate locations outside the control room is provided: (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent cold shutdown of the reactor through the use of suitable procedures.

The YGN 3&4 main control room and remote shutdown panel are designed in accordance with human factors regulatory requirements and guidelines that are based on Korean anthropometric data. A separate HFE Group has been organized for the YGN 3&4 project to implement detailed HFE guidelines in the control room environment.

18.0.2 Standard Review Plan : Review Process

As outlined in the SRP, a utility that is involved in the design process is reviewed in three consecutive stages:

a. The PSAR stage covered the planning, preliminary design, and criteria.

b. The FSAR stage covers the final design, drawings, and procedures.

c. The final review includes audits of the control installations and interviews with operators and others in order to identify deficiencies not detected previously or nonconformance with the SAR commitments.

The utility has demonstrated throughout the design process that it has met the requirements of GDC 19, has incorporated accepted human factors engineering principles in the design of the MCR and remote shutdown capability, and has found the operator-machine interfaces of the control room and remote shutdown capability adequate to support safe operation of the plant. A systems analysis has been conducted and documented using existing guidelines and good HFE practice in order to identify man/machine interface requirements; including the allocation of functions to man and machine (manual and automatic), and the identification of information and controls that are provided to the operators. The information and controls needed for emergency operations of the plant are identified and provided. In addition, the allocation of functions to man and machine are addressed and the systems are optimized to take advantage of the strengths of human operators and automatic systems. The purpose of having full participation by HFE personnel during the design process is to minimize post design problems and changes. The issues addressed in NUREG-0700 are used as a checklist to assure acceptable human factors coverage.

The designs of the MCR and control centers outside the control room comply with accepted HFE principles. Functional relationships between the MCR and these other control centers are established, which assure compatibility during all modes of plant operation. The applicant can submit documentation that adequately addresses the following areas :

a. Control room workspace
b. Workspace environment
c. Annunciator warning systems
d. Controls
e. Visual displays
f. Auditory signal systems
g. Labels and location aids
h. Process computers

i. Panel layout

j. Control-display integration

18.0.3 Deficiencies in Operating Korean Nuclear Power Plants

A recent (June 1990) three volume report prepared by KOPEC, titled "Final Report for Nuclear Plant, Main Control Room Design Review" (KOPEC/90-P-001, 002, 003) describes 281 human engineering deficiencies (HEDs) at six Korean Nuclear Power Plants (Kori 1,2,3 & 4, and Yonggwang 1 & 2). These HEDs were isolated while KOPEC was performing a detailed control room design review (DCRDR) at these plants, which includes the following activities : operating experience review, control room inventory review, control room survey using NUREG-0700, system function review and task analysis, verification of task performance capabilities (availability, suitability), validation of control room functions, assessment of HEDs, and the recommended implementations regarding HEDs. The importance of these reviews to YGN 3&4 is that the major types of deficiencies can be avoided through proper analysis and design implementations by utilizing a "lessons learned" approach from these deficiencies.

The information contained in this report has been utilized during the development and implementation of the YGN 3&4 control room design. Consistent deficiencies within and between nuclear plants has assisted the designers of YGN 3&4 by helping them to avoid the same recurring problems of previous plants. Proper attention to human factors principles, especially recurring design problems during the preliminary stages of plant development, often has resulted in reductions of the costs and time for development.

18.0.4 Human Factors Program Plan Activities

18.0.4.1 Introduction to Human Factors Plan

The purpose of this plan is to ensure the early, complete, and continuing inclusion of human factors engineering in the YGN 3&4 design process, as stipulated in NUREG-0737, Supplement 1 and the Standard Review Plan (SRP) NUREG-0800, Chapter 18. This plan makes a commitment to thorough human factors engineering (HFE) in the YGN 3&4 design by fulfilling the intent of NUREG-0718 and the following licensing requirements (construction permits) for control room design reviews.

This plan is developed in accordance with the Human Factors Plan outlined in EPRI NP-3659 and the guidelines set forth by the USNRC in NUREG-0700. The major HFE activities are performed by the HFE Group; but support from other disciplines (e.g. mechanical, nuclear and electrical engineering) and other groups in the I&C discipline are provided for task analysis, function analysis and other activities which require the involvement of other disciplines. In addition, expert advice has been sought from the utility's operations and maintenance staff, experienced operators and engineers, as well as the NSSS-supplier's I&C engineering and simulation personnel.

The twenty-five steps of the Human Factors Plan are described in the remaining portions of Section 18.0. These steps follow rather closely the developmental stages of planning, analysis, design and evaluation, which are outlined in EPRI NP-3659. However, all facets of human factors work are not overly defined and outlined since they are routine, continual and implied by the steps described in the plan. For example, the analyses of vendor panel drawings, the reviews of applicable functional layouts and design documents, and the issuance of reports on aspects of human factors involvement fall within this grouping. Therefore, they are part of the plan's activities but are not described in detail. Also, while the steps listed in this plan are in general chronological order, there is significant overlap. That is, some of these activities may be performed concurrently or slightly out of sequence.

18.0.4.2 Develop the Human Factors Programs Plan

A comprehensive human factors program plan for the YGN 3&4 project was developed during the early stages of the project. This plan, as represented by this portion of the FSAR, documents a constant and systematic HFE involvement on the part of the utility. The plan assures that key elements of human factors involvement are not inadvertently overlooked.

The role of human factors personnel in program planning is to support management and other responsible engineers in making developmental decisions that can affect operations personnel in the performance of their duties, and to produce timely inputs that consider the man-machine system interfaces and the limitations and capabilities of the human component. The objectives of applying human factors principles, guidelines and criteria throughout the developmental cycle of the plant are to reduce the task demands upon the operators, to decrease the potential for human errors, and to increase the efficiency of plant operations.

18.0.4.3 Develop Comprehensive Human Factors Criteria

Experienced fuman factors specialists have, early in the project, developed a Human Factors Guideline document which basically adheres to the outline in the SRP. This document lists (for the MCR, remote shutdown (RS) system, and emergency facilities) the specific human factors criteria to be adhered to. Areas of coverage are the ambient environment, instrumentation, alarms, traffic flow, anthropometry, labeling, computer systems, and other areas as delineated in Section 18.1. The Human Factors Guideline document was developed based on the latest USNRC Human Factors Guidelines (NUREG-0700), industry standards from EPRI and INPO, good practices at other plants, and utility preferences. Subsequent requirements are to be evaluated on a case by case basis for incorporation in the document. This document is available for vendors, KEPCO, and all disciplines working on the project to assure standardized practices.

18.0.4.4 Prepare Main Control Board (MCB) Size Dimensions

Early in the project, the HFE Group designed the main control panels in the control room based on anthropometic data that would accommodate the 10th to the 90th percentiles of Korean males between the ages of 20 and 50 years. These data were collected for the Korean Physical Standard Measurement Report (1986) by the Korea Standards Institute (KSI). The sample size in this report is approximately 20,000. These data are depicted in Table 18.0-1 and Figure 18.0-1.

Due to the lack of data for the functional reach of Korean males, the functional reach is calculated by adding 3 cm to the measured arm lengths of Korean males, with the extended arm parallel to the floor, from the top of the shoulder bone to the tip of the middle finger (dimension #6 in Table 18.0-1). Functional reach, as defined in NUREG-0700, is measured with the right arm extended horizontal to the floor and both shoulders against the wall, from the wall to the tip of the right index finger. The addition of 3 cm to the existing data is believed to be a sufficient correction to the differences between the middle and index fingers, and between the top of the shoulder bone and the back of the shoulder. This calculation is important to the depiction of functional reach and line of sight (LOS) for the 10th and 90th percentiles on the YGN 3&4 main control panels and auxiliary operator's controls (see Figures 18.0-2 through 18.0-5).

The extended functional reach defined in NUREG-0700, Exhibit 6.1-5 would be approximately 9.8 cm longer than the functional reach given. However, the exact dimensional information is not available in KSI data. 1

18.0.4.5 Functionally Determine Main Control Board Allocations

Based on human factors references (EPRI NP-3659, NUREG-0700) and control room arrangements at reference plants, a functional layout of the MCR was produced which clearly shows where systems with MCR interfaces are located on the main control board. The layout was chosen to take advantage of the operators' previous experiences and to mimic natural process flows from the reactor outward. System allocations were discussed with experienced operators. The control room complex arrangement is provided in Figure 18.0-6.

The main control room at YGN 3&4 is not a system in itself. It is a collection of portions of many systems. Those portions are the ones which provide all necessary and sufficient instrumentation and controls from which action can be taken to operate the plant safely under all normal operating conditions, and to maintain it in a safe state under accident conditions. All system parameters requiring continuous monitoring and/or control are included on the main control boards (MCB). These parameters are from the nuclear systems, the engineered safety features system, electrical systems, balance of plant systems, and any post-accident monitoring systems. Plant computer displays, the critical functions monitoring system, fire protection, and bypassed/inoperable status indication also are included on the MCBs.

The control room also includes the plant annunciator system, control room lighting and environment controls, the operator workstations, and such additional facilities as storage space, desks, drawing racks, and printers. Each system included in the MCR functions according to the description in its individual "System Functional Description" and "Function Analysis Summary". Those portions included in the control room function according to operational considerations, and have power supplies in accordance with requirements in applicable system design criteria. Where Class 1E equipment is used, electrical and physical separation criteria are in accordance with IEEE standard 384.

Communications from the MCR are designed to allow the control room staff to interact with on-site and off-site personnel in vital areas as needed for safe operation of the plant under all conditions. Sound-powered telephones, regular phones, hot-lines for communications to the technical support center, operations support center, emergency operations facility, and other offsite locations as determined by the utility, and plant page connections are provided as needed to meet this requirement.

The entire MCR is designed to meet the control room staff's (two full operators, two assistant operators, one shift supervisor(SS), and one shift technical advisor (STA)) functional needs. These needs include the minimization of the possibility of human error and a design which considers operator comfort and efficiency. Toward this end, comprehensive HFE is incorporated into the design. This includes control room environment, operator workstations and anthropometry, MCB configuration and layout, computer display design, control room labeling, demarcation and mimics, control room traffic flow, annunciator system design, equipment accessibility, job aids, and auxiliary facilities (such as drawing racks, toilet, etc.). To enhance operator efficiency, standardized color-coding and hardware types, direction of control operation, labeling, annunciator placement, and computer display operation are used.

The paragraphs that follow present a brief description of control room operations, control and instrumentation functions, types of instrumentation, test and inspection duties, and component design specifications.

18.0.4.5.1 Operational Descriptions

Operational descriptions are presented for startup and shutdown, normal, and abnormal conditions within the MCR.

a. During normal plant startup and shutdown, the MCR will be fully functional. Controls and indications for such startup support systems as the startup transformers, startup feedwater pump, control element drive mechanism, reactor control panels, and chemical and volume control are included on the MCBs. Instrumentation necessary to control the plant from cold shutdown, to hot standby and on through various power escalations to 100% power operation are available.

For shutdown, all instrumentation necessary for the operator to bring the plant through normal shutdown from full power operation to hot and cold shutdown are available. This includes electrical power control and monitoring, main feedwater, the shutdown cooling system, steam dump, and other functions necessary for safe shutdown.

Instrumentation and controls necessary to keep plant parameters for pressure, temperature and flow in bounds during startup and normal shutdown are provided. Status and details, on these portions of each control room system used during start up and shutdown, are found in the functional summaries for the individual systems.

b. Normal operation for the MCR is defined as that condition when the plant is operating at full power (steady-state whether 100% power or some other defined limit) and when the turbine-generator is on-line. During this condition, all MCB instrumentation is functional.

Instrumentation necessary for normal operation includes those systems involved in electrical generation and distribution throughout the plant. The turbine and generators, moisture separators, heat sink (main feedwater, steam generators, main steam, hotwell/ condenser), power monitoring, and pressurizer are included on the MCB. In addition, support systems for normal plant performance such as chemical and volume control, fire protection, HVAC, and radiation monitoring are on the MCBs.

c. Abnormal operation is defined as any situation where the plant is not operating at a steady state, not undergoing normal startup or shutdown, and not in cold shutdown or hot standby. The control room is functional and provides necessary control and indication for plant control under all abnormal conditions and design-basis accidents. The control room environment is adequately protected from the effects of radiation, fire, smoke, and toxic gas; and continues to function in a manner allowing the operators to adequately monitor and control the plant.

18.0.4.5.2 Control and Instrumentation Functions

Two basic groups of control functions are included in the MCR; monitoring and control of basic safety functions, and monitoring and control of plant performance and operating functions.

a. The basic safety functions are integrated into the basic plant performance functions described in part b. below. Measurement and indication of type A, B, C, D and E variables listed per Regulatory Guide 1.97 are provided to monitor the consequences of design-basis accidents. The following basic safety functions are controlled from the MCR:

1. Reactivity control
2. Reactor core cooling and primary heat removal
3. RCS integrity
4. Radioactivity control
5. Containment integrity

b. The following 17 plant performance and operating functions are controlled from the MCR:

1. Control of reactor core reactivity includes two basic functions; short-term reactivity control (monitoring and control of CEA selection, rod control, neutron flux, and average primary temperature), and long-term reactivity control (monitoring and control of boron concentration and rod position).

2. Control of energy flow involves energy flow being controlled from the reactor, through the reactor coolant system to the steam generators, main steam system, turbine, and condenser. Indications and controls associated with this function include reactor power, total steam-generator energy (temperature, pressure), individual steam-generator energy fraction, turbine speed, feedwater pump discharge pressure/steam-generator differential pressure, generator power, reactive power, and time history of energy flow and storage through the main steam system.

3. Electrical control includes control of excitation, voltage regulator control, turbine governor control, and control of electrical energy flow from the generator.

4. Energy balance control is essentially related to cooldown. The feed control functions include decay heat removal (shutdown cooling), steam-generator control for cooling, component cooling water and essential service water.

5. RCS inventory control involves monitoring and control of the RCS, including reactor drain tank and refueling water storage tank volumes, leak and flow information, makeup and letdown, pressurizer, and volume control tank information.

6. Thermodynamics of coolant and chemistry involve subcooling, rcs pressure, hot and cold leg temperature monitoring, and boron concentration.

7. Secondary steam inventory and thermodynamic state involve controlling and monitoring the condenser hotwell, condensate storage tanks, heater drain tanks, heater shells, feed and drain piping inventory, and steam generator blowdowns.

8. Distribution of electric power involves distribution of normal and emergency power to plant components. It includes the distribution control and monitoring of ac and dc power to the extent required to support MCR operations.

9. ESFAS controls involve monitoring engineered safety features actuation system (ESFAS) status and control of ESFAS via manual actuation.

10. Radiation release control and containment integrity involve on-site and pertinent off-site radiation monitoring, combustible gas and hydrogen monitoring, and containment pressure and temperature control.

11. Heating, ventilating and air conditioning (HVAC) for safety-related components and systems and for containment are controllable from the MCR. In addition some non-safety-related functions are included.

12. Fire protection (FP) system functions, especially alarms, are monitored from the MCR. All controls for packaged fire suppression and detection systems are on local control panels. Individual fire suppression, with actuation and fire detection

alarms, are displayed in the MCR along with common trouble alarms for each panel. Water supply system valve indications are in the control room.

13. The critical function monitoring system (CFMS), which is a subset of the plant monitoring system (PMS), is monitored from the MCR on the PMS CRTs and other plant process-computer displays.

14. Plant communication systems are fully interfaced with the MCR.

15. Miscellaneous support systems, those subsystems and systems that directly support one or more key plant systems, especially those functions requiring prompt operator action, are process-related, and are located in the MCR.

16. Other systems, such as control room lighting, are controlled from the MCR, although not from the MCBs.

17. Bypass and inoperable status indications at the system and train levels are provided as an MCB function.

18.0.4.5.3 Instrument Types and Equipment

The following 11 types of instruments and equipment are used in the MCR.

a. The annunciator alarms and associated hardware including horns; lightboxes; acknowledge, test, reset and silence pushbuttons; and associated wiring.

b. Cathode ray tubes (CRTs) for the CFMS, radiation monitoring and plant computer displays, mounted on the MCB and/or the operators' console. Screens are color monitors with custom keyboards as needed and glare shields.

c. White status lights for bus, component, train and system indication. Station lights are rectangular with engraved lenses and multiple bulbs. Backlit pushbuttons have an adequate test feature incorporated.

d. Pushbutton controls for pumps, valves and similar control functions, the same size and shape as indicator lights.

e. Analog meters, vertically oriented, whenever possible. Meters display analog monitoring trend information or digital precise information for various MCB subsystems.

f. Digital recorders used to display long term trend information for various MCB systems. 460

g. Rotary controls and other control and indicator types, as needed and as approved by human factors engineering. Associated wiring and logic are included in the control room design. Control room environment fixtures (lights, baffles, fans, dampers, thermostats, and humidity control) are included.

h. Operator's console including CRT displays, printers, and necessary keyboards, as well as pertinent communications gear.

i. The MCB itself, not to be considered instrumentation, but treated as a fixture similar to desks, drawing racks, carpets, storage cabinets, etc.

j. Plant protection system (PPS) and auxiliary protection system (APS) cabinets, located behind the MCB. However, none of the functions associated with this hardware involve a routine man-machine interface for control room operators.

k. The customized Shift Supervisor's workstation which does not contain any instrumentation except for necessary communications gear and data displays.

18.0.4.5.4 Test and Inspection

The three types of tests and inspections performed on components and equipment located in the MCR; construction testing, pre-operation testing (component and system), and in-service inspection (safety and non-safety related components).

a. Construction Testing for the MCBs and various vendor-supplied panel inserts was performed by the fabricator prior to delivery to YGN 3&4.

b. Component Pre-Operation Testing is not performed. Individual components are tested as part of system pre-operation testing.

c. System Pre-Operation Testing in the MCR is performed on each control room system and subsystem, as part of the overall system testing. The MCR is not tested as a separate system.

d. In-service inspection for all safety-related components is provided in accordance with requirements in the applicable Technical Specifications.

e. In-service inspection for all non-safety-related components is provided in accordance with the utility's standard inspection and testing intervals, and procedures.

18.0.4.5.5 Component Design

The main component of the MCR is the main control boards (MCB). The MCB has been designed as described in the "Procurement Specification - Main Control Board and Associated Instruments", Rev.3 (9-182-J772). It is designed to accommodate all controls and instrumentations required to perform the functions outlined in Subsection 18.0.4.5.2. The MCB is designed for the MCR environment and includes a complete HFE analysis. The MCR accommodates the necessary cables, supports, and other internals; and will meet pertinent maintenance requirements.

18.0.4.6 Perform Functional Analysis of Systems

A functional analysis was performed on each system that has an interface with the MCR. These analyses contain system functional descriptions; instrument and control requirements; system constraints in terms of regulatory requirements, utility dictates and vendor inserts; and component operations (monitor, manual, automatic) and placement (local, main control room). This information is outlined in both "Function Analysis Summary" and System Functional Description" documents for each system, which were prepared by the responsible engineer (RE) for that system.

These documents satisfy the functional review requirements outlined in NUREG-0700 for the task analysis of operator tasks, which is a part of the MCR design process. For the purposes of the function review and task analysis, a system function or subfunction is defined as a type of activity (or a static role) performed by one or more system constituents (people, mechanisms, structures) to contribute to a larger activity or goal state. A task is defined as a specific action performed by a single system constituent (person or automated equipment) that contributes to the accomplishment of a function. Functions are reviewed in this process so that the organization of MCR operator tasks can be laid out clearly. In the development of the YGN 3&4 control room design, analyses were performed in an effort to optimize the allocation of functions and the tasks that enact the functions.

A report prepared by KOPEC, titled "System Descriptions of Systems with a Control Room Interface", dated August, 1992, presents brief system descriptions for each system having a MCR interface. Each of these system descriptions are grouped by the location of their main control panel (PM01J to PM12J). In addition, because of the emphasis placed by the Standard Review Plan (NUREG-0800) upon emergency operations and its impact on operator duties and plant safety, operational descriptions during abnormal and emergency operations for each system are described. The advantage of such a report is that it places the critical system functional material related to control board inventory, annunciators, operator actions, information and control requirements, emergency procedures, and task analysis under one cover. In all, the 64 systems within the MCR the 11 main control panels, and the fire protection panel (PM12J) are described in a the report. The purpose of these presented descriptions is to set the foundation for the analytical reviews and HFE work that follows. These functional outlines become the basis for the design of the MCR; the instrument and control requirements for operator and plant effectiveness; the normal, abnormal and emergency procedures; operator and diagnostic training; and the integration with the safety parameter display system, the emergency operating facilities, the requirements of Regulatory Guide 1.97, the remote shutdown room, and the annunciator warning system.

18.0.4.7 Produce a Mockup

A mockup was designed and built of the main control panels in full scale. This mockup was not a functioning model, in that it could not be programmed to perform automatic routines. Therefore, it was a static representation of the proposed MCB layout. The purpose of this static mockup was to permit the utility to perform evaluational studies utilizing a three-dimensional configuration. The mockup performed the following functions:

a. Provide a human factors tool that integrated the system functional descriptions into a proposed design of the MCB, for the purpose of performing a task analysis of operator tasks.

b. Evaluate different panel layouts and control room configurations through walkthroughs, interviews, questionnaires, and observations.

c. Determine workspace differences by simulating operational tasks.

d. Assess the instrument and control requirements of the components to be located within the control room by their interface with the generic procedures.

e. Provide a setting in which to interview engineers and operations personnel for purposes of MCB design and integration.

f. Demonstrate a proposed and evaluated MCB configuration to the utility. An attractive feature of a static mockup is that it can be readily changed to agree with design changes.

A full size metal-sheathed, wood framed representation of the basic YGN 3&4 MCB was prepared for the task analytical activities. Onto this frame, photo representations of the controls and indicators for YGN 3&4 were attached. The photo representations were made from the best available vendor information. The component inventory was based on the P&IDs and C&IDs at the time of mockup updating. These were magnetically mounted such that they could be easily reconfigured for the evaluation of candidate system arrangements. The initial layout represented the current panel elevation drawings prepared by the A/E's instrument and control (I&C) department. Demarcation, mimic, and label facsimiles were also added to the mockup.

The mockup was not intended to be a full-color, 100% fidelity representation of the MCB, but was designed as a working tool to aid in evaluating MCB design. It was important that the mockup possessed sufficient fidelity to allow the participants to accurately interpret the MCB layout. The mockup did not contain a representation of indicator light colors, or of meter and recorder scales. Many design details such as meter scales were not finalized at the time of the task analysis. Although annunciator colors, lighting and accurate labeling were not shown, the alarm windows were correctly captioned and the window boxes were identified by paper representation of the labels.

The mockup was used at the Yonggwang site. The practicality and usefulness of the mockup being onsite can be summarized as follows: to assist in the development of plant specific procedures, to facilitate operator training through procedural walkthroughs and panel layouts, to enable further human factors and system engineering reviews of the MCBs, and to increase communications between the different engineering disciplines and organizational components (including the different vendors).

18.0.4.8 Produce Elevation Drawings

Based on human factors engineering guidelines (such as EPRI NP-3659, NUREG 0700, and the YGN 3&4 Human Factors Guideline Document) and the system functional descriptions, preliminary elevation sketches were produced. These drawings depicted the control and indicator arrangements on the main control panels, and the preliminary demarcation and mimic lines, which outlined the relationships between these components. These preliminary layout designs of the MCBs were evaluated during the task analysis of operator functions. This activity resulted in revisions to the layout configurations on each of the MCBs, and to the elevation drawings of these panels. These revised elevation drawings for PM01J to PM12J are depicted in Figures 18.0-7 through 18.0-18.

18.0.4.9 Develop Task Analysis Plan and Supporting Documents

Clearly defined outlines for the task analytical process were developed listing the methodology to be followed, goals, personnel, documents, and other necessary materials. Supporting documents, such as checklists and questionnaires, were also developed and presented in these documents. The three following documents were used to structure the task analytic process :

a. Task analysis method, Yonggwang 3&4 (9-740-J-409-3, Revision A).
b. System-by-system task analysis, dated May 24, 1989.
c. Crew task analysis, dated January 25, 1990.

18.0.4.10 Identify Basic Instrument Types

Generic types of controls and indicators on the MCBs were selected early in the design, prior to the task analysis. Hardware met generic and plant-specific HFE guidelines. Hardware was also compatible between the BOP and NSSS panels, and between the vendor inserts and the rest of the MCR. As a result of the task analytical efforts, instruments and controls were added to, replaced, or removed from the control panels. They may also have been moved to a different location. The remaining information in this section discusses the generic instruments and controls that presently are to be located in the MCR; and their compatibility with the performance requirements in the procedures, the system functional descriptions, and the Human Factors Guideline Document of YGN 3&4. Although most of the components on the MCBs follow the prescribed guidelines outlined in this section, some of the vendor panels (NSSS and T/G) are not consistent. These anomalies will be isolated with their differences being taught to the operators.

18.0.4.10.1 Visual Displays

Displays are selected for their capability to distinguish significant levels of controlled system parameters. The display should provide feedback for any deliberate movement of a control and ensure optimum visibility, making it easy to locate and to read, without parallax, from the operating position. A general discussion of the types of meters, recorders, light indications, and digital counters used to display system parameters is provided below.

a. Meters are available in two types: vertical and circular. The vertical meters can have either single or dual indicators. Typical scale layouts are depicted in Figure 18.0-19. Thirteen drawings of vertical meters are shown: one single scale indicator, seven typical single scales, one dual scale indicator, and four typical dual scales. A circular meter is also depicted in Figure 18.0-19. On control panel PM10J, there are four synchroscope circular meters (with each meter having two circular white indicator lights for running and incoming) and one generator negative sequence ammeter. The dimensions of these GE type AB40 circular meters are 4.3 inches on each side. The following additional information is provided concerning vertical meters.

    1. The models utilized are Foxboro N-257H-01K/01C (for single scale) and N-257H-02K/02C (for dual scales). The exception to this rule is that there are two sigma indicators on PM10J, which depict synchroscope voltage running and incoming.

2. The housing dimensions are 2.3 inches (width) and 4.7 inches (height) for the Foxboro meters, and 2.3 inches (width) and 6.1 inches (height) for the two single scale sigma meters.

3. Each scale locates the scale units at approximately 80-90% of scale range.

4. Successive graduation values on linear scales are in increments of either 1, 2, 5, 10, 20, 50 or 100. Log scales utilize D.5 decades.

5. Most scales are linear

6. The red pointer is on the right (for both single and dual indicators), and the green pointer is on the left (for dual indicators).

7. The major meter scales use the following engineering units:

   - Pressure - kg/cm² A, kg/cm² G, cm H_2O, mm HgA
   - Flow - L/min
   - Level - percent
   - Temperature - degrees Celsius
   - Power - percent, dpm, w/cm, cps, mw, var
   - Moisture - percent RH
   - Voltage - volts
   - Current - amps
   - Speed - rpm
   - Radioactivity - cpm
   - Boron Analysis - ppm

b. Recorders depict trend information and material that may be needed for later reference. They can be divided into four types ; one, two and three points, and multipoint. YOKOGAWA DX-364 (one point, two points, and three points) have 5.67 inches of height and 2.8 inches of width. They are vertical recorders. Although most of the vertical recorders are YOKOGAWA models, there are also five CHINO recorders (KR2160-N2AA) on PM10J. These CHINO recorders are 5.7 inches on all sides. The information presented in Part a. regarding range of scale, successive graduation values, and engineering units also pertain to recorder scales. These recorders contain bargraph indicator display on LCD. These bargraph indicators display depict the present value of the signal being recorded. Most of the recorders are linear except for some of the power (JR) scales and radioactivity recorders (which are in cpm units). A YOKOGAWA DX-364 recorder is depicted in Figure 18.0-19. 529 460

The Eurotherm, 4250M integrates the functions of a data logger, multipoint recorder, digital indicator and relay output in one instrument. This horizontal recorder is depicted in Figure 18.0-19. The dimensions are 14.2 inches of width and 11.3 inches of height. These recorders are used to measure the bearing temperatures of the reactor coolant pumps (RC-TJR-152/162 and 172/182), which have the engineering units of degrees Centigrade. 293

These are two components on PM10J that could be considered as functioning as recorders : generator gross print demand and the auxiliary gross print demand. Every 30 minutes the kilowatt-hours that were used are recorded on a paper recorder roll. These two components are the GE/PD 55F model with the dimensions of 8-1/3 inches (width) and 9-1/3 inches (height). There is no recorder inches (width) and 9-1/3 inches (height). There is no recorder scale information.

c. Indicating lights at YGN 3&4 provide rapid and convenient bulb replacement with power on, without hazard to personnel or equipment. Each status light indication is to have twin LEDs. Illuminated indications are to infer status with the light intensity being at least 10% greater than the surrounding panel. The column in the center below represents the Red LED, which is the top status light of the component and indicates a flow of energy; while the right column below is the Green LED that signifies a lack of energy flow. This status light is on the bottom of the component. The left column represents the type of equipment being displayed. Indicator light color coding and labels are as follows:

1. Valves or dampers	Open (Red)	Close (Green)
	Open/Mod	Close
	Open	Close/Mod
2. Pumps	Start	Stop
3. Heaters	On	Off
4. Breakers	Close	Open (or Trip)
5. Neutral grounds	Grounded	Floating
6. Turning gear	Engaged	Disengaged

Besides these generic lights, there are some indications which have only one specific function (each indication has two LEDs):

1. Boron concentration range on PM04J (two white lights, 1250 ppm and 5000 ppm).
2. Radiation range on PM04J (five white light indications, 10^2 to 10^6).

3. Pressurizer safety valves on PM04J (open, red light; close, green; leak, yellow).
4. Average temperature loop select on PM05J (two white lights, loop 1 and loop 2).
5. CEA withdrawal/insert on PM06J (five white lights; withdraw rate hi/lo, hold, insert rate hi/lo).
6. Reactor Regulating System in test on PM06J (white status light indication).
7. Main transformer cooling fan status on PM10J (three amber lights; status 1, status 2, status 3).
8. Switchyard breaker/disconnect switch status on PM11J (three sets of green and red lights for close and open indications).

d. Counters present information that is useful when there is a need for quick, precise reading of quantitative values and trend information is not needed. There are two types of counters: electro-mechanical and digital. Examples of electro-mechanical counters are the Kessler Ellis M16.11, which measures reactor and boric acid makeup water flow (FQI-210X and 210Y); and the Eagle Signal HK Series time totalizer, which measures the containment sump pump running time.

The dimensions for these two components are 1.6 inches of height and 2.2 inches of width (Kessler Ellis), and 3.2 inches of height and 2.6 inches of width (Eagle Signal). The Eagle Signal instrument has five digit wheels that measure the total time the unit is energized in seconds.

Examples of digital counters are the Tsuruga 3153 A-19, (dimensions are 7.6 inches width, 3.8 inches height), which measures generator electrical power and grid freuency on PM10J; and the AUTONICS FX6-I (2.8 inches on all sides), which measures makeup flow on PM08J and surge tank water flow on PM09J. Other digital counters measure feedwater pump speed (PM08J) , tap position(PM1OJ , PM11J), generator power over time (PM1OJ) , and the amount of letdown boron(PMO4J).

18.0.4.10.2 Controllers

The controllers or manual/automatic stations in the YGN 3&4 control room are categorized mainly into four generic groups : N-2CDA-N1, N-255HA(M), N-250HM-M2NH-F and T640. Three of these controllers are depicted in Figure 18.0-19. These controllers are located on PM04J, PMO5J, PM07J and PMO8J. Their dimensions are 5.7 inches of height and 2.8 inches of width (N-2CDA-N1, T640), and 5.7 inches of height and 1.9 inches of width(N-250HM-M2NH-F). These units display process measurement, setpoint, output, and manual/auto status. The vertical scales and engineering units of these controllers are similar to those discussed in Subsection 18.0.4.10.1, Item A.7. 387

18.0.4.10.3 Controls

Controls are selected to ensure ease of operation and to minimize operator error. Controls are operable in sufficient time, under expected dynamic conditions, and within the limits of manual dexterity, coordination, and reaction time; and have sufficient durability to retain their appearance and functional characteristics during the expected service life. A feedback indication of control activation using a perceptible feel, audible click, visual light and/or pointer movement is incorporated into the design. Sufficient visibility is provided to ensure that the control is easily located, and the setting is easily read, without parallax, from the operating position. The following paragraphs describe from a generic perspective the types of illuminated pushbuttons, protective switchguard pushbuttons meter/ pushbutton combinations, non-illuminated pushbuttons, and rotary handswitches.

a. Illuminated pushbuttons are used either to initiate the operation of a mechanical device (valves, dampers, pumps, heaters, breakers) and to give visual feedback when an extreme position has been reached, or for control and monitoring the status of an operation mode for these devices. The surface area of these buttons is big enough for the finger to be able to press the button easily and apply the necessary pressure. The pushbuttons are white with black engraving on the lens (except in rare cases of partial valve opening indications). The illumination status is provided by a dual set of LEDs for each status location. The LED colors are Red (energy flow; open, close (breakers), start, on, open/mod, or jog open), Green (close, open (breakers), trip (breakers), stop, off, jog close, trip, close/mod), Yellow (trouble, disabled), and Amber (ESF-1, ESF-2, auto, lead, open blocked, exercise, emergency off, sync, override, mid pos, permissive to close). The illuminated lights have one, three or four positions with their heights being respectively 2, 4 and 5 inches. These three components have the same width of 2 inches. Examples of these lights are displayed in Figure 18.0-20.

Dampers and valves use the words Open and Close, pumps and fans Start and Stop, heaters On and Off, and breakers Close and Trip or Open. The pushbuttons can be manually activated by the operator, or automatically operated by specific system interlocks. When the desired status is achieved, the LEDs illuminate. A flashing yellow light for Trouble indicates equipment trouble, while the Disabled light signifies that the equipment cannot be operated. The flashing yellow light goes to a steady yellow light when the Trouble/Disabled pushbutton is activated. The light goes out when the condition returns to normal. Under normal conditions, activation of the Trouble/Disabled light functions as a press-to-test, which illuminates all of the indicator lights of a component.

There are five single pushbutton components. They have the following labels and LED lights: Close (green, to quickly close the dampers and isolate the control room when toxic gas is sensed), Start (red, to quickly start the fire pumps), Emergency Off (amber) and Reset (two pushbuttons used to turn off and reset the steam bypass control system), and Exercise, 10% Closed (amber, upon activation, the isolation valve closes to the 10% position and then reopens fully).

Other status lights with red and green indications that require an explanation are:

1. Open/Mod status represents a manual activation of the pushbutton to permit modulation of the valve/damper opening by another system component in order to maintain a designed flow. An example of this component is in Figure 18.0-20. A variation of this configuration is the turbine bypass control valves on PM07J (Open/Mod and Quick Open), which can be placed in a standby status (Quick Open) awaiting the appropriate permissive conditions for valve opening (red). Another variation is the CBD flask tank vent discharge valves on PM07J, which require the selection of either valve 29A or 29B and 30A or 30B to be opened/modulated. The selection of either valve position illuminates a red light. An example of this component is in Figure 18.0-20.

2. Open and ESF-1 or ESF-2 status lights signify that a safety command signal cannot be overriden (Priority-1, ESF-1) or can be overriden (Priority-2, ESF-2). On a Priority-2, manual operation of the Open and then Close pushbuttons will close the valve or damper (with a green light appearing).

3. Open and Override signifies that the isolation dampers on PM01J can be opened manually (red light) or the failed closed position can be overriden by the appropriate fan being started (amber light). The damper can then be opened manually.

4. Open and Mid Pos or 15% Open or 20% Open signify valves that partially open (either manually or automatically) due to an interlocking condition with their associated pumps (amber light). After pump start, the valve can be fully opened upon activation (red light).

5. Start and ESF-1 or ESF-2 is similar to Item 2 above. An example of this component is depicted in Figure 18.0-20.

6. Start and Lead is used on the two water box priming pumps on PM08J. The pumps can be started either manually or automatically when both pumps are in the Auto position (one of the pumps will start as the lead pump or upon the failure of the other pump). Both the red and amber lights illuminate when the lead pump starts, while the other pump still maintains an amber light for Auto.

7. Hi/Start signifies when one containment fan cooler (rated 50%) in each train operates. This situation results in four fan coolers being on line at high speed.

8. Lo/Start and ESF-1 occurs during an SIAS when four containment fan coolers (one in each train) are in operation at low speed.

9. Jog Open status is the manual throttling of a valve position to establish the appropriate opening. An analog meter indication, either integral to the associated switch or separate from the

switch, is used in the determination of the appropriate opening. An example of this component is depicted in Figure 18.0-20.

10. Close/Mod is similar to Item 1 above but the operation represents modulation toward the close position.

11. Close and ESF-1 or ESF-2 is similar to Item 2 above, but the manual override of ESF-2 uses the Close then the Open pushbuttons to open the valve or damper. A variation of this configuration is the four pushbutton main steam isolation valves with Fast Close and ESF-2 on the third pushbutton, and Slow Close on the bottom pushbutton. Slow Close is used during normal operations, while the Fast Close position is activated during emergency conditions.

12. Close and 45° Close is similar to Item 4 above, but the operation represents partial valve closure, the pump stopping, and the valve being fully closed.

13. Stop and ESF-1 or ESF-2 is similar to Item 3 above.

14. Jog Close is similar to Item 4 above.

15. Auto position is found on four pushbutton components. Its function is to indicate after actuation that the positions of either Open and Close, Start and Stop, or On and Off are being controlled automatically by system sensing elements.

16. Open Blocked is also found on four pushbutton components. It is a type of administrative procedure to prevent inadvertent opening of the valves during normal operation. When this status light position is pressed, the amber light comes on and the

valve cannot be opened. If the status light is pushed again, the valve cannot be opened. If the status light is pushed again, the amber light goes out and the open function can be again used.

17. Auto and Lead represents the situation, when two boric acid makeup pumps or two reactor makeup water pumps on PM04J are placed in the auto position and the first pump is designated the lead pump (both amber lights are lit).

18. Close and Permissive to Close is a pushbutton on a circuit breaker handswitch, which indicates that the appropriate electrical conditions exist for breaker closure (amber light). Upon activation, the breaker will close (red light).

19. Trip and Sync represent two related modes on a circuit breaker handswitch. When the breaker is tripped, the control mode is transferred from not-in-sync to synchronization mode (amber light). When in the sync mode, other breakers are blocked from using the same synchronoscope. After sync mode selection, the circuit breaker can be closed (red light), which transfers the circuit into the not-in-sync mode.

20. Direct is located on the load follow supply valve handswitch on PM04J. When Direct (amber light) is selected and valve 527 (red) is opened, makeup (either borated water or reactor water dependent upon the mode selected) is pumped directly to the charging pump suction header.

A separate generic group of illuminated pushbuttons (three positions) are those chemical and volume control (CV) system hand-switches, that are located on PM04J. These handswitches require that a specific function be selected through the use of a specific bypass or diversion valve. An example of this type of pushbutton component is depicted in Figure 18.0-20. Both the top and bottom pushbutton labels are outlined below. Selection of either position illuminates a red light.

1.	VCT (Volume Control Tank)	HUT (Holdup Tank)
2.	VCT	PHIX (Preholdup Ion Exchanger)
3.	Gas Stripper	PHIX
4.	Gas Stripper	EDT (Equipment Drain Tank)
5.	PUR. EX (Purification Ion Exchanger)	VCT
6.	PRM & BOR (Process Radiation Monitor and Boronometer)	Bypass

Another similarly related four position pushbutton component of the CV system is the makeup mode selector: Borate (red light), Auto (amber), Dilute (red), and Off (green). The Off position terminates the makeup modes of operation. The three distinct integrated makeup operation modes are:

1. In the borate mode, the operator presets a fixed volume of borated water to be pumped to the VCT or directly to the charging pump suction header.

2. In the automatic mode, blended makeup flows to the VCT to automatically maintain normal VCT level.

3. In the dilute mode, the operator presets a fixed volume of reactor makeup water to be pumped to the VCT or directly to the charging pump suction header.

One other selector component is the charging pump auto selector switch on PM04J. This handswitch has three yellow light positions: Pump 1&2, Pump 2&3, Pump 3&4. The selection of a specific charging pump position enables the two charging pumps in that position to be started either manually or automatically by each of the individual pump handswitches.

b. Protective switchguard pushbuttons (or hinged shields) are used to prevent accidental activation of a control. Hinged shields are transparent plastic covers, which are placed over a control for the purpose of causing the operator to pause and to think prior to activation. These guards have the hinged shield anchored so that the operator does not have to hold the shield up while operating the control. The hinged shields on the MCB are used either over the Open, Close, Jog Open, or Jog Close status position on the valve pushbuttons. The use of this shield is restricted and is only utilized when it is called for by administrative procedure.

c. Meter/pushbutton combinations use four different meter indications with the three and four position pushbuttons: percent load ammeters (pumps, fans, heaters), percent position (valves), ammeters displaying amperes (breakers), and voltmeters (breakers). Examples of the three and four position components with an attached meter are depicted in Figure 18.0-20. There is also a double ammeter pattern with meter placement on each side of the breaker pushbuttons. The height of these components are 4 inches (three positions) and 5 inches (four positions). The single meter components have a width of 2-1/2 inches, while the width of the double meter components is 3-1/4 inches.

d. Non-Illuminated Pushbuttons are the six trip buttons on PM06J, the four emergency start/stop buttons on PM10J, the startup transformer 03XN on-load tap change (raise and lower pushbuttons with a white in-progress light), the annunciator pushbutton stations on the eleven main control boards, and the first out annunciator station on PM06J. Each annunciator station contains Silence, Acknowledge, Reset and Test pushbuttons; whose pushbutton colors are respectively red, yellow, blue and black. The dimensions of the horizontal annunciator stations are 3 inches (height) by 11-1/2 inches (width), while the vertical on-load tap change station is 7.6 inches (height) and 3.4 inches (width). The 10 buttons on PM06J and PM10J utilize protective housings, that are guards whose installation is on the pushbutton's side, not on its top. This guard prevents inadvertent actuation but does not cause the operator to take extra action or pause. The color of these 10 pushbuttons is red, and their diameters are one inch within a bezel measuring 1.5 inches on all sides.

e. Rotary Handswitches are considered in this document to include any control whose movement is circular and parallel to the control board surface. This definition includes hand operated (oval, knurled and pistol handles) and finger operated (thumb and forefinger) controls. These handswitches include the Electro Switch Series 20K and 20P (with position lights). Both of these handswitches are depicted in Figure 18.0-21. The different 20K and 20P series components are : two, three and four positions maintained; two and three positions with spring return to a specific position; and off (pull-to-lock) with a spring return. The position/status lights on the 20P Series are (from left to right sides) amber and red, green and red, and two white lights. There are three types of rotary handswitches: pistol grip (used with ESFAS safety related controls), oval (electrical components selector switch), and knurled (voltmeter and ammeter switches). Examples of the labels on the rotary handswitches from the left to the right positions are (with the handle type and light colors in parenthesis):

(1)	Normal (white light)		AAC (white light) (oval)
(2)	Normal		Bypass Inoperable (pistol grip)
(3)	Single		Three (pistol grip)
(4)	Refuel		Normal (pistol grip)
(5)	Stop (green light)		Start (red light) (oval and pistol)
(6)	Lower		Raise (oval)
(7)	Normal		Actuate (pistol grip)
(8)	Disable		Enable (pistol grip)
(9)	CH.1	High	CH.2 (pistol grip)
(10)	CH.1		CH.2 (pistol grip)
(11)	P-100X (white light)		P-100Y (white light) (pistol grip)
(12)	L-110X (white light)		P-110Y (white light) (pistol grip)
(13)	L-110X (white)	Both	L-110Y (white) (Pistol)
(14)	MCB (white light)		RSP (white light) (pistol grip)
(15)	SWYD		MCR (oval)
(16)	Man	Off	Auto (oval)
(17)	Off (Pull-to-Lock)		Auto (amber) Run (red) (pistol)

(Due to different logic, another handswitch is green at the Off position and red at the Run Position)

(18)	Off	A	B	C	(knurled)
(19)	Off	A-B	B-C	C-A	(knurled)

Similar to the Electo Switch controls are the four GE/SBM handswitches (Manual/Auto on the generator regulator, Lower/Raise on two voltage adjusters, and Trip/Close on the exciter field breaker), and the two startup 03XN on-load tap change controls (Manual/Auto and Local/Remote) on PM10J. These six handswitches are to have pistol grips, and they are intended primarily for the control of electrically operated equipment. The GE/SBM are 2.5 inches (height) and 2.6 (width), and the tap change controls are 1.8 inches on all sides.

Other examples of rotary controls are the three knobs used for volume control and range selection on PM06J (diameters of 1.2 inches), and the two toggle-switch/T-switch controls (startup channel select on PM06J, and touch panel T-switch on PM09J). The dimensions of the channel selector are 1.3 inches on all sides, while the T-switch is 4.8 inches (height) and 1.7 inches (width).
And the Yongsung rotary switch/cam switch controls are used for backup channel selection of several M/A stations in PM04J. The rotary switches are 1.3 inches (height) and 1.4 inches (width), while the cam switches are 2.4 inches on all sides. 301

18.0.4.10.4 Miscellaneous Controls and Displays

This section is mainly concerned with vendor panels, the CRT displays and keyboards (or touch panels) that are found on PM05J, PM06J, PM08J and PM09J; and the CEA core mimic that is located on PM06J. In addition, the Status lampboxes on PM03J, PM09J and PM12J; and the annunciator lampboxes above every panel are discussed. Examples of these components are depicted in Figure 18.0-22.

a. The components depicted on Sheet 1 of 3, Figure 18.0-22 are mainly NSSS vendor panels, which are located on PM06J. They are associated with the reactor protection (RP) system, the core element assembly drive (RD) system, the plant monitoring (CX) system, and the annunciator (AN) system. The RP system's functions are to protect the reactor core and its coolant system pressure boundary; to assist the ESFAS in limiting the consequences of certain accident conditions; and to provide equipment protection, alarms and limiting signals. The CEA position display CRT, CEA CRT keypad, the four core protection calculator (CPC) operator modules, and the four plant protection system (PPS) operator modules are part of the RP system. The RD system's function is to control the motive power and holding power to the CEDMs; and thus control the direction, rate and duration of the CEAs. The CEA core mimic, the CEA position display CRT, and the CEDMCS operator module are components of the RD system. The CX system scans, calculates, alarms, logs, and evaluates the plant parameters, as well as it performs specific BOP performance calculations. The critical function monitoring (CFM) and the utility CRTs, and their two keyboards are associated with the CX system. The alarm CRT and the alarm CRT function key are components of the annunciator (AN) system, whose primary function is to alert the operator by means of visual and audible signals of abnormal conditions involving important plant variables and changes of equipment status that require operator attention.

b. The two reactor coolant (RC) system components depicted on Sheet 2 of 3, Figure 18.0-22 are NSSS vendor panels that are located on PM05J. The two inadequate core cooling monitoring system (ICCMS) plasma display units depict critical information related to core functioning. The reactor power cutback control panel (RPCCP) allows the reactor to stay online during load rejections of any magnitude, and during the loss of one operating feedwater pump. This is done by the RPCCP when it rapidly reduces reactor power by dropping selected banks of CEAs.

c. The remaining components on Sheet 3 of 3, Figure 18.0-22 are Turbine-Generator vendor panels that are located on PM09J. These components are associated with the main turbine (TA) system, hydrogen and carbon dioxide (TB) system, and the turbine supervisory (TS) system. 536
The turbine protection and control (TPC) system is a part of the TA system. There are two TPC monitors, a TPC backup panel, and two TPC keyboards & trackball mouses. The TPC system provides manual and automatic control, protection and monitoring for the turbine-generator(T/G) during normal operation of the unit, and the system

includes features that automatically protect the T/G against specific abnormal conditions (overspeed., loss of oil, overheating). The turbine-generator supervisory instrumentation (TGSI) system is a part of the TS system. There is a TGSI keyboard & trackball mouse, a TGSI monitor. 536

These components are designed to give the operator an improved capability for visually monitoring and controlling the operation of the T/G. The generator gas monitor is a component of the TB system, whose function is to monitor the hydrogen used to cool all of the generator components (except the stator winding) using hydrogen gas as the coolant.

d. The feedwater pump turbine panel depicted on Sheet 2 of 3, Figure 18.0-22 is a NSSS vendor panel, which is located on PM08J. There are two of these panels on PM08J, one for each pump of the feedwater (FW) system. These turbine-driven FW pumps provide required feedwater flow to the steam generators, and they are directly coupled with their turbine drives. This vendor panel consists of the following: 536

1. Three digital meters: remote speed set, speed setpoint, and turbine speed.

2. Seven pistol grip rotary handswitches with accompanying illuminating indicator lights: turning gear control, governor, governor valve ramp, governor speed set, governor remote

control, stop valve test, and emergency trip.

3. Dual meter indicator: governor valve positions for low- and high-pressure valves.

4. One auto/manual remote speed set controller.

e. There are two status lampboxes on PM03J, whose function is to display bypassed and inoperable status indication and engineered safety feature (BISI/ESF) information relating to Divisions A and B. The one lampbox on PM09J indicates opening status for 36 drain valves (main stop valves, turbine steam, moisture separator reheater shell, reheat steam). The three status lampboxes on PM12J are for fire protection. The dimensions of the status lampboxes are 33.2 inches (width) and 7 inches (height) with a 4 by 10 box design on PM03J, and 17.5 inches (width) and 9.2 inches (height) with a 6 by 5 box design on PM12J. An example of the PM03J lampbox is depicted on Sheet 2 of 3, Figure 18.0-22. 536

f. On the eleven main control boards, there are 28 annunciator windowboxes. Examples of two different windowboxes are depicted on Sheet 2 of 3, Figure 18.0-22, annunciators are grouped by function 536 and system. Alarms are identified by their position in the row (1 to n) by column (A to Z) matrix. The matrix of rows and columns reflect information on systems and problems, columns reflect systems (when possible), and rows display common trouble types or problems.

18.0.4.11 Perform Task Analysis

As part of the Human Factors Engineering Program for the YGN 3&4 main control room (MCR) design, a task analysis (TA) had been carried out using two steps: a preliminary task analysis (PTA) and a crew task analysis (CTA). The PTA was performed from the middle of February to the end of April 1989. The purpose of this investigation was to give the utility an opportunity to evaluate the preliminary main control board (MCB) design, and to determine the proper availability of the components within the control board inventory. Included in these analyses were the procedural walkthroughs, the MCB mock-up review, and the system-by-system analyses by the utility. This team consisted of system engineers, human factors engineers, NSSS-Supplier consultants and KEPCO's experienced operators.

The CTA was performed from February 12 to 23, 1990. The purpose of the CTA was to give their operators an opportunity to orient themselves to the YGN 3&4 MCB design and to allow utility operators an opportunity to review the MCB design again. This analysis was performed using operating crews rather than by the single operator methodology of the PTA. The two operating crews of the CTA were handled similarly in terms of methodology and preparation, which consisted of orientation sessions of the YGN 3&4 control room and its design philosophy.

Walkthroughs were conducted using CEN-152, Combustion Engineering's (CE) generic Emergency Procedure Guidelines (EPGs), and CE's Normal Operating Guidelines (NOGs). Following this phase, each operator was given an opportunity to review the control panels, ask questions, and review reference documents. BOP system engineers and NSSS-Supplier consultants were continuously available to provide necessary explanations regarding design and operation. The purpose of this analysis was to locate flaws which could impede safe and efficient operation of the plant in emergency situations.

Information pertaining to these studies is contained in the YGN 3&4 Main Control Room Task Analysis Summary Report", dated December, 1991. The objective of this report is to document both the PTA and CTA methodologies and their results. In the event of future licensing questions concerning MCB design, this document could be used as a reference. It verifies that each system with MCR interface was reviewed, and that the comments and concerns raised during these sessions were addressed. More significantly in terms of life-cycle development and budgetary costs, a properly tested design early in the design process usually generates fewer changes later in a plant's development and operational use. Proper attention to human factors principles, control panel and workspace layout, and system design during the preliminary stages, as this report outlines, often can result in reductions of the costs and time for development, when compared to emerging nuclear plants that have not been as scrupulous in their efforts.

The parts that follow discuss the materials, team compositions, and the seven task analysis activities of the two studies (PTA, CTA).

a. Materials

The principal materials used for the YGN 3&4 PTA and CTA were a full scale mockup of the YGN 3&4 preliminary control room design, and various documents considered important to the two studies. Information related to the mockup is discussed in Subsection 18.0.4.7. Most of the BOP system design documents (such as piping and instrumentation diagrams (P&IDs), logics, control and instrumentation drawings (C&IDs), system functional descriptions (SPDs), and system design criteria (SDCs)) and NSSS documents (like measurement channel block diagrams (MCBDs), functional control logic diagrams (FCLDs), and interconnection wire diagrams (IWDs)) were used as references during both the PTA and CTA sessions. Since the sessions were conducted in the mock-up room of the A/E's headquarters, the materials were readily available whenever questions arose. In addition, during the walkthroughs with the operators, the generic Normal and Emergency Operating Guidelines were used.

b. Preliminary Task Analysis Team

Over 50 individuals participated in the YGN 3&4 Preliminary Task Analysis in one capacity or another. This included system engineers and managers in Mechanical, Nuclear, Electrical and I&C disciplines. Personnel from I&C consisted of human factors, logic and system engineers who were involved in the preparation of the MCB elevation sketches. Three experienced senior operators from the utility were used in the walkthroughs. Special NSSS consultants from Combustion Engineering (CE) were also present.

Two human factors staff members were present during all phases of the analysis. The lead human factors engineer was experienced with task analysis. He coordinated the activities and compiled the comments. Those I&C main control board section design engineers responsible for each section of the MCB were present to initially prepare the mock-up, and again as their sections were scrutinized during the system-by-system reviews. Also. YGN 3&4 project staff was available for consultation whenever a question or difficulty arose that required their attention.

c. Crew Task Analysis Team

Over 30 individuals participated in the YGN 3&4 Crew Task Analysis in one capacity or another. These included system engineers and managers from several disciplines from the A/E, experienced operating crews from KEPCO's Kori and Yonggwang sites, and special NSSS consultants from CE.

Three human factors staff members were present during all phases of the analysis. The lead human factors engineer was experienced with task analysis. He coordinated the activities and compiled the comments.

The operating crews from the different sites (Kori and Yonggwang) were not integrated with one another. The goal was to have each group function as an actual crew by allowing them to assume the same specific roles that they would within an operating scenario. The crews were also kept apart so that the comments of one crew would not bias the other crew.

d. Task Analysis Activity of Task Identification (PTA and CTA)

Task identification is traditionally the first phase of task analysis. It consists of having someone familiar with control room operations and/or system design identify the high-level tasks which must be performed in the control room. These are called out in NUREG-0737, Supplement 1 as well as being identified by CE in their guidelines. CEN-152, Emergency Procedure Guidelines (EPG's), contains Entry Conditions and Operator Actions which describe the task for each of the following emergency scenarios: standard post trip actions (SPTA), reactor trip recovery, loss of coolant accident (LOCA), steam generator tube rupture (SGTR), excess steam demand event (ESDE), loss of feedwater recovery (LOFR), loss of forced circulation (LOFC), and functional recovery guidelines (FRG).

Similarly, for each normal operating guideline (NOG), the objective, operator action, and prerequisite sections clearly identify tasks to be performed. The tasks identified in the EPG's and NOG's are generic, and are not actual plant specific procedures. However the tasks outlined are of a sufficiently high level to have fulfilled the needs of the analyses. In addition the review of the NOG's should further demonstrate the completeness of its investigation into the availability of critical instruments and controls, and the adequacy of the panel layout. Most verification, validation, and task analytical activities do not utilize a plant's normal operating procedures in their reviews.

The next six parts (Items e to j) discuss the remaining task analytic activities of the PTA and CTA.

e. Procedure Guideline Walkthroughs (PTA and CTA)

The experienced control room operators were used during the guideline walkthrough phase. In addition, the human factors engineers were present. A CE representative with operations and design experience also was present. During the walkthroughs, the lead human factors engineer (HFE) carefully read each step of the EPGs and NOGs. The operator then had to locate the controls and indicators necessary to perform the step. The operator called out the numbers and designators of the hardware and the HFE noted these on a worksheet. During the CTA the shift supervisor for each crew assigned the specific tasks to be performed to the proper individual operator. Any comments or concerns raised by an operator or a crew regarding the MCB design were noted for later resolution. The results of these analyses are the lists of comments and resolutions outlined in the summary report. Also included in this report are the results from the questionnaires, which were completed by each operator after the walkthroughs. A specific list of questions were asked of each operator in order to determine whether there were any significant Human Factors problems.

f. Utility Review (PTA and CTA)

Subsequent to the guideline walk- throughs of the PTA, the mock-up was made available to KEPCO for several weeks so that any staff members could review the MCB design. During the CTA, experienced operators made additional comments and independently noted them for themselves in parallel with the efforts to record his comments during the walkthroughs. From these two separate efforts, KEPCO submitted a list of comments from their operators. Although these comments may have been outside the scope of this study, their results underscore the attempt by the A/E to conduct a valid and complete analysis. These comments were analyzed with appropriate resolutions which also are outlined in the summary report.

g. System-by-System Analyses (PTA only)

The final phase of the PTA was the system-by-system review. In this phase, each plant system having an MCB interface of more than two or three pieces of hardware was reviewed, one system at a time. For each system, the Human Factors, logic, and system engineers were present. In many cases there were two system engineers, one for Instrumentation & Control and one representing either the Mechanical, Electrical, or Nuclear discipline, as appropriate. In addition, a CE I&C system expert was present for the review of the NSSS systems and systems with an NSSS interface. The participants reviewed the board layout and compared MCB inventory with project documents. All comments raised were placed on the comment resolution forms and resolved by the appropriate engineer. System engineers also completed questionnaires designed to identify details of regulatory constraints, system functions and MCB inventory.

h. Board Review (CTA only)

Prior to any walkthroughs and at the end of each working day, the operating crews were afforded the opportunity to familiarize themselves with YGN 3&4 system designs and MCB layout. During this time both the A/E and CE provided detailed explanations and answered questions. The operators made numerous comments regarding both MCB design and YGN 3&4 system design. These comments were recorded for resolution. However, since they do not pertain to the actual CTA process and walkthroughs, they are not addressed in this report. Rather, the board review comments were addressed via separate correspondence.

i. Electrical Board Review (CTA only)

Because there were numerous issues regarding the layout and inventory of the YGN 3&4 MCB sections for the MP (main power), AP (auxiliary power), DG (emergency diesel generator) and SY (switchyard) systems, the operators and pertinent project staff met for one day to review the design of this section.

j. Wrap-up Session (CTA only)

At the conclusion of each week, a wrap-up session was held in which each crew had a chance to summarize, clarify, and reconsider comments which they had raised. Pertinent electrical board or wrap-up comments, which affected CTA results, are reflected in the comment resolution forms.

18.0.4.12 Reconfigure MCB Arrangement

Based on the task analysis results, the arrangement of controls and indicators on the main control board design were modified. Some of the factors that were taken into account were the functional use of the controls, the technical details regarding system and plant operations, and operator preferences and needs. Based on the resulting rearrangements of the control panels of the mockup, elevation sketches were revised into elevation drawings. As previously discussed, these revised drawings are contained on Figures 18.0-7 to 18.0-18.

The data collected during the task analytic sessions are presented in the following paragraphs of this section. The Preliminary Task Analysis (PTA) results are contained in Part a., while the Crew Task Analysis (CTA) discrepancies are contained in Part b. Part c. contains the KEPCO comments of both the PTA and CTA, which were summarized by the operators. Part d. is a summary of the study and its results.

a. PTA Results

There were 254 comments, which were divided into three groups based upon resolution status and action: deleted, closed/no action and closed/action-taken. All of the 254 items were considered resolved because they were either deleted or closed. A deleted item is one which is considered to be technically not possible, written without sufficient information, and/or contradictory. Six items were deleted. A closed/no-action comment is one that is closed either because the comment asks a specific question which is then answered, the proposed resolution is an unnecessary or undesired action, or the desired resolution utilizes the existing design. Ninety items were in this category. In the closed/action-taken category, 158 items were closed with the following implemented actions:

1. Item resolved by revising the elevation drawing (119 items).
2. Item resolved by revising the component list (26 items).
3. Item resolved by revising the annunciator windowbox drawing (2 items).
4. Item resolved by revising the interposing logic system (ILS)/ vendor specifications (1 item).
5. Item resolved when plant specific procedures are written and operator training is conducted (5 items).
6. Item resolved by inputting specific information into the CRT (2 items).
7. Item resolved by revising data sheet (1 item).
8. Item resolved by revising the logic diagram (2 items).

Within this same category of closed/action-taken items, the 158 comment descriptions were classified further as to the type of action that was or will be taken:

1. Used enhancements (52 items). Enhancements represent labels, mimics, and demarcation lines. The resolutions entailed renaming, relabelling, verifying, and adding labels to the control panels. The addition of demarcation lines, mimic lines, origin points and symbols as well as the deletion of mimic lines also were classified within this group.

2. Added or deleted components and information (57 items). The addition, replacement, modification, and deletion of annunciators, status lights, controls, displays and CRT data were within this group.

3. Moved components (44 items). The movement, realignment, rearrangement and relocation of annunciators, status lights, controls and displays were part of this group.

4. Write procedures and conduct training (5 items). The writing of plant specific procedures and the proper handling of operator training using these procedures were placed within this group. Although these items are necessary future actions, it was assumed that when they are performed the comments would be resolved.

b. CTA Results

The 119 comments in this review were categorized as to 43 closed/no-action items and 76 closed/action-taken items. The definition of a closed/no-action item is the same as the one given previously in Part a. of this section. The 76 items in the closed/action-taken group were closed with the following implemented actions:

1. Item resolved by revising the elevation drawing (44 items).
2. Item resolved by revising the component list (6 items).
3. Item resolved by revising the annunciator windowbox drawing (9 items).
4. Item resolved by revising the ILS/Vendor specifications (3 items).
5. Item resolved by proper intilization of the human factors guidelines (4 items).
6. Item resolved by revising CE's EPGs (2 items).
7. Item resolved by inputting specific information into CRT/TGSI. (2 items).
8. Item resolved by revising P&ID/C&ID (3 items).
9. Item resolved by revising logic diagram (1 item).
10. Item resolved by revising data sheets (2 items).

The 76 closed/action-taken items were further classified as to the type of action that was taken:

1. Used enhancements (8 items).
2. Added, modified or deleted components and information (40 items).
3. Moved components (26 items).
4. Revised existing generic procedures (2 items).

c. PTA and CTA Results Summarized by the Utility

After the PTA and CTA, KHNP operators, who participated in the task analyses, had changes to discuss internally with the engineers, and summarized their comments on the YGN 3&4 MCB design. There were 103 comments for the PTA and 74 comments for the CTA. The redundancy of comments between the PTA and CTA discrepancies, when compared to the utility's comments, are respectively 29 and 68.

The 177 comments in this review were grouped as 12 deleted items, 47 closed/no-action items, and 118 closed/action-taken items. The definitions for deleted and closed/no-action items are the same as those given previously in Part a. of this section. The 118 items of the closed/action taken class were closed with the following implemented actions:

1. Item resolved by revising the elevation drawing (82 items).
2. Item resolved by revising the component list (4 items).
3. Item resolved by revising the annunciator windowbox drawing (9 items).
4. Item resolved by revising the ILS/vendor specifications (5 items).
5. Item resolved by proper utilization of the human factors guidelines or other documented requirements (7 items).
6. Item resolved by inputting specific information into monitor/ TGSI (4 items). 536

7. Item resolved by revising P&ID / C&ID (3 items).
8. Item resolved by revising the logic diagram (1 item).
9. Item resolved by revising data sheets (2 items).
10. Item resolved when plant specific procedures are written and operator training is conducted (1 item).

These 118 comments were further classified as to the type of action that was or will be taken:

1. Used enhancements (18 items).
2. Added or modified components (48 items).
3. Moved components (51 items).
4. Write procedures and conduct training (1 item).

d. Summary of Task Analysis Studies

The purpose of this section is to present the findings of two separate, but related, task analytical studies to isolate potential design deficiencies in the main control room. The first study, Preliminary Task Analysis (PTA), was conducted during February to April 1989, and involved individual operator walkthroughs of the mockup using the generic emergency procedure guidelines (EPGs) and the normal operating guidelines (NOGs). In addition, engineers performed their own inspections of the mockup with a resultant list of comments and potential problems to be resolved. During February 1990 the second study, Crew Task Analysis (CTA), was performed. Similar to the first study, walkthroughs of the mockup using the generic operating procedures were conducted. The difference between the two studies was that the second effort utilized operator crews rather than individual personnel during the analysis. The utility again submitted a list of comments based on their observations during the crew walkthroughs. From these combined analytical sessions, 550 comments were reported.

The most significant point to be made regarding this combined effort is that it was conducted early in the developmental cycle of YGN 3&4. Many systems (including power plants, military hardware, home appliances, automobiles, etc.) have been developed without sufficient attention to the problems relating to safety, the human-interface, and system design. These systems usually pay higher in terms of maintenance man-hours, operational downtimes, and financial costs when the system becomes operational. A properly tested design early in the developmental process usually generates fewer changes later in a plant's development and operational use. Proper attention to human factors principles, control panel and workspace layout, and system design during the early stages of development, as this report outlines, should result in reductions of costs and schedule time, when compared to the situation of not having been as attentive during the early stages. For example the PTA isolated 220 closed/action-taken items while the CTA listed 130 items. These numbers include the utility's comments in Part c.

18.0.4.13 Review Functional Layouts of Other Critical Areas

Responsible engineers (RE) and designers developed functional floorplan layouts, not only for the control room, but also for critical areas of operator interface (such as the computer room, remote shutdown room, and the emergency response facilities). These areas have to be acceptable from a human factors design principle perspective. These guidelines are outlined in NUREG 0700, EPRI NP-3659, and the YGN 3&4 Human Factors Engineering Guideline Document. Drawings of the plant locations and/or layouts of the control room, computer room, remote shutdown room, emergency operating facility, the technical support center, and the remote shutdown panel are depicted on Figures 18.0-23 to 18.0-26. The paragraphs that follow outline information pertaining to the remote shutdown panel within the remote shutdown room, and the emergency response facilities.

a. The Remote Shutdown Panel (RSP) consists of A and B panels and one non-safety panel (N channel) containing miscellaneous controls and indicators, associated instrumentation, and controls and transfer switches. See Figures 18.0-26 (Sheets 1, 2, 3) for the layout of these three panels. The purpose of the RSP is to bring the plant to a condition of hot shutdown in the unlikely event that the control room must be evacuated because of nonhabitability due to a fire. The RSP shall also be operational per the guidelines of 10 CFR 50, Appendix. A, GDC 4 and 19, in addition to fire protection per Appendix. A, GDC 3 and NUREG-0800 (Section 9.5.1, Fire Protection Program). Operation from the RSP shall be able to bring the plant from any critical mode to hot shutdown. The function of the RSP includes maintaining the plant in hot shutdown until the control room can be reentered, or until cold shutdown can be achieved using local control stations and emergency procedures. Either A or B train controls and instruments are independently capable of performing the function. Transfer switches are used to activate the function. A control room alarm is provided to alert operators of inadvertent transfer of control to the RSP.

   The following functions are performed during plant operations:

   1. The RSP does not function during normal plant operation. Normal system operation consists of control of the plant to achieve and maintain a hot shutdown condition in the event of control room evacuation.

   2. The RSP does not function during plant startup and normal shutdown. Startup and shutdown of the RSPs is achieved through

use of the transfer switches located in the auxiliary electrical equipment rooms and remote shutdown rooms. Some indicators on the RSPs are continually operational, and do not require a transfer of control. However, controls on the RSP are activated only in the event of control room evacuation, and are de-activated upon reentry to the main control room.

3. The RSP operates a post-reactor trip under the abnormal plant condition of control room evacuation. There is no system abnormal condition of operation for RSP. Either the A or B train (or both) are operation-ready at any time when the plant is running.

4. The following, functions are necessary at a system level, to achieve hot shutdown, and therefore are included on the RSP. Hot shutdown is defined as when the reactivity condition (Keff) is less than 0.99, 0% of rated thermal power (excluding decay heat) and cold leg temperature is between 350°F and 210°F. Auxiliary feedwater controls are needed for the steam-generator heat sink. Control of steam disposal is also a necessary function along with pressurizer pressure and heat controls, and some control of the main steam and of the reactor coolant system volume.

5. Additional functions require RSP indication. Among these functions are reactor coolant temperature, nuclear power, pressurizer status, steam-generator status, primary reactor coolant inventory, condensate inventory, and auxiliary feedwater status. Also, the functions of reactor trip (done from the control room prior to evacuation) and control transfer are included in control functions pertaining to the RSP.

The RSP consists of all controls & instruments described previously, including BOP and NSSS scope, for inclusion on the A, B, or N remote shutdown panels. The system also includes transfer switches as necessary to transfer operation from the main control room to the RSP. There are no mechanical components (pumps, valves, etc.) assigned to the RSP. Table 18.0-2 outlines the instrumentation that is necessary to provide adequate instrumentation and control for the purpose of performing the RSP function.

b. The emergency response facilities (ERF) pertain to the technical support center (TSC), the operations support center (OSC), and the emergency operations facility (EOF). The emergency response system (ER) contains the ERF's and the postaccident monitoring system (PAMS), which also has the safety parameter display system (SPDS). Therefore, there are six basic portions to the ER system. The YGN 3&4 TSC consists of one combined TSC located in the Unit 3 access control building and a satellite TSC (STSC) for Unit 4. The combined TSC is to be shared by Unit 3 and Unit 4. The Unit 4 STSC, which is located in the Unit 4 computer room, is intended to facilitate close communication between the Unit 4 main control room operators and the combined TSC during a Unit 4 emergency. The TSC provides management and technical aid to plant operations personnel during plant transients and accidents. The OSC provides an onsite emergency assembly location for operations support personnel to assemble and coordinate logistic support. It is located in access control building at el. 135 ft 0 in. The EOF is an offsite support center. It is used for monitoring pertinent plant information to determine offsite protective measures. The safety parameter display system (SPDS) is a computer-controlled system which is furnished by Combustion Engineering (CE) under the NSSS scope of supply. The SPDS assists the control room staff in evaluating plant status and in postaccident monitoring. However, the SPDS alone does not constitute the entire postaccident Monitoring System (PAMS). The post-accident monitoring system is a series of indications designed to give the control room operators a reliable set of data on key plant parameters in a postaccident situation. More is to be stated about the SPDS and system requirements in Section 18.2. These combined facilities and systems (TSC, STSC, OSC, EOF, PAMS, and SPDS) make up the emergency response facilities and postaccident monitoring (ER) system for YGN 3&4.

The following functions are performed during plant operations:

1. The ER System is not used during normal plant startup nor during hot or cold shutdown. The emergency response facilities themselves do not require startup or shutdown. SPDS and other systems or hardware used in the ER facilities such as communications gear are available for use at any time during the design life of the plant. SPDS and PAMS are to be continuously available and on-line. The facility rooms of ER are staffed based on criteria determined by the utility. TSC HVAC is not required to be on when the TSC is not staffed. STSC is within the Unit 4 main control room complex environmental envelop with the operational mode being similar to the computer room.

2. During normal plant operation, the ER system is idle except for PAMS and SPDS, which is operational during all plant conditions. Normal operation for ER is during transient or postaccident plant conditions.

3. During transient plant operations, the ER system is operational and the facilities are fully staffed with required personnel as determined by the utility. There is no transient system mode of operations for the ER system. All hardware, software, and

facilities of the ER system are functional under ER operation.

4. The TSC and the Satellite TSC have no direct plant control functions. The TSC and/or STSC function to provide plant management and technical support for operations personnel during emergencies. It also functions to perform communications and peripheral duties normally done from the control room and to reduce control room traffic. In addition, the TSC and/or STSC provide the functions normally associated with the EOF until the EOF becomes functional. Functions associated with TSC and/or STSC operation include plant analysis from data taken prior to and during accidents; and communications with the OSC, EOF, control room, and Nuclear Safety And Security Commission (NSSC). 582

5. The operation support center has no direct plant control functions. The function of the OSC is to provide an assembly area separate from the TSC, STSC, and control room, but still onsite, where plant logistics support is coordinated during an emergency. The chief function at the OSC is reliable voice communication with the control room, TSC, STSC, EOF, and offsite locations.

6. The emergency operations facility has no direct plant control functions. The function of the EOF is to evaluate the plant radiological, meteorological, and plant system data, in order to allow the plant staff to adequately monitor environmental conditions and to perform necessary emergency offsite duties. Activities which allow this to be done involve the gathering, storage, and display of pertinent data needed to analyze the emergency situation. In addition, administrative functions include information exchange and communication with the TSC,

STSC, control room, NSSC and local authorities. 582

7. The safety parameter display system and postaccident monitoring system has no direct plant control functions. The SPDS functions to assist control room personnel to determine plant status during and after accident situations as well as during normal operation. Control of SPDS is via operator keyboard input. The PAMS function is to provide postaccident control room monitoring of variables listed in Regulatory Guide 1.97. These variables are those required to mitigate the consequences of an accident.

The ER system contains no major mechanical components. It is primarily a facility and software system. The integrated ER system meets regulatory requirements for emergency response facilities and the SPDS, as provided in appropriate regulatory documents. The components of the system are the TSC, STSC, OSC, EOF, PAMS and SPDS. The SPDS is designed and provided by the NSSS supplier. The instrumentation provided within each of the six portions of the ER system are outlined below:

1. Both the TSC and the STSC are located in the Access Control Building near the control room to facilitate necessary i- 1
nteraction with control room personnel, and the TSC contains adequate space for 25 personnel, while the STSC has space for 4 personnel at a minimum. Data system equipment (including safety parameter display system displays, keyboards, and a hard copy device) are provided along with a minimum of ten regular telephones, "hotlines" as determined necessary by KEPCO, and other communications equipment, which is deemed necessary by the client to remain in contact with the control room and other emergency centers. Instrumentation contained within the EOF is also provided for the TSC and the STSC.

2. The OSC contains communications equipment as its only instrumentation. This equipment is sufficient to carry on reliable voice communication with the TSC, STSC, control room, EOF, and necessary offsite locations during emergency conditions.

3. The EOF contains sufficient workspace for the staffing level determined by the utility. In addition, an area is provided for storage of plant records and up-to-date procedures. The EOF instrumentation consists of CRTs, keyboards, hard copy devices, and other hardware necessary to monitor plant data systems such as the SPDS. In addition, instrumentation or other EOF facilities, such as display boards and files, are to provide for data storage and retrieval. Instrumentation for display of radiological, environmental, and meteorological data variables (as specified in Regulatory Guide 1.97), applicable variables from NUREG-0737 Supplement 1 and NUREG-0718, and meteorological variables listed in Regulatory Guide 1.23 (Safety Guide 23) are to be included. This historical data must be available for a minimum of two hours previous to the accident and 12 hours postaccident. The instrumentation for this data may be computer, hard copy, or another method approved by KEPCO.

4. NSSS instrumentation associated with SPDS is discussed in NSSS documents for those systems. SPDS is designed by CE. PAMS instrumentation includes indications for those variables listed in Regulatory Guide 1.97.

18.0.4.14 Review Design and Procurement Documents

The human factors group continuously conducts thorough reviews of design and procurement documents of all systems and subsystems with critical human factors interfaces. One of the criteria used in these reviews is to assure that all applicable portions of these systems conform to the Human Factors Engineering Guideline Document for YGN 3&4. The design of the control room and control centers outside the control room must comply with accepted human factors engineering principles. Functional relationships between the main control room and these other control centers are established, which assure compatibility during all modes of plant operation. These reviews have adequately addressed the following areas, which are considered important within the Standard Review Plan : control room workspace, workspace environment, annunciator warning systems, controls, visual displays, auditory signal systems, labels and location aids, process computers, panel layout, and control-display integration.

For example, the following documents have been reviewed and revised with changes having been made when necessary utilizing human factors design principles:

a. Piping and instrumentation drawings (P&ID)
b. Control and instrumentation drawings (C&ID)
c. Control logic diagrams (CLD)
d. Board elevation drawings of the MCBs and the RSP
e. Annunciator window arrangement drawings
f. CRT screen designs
g. System design criteria
h. System functional descriptions
i. Function analysis summaries
j. Procurement specifications

18.0.4.15 Conduct Human Factor Reviews of Vendor Designs

Continuous reviews are conducted by the human factors group of vendor drawings and documents that involve critical man-machine interfaces. These reviews are performed to assure consistency of the various vendors with the MCB hardware and that all applicable items provided by the vendors, insofar as contracts allow, meet the guidance outlined in the Human Factors Engineering Guideline Document. When discrepancies are found, comments are made to the appropriate vendor with the purpose of finding an appropriate resolution. The following vendor documents have been reviewed utilizing human factors design principles.

a. NSSS Supplier - documents and drawings.

1. Piping and instrumentation drawings (P&ID)
2. Measurement channel block diagrams (MCBD)
3. Functional control logic diagrams (FCLD)
4. System descriptions
5. Interface requirements
6. Design specifications
7. Remote shutdown panel arrangement drawing
8. Other documents and drawings required for HFE review

b. Turbine/Generator Supplier documents and drawings.

1. Turbine/generator instruction manual
2. Supervisory instruments instruction manual
3. Turbine protection and control (TPC) and turbine-generator supervisory instrument (TGSI) documents and drawings. 536
4. Other documents and drawings required for HFE review.

c. BOP Equipment Supplier - documents and drawings

1. P&ID, C&ID, control logic diagrams
2. Panel arrangement and color
3. Nameplate and labeling information
4. Instruction manuals

5. Other documents and drawings required for HFE review.

18.0.4.16 Review Computer System Design

All applicable vendor supplied computer hardware and software (including SPDS) is reviewed when appropriate. CRT hardware and placement is analyzed to assure efficient use and good human factors applications. Keyboard, computer room layout, and other pertinent computer system features is and will be reviewed to assure that they interface correctly with the MCB design. Additional information concerning the plant monitoring system (CX) and the SPDS can be found respectively in Section 18.0.4.6 and Section 18.0.4.13.

18.0.4.17 Review Emergency Response Facility Design

Human factors input is given when appropriate to the design of the technical support center and emergency operations facility, in order to assure that their locations are well placed, properly laid out, and contain required information. Factors such as monitoring, documentation, floor plan, and the ambient environment is considered in these reviews. More information concerning the emergency response facilities can be found in Section 18.0.4.13.

18.0.4.18 Review Communications System Design

The human factors group (HFG) has aided in the design of the overall YGN 3&4 plant Communications Systems (CQ), such as "Hot-lines", plant page, radios, sound powered phones, plant phones, and normal phones. For example, the HFG during the task analysis isolated the problem of there being an insuffient number of phones in the control room. A resolution to this discrepancy was found with assistance from the HFG. Also, guidance is given in the Human Factors Engineering Guideline Document relating to communications systems. The purpose of this assistance from the HFG is to assure that these systems satisfy all operational needs under all plant conditions and can be easily used as part of an integral whole plant communication system for all operational scenarios. The following paragraphs outline the criteria used for designing and specifying the onsite and offsite communications systems for YGN 3&4.

a. System functions during normal plant operations of the CQ System are centralized in the main control room. This system is designed to provide reliable in-plant and plant-to-offsite communications. The communications system interfaces with the public telephone system. The following communication systems shall normally be available:

1. The paging phone systems for Units 3&4 are independent of each other. Each system is capable of parallel operation. This system consists of handset stations and loud speaker assemblies located throughout the plant. Paging phone locations include operator stations, [redacted], [redacted]. Handset stations have their own amplifier and volume control. Each station has a two channel paging capability and five channels for simultaneous bidirectional voice communications between two or more areas. Acoustic booths are utilized in high noises areas. The paging phone systems serve as the backup evacuation alarm system.

2. The Sound Powered Communication System consists of sound powered jacks, which are installed throughout the plant as an aid for testing and calibration of instrument and control circuits. The sound powered communication system for each unit is independent of the other unit. This system is capable of simultaneous bidirectional communication and consists of portable headsets with carrying cases and extension cords, jacks, a switching box for connecting different areas, and portable multichannel

equipment. Each unit is divided into eight zones. The sound powered communication system for each zone has three channels. The zones are capable of being interconnected via a switching box in the main control room. Sound power jack locations include [redacted].

3. The evacuation alarm/public address (P.A.) system consists of independent systems for Units 3&4. Each unit is divided into six zones to provide area alarm/P.A. capability. There are five types of alarm signals generated by the multitone generator (per ANSI Standard N2.3) with audible alarms being accompanied by visual alarms in high noise areas for the evacuation alarm system. Speaker locations include [redacted]. Volume control for individual speakers are accomplished at necessary areas locally. The backup evacuation alarm system utilizes the same multitone generator as is used in the evacuation alarm system in conjunction with the paging phone system. The backup evacuation alarm system is automatically initiated if the normal system fails.

4. The direct wire telephone system functions as a backup system for the paging phone system providing simultaneous bidirectional communications between various plant areas. There are independent direct wire telephone systems for units 3 and 4. The main components of each direct wire telephone system consist of a electronic private automatic branch exchange (EPABX), MFC telephones, and signal lamps (for high noise areas). The PABX shall have "multi-party" calling capability and a "hot line" feature. Signaling is accomplished by speakers located near each station which emit an audible frequency. A speaker and a

lamp are provided in high noise areas to alert the operator being called. Acoustic booths are also provided in these areas. The direct wire telephone locations include [redacted]

5. The clock system consists of one master clock and approximately 15 subsidiary clocks located throughout each unit. The clock system for each unit is independent of the other. The master clock monitors and controls subsidiary clocks. Subsidiary clocks are wall mounted wherever possible. Subsidiary clock locations include instrument racks, major control panels, and the guard houses.

6. The PABX system provide a convenient means of communication between major buildings and offsite. The telephone locations include [redacted] Switching and distribution equipment for the PABX system is compatible with the YGN 1&2 design, and is of the MFC type. The system is to be connected to the existing main facilities.

7. The ERF telephone system provides direct hotlines between onsite and offsite emergency facilities, including the [redacted] This system uses an independent line associated with the Unit 3 direct wire telephone PABX. The [redacted] have control capability of the evacuation alarm system, and they have the capability of monitoring major plant parameters. The ERF telephone system includes telephones and FAX copiers.

8. The guard house telephone system has telephones at each guard post to provide simultaneous bidirectional communications between the posts. "All call", multiparty, and individual calling capabilities are provided. The system consists of a

dedicated PABX and associated telephones.

b. During abnormal and accident plant operations, the communications systems is designed with sufficient redundancy, and independence to mitigate the consequences of design basis events.

c. The normal power supply for communication systems is 220 Vac, 1ϕ, 60 Hz with access to a diesel generator source. The standby power supply consists of independent dc power supplies for each system. Each dc power supply consists of a battery, battery charger, and associated equipment.

The following systems have both normal and standby power supply systems to ensure stable system operation:

1. Paging phone system
2. Evacuation alarm/P.A. system
3. Sound powered communication system
4. Clock system
5. Direct wire telephone system
6. Guard house telephone

d. Separation and physical protection requirements are :

1. Communications cables are routed in dedicated raceway systems independent of plant control systems.

2. Communications equipment and cables are located above postulated flood levels, when practical.

18.0.4.19 Review Annunciator System Design

human factors engineering support is and has been given to the design and implementation of the control room annunciator system. The Human Factors Engineering Guideline Document addresses color coding, format, lettering, alarm sequence, annunciator horn characteristics, and other salient aspects of the annunciator system. During the manufacturer's design and evaluation phases, extensive human factors support has been provided in review of vendor design drawings and documents. The paragraphs that follow in this section functionally describe the annunciator system (AN) at YGN 3&4.

The annunciator system for the main control room is designed to alert the operator by means of visual and audible signals of abnormal conditions involving important plant variables and changes of equipment status that require operator attention. Conversely, static equipment, status and conditions for which the operator can take no action, is not alarmed unless they require immediate operator awareness (such as ESF actuation). The annunciator system has no direct process control or protective functions, but is used to inform the operator when abnormal conditions occur for which he can take corrective action.

The annunciator system processes alarms for both nuclear steam supply system (NSSS) and Non-NSSS system inputs. The window arrangement, engraving, color coding, labeling, and window box markings follow the project human factors engineering requirements. The alarm logic is compatible with either normally open or normally closed field contacts. In some cases, more than one alarm is indicated on a single window by use of multiple-input circuits in order to reduce the number of windows without loss of individual alarm indications. In these cases, related inputs may be combined on a single window with a common legend (for example "tank level high" and "tank level hi-hi"). Multiple inputs indicating single aspects of a common problem may also be combined. On one window for example, multiple temperature detectors for a "temp high" alarm or various indications of a pump trip (current to pump motor, rpm, discharge flow) may be displayed. In other cases, more than one alarm may be indicated on a single window by paralleling the field contacts, if no loss of useful information occurs. Other devices in the control room or equipment area are required and must be available to determine the specific alarm, when any multiple input alarm is used which requires a control room action by the control room operators.

Selected alarm signals are retransmitted from the annunciator to the computer. In the computer these alarm signals are used for alarm logging, cathode ray tube (CRT) display, and display of individual input alarm identification. The repeater contacts are provided to operate independently of the annunciator logic circuits. The repeater contacts do not operate during annunciator test. Alarm circuits are designed to minimize nuisance alarms that occur when trouble does not actually exist. The annunciator is not used to display system or equipment status that is not related to system or equipment trouble. Alarms from equipment common to the two generating units when required are wired independently to the two annunciator systems. Two field contacts are provided on common equipment for this purpose.

For the main control room plant annunciator, normal input power is from 120 Vac non-safety-related buses, and reserve input power is from a non-safety-related 125 Vdc system. On loss of normal power, the transfer to reserve power is automatic and "bumpless", and is alarmed to the operator. On return of ac power, the transfer back to normal power is also automatic and "bumpless", and is alarmed to the operator. The system includes all necessary voltage regulation equipment. All annunciator equipment including peripherals is powered from the same buses.

There is no special requirements for different modes of plant operation. The plant annunciator system operates and functions properly during all modes of plant operation. Annunciator windows (individual tiles) are color coded to alert operators of key alarms, and to adopt a prioritization system which will enhance control room operations. Prioritization and color coding are outlined in Table 18.0-3. Further information relating to the annunciator alarms are depicted in Tables 18.0-4 and 18.0-5, which outline the Normal alarm and first-out alarm sequences of the annunciator system.

The annunciator control pushbuttons mounted on the main control board include silence, acknowledge, reset and test pushbuttons for the normal and first-out annunciator system. The horns are equipped with a tone control mechanism for both amplitude and frequency so that the operator can distinguish the tones between control board sections. The alarm coding satisfies the human factors requirements. The plant annunciator system consists of window boxes, audible devices, and pushbutton stations, which are mounted on the main control boards; and of separate logic cabinets containing logic devices and input cabinets located in the auxiliary electrical equipment room. The specific annunciator pushbuttons are outlined below :

a. A Silence pushbutton is a momentary pushbutton common to all points. When pressed, it silences the audible alarm irrespective of the zone in which the alarm has occurred.

b. An Acknowledge pushbutton is a momentary pushbutton for all annunciator points located in the same zone. When pressed, it silences the audible alarm, stops the flasher, and causes the light to stay "ON".

c. A Reset pushbutton is a momentary pushbutton common to all annunciator points in the same zone. After field contacts have cleared, the reset control extinguishes window illumination. (The ringback chime sounds once prior to reset at the time an input contact clears.)

d. A Test pushbutton is a momentary pushbutton for all annunciator points in the same zone, and is pressed to test lamps and audible devices, except repeater contacts to the computer.

18.0.4.20 Review Final MCB Verification

Following delivery of the main control boards, the as-received MCBs are to be inspected in order to assure that they conform to the criteria set forth in the procurement specifications. Variables such as size, color, shape, location, and structure are used in the verification. In addition, the component lists, elevation drawings, data sheets, task analysis results, and other documents that can aid in the verification process are compared to the instruments and controls on the as-received panels.

18.0.4.21 Review Plant Procedure Development

"Guidelines for the Preparation of Emergency Operating Procedures", NUREG 0899, identifies the elements necessary for the utility to prepare and implement plant specific emergency operating procedures (EOPs). The purpose of the EOPs are to provide the operator with directions to mitigate the consequences of a broad range of accidents and multiple equipment failures. Although NUREG-0899 applies mainly to EOP development, these guidelines also could have applicability in the development of the following documents, which are necessary for plant operation: general operating procedures, system operating procedures, Technical Specifications, and alarm response procedures.

The guidance in NUREG-0899 is intended to reduce the frequency and extent of revisions to EOPs by recommending a development and validation/verification process, which results in technically accurate and usable EOPs. This document provides guidance on the following items: EOP developmental process (the preparation and validation/verification of EOPs), development and validation of the technical guidelines, preparation of the plant-specific writer's guide, and EOP usage and maintenance.

18.0.4.22 Perform Final Verification and Validation

The objective of the task capabilities verification process is to assure that operator tasks can be performed in the existing control room with minimum potential for human error. The focus is on instruments and equipment, not on operator skills and knowledge.

The premise is that the main control room should provide all information and control capabilities called for by the operator task action requirements. The process of task capabilities verification consists of two steps. The first step is to verify the presence (or absence) of instruments and equipment that provide the information and control capabilities necessary to implement each task. This step is referred to as the verification of availability. The second step is to determine whether the man-machine interfaces provided by the displays, controls, and other control room features are effectively designed to support task accomplishment. This step is referred to as the verification of human engineering suitability.

The materials for the verification of availability are the control room inventory (or components list), and the task specifications prepared in the system function review and task analysis. The inventory is organized by panel; and include identification of systems, subsystems, and major components of the plant process equipment associated with each panel. The inventory also identifies the system/subsystem functions, and the uses and formats of the controls and displays on the panels. A similar organization is performed for the specification of task requirements derived from the task analysis, whose method and results are outlined in Subsections 18.0.4.9 and 18.0.4.10.

The objective of the verification of suitability is to identify interface problems that may affect task performance, but may not be evident when control room components are examined without reference to specific task use (as in the control room survey). The practical availability of inventoried displays and controls will be carefully assessed. For example, displays may be separated from the controls with which they are used; or several displays which need to be read to identify a process event may be dispersed so that they are difficult to monitor and correlate. Such conditions are to be recorded as human engineering discrepancies. The control room survey checklist (section 6 of NUREG 0700) is also used.

The information needed for the task capabilities verification process comes primarily from the task analysis, the control room inventory, and section 6 of the guidelines. If the results indicate that the main control room may contain instruments unnecessary for operator tasks, then engineering and procedures documents, operational and maintenance directives, and regulatory requirements are to be consulted as necessary to investigate the use of the items. The verification of task performance capabilities can result in additional human engineering discrepancy records.

The objective of the validation process is to determine whether the functions allocated to the control room operating crew can in fact be accomplished effectively within the structure of defined operating and emergency procedures and the design of the control room as it exists. In addition, the process of verification discussed above is associated with task execution, and evaluates the interfaces at each workstation. The process of validation discussed here is associated with function execution and evaluates the integrated control room configuration.

Emphasis should be placed on ascertaining and evaluating plant status and diagnosing transients. The ability of the existing display systems to support those functions is a key concern, since the quality of the operator-process interface is highly dependent on them. For example, the number of process parameters displayed, the format of the displayed data, and the dynamic response needed from instruments/displays/indicators can impact operator workload. Integrated display of a small number of parameters may impose a manageable cognitive workload, so that an individual operator can obtain the correct state of the plant process. Conversely, the display of a large number of parameters; lack of integration of parameters; and dispersion, inconsistency, or slow response times of displays may necessitate division of responsibility, result in confusion, and prolong the time required before the correct state of the plant process and its implications for safety can be determined.

The approach directs control room personnel to walk and talk through event sequences selected from among those studied in the systems function review and task analysis. Walkthroughs provide an opportunity for performance dynamics to be seen, and permit assessment of the interaction of the entire operating crew with each other and with the Control Room workstations. Operator workload, effects of the arrangement of functionally related instrumentation, and the feasibility of task completion assessed in the context of operating sequences that exercise the functions allocated to the control room operating crew. Operator sequences and the operational events to be used during the validation process are not specified at this time.

The operator walkthroughs are recorded (audio and video) for later analysis as required. Debriefing and tape review sessions are necessary, with operators to assist in the analyses and interpret the operations. A review of the Human Engineering Guideline checklists (NUREG-0700) is recommended after each walkthrough to consider items that require reference to the dynamic operational sequence. In particular, the guidelines for panel layout and control-display integration are applied in this context. In addition, previous checklist discrepancies may require reevaluation based on interactive requirements.

The primary results of the validation process include observations concerning: the operator difficulties in responding to the events, the impact of previously identified human engineering discrepancies, and any specific discrepancies that were not documented in previous tasks. Discrepancy records prepared from these observations are used as inputs for further investigation. These potential discrepancies need to be complied for assessment of their safety implications, and for delineation of control room design improvements.

18.0.4.23 Perform Final Checklist

The control room survey is a systematic comparison of control room design features with Human Engineering Guidelines presented in Section 6 of NUREG-0700 checklists. Direct observation and measurement of specific features within the control room are necessary. The objective of the control room survey is to identify any characteristics of instruments, equipment, layout, and ambient conditions that do not conform to precepts of good human engineering practice, regardless of the particular system or task requirements. This is discrepancy identification from the component perspective. The safety significance identified in the Control Room survey is recorded, and examined later in terms of assessing their impact upon operator and plant performance, and the need for implementation within the main control room. NUREG-0700 utilizes a checklist format in order to facilitate its use and to assure that all guidelines are addressed. The following areas are reviewed during the survey; control room workspace, communications, annunciator warning systems, controls, visual displays, labels and location aids, process computers, panel layout, and control-display integration.

18.0.4.24 Prepare Documentation

At all stages of design work, adequate documentation has been produced to verify human factors involvement in control room design. These documents are prepared in such a way that later review or outside audit is able to interpret them, and verify their purpose and content. This documentation includes, but is not limited to the following:

a. Human Factors Guideline Document which is discussed in Subsection 18.0.4.3 and Section 18.1.

b. Human Factors and Task Analysis Plans which are discussed is Subsections 18.0.4.1, 18.0.4.2, and 18.0.4.9.

c. Task Analysis Summary Report, which discusses the method, mockup development, and results of the studies, is outlined in Subsections 18.0.4.7, 18.0.4.9 and 18.0.4.11.

d. System functional descriptions which are discussed in Subsections 18.0.4.5 and 18.0.4.6.

e. Elevation drawings of the main control boards which are described in Subsections 18.0.4.4, 18.0.4.7, 18.0.4.8, and 18.0.4.12.

f. Component lists (or inventory data sheets), and control logic diagrams which are discussed in Subsections 18.0.10, 18.0.4.14, 18.0.4.20, and 18.0.4.22.

g. Functional layouts of the control room and other key areas which are described in Subsections 18.0.4.5, 18.0.4.13, and 18.0.4.17.

h. Design and procurement documents which are outlined in Subsection 18.0.4.14.

i. Vendor design documents which are outlined in Subsection 18.0.4.15.

j. Communications and computer system design documents which are discussed in Subsection 18.0.4.16, and 18.0.4.18, and Section 18.2.

k. Annunciator window design drawings which are outlined in Subsection 18.0.4.19.

l. Control design review activities which are outlined in Subsections 18.0.3, 18.0.4.5, 18.0.4.6, 18.0.4.7, 18.0.4.9, 18.0.4.10, 18.0.4.11, 18.0.4.19, 18.0.4.20,. 18.0.4.22, and 18.0.4.23.

18.0.4.25 Outline Organizational Structure

Another important part of this program is to demonstrate, as part of the control room design activities, that the human factors group has support from management, system engineers and other knowledgeable personnel in the performance of their duties. People with various types of training and experience are needed to perform the required tasks. The project involves outside specialists, licensee headquarters personnel, and personnel from the individual plant Units; all of whose contributions and interactions must be coordinated. In addition, it is necessary to use a substantial body of reference materials and data, and to keep project working papers organized so that analyses can be integrated and important documents prepared. A project of this nature calls for thorough planning and preparation.

Management attention to the planning process is important, whether it be from KEPCO, KOPEC, KHIC and the vendor/consultants (such as Sargent and Lundy, and Combustion Engineering). Management tasks include overall support of the control room design process, and integration of the design review with other studies and analyses involving human factors concerns. This involves careful review of NUREG-0700 along with other communications/guidelines, which address the overall human factors review program. NUREG-0660 states that all measures considered for correcting discrepancies in the control room design should be considered in conjunction with other design measures to improve control room human engineering. Two such measures are development of a safety parameter display system and upgrading of emergency support facilities. The control room design review has and will continue to have bearing on other NUREG-0660 tasks with human factors implications. Examples include assessment of shift manning, training and qualifications of personnel, and procedures development. Management attention to the coordination of all of these tasks within the human factors engineering framework is essential.

18.0.4.25.1 Integration of HFE Within the Project Organization

Figure 18.0-27 depicts the YGN 3&4 A/E project organization from the project manager to the various instrument and control (I&C) groups (J1 to J5) and their responsible engineers (RE). The human factors specialists is within the J4 group (process computer applications and human factors) within the instrumentation and control (I&C) discipline. Whose function is to coordinate and to take a leading role and all of the project HFE-related activities with the REs of all the engineering groups in the project, to advise and review on all matters pertaining to human factors, and to be an integral part of the KOPEC project organization. Further information, relating to his and the human factors engineering activities (which includes past, present and future) and their integration within the project organization, are outlined in Subsections 18.0.4.7 to 18.0.4.24 and 18.0.4.26.

The human factors engineering (HFE) team of the A/E has been organized within the I&C discipline since the beginning of the project. This team, throughout the life of the project, has been comprised of one experienced HFE specialist from S&L, one KOPEC HFE Engineer, and one KOPEC senior engineer, who have coordinated and carried out the overall HFE activities. In addition, the HFE Team is and has been affiliated with a wide range of various project entities in order to fulfill the several kinds of review functions, which are: technical task performance, project direction, administrative support, and documentation support. This affiliated group is called the review team. The number of people who are needed to conduct the control room design activities of the review team can vary; dependant upon the type of activity and the time of performance in the developmental cycle. In general, it appears that the basic technical review team includes a nuclear systems engineer, engineer/architect with control room design experience, senior reactor operator or operations technical advisor with operating experience, and human factors engineer.

Needs for expertise not provided by the basic review team have been met by bringing in specialists or consultants. For example, these individuals have directed performance of the review of system functions and analysis of control room operator tasks, prepared and/or administered the operator questionnaire/ interview, conducted environmental measurements in the main control room, and identified and proposed alternative design modifications to correct team-identified control room design discrepancies.

Technical team direction and support is needed. A review team manager is assigned to provide team management coordination; direct and support day-to-day team activities; arrange for consultant/specialist support when needed; and direct the evaluation, implementation, and reporting process. This manager is usually the J4 engineering group leader, who is assisted by the HF specialist in the conduct of his duties. This Manager is also responsible for scheduling and controlling all activities within the main control room or control room mockup, including assignment and involvement of operators to assist the review team. He has to coordinate some of the activities with his KEPCO counterpart as well as with representatives of KHIC, NSSS and the turbine-generator (T/G) vendor.

Administrative and documentation support is made available to the technical team and team manager. Principal tasks other than typical administrative support tasks involve the acquisition and maintenance of reference materials, management of review team documents (for example, control room survey and measurement reports), and control of special documentation systems such as photographic documentation. Again coordination with KEPCO and the vendor organizations is critical to the performance of the manager's duties.

18.0.4.25.2 Integration of HFE Within the I&C Discipline

Within the I&C discipline, there are five Groups: J1-System, J2-HVAC and Monitoring Systems, J3-Equipment, J4-Process Computer Applications and Human Factors, and J5-Physical. The functions of these five groups are outlined in the following paragraphs.

a. The J1 (System) group's functions are to prepare, issue and update the following I&C responsible items;

   1. Documents

      - Design Criteria Manual (DCM, I&C Portions Only), system design criteria (SDC), system functional descriptions (SFD), functional analysis summary (FAS), piping system design specifications, and other relevant specifications.
      - Instrument Index (initial input only)
      - Instrument & valve data sheets (initial input plus subsequent update for responsible specifications, and initial input only for specifications by others)
      - Plant computer balance of plant (BOP) database input (initial input for responsible systems plus subsequent updates)
      - Instrument setpoint index (initial input plus subsequent updates)
      - Equipment index (initial input only)
      - Preliminary Safety Analysis Report (PSAR) and Final Safety Analysis Report (FSAR) (excluding Chapter 18)

2. Drawings
Piping and instrumentation ddiagram (P&ID), control and instrumentation drawing (C&ID), control logic diagram (CLD), level setting diagram (LSD, loop), LSD (level), master diagram (MD).

3. Calculations
Instrument setpoint and margin calculations

This group also performs technical bid evaluations, and reviews and comments on vendor submittals for responsible specifications; provides inter and intra discipline reviews and comments through document review notices (DRNs), drawing comment distribution forms (DCDFs), and supplier document review forms (SDRFs) ; and has a NSSS and T/G coordination function.

b. The J2 (HVAC & Monitoring Systems) group, similar to the J1 group, performs technical bid evaluations, reviews and comments or vendor submittals, and coordinates inter and intra discipline reviews and comments on technical matters. This group also prepares, issues and updates the following I&C responsible items:

1. Documents

- DCM (I&C portions only), SDC, SFD, FAS, PSDS, specifications
- Instrument index (initial input only)
- Instrument & valve data sheets (initial input plus subsequent updates for responsible specifications and initial input only for specifications by others)
- Plant computer BOP database input (initial input only)
- Equipment index (initial input only)

2. Drawings
P&ID, C&ID, CLD, LSD (loop), LSD (level), MD

3. Calculations

- Instrument setpoint and margin calculations
- Sample line sizing calculations

c. The J3 (Equipment) group performs technical bid evaluations, and reviews and comments on vendor submittals. In addition, this group prepares, issues and updates the following I&C responsible items:

1. Specifications
2. Instrument index (subsequent updates after initial input by others)
3. Instrument & valve data sheets (subsequent updates after initial input by others for responsible specifications)
4. Valve index (initial input plus subsequent updates for I&C scope only)

d. The J4 (Process Computer Applications & Human Factors) group prepares, issues and updates the following I&C responsible items:

1. Documents

- SDC, SFD, specifications, HF guidelines, general arrangement changing request (GACR; MCR complex, RSP room and radwaste control room)
- Instrument index (initial input only)
- Instrument data sheets (subsequent updates for responsible specifications after initial input by others for responsible specifications)

- ° Plant computer BOP database input (initial input only)
- ° MCB and RSP (BOP) component list
- ° MCB annunciator list
- ° Equipment index (for panels in the MCR complex, RSP room and radwaste control room)
- ° PSAR and FSAR (Chapter 18 only)

2. Drawings

- ° Control logic diagrams (CLD, electrical systems), functional interconnection diagram (FID, all systems)
- ° MCR complex and radwaste control room arrangement drawings
- ° MCB elevation drawings (initial input plus subsequent updates)
- ° Local control panel (LCP) elevation drawings (initial input plus subsequent updates)
- ° HVAC panel elevation drawings (initial input plus subsequent updates)
- ° MCB component sketches
- ° MCB and LCP annunciator window layouts

This group also performs technical bid evaluations, reviews and comments on vendor submittals for responsible specifications, coordinates inter and intra discipline reviews and comments on technical matters, and prepares and updates the MCR mockups for the task analysis reviews.

e. The J5 (Physical) group, similar to the other groups, performs technical bid evaluations, reviews and comments on vendor submittals for responsible specifications, and coordinates inter and intra discipline reviews and comments on technical matters. In addition, this group provides drafting support for I&C drawings; and prepares, issues and updates the following I&C responsible items:

1. Specifications, GACR (outside the MCR complex, RSP room and radwaste control room), opening and penetration requests

2. Equipment index (subsequent updates after initial input by others for panels outside the MCR complex, RSP room and radwaste control room)

3. Instrument installation details (IID), instrument location drawings (ILD), instrument arrangement distribution drawings (IAD), level instrument briddle drawings (LBD), and isometric drawings (ISO).

To summarize, it is important to emphasize that the human factors engineering function is facilitated by its placement within the KOPEC organization. The analysis and review of the output of the J4 group, and its interface with the other I&C groups, assist both KEPCO and KOPEC throughout the planning, design and evaluation stages of the nuclear plant's development, in terms of human factors engineering. The more HFE is a part of the developmental cycle, the earlier it is introduced into the design process, and the higher the trust and respect afforded it by management usually result in reduced costs and time for development and increased efficiency and use during its operation. The location of HFE within the organization and its interface with other ongoing work can only facilitate its positive impact upon the project.

18.0.4.26 Prepare Integration Plan

A report, "Human Factors Integration Plan", dated July, 1992, which has been prepared by KOPEC, contains an outline of regulatory requirements, an integration strategy and program performance objectives. The basic intention of this integration plan is to utilize as much of the on-going and completed work at YGN 3&4 as possible relating to NUREG-0737, Supplement 1. Therefore, the purpose of this integration plan is to utilize and to integrate the results of previous activities within the context of future goals and initiatives. The objectives of this plan are to assist the plant's human factors efforts by satisfying regulatory requirements, providing internal guidance, helping to coordinate all initiatives, and being a supporting document to the information presented in the Final Safety Analysis Report (FSAR).

A significant amount of review and design work has been performed over the past few years for YGN 3&4. For example, the control room design process was one part of an overall program to improve the plant's emergency response capabilities. Although extensive in nature, the needs of integrating the results of these activities and of merging these activities with present initiatives remain. This integration effort helps to establish a foundation from which control room modifications can be made, procedures can be revised, training materials can be changed, and regulatory requirements can be met.

Although these initiatives are independent of one another, there are elements within these activities that are related through the use of human factors engineering design principles. The human factors principles applied during the control room design process are the same guidelines used to review the applicability of the safety parameter display system (SPDS, which is a part of the Postaccident monitoring system), the availability and design effectiveness of the instrumentation contained in Regulatory Guide 1.97, the correctness and completeness of the emergency operating procedures (EOPs), and the usability of the emergency response facilities (ERF).

Another example of the binding effect of human factors is the performance of a good task analysis. As part of the design process, a top-down approach starting with a review of systems, subsystems, and their functions is necessary to assure that all operator functions and tasks are considered. When the top-down analysis is completed, a bottom-up procedure is conducted which traces backup the chain by assessing the potential effects of design-related performance errors on system safety. The primary objective of this process is to establish the input and the output requirements of control room operator tasks. However, a task analysis phase that is appropriately planned becomes the cornerstone of many other reviews besides establishing the instrument and control requirements of the control room. The task analysis data are used as part of the Regulatory Guide 1.97 review, procedures upgrade, control room design assessment, spds design, simulator design, training program needs and design, and the assessment of the emergency response facilities. Therefore, the task analysis plays an important role in the identification of design problems and the performance of the verification process, which involves the evaluation of technical accuracy and of information and control capabilities.

Through the integration of previously completed and on-going activities, an integrated program emerges that satisfies regulatory requirements and provides internal guidance to the plant. The Integration Plan Report describes how the activities outlined in NUREG-0737, Supplement 1 are coordinated to meet the desired goals of YGN 3&4. The paragaphs of this report outline the critical program elements of the integration plan, and an integration strategy for its implementation.

18.0.5 References

a. EPRI, NP-3659, "Human Factors Guide for Nuclear Power Plant MCR Development," 1984.

b. EPRI, NP-3448, "A Procedure for Reviewing and Improving Power Plant Alarm Systems," 1984.

c. NUREG-0700, "Guidelines for Control Room Design Review," 1981.

d. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," 1981.

e. NUREG-0737, Supplement 1, "Requirements for Emergency Response Capability," 1982.

f. KSI, "Korea Physical Standard Measurement Report," 1986.

g. KOPEC, "System Functional Description for Yonggwang 3&4," Volumes I, II, III, Rev. 0.

h. Combustion Engineering Inc., "System Description for NSSS," 10487-FS-SD-210 to SD-550, Rev. 3.

i. GE Steam Turbine-Generator Instruction Manuals, Volumes IA, IB, IIA. IIB and IIIB, Rev. A.

j. KOPEC/90-P-001, 002, 003, "Control Room Design Review Final Report for Kori 1, Kori 2, and Kori 3&4," Jun. 1990. 1

k. KOPEC/9-740-J-412, "Main Control Room Task Analysis Summary Report for Yonggwang 3&4," Dec. 1991.

l. KOPEC/9-740-J409-1 (HF-10) "Human Factors Engineering Guideline for Yonggwang 3&4, Rev. 0.

m. KOPEC, "Function Analysis Summary for Yonggwang 3&4" Volume I, Rev. 0.

n. KOPEC/9-182-J772, "Procurement Specification Main Control Board and Associated Instruments for Yonggwang 3&4", Rev. 2.

o. KOPEC Report, "System Descriptions of Systems with A Control Room Interface", August 1992.

p. KOPEC Report, "Main Control Room Task Analysis Summary Report", December 1991.

q. KOPEC Report, "Human Factors Integration Plan", July 1992.

TABLE 18.0-1

MEASUREMENT OF PHYSICAL STANDARDS FOR KOREAN MALES (20-50 YEARS OF AGE)

(Units : cm)

No.	Description	Physical Standard (%)		
		10%	50%	90%

* Add 2.5 cm to #1-#3, #5, #13 when considering height of shoes

** Add 3 cm to #6 for functional reach dimension.

*** Add #13 to #7-#10 for total height from floor.

TABLE 18.0-2

NECESSARY INSTRUMENTATION FOR THE PERFORMANCE OF THE RSP FUNCTION

A. Indicators

Neutron logarithmic power
Hot/cold leg temperature
Pressurizer (PZR) pressure and level
SG pressure and level
Refueling water tank level
Charging pump discharge pressure and flow
Safety injection tank (SIT) pressure
Shutdown cooling HX inlet/outlet temperautre
LPSI pump discharge flow
Letdown pressure and flow
VCT level
Boronometer inlet temperature
Regenerative HX outlet temperature
Condensate storage tank level
Auxiliary feedwater (AFW) flow
AFW pump suction/discharge pressure

B. M/A Stations

Atmospheric steam dump inlet pressure
AFW flow to SG level

C. Indicating Lights

PZR pressure pretrip/bypass
SG pressure pretrip

D. Switches

Reactor coolant pump (RCP) control
PZR backup heater control
PZR aux spray valve control
Letdown isolation valve control
RCP seal bleedoff valve control
SIT atmospheric vent valve control
Charging pump control
Mini-flow line isolation valve to RWT
MSIS actuation
PZR pressure setpoint reset and bypass
SG pressure setpoint reset
Atmospheric steam dump valve control with position indicator
Atmospheric steam dump block valve control
AFW regulating valve control
AFW isolation valve control
AFW pump control
Component cooling water pump control
Essential service water pump control
Control room HVAC fan and damper control
Containment building HVAC fan control
Class 1E D/G supply PCB control

TABLE 18.0-3

PRIORITIZATION AND COLOR CODING OF ANNUNCIATOR WINDOWS

Priority	Color		Definition
First Priority	Red	-	Plant shutdown (alarms that follow a reactor trip or cause plant shutdown)
		-	Radiation release
		-	Plant conditions requiring immediate operator action to prevent automatic plant shutdown, radiation release, or the need for manual shutdown
Second Priority	Amber (Yellow)	-	Tech. spec violations which will require plant shutdown if not corrected
		-	Plant conditions which will, if not corrected within a reasonable time cause radiation release or plant shutdown
Third Priority	White	-	Plant conditions representing problems (e.g. system degradation) which affect plant operability but should not lead to plant shutdown, radiation release, or Tech. Spec. violations
Safeguard Priority	Greenish -Blue	-	Alarms associated with actuation of engineered safeguard systems 2

TABLE 18.0-4

NORMAL ALARM SEQUENCE OF ANNUNCIATOR SYSTEM

Condition	Operator Action	Field Contact	Window	Alarm Audible	Ringback Audible
Normal	None	Close (or Open)	Off	Silent	Off
Alarm	None	Open (or Close)	Flashing	Sounding	Off
Alarm	"Silence"	Open (or Close)	Flashing	Silent	Off
Return to Normal Before Acknowledge	None	Open (or Close)	Flashing	Silent	Off
Alarm	"Acknowledge"	Open (or Close)	On	Silent	Off
Alarm	"Acknowledge"	Close (or Open)	Slow Flashing	Silent	On(*)
Return to Normal After Acknowledge	None	Close (or Open)	Slow Flashing	Silent	On(*)
Normal	"Reset"	Close (or Open)	Off	Silent	Off
Normal	"Test"	Close (or Open)	Flashing	Sounding	Off

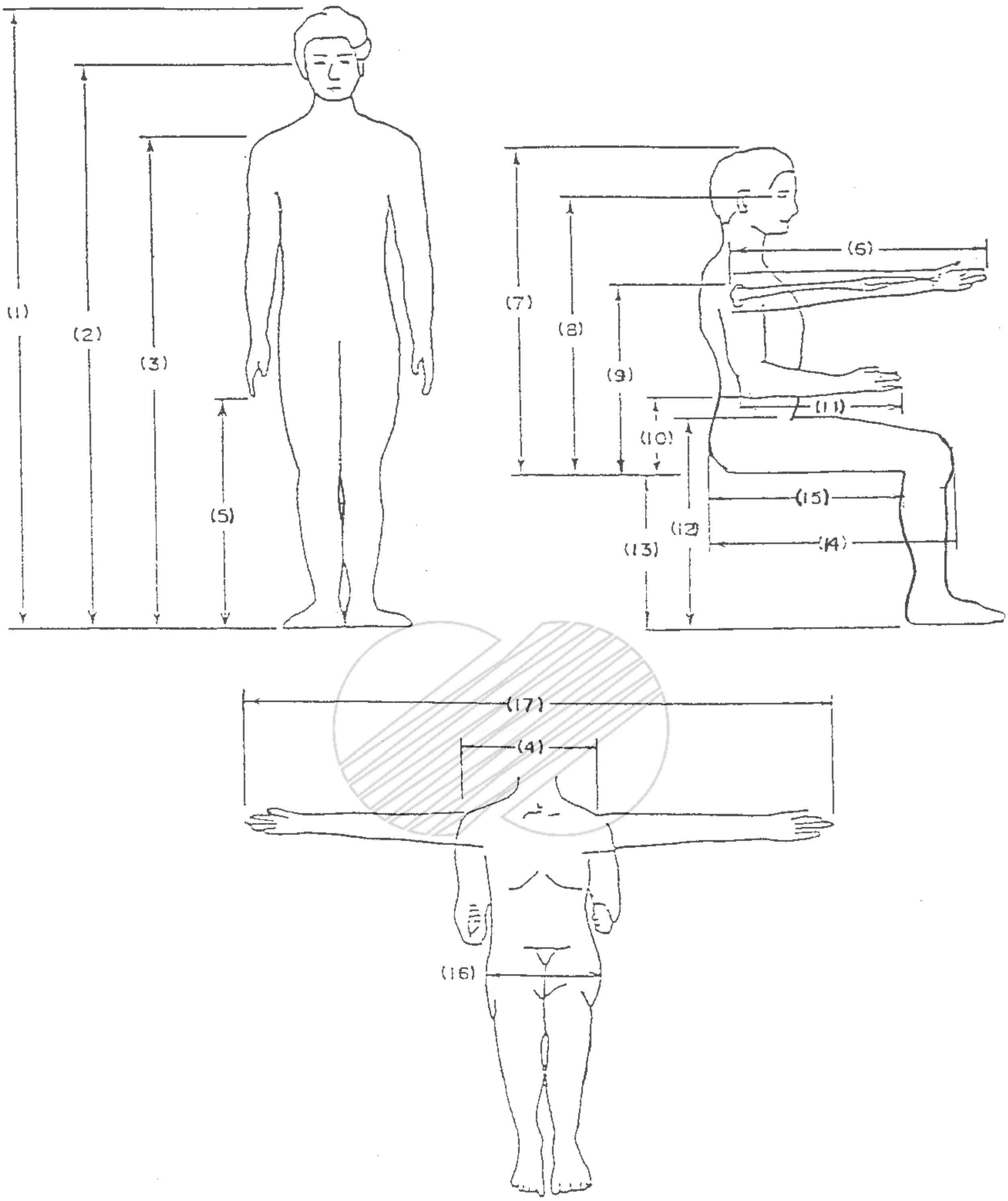
---

* Single chime stroke

TABLE 18.0-5

FIRST-OUT ALARM SEQUENCE OF ANNUNCIATOR SYSTEM

Condition	Field Contact	Window	Alarm Audible	Ringback
Alarm	Abnormal (First Alarm)	Fast Flashing	Sounding	Off
Alarm	Abnormal (Subsequent)	Flashing	Sounding	Off



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STANDARD PHYSICAL MEASUREMENTS

Figure 18.0-1

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90TH PERCENTILE OF KOREAN MALES LOS (LINE OF SIGHT) AND FUNCTIONAL REACH CAPABILITY OF YGN 3&4 MAIN CONTROL PANEL

Figure 18.0-2

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10TH PERCENTILE OF KOREAN MALES LOS
(LINE OF SIGHT) AND FUNCTIONAL
REACH CAPABILITY OF YGN 3&4
MAIN CONTROL PANEL
Figure 18.0-3

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90TH PERCENTILE OF KOREAN MALES LOS
(LINE OF SIGHT) AND FUNCTIONAL
REACH CAPABILITY OF YGN 3&4
AUX. OPERATOR'S CONSOLE
Figure 18.0-4

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10TH PERCENTILE OF KOREAN MALES LOS
(LINE OF SIGHT) AND FUNCTIONAL
REACH CAPABILITY OF YGN 3&4
AUX. OPERATOR'S CONSOLE
Figure 18.0-5

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CONTROL PANEL, SYSTEM ARRANGEMENT

Figure 18.0-6

Amendment 326
2006.08.09

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YONGGWANG 3 & 4 FSAR

BOARD ELEVATION (PMOJ)
HVAC SECTION

Figure 18.0-7

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[redacted] 7-3(Sh. 18 of 18)
[redacted] J161-002

[redacted]

Amendment 432
2009. 3. 4

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BOARD ELEVATION (PM02J)
MISCELLANEOUS SECTION

Figure 18.0-8

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BOARD ELEVATION (PM03J) : ESF SECTION
(Sheet 1 of 2)

Figure 18.0-9

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Amendment 204
2001.12.28

204

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BOARD ELEVATION (PM03J) : ESF SECTION
(Sheet 2 of 2)

Figure 18.0-9

Amendment 370
2007.12.12

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YGN 3 & 4 FSAR

BOARD ELEVATION (PM04J)
CVCS & RCS SECTION

Figure 18.0-10

Amendment 2
August 1995

18)

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BOARD ELEVATION (PM05J)
RCS SECTION

Figure 18.0-11

Amendment 2
August 1995

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
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BOARD ELEVATION (PM06J)
RX CONTROL AND PROTECTION SECTION

Figure 18.0-12

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관련 도면목록 : Table 1.7-3(Sh. 18 of 18)

관리도면 [redacted]

Amendment 486
2010. 5.17

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BOARD ELEVATION (PM07J)
AUX. FW/MAIN STEAM SECTION

Figure 18.0-13

Amendment 438
2009. 4. 30

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BOARD ELEVATION (EM080)
CONDENSATE & FEEDWATER SECTION

Figure 18.0-14

Amendment 399
2008.9.5

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BOARD ELEVATION (PM09J)
TURBINE & AUXILIARIES SECTION

Figure 18.0-15

Amendment 288
2004. 12. 21

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BOARD ELEVATION (PM10J)
SITE AND AUXILIARY POWER SECTION

Figure 18.0-16

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관련 도면목...
관리도면 : ...

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BOARD ELEVATION (PM11J)
SITE AND AUXILIARY POWER SECTION

Figure 18.0-17

본 도면은 참고용 도면임
관련 도면목록 : Table 1.7-3(Sh. 18 of 18)
관리도면 : MCBE, 9-741-J161-012

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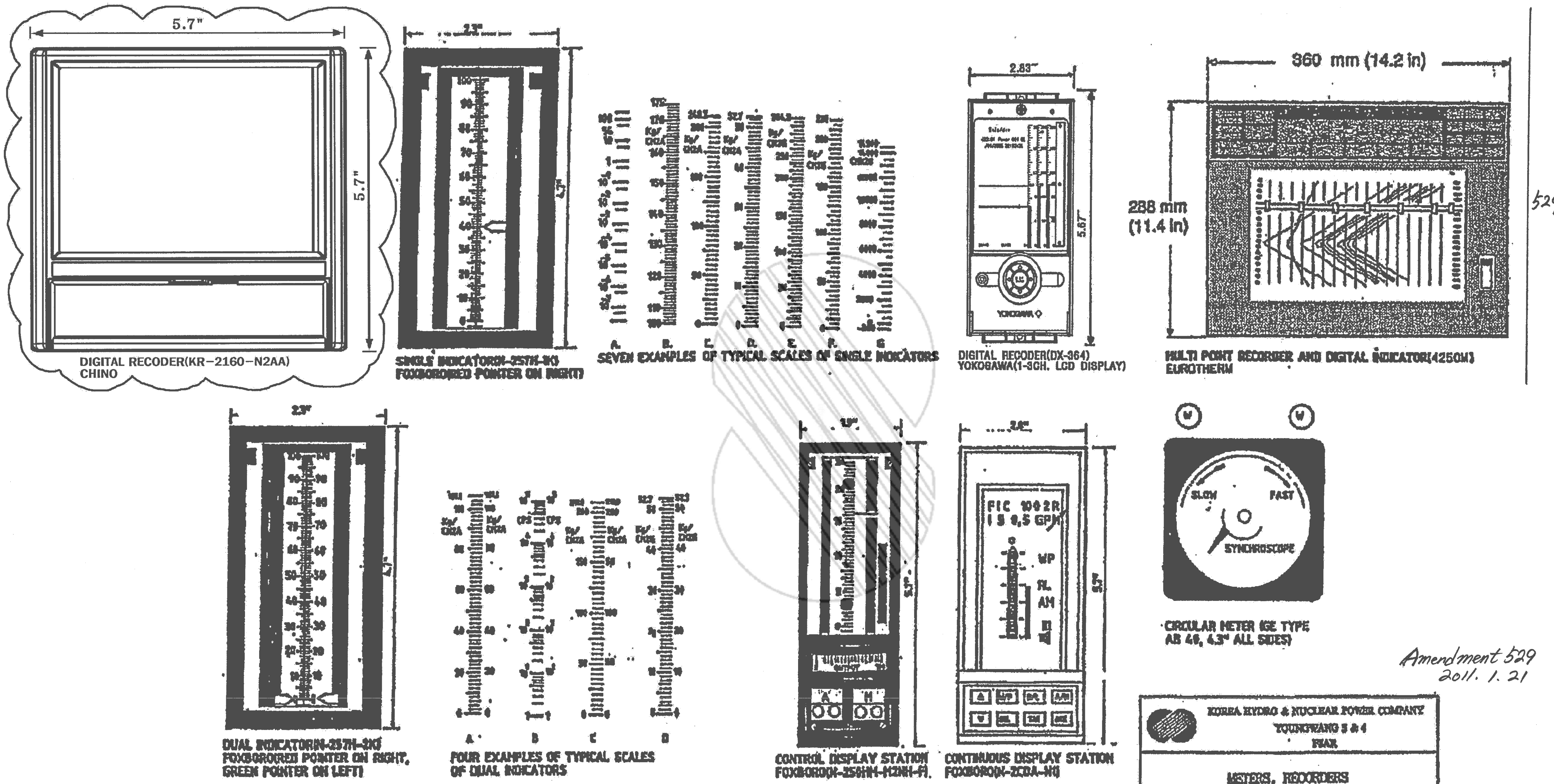
BOARD ELEVATION (PM12J)
FIRE PROTECTION SECTION

Figure 18.0-18



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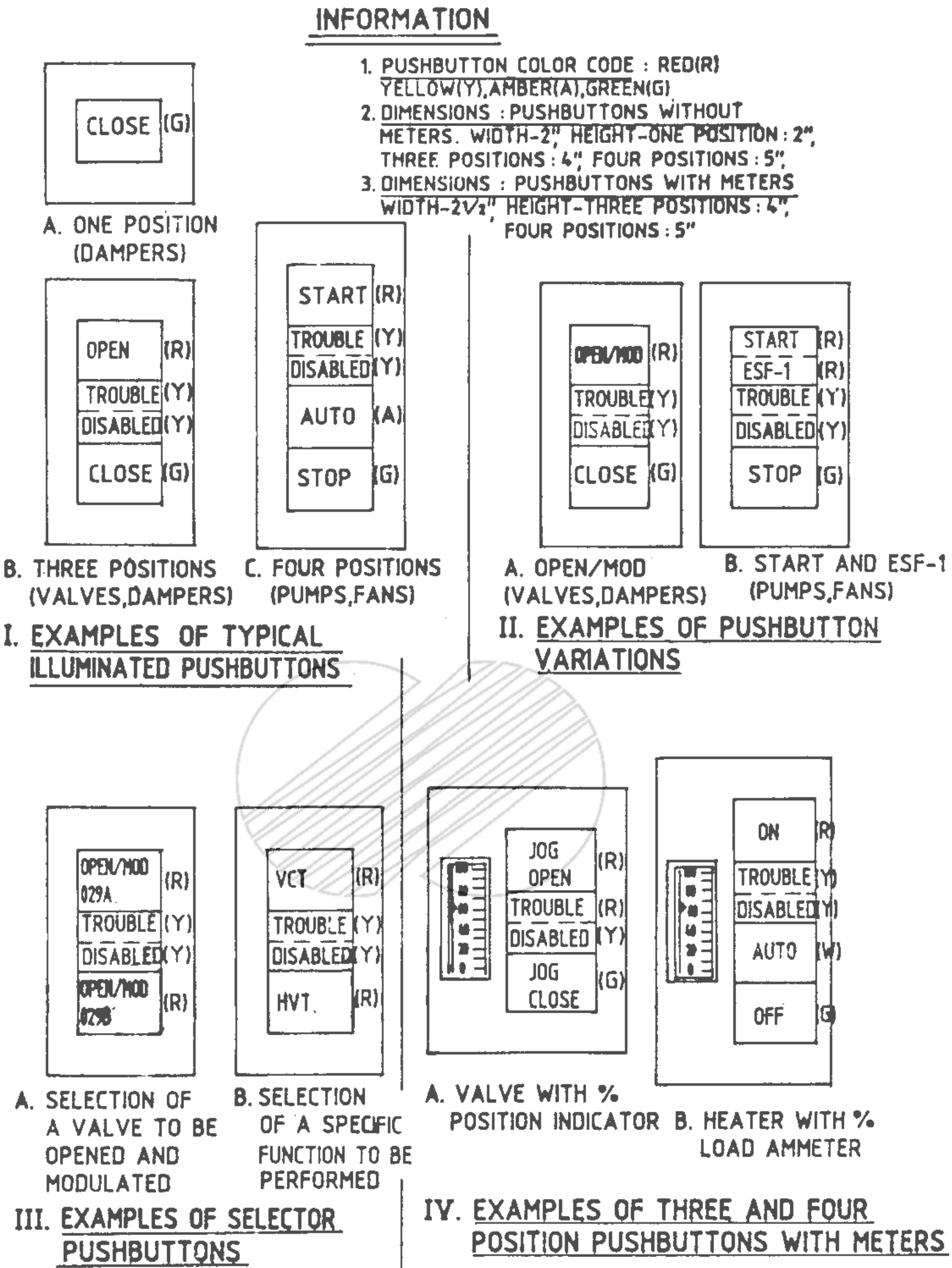
METERS, RECORDERS
AND CONTROLLERS

Figure 18.0-19



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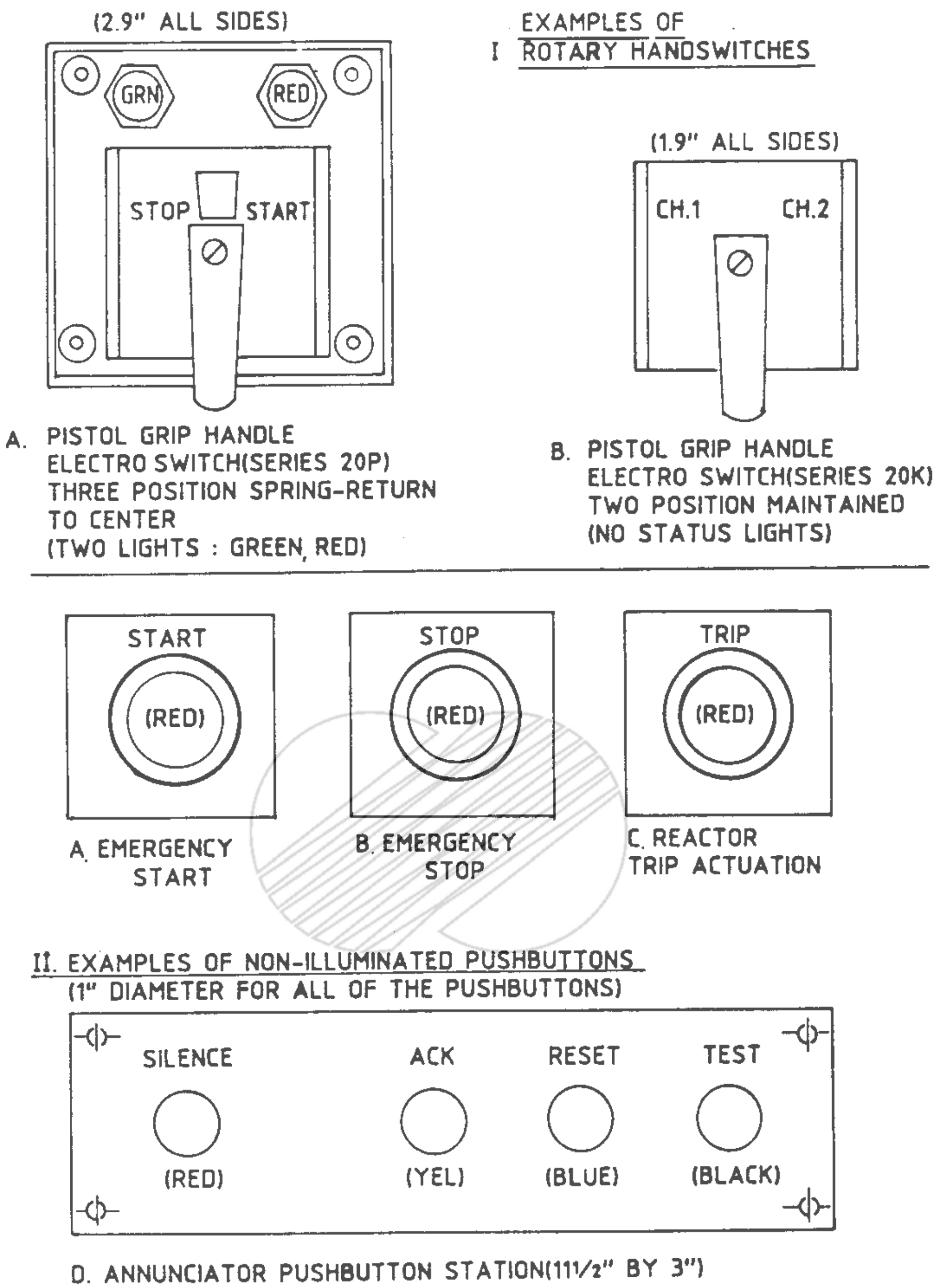
ILLUMINATED PUSHBUTTONS

Figure 18.0-20



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ROTARY HANDSWITCHES AND
NONILLUMINATED PUSHBUTTON

Figure 18.0-21

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MISCELLANEOUS CONTROLS AND DISPLAYS
(Sheet 1 of 3)

Figure 18.0-22

Amendment 383
2008. 3. 28

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MISCELLANEOUS CONTROLS AND DISPLAYS

(Sheet 2 of 3)

Figure 18.0-22

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Amendment 536
2011. 2. 10

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MISCELLANEOUS CONTROLS AND DISPLAYS
(Sheet 3 of 3)

Figure 18.0-22

SYMBOL

EXTERNAL FIRE HAZARD

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PLANT SITE (LOCATION OF CR, RS ROOM, TSC)

Figure 18.0-23

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(... of 18)

Amendment 467
2009.12.22

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CONTROL ROOM & COMPUTER ROOM

Figure 18.0-24

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TSC AND EOF FACILITIES

Figure 18.0-25

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REMOTE SHUTDOWN FRONT PANEL
LAYOUT CHANNEL B
(Sheet 1 of 3)

Figure 18.0-26

Amendment 2
August 1995

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REMOTE SHUTDOWN FRONT PANEL
LAYOUT CHANNEL A
(Sheet 2 of 3)

Figure 18.0-26

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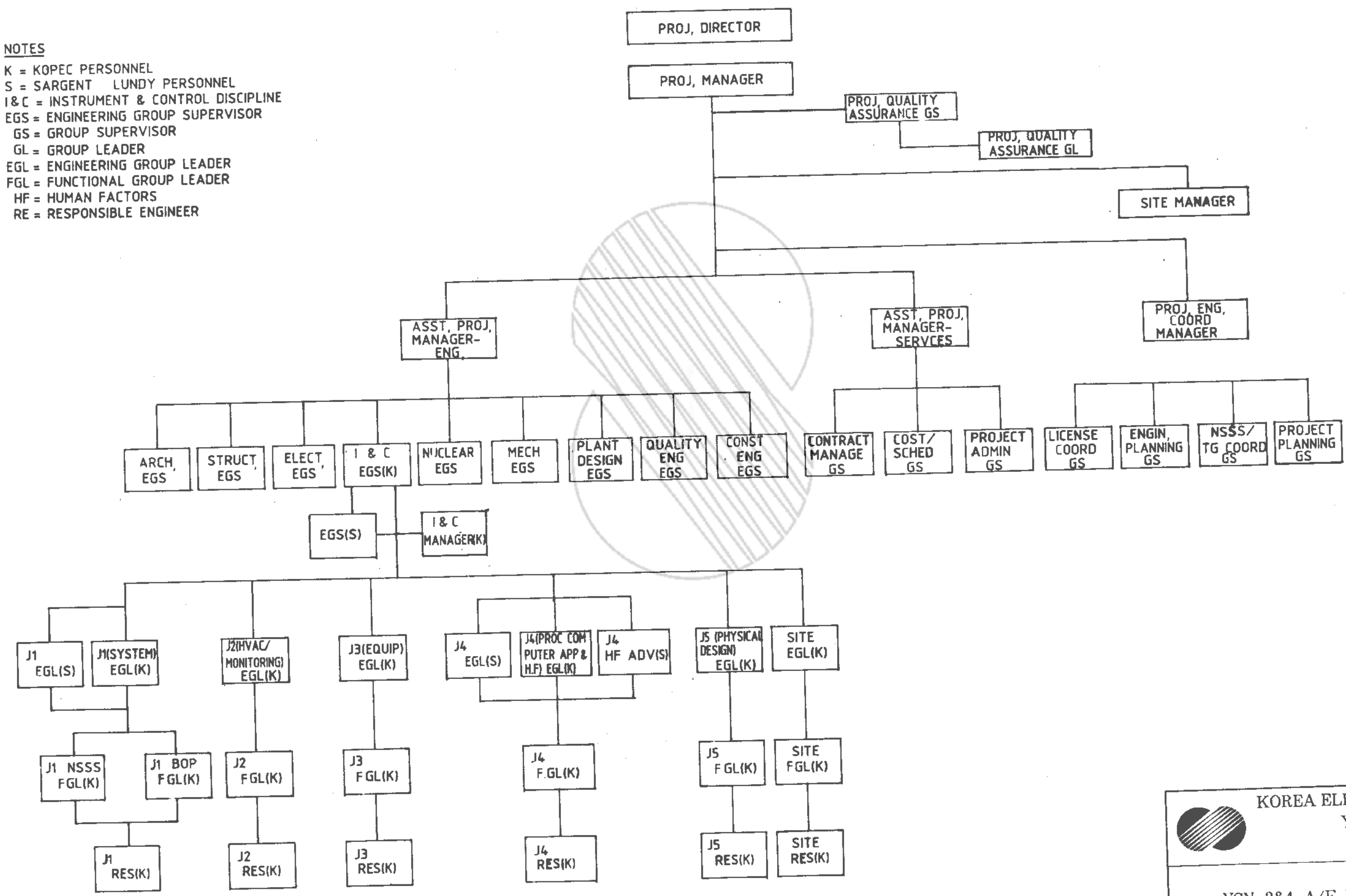
REMOTE SHUTDOWN FRONT PANEL
LAYOUT CHANNEL N
(Sheet 3 of 3)

Figure 18.0-26

YGN 3 & 4 PROJECT ORGANIZATION

NOTES
K = KOPEC PERSONNEL
S = SARGENT LUNDY PERSONNEL
I&C = INSTRUMENT & CONTROL DISCIPLINE
EGS = ENGINEERING GROUP SUPERVISOR
GS = GROUP SUPERVISOR
GL = GROUP LEADER
EGL = ENGINEERING GROUP LEADER
FGL = FUNCTIONAL GROUP LEADER
HF = HUMAN FACTORS
RE = RESPONSIBLE ENGINEER



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YGN 3&4 A/E PROJECT ORGANIZATION

Figure 18.0-27

18.1 CONTROL ROOM DESIGN GUIDELINES

The main control room (MCR) design at YGN 3&4 adheres to the principles of human factors engineering. (These principles are also applied to the remote shutdown panel and the SPDS as described in subsequent sections). Relevant requirements of General Design Criterion (GDC) 19 are met by assuring that man-machine interfaces are adequate for safe plant operation.

Human factors engineering design principles for the MCR include those outlined in Section 18.0. They are described at greater length in this section. Specific technical details, design criteria and guidelines are found in the YGN 3&4 Human Factors Engineering (HFE) Guideline Document. There are usually multiple specific methods of applying human factors principles to design. There are also ranges of acceptable equipment. For these reasons, the technical details in this section are subject to change based on discovery of better methods or products, design interface requirements, regulatory constraints, hardware availability, and other mitigating factors.

Human factors engineering addresses the efficient and safe operations of the control room from the operator's perspective. When making design changes in the control room, it is important to consider how the changes will affect the operator in terms of the availability of necessary information, the adequacy of controls for the tasks to be performed, the efficiency of the overall panel layout, and the suitability of the environment. The general guidelines and plant-specific conventions included in this section and the HFE guideline document breakdown these operator task requirements into specific criteria, providing a thorough and efficient method for reviewing design changes.

The main body of this section contains human factors design conventions adapted from NUREG-0700, as well as plant specific conventions to be utilized at YGN 3&4. The conventions are to be used by design engineers in generating control room design changes or when performing a human factors review.

Guidelines relating to computers (process, SPDS, etc) are not outlined in this section of the FSAR. However, the following subject material is outlined: control room workspace, environment, panel design and layout, visual displays, controls, annunciators, and enhancements. Additional information relating to the control room and its instrumentation (Subsection 18.0.4.6), control panel size dimensions (Subsection 18.0.4.5), basic instrument types (Subsection 18.0.4.10), and MCB arrangement and elevation drawings (Subsection 18.0.4.12) are found in the previous section.

18.1.1 Control Room Workspace

The layout of the control room is shown in Figure 18.0-6. The main control boards (MCB) form a horseshoe or U-shape pattern around the operator's console and shift supervision's desk. The operator's console is near the NSSS panels of PM03J through PM07J, and the shift supervisor's desk is midway between PM02J and PM10J. This layout allows for efficient traffic flow, and the peformance of all necessary tasks.

Each of the main control panels is divided into three sections due to varying slopes with the horizontal panel: benchboard, vertical section, and annunciator. The annunciator section is between 197 and 255 cm above the floor with a 17 degree slope from the vertical. The vertical section is between 97 and 197 cm above the floor. Within this section the status lights and digital indicators (which are located approximately above 170 cm) tend to be placed above the other controllers and displays (including analog indicators) of this panel section. Finally the benchboard section has an elevation between 75 and 97 cm with a 17 degree slope with the horizontal plane. The vertical section contains indication devices such as M/A stations, while the benchboard contains mainly control switches. The controllers and the indicators are integrated to reflect process flow as depicted with mimics.

18.1.1.1 Similarity Between Units 3 and 4

To the fullest extent practical, the YGN 3&4 control rooms are identical. However, there are some differences on the switchyard and electrical distribution controls, as well as other places where both units share common facilities. Both control rooms are to have identical floor plans, environments (temperature, humidity, lighting), system configurations, panel arrangements, and panel size and shape.

Documentation, labeling, nomenclature, and abbreviations for YGN 3&4 are also to be identical, whenever technical accuracy permits. This similarity includes Technical Specifications, plant procedures (emergency response, alarm response, normal operating, etc.), and other written guides; as well as the labeling format, letter height, width, nomenclature, color, and placement.

18.1.1.2 Mirror Imaging

Since mirror imaging can significantly increase the chance of operator error and lead to negative transfer of training, it is to be avoided. Mirror imaging of YGN 3&4 is not desired on any control panels in the main or remote shutdown control rooms. However where a mirror image represents the actual physical configuration and P&ID representation of a portion of a system, exceptions may be evaluated for acceptance on a case by case basis by HF experts. Further, mirror imaging on local control panels (for A and B trains of a process, for example) is not done within either unit.

18.1.1.3 Communications

The control room is equipped with sufficient communications gear to allow easy communication with the rest of the plant and offsite facilities; including the emergency operating facilities (EOF) via regular and emergency phones, sound powered phones, and the plant page system. The communications system is to be conveniently located, easy to use, and provide for all normal and emergency needs without interfering with the operation of the rest of the control room. This operability constraint includes the capability of communication equipment to be effective under the conditions of wearing anticontamination clothing, breathing air or face masks, or using an emergency power source. Besides the paragraphs that immediately follow, more information concerning the communications system (CQ) can be found in Subsection 18.0.4.18.

The plant page system has [redacted] for announcements and calling, and [redacted] for communication (discussion). Only the highest numbered paging channel is to be audible [redacted] loudspeakers. This channel is be designated by a special label on the handset. [redacted] and designated for use as follows: [redacted]

Eight or more normal telephones are provided [redacted] for local and/or long distance calling. Phones are "touch tone" to provide maximum feedback to operators, and they are of the highest quality (low static, interference, and maintenance). Phones are placed to facilitate use by operations and engineering personnel. One on the drawing table, two each on the operator's console and shift supervisor's desk, and three at the technical advisor's workstation area are provided. [redacted] at a minimum.

Direct telephones are provided at a centralized work location [redacted] in order to facilitate contact with regulatory groups, the Korean Ministry of Science and Technology, and offsite technical support. A hot line system is used for direct communication with [redacted] Other special communication links, as required by the client, are included.

Sound-powered phones and microwave telephones are to be installed as needed by KEPCO. As a minimum, 11 jacks for sound powered phones are distributed [redacted], plus one on the [redacted] Jacks are provided for the auxiliary console and the shift supervisor's desk. In all cases, phones, radios, and other communications gear comply with the sound characteristics given in EPRI NP-3659.

18.1.1.4 Habitability

The control room has safety HVAC systems and other protection to assure that it is habitable under all plant conditions of toxic gas, radiation, and smoke (except for those control room evacuation situations called out in regulatory requirements defined in 10 CFR 50 Appendix A, General Design Criteria 19, NUREG-0737 Supplement 1, and discussed in Section 6.4 and Chapter 14). Toxic gas limits are defined in Regulatory Guides 1.78 and 1.95.

18.1.1.5 Access and Egress

Access to MCBs is controlled by an owner defined waiting area beyond which visitors may not enter without shift supervisor approval. Access is restricted to prevent excess traffic and noise. All plant staff not normally assigned to the main control room are considered visitors. Suggested visitor area delineators are rope, railing, or floor color. Viewing windows are provided so that "lay" visitors need not enter the control room. These viewing windows do not extend from the ceiling to the floor, but begin approximately one meter from the floor and are designed in accordance with applicable standards and criteria (such as seismic, structural, and fire considerations).

Access to the control room region (MCR, kitchens, restrooms, Shift supervisor's office, etc), is via a keycard or similar security arrangement. Control room egress is restricted by locked doors. Egress from the control room region, if normally accomplished by keycard, is to be automatically passable in emergency conditions. Access and egress ways from the RSP and control room are four feet wide at a minimum in order to permit two individuals to pass at all times.

18.1.1.6 Storage Space

Adequate, accessible storage space for all required documents, drawings, and equipment are provided. It is recommended that cabinet space be provided beneath the visitor windows and at the shift supervisor's workstation for this purpose. Controlled copies of all current plant normal and emergency procedures are located in the control room, and in the remote shutdown rooms. Copies of the EOPs are located in a binder, clearly identified, on a procedure rack at or near the operators' desk. Drawings, as needed by operators (including a full set of P&IDs, Logics, and C&IDs), are to be kept available on a dedicated drawing table large enough to accommodate A0-sized pages. Drawings are attached to a standard drawing mount of equivalent size so that they may be easily flipped through. These drawings are also available at the RSP. The main control room is equipped with adequate file cabinets and bookspaces to accommodate Technical Specifications, reference manuals, and other similar documents. The wall section below the visitor's window is dedicated to storage space.

Adequate space also is provided for keys, hardhats, coats, and flashlights as well as other normal operator equipment and belongings at the main control room, RSP, and computer room. A one week supply of necessary recorder paper, light bulbs, and similar support items are kept in these rooms. In addition, air packs, emergency breathing air system masks, emergency apparel, fire equipment, and similar emergency equipment also have adequate and immediately accessible storage space in the main control room or in an immediately adjacent unlocked area. Inventory of emergency equipment is facilitated by its storage in an orderly area.

18.1.1.7 Maintenance Activities

The control room panels, layout, and environment support normal maintenance activities and minimize disruption of operators. Panels are free standing, have access from the rear, are easy to open, have internal access to the best extent practical, and have no obstructions from fire separation barriers, seismic supports and internal cable raceways. Permanently installed lighting is provided inside the main control panels. In addition, convenience outlets are provided for powering portable temporary lighting that may be required periodically for maintenance. Details on interior lighting may be found in the MCB procurement specification. In addition, provisions are made to assure that the MCB area is accessible for larger, one-of-a-kind maintenance tasks.

18.1.2 Control Room Environment

The control room environment provides comfortable ambient surroundings for operators under all plant conditions, and have the capability of being maintained within comfortable humidity and temperature envelopes. Aspects of the environment are adjustable from within the control room.

18.1.2.1 Auditory Environment

Background noise is low enough so that all annunciators and other auditory indicators are clearly distinguishable, and easy communication between operators is possible. Maximum ambient noise is not to exceed 65 dB inside the MCB ring (the area circumscribed by the MCB) at peak times, such as immediately following a reactor trip or when visitors are present. The normal ambient noise level inside the MCB ring is 60 dB or less. This guideline also holds true in the RSP area. Computer room noise levels are 55 dB or less, while the decibel levels of annunciators is limited but adjustable to greater than 10 dB above the mean background noise level. All readings are in dB(A). Sources of background noise are controlled: by limiting individual access to the control room through the use of locked doors, key card usage, and shift supervisor's permission; by reducing noise levels through the use of noise control devices and sound absorbent properties; and by restraining unnecessary plant page usage in the control room.

18.1.2.2 Illumination

Illumination is sufficient in all areas to perform necessary tasks in a safe and accurate manner, but not so high as to cause serious glare problems. lighting levels are in accordance with NUREG-0700, Illumination Society Guidelines, and EPRI NP-3659. These levels are depicted in Table 18.1-1. These levels vary greatly over a given workstation, and supplemental lighting is provided for personnel performing specialized visual tasks in areas where fixed lighting is not adequate.

Illumination level is defined as the amount or quantity of light falling or a surface, while luminance (or brightness) is a measure of the amount of light emitted or reflected from a certain area of a surface. The task area luminance ratios are given in Table 18.1-2. Reflectance is a measure of how much light is reflected from a surface. Stated another way, it is the ratio of the luminance of a surface to the illumination on the surface. The permissable reflectance levels are depicted in Table 18.1-3.

Emergency lighting is an alternate system that is activated in case of a power failure, and is independent of any other plant lighting system that is available in the control room. Emergency lighting is activated automatically and immediately upon failure of the normal control room lighting system, whose failure does not degrade operability of the emergency lighting system. Auxiliary ac lighting provides light to designated egress ways, equipment, and the control room at normal ac illumination levels when possible. These lighting levels exceed or are equal to the minimum battery pack levels specified below. Battery packs, on the other hand, provide light to the remote shutdown panels (RSP) and main control room at minimum levels between 10 to 30 footcandles.

Glare is kept low enough so that CRT screens, lit annunciator tiles, backlit indicators, labels, glass, plexiglass, and plastic-faced indicators, plus drawings and documents are easily read. The following steps are taken to control glare:

a. Use low reflectance wall material, low glare and matte finish floor material, ceiling light diffusers, and low glare label material.

b. Specify flat black or grey color, and textured surfaces on vendor hardware (for example, metal meters and recorders).

c. Paint control panels with semigloss or below.

d. Prevent light from falling on CRT screens.

18.1.2.3 Humidity, Temperature and Ventilation

The heating, ventilation and air conditioning (HVAC) system maintains a clean air quality with humidity and temperature levels constantly within human comfort ranges. The following criteria are met in the control room.

a. Normal mean temperature is selected at a value between 70°F (21°C) and 77°F (25°C).

b. Temperature difference from head level to floor level does not exceed 6°F (3.3°C).

c. Control room, computer room, and RSP rooms are maintained at 40-60% relative humidity.

d. Humidity levels are not adversely impacted by seasonal/climatic fluctuations. Therefore, humidification is required in winter months and dehumidification in warmer months.

e. HVAC ducts are designed such that hot or cold air does not blow directly on operators.

f. Control room HVAC is capable of introducing at least 15 cfm (0.42 m^3/min) of air per MCR occupant, based on up to 15 occupants.

g. Air velocity does not exceed 45 ft/min measured at head level. The control room is free of noticeable drafts.

18.1.2.4 Operator Comfort

Operators spend long periods on duty; sitting and standing, using restrooms, eating and drinking. These activities are carried out in comfort, without causing undo absence from the control room. For example, operators are able to obtain water, coffee and preferred beverages without leaving the general control room envelope; while the restroom facilities for operators are near the main control room. Their seats are comfortable for long periods, high enough to view indicators, and placed outside of traffic flow patterns.

18.1.3 Control Panel Design and Layout

The equipment is designed to meet the requirements of the 10th to the 90th percentiles of the Korean male population between the ages of 20 to 50 years. The anthropometric data relating to this population are contained in Table 18.0-1 and Figure 18.0-1. The main control panels are designed for standup operation. In positioning controls for standup operation, the range of suitable control height is within the reach radius (functional reach) of the 10th percentile users. The principal factors affecting the readability of displays are:

a. Display height and orientation relative to the operator's line of sight (LOS) when he is directly in front of the display.

b. Display distance and orientation relative to the operator's straight-ahead LOS when he must read the display from an off-side position.

c. Size of the display markings relative to the distance to be read. Figures 18.0-2 and 18.0-3 depict the Functional reach and line of sight (for vertical orientations) of the 10th and 90th percentiles on the YGN 3&4 main control panels. From these figures, it is evident that the criteria for the display height and orientation, and for the functional reach are met; as outlined in NUREG-0700. For example, all of the displays are mounted within the upper limit of the visual field above the horizontal line of sight), and the angle from the line of sight to the face plane is equal to or greater than Also, all of the controls can be reached within the vertical plane.

Figures 18.0-4 and 18.0-5 depict the functional reach and line of Sight for the 10th and 90th percentiles on the YGN 3&4 auxiliary operator's console or sitdown console. Display positioning follows the same guidelines as these for the standing operator except they are now measured from the seated position. The controls must be within the reach radius of the 10th percentile users. Inspection of these figures indicate that the criteria for the display height and orientation, and for the functional reach are met.

The main control room panels conform to the following dimensions, which are als depicted in Figures 18.0-2 and 18.0-3:

a. Benchboard height is [redacted]. Benchboard begins above standing knee position. Height chosen is the 90th percentile knee height plus [redacted]

b. Benchboard angle is needed to accommodate dimensions shown (HF criterion is [redacted]. For YGN 3&4 this angle is equal to [redacted]

c. Basic depth (front of backboard to rear of panel) does not exceed [redacted] (for ease of maintenance).

d. Lean barrier (front of panel just below benchboard section) is [redacted] to lessen an operator's chance of inadvertantly actuating the controls while leaning and to prevent injury from uncomfortable sharp edges.

e. Benchboard depth is chosen to assure that the operators can reach the backboard easily, based on the arm length or functional reach (shoulder to fingertip) of the 10th percentile male. Based on this, depth is [redacted]

f. Vertical section height is chosen to assure that the operators can reach the topmost controls on the backboard, based on the standing arm length or functional reach (shoulder to fingertip) of the 10th percentile male.

g. The annunciator windowbox is located at approximately [redacted] above floor level. This dimension is based on a [redacted] maximum allowable viewing angle in NUREG-0700 and the eye height of the 10th percentile male.

h. The panel height is based on desired ceiling height for the MCR. The HF principle is that minimum ceiling height is [redacted] greater than the operators' view of the highest indicator, in order to avoid the operators from looking directly into the ceiling lighting. Based on this, total height of the panels is to be [redacted].

i. Top of annunicator windowbox is [redacted] greater than the indicator height to allow a margin for alarm labels.

j. Facade height = total height of panel - top of windowbox height or [redacted]

k. Vertical panels, such as the RSP, do not have any controls below [redacted] above the floor, and no indicators except alarms above [redacted]

For the location of components above the floor for vertical panels, such as the remote shutdown panels and other local panels, the height guidelines that are to be followed are :

	Controls Min-Max	Displays Min-Max
Components used frequently or precisely	91 - 135 cm (36 - 53 in.)	127 - 170 cm (50 - 67 in.)
Components having normal usage	91 - 178 cm (36 - 70 in.)	107 - 183 cm (42 - 72 in.)

The following paragraphs discuss the internal arrangements of the panels components.

18.1.3.1 Panel Consistency and Standardization

Panels are consistently laid out to reflect system operation and functional mimic flow paths. Standardized hardware types are used throughout the main control room. For each type of control function or indicator function, only one hardware type is used. For example, all controls for breakers are the same model. This does not mean, for instance, that all recorders are the same. It means that all recorders which perform a similar function (e.g., trend data for a linear variable from five input points, over a certain range and frequency of reading) are of the same model. Consistency between NSSS-supplied and BOP hardware also are maintained, where practical. Layout also is consistent with regards to the relationships between components. For example, banks of meters, if set up in a certain configuration in one section of the panels, are the same on other panel sections.

18.1.3.2 Display and Control Groups

Related instruments and controls are grouped together and arranged to reflect system process. These components make use of spacing and clustering to represent functional and operational groups. Related indicators are placed adjacent and related process controls are in proximity to each other. For example, components for each system are integrated and grouped below relevant alarms. In general, annunciators are at the highest panel elevation, status lights and LED meters below them, and other controls and indications either on the benchboard of the panel or located below the 170 cm elevation on the backboard.

System controls and indicators are integrated to reflect process flow through the various plant systems of YGN 3&4. Actual flow lines between instruments and controls are shown on the main control boards using mimic lines. Uncomplicated systems with only a few components do not need line mimics. General arrangement of mimic flow is from top to bottom. Within this arrangement, left to right is used. In some cases, complex flowpaths may require some backtracking (right to left, or bottom to top), but the general flowpath is top to bottom and left to right.

Hardware is arranged on the control panels so as to blend displays and controls in a manner that reflects process flow through the system. For example, pump and valve controls reflect their relative locations in the flowpaths in the plant with relevant indicators, such as discharge pressure and flow located adjacent to these controls. This type of arrangement is not done for small, uncomplicated systems that have only a few controls and indicators.

18.1.4 Visual Displays

Visual displays are easy to read, unambiguous, easy to maintain, and they provide needed, relevant information. Displays are selected using the criteria outlined below:

a. The capability is provided to distinguish significant levels of controlled system parameters.

b. Actual system/equipment status is displayed for all important parameters.

c. Displays identify whether they reflect demand or actual status.

d. The required level of reading accuracy is provided.

e. The operator receives feedback for any deliberate movement of a control.

f. Optimum visibility is ensured by making it easy to locate and to read, without parallax, from the operating position.

g. There should be no time lag between a system condition change and the display indication. However, if there is a time lag between control actuation and ultimate system state, there is an immediate indication of the process and direction of the parameter change.

h. Redundancy is limited to cases where it is needed for backup or to avoid excessive operator movement.

Visual displays are arranged to fit into mimics when possible. When banks of indicators are used, they reflect an organization which is clear to the operators, such as all indicators for one tank or multiple indications of the same variable. Banks of indicator lights are arranged to accurately reflect system train (A or B) or operation sequence. Horizontal arrays are preferable to mimic process flow, rows of lights indicating flow are located horizontally when practical. When possible, indicator lights are set into process flow mimics, and are located close to (preferably immediately above) relevant controls.

18.1.4.1 <u>Indicating Lights</u>

Indicator lights are easy to maintain, and easy to see against background lighting and glare. The indicating lights are at least 10% brighter than the surrounding panel, which can be clearly recognizable under the highest predicted ambient light conditions. A supply of indicator bulbs and light emitting diodes (LEDs) are kept in the control room for routine replacements. Bulbs and LEDs are replaced as soon as they are discovered to have burned out or become defective. LEDs have replaced indicator bulbs as much as possible because of their longer service life.

Color coding provides clear status information on lights and is derived from lens color, and not by a layer of colored material inside the cover. Color coding for indicator lights is as follows: Red connotes equipment or process operating, or the flow of energy (open, running, on); Green means the equipment or process not operating, or the nonflow of energy (close, stop, off); White or Yellow represents a trouble/disable condition or an abnormal operating situation; and Amber has numerous meanings of less critical operator information or attention (ESF actuation, AUTO).

Lettering and wording are clear, consistent, and readable under all conditions. The letters are sized so as to subtend a sufficient number of degrees of visual arc for ready comprehension. Nomenclature is consistent for standard words or all indicators. Legends and component names are not only to be engraved on indicators, but on labels so that the control name is visible even when bulbs are burned out or power is lost.

18.1.4.2 Meters and Recorders

Meters are easy to use, and they are accurate and unambiguous under all conditions. Recorders are easy to use and maintain, and contain features allowing precise readings. Meter scales have clear divisions, which are nonlogarithmic and utilize major, intermediate and minor scale divisions. All scale divisions are in 1's, 2's, 5's or 10's (preferably 1's or 10's). Scales are in units preferred by operators for interpreting the variable. Metric units are used on all meters and indicators. Scales begin and end at major scale divisions and are consistent with range limits. Log scales are permissable for certain power meter and radiation level applications. Exceptions to this practice may be individually evaluated based on technical considerations.

In the event of power loss, meters fail to zero or offscale. Meter power supply is noted on the label, if meters receive emergency power from different sources. That is, if there are conditions where some control room meters are powered and others are dead, the operator has an indication of the power supply.

Other pertinent information relating to meters and recorders is described below:

a. Meters are equipped with red pointers for easy viewing and contrast with the meter scale. Bright green as a second pointer on dual meters is also used.

b. Multiscale meters (including dual) may be applied where such devices have operational benefits, such as data comparison, or a control board arrangement that is benefited by their use.

c. Meters and recorders are designed for easy calibration and maintenance. Paper is easy to change on recorders as, is ink sacs and pens.

d. All multipoint recorders have digital readouts as well as pen tracks.

e. Meters and recorders have glare resistant or treated (sprayed) faces, unless lighting tests are performed to determine that the covers are not necessary. Indirect lighting reduces glare, and the light source is not within 60° of the operator's visual field. Glare treatment does not inhibit easy use of the devices.

18.1.5 Controls

All controls are easily discriminated, standardized across function, grouped according to function and generally within system, and chosen with good human factors incorporated into the hardware. In addition, they are chosen and located in order to facilitate rapid, easy, and error-free use.

Controls are arranged to avoid operator confusion and to accurately mimic system flow. They are located so as to allow adequate room for plastic mimic lines and hierarchical labeling. The number of controls and their use are chosen to support the results of function and task analyses, and to accurately reflect genuine process control needs. Primary controls (such as reactor controls, frequently used controls, and safety system key controls) are in easy-to-reach locations on the MCB benchboard or lower vertical section. These controls are located on the MCB sections that are close to the center of the main control room. Controls with handles are not located within 10 cm (from the bottom of the control handle) of the edge of the panel (to prevent inadvertent activation).

18.1.5.1 Coding and Types of Controls

Controls are functionally coded such that valve, pump, breaker, annunciator, trip and actuation, and reactor controls are all readily discriminated. A combination of methods such as enhanced mimics, hardware types, location, and color coding are used to accomplish this . For example, fan and pump controls have blue bezels, while other controls (such as breakers and valves) have black bezels. All control types are standardized to function. That is, if a pushbutton control switch is used for one type of task, such as valve operation, it is used for that task in all instances.

Specific information relating to the different types of controls are described below:

a. Pushbutton controls have easily removable covers for bulb or LED replacement. As a general practice, pushbutton controls are vertically aligned. Legends are readable under ambient light conditions, regardless of internal illumination.

b. All rotary control knobs incorporate the following features: good control resistance, grooved or textured edge, a 2.5 cm minimum diameter, and clear linear scale markings (a detent at each position if possible).

c. Toggle switches, levers, partial rotation controls, slide switches and rocker switches (as well as pushbuttons, rotary controls, and J-handle controls) conform to human factors criteria for size and shape.

Except for the main control room and the remote shutdown panels, and AAC control panel, no other controls in the two units are in the scope of Chapter 18 or NUREG-0800.

18.1.5.2 Prevention of Inadvertent Activation

To prevent accidental activation of any controls, the main control boards include limiting the use of J-handle controls, setting the controls away from the control board edge, and designing the panels with a flat vertical edge below the benchboard to inhibit overhanging. Restricted use controls have barriers to prevent inappropriate actuation. These controls use either protective housings, hinged shields, or keylocks, in order of preference. The method utilized depends on the need for rapid operator access, and the seriousness of consequences following an accidental activation. The following devices are used at YGN 3&4:

a. Protective housings are a type of control in which a round pushbutton has a guard on its side but not on its top. This prevents inadvertent actuation, but does not cause the operator to take extra action or pause. These housings are used on manual trip buttons, such as reactor manual trip and turbine manual trip.

b. Hinged shields are transparent plastic covers, which are placed over a control for the purpose of causing the operator to pause and to think, as well as to prevent accidental actuation. This type of switchguard is used only when called out by administrative procedure. These guards have the hinged shield anchored so that the operator does not have to hold the shield up while operating the control (the shield hinge takes control panel slope into account so that the hinged shield does not fall open nor stay closed). Lock wires are not to be used on these shields.

c. Keylocks are used only when access must be restricted, and there is a real danger of unauthorized use of the controls. Keylocks use double sided teeth on the keys, and have "up" as the locked position for the control. Keys are only removable when the switch is locked, and are available at all necessary times in a timely fashion from a well-marked controlled repository.

18.1.6 Annunciators

Annunciator system is the primary control room interface to immediately alert the operator to out-of-tolerance changes in plant conditions. The annunciator warning system consists of three major subsystems: an auditory alert subsystem, a visual alarm subsystem, and an operator response subsystem. Together, these three subsystems are designed to provide a preferred operational sequence for annunciator warnings. Additional information relating to the alarm sequence can be found in Table 18.0-4. Control room annunciators follow good human engineering design criteria in order to be immediately and correctly noticed, accurately responded to in a timely fashion, easily acknowledged and reset, and easily discriminated. Annunciator hardware should not be field-adjusted in an uncontrolled manner.

Alarm signals have adequate decibel (dB) levels to be heard above mean background control room noise levels. Alarm signals are coded by location and tone quality to reflect the region of the control boards on which the alarmed annunciator tile is located.

Annunciator horns are easily heard and discriminated by zone, using frequency and modulation (as well as tone). At least six annunciator horns (generators) are used within the YGN 3&4 control rooms; each alarm zone (a maximum of four tone types) is to render a different sound by means of varying the signal/noise ratio, center frequency, and frequency and modulation codes. This information is contained in Table 18.1-4. Intensity levels are adjustable to a minimum of 10 dB above ambient noise levels. Ambient noise levels, under power operation, are measured by the utility prior to making this adjustment.

Before plant operation, signal type assignments are field tested with operators. Main control room annunciator hardware is provided with adjustable signals (horn, warble, chirp, chime, hi-lo, etc.) so that they may be field adjusted. Field adjustment, after startup, is carefully controlled by the utility.

Annunciators are grouped by function and system. Windowboxes for the relevant system are located above related controls. The annunciator system is labeled by column to reflect subsystems, A and B trains, and similar system divisions whenever practical. Alarms are identified by their position in the row by column matrix. The matrix rows and columns reflect information on system and problem. Columns reflect systems when possible, and rows display common trouble types. For example, A and B train alarms for a system are in adjacent columns, while alarms for identical pump trips are in rows. Designators are numbers 1-n for rows and letters A-Z for columns.

The control room alarm system has four discriminable controls : a global silence, and zone-oriented acknowledge, test and reset buttons. The four controls are pushbuttons of large (2 cm or greater) diameter. The global silence button is spaced a minimum of 2 inches apart from the others. These pushbuttons are located (in most cases) in the center of the panel near the lower edge of the benchboard section. Annunciator controls are separated by demarcation from the other controls on the panel.

Additional information relating to the Annunciator System can be found in Subsection 18.0.4.19. The following paragraphs are more specific to the operation of the annunciator system; such as prioritization, flash rates, labeling, multi-point windows, "dark board" concept, periodic testing, out-of-service windows, and alarm procedures.

18.1.6.1 Color Coding and Prioritization

A prioritized color coding scheme is used to assist the operator to identify key alarms and to respond in a timely fashion: First Priority is a red tile (reactor trip, plant shutdown, radiation release, immediate operator action), Second Priority is an amber or deep yellow tile (Technical Specification violations or other conditions which could lead to a plant shutdown or radiation release), Third Priority is a white tile (degradation of system function requiring monitoring or corrective action, which does not lead to plant shutdown). Additional prioritization codes are given in the placement of alarms in each windowbox, and in the use of an engraved marking on each key alarm window tile. For example the following vertical hierarchy is used: Reactor and Engineered Safety Features (ESF is greenish-blue tiles) alarms are 2
on the top rows; the next rows contain second and third priority alarms; while the fluid systems are last with pressure, flow, level, and temperature being ranked in importance (assuming there are no other priority ratings). Suitable backlighting and bold lettering are used to provide adequate light and dark contrast.

"First-Out" annunciators are independently coded for priority by being placed in a unique location. For those windowboxes which have a portion designated as first-out, the first-out windows are always located at the same place on the windowbox. Only the reactor system has a separate first-out annunciator windowbox. Initial first-out inputs are announced by a rapid flashing of the windows, while subsequent ones are indicated by the normal flash rate.

18.1.6.2 Tile Flash Rates

Flash rates are chosen according to industry guidelines in order to provide reflash cues and acknowledge cues which are perceptually discriminable. Three window flash rates are used at YGN 3&4 (with on-off percentages being equal): fast flash (4/sec) for initial First-Out alarms, normal flash (2/sec) for | 2
signals on all non-first-out alarms, and slow flash (1/sec) for normally cleared alarms (ringback).

18.1.6.3 Labeling and Engraving

Annunciators are labelled to readily identify each windowbox and system, as well as major subsystems. Tiles are engraved with an extra-bold font, and a standardized format to provide for easy reading and problem identification. Wording is placed on each alarm tile as follows : first line is the alarm source (for example, pump A, AFW), second line contains the problem (open, power lost), and the third line is the degree of severity (lo-lo).

If a three line format is not needed, a two line tile is acceptable. More than three lines on a tile is avoided. Lettering height is such that 14 characters may fit on a line. Stroke width is wider than that traditionally used, with a 3:8 ratio to height. Hence letter height is a minimum of 3/16 inch.

Alarm rows and columns (matrix designators) are clearly labeled. All alarm labels are black letters on a white background except matrix designators; which are white on black and conform to the letter styles, heights and stroke widths of EPRI-3448. System labeling is used with the lettering following the same standards for labeling. Each windowbox is assigned a serial numeric designator. Only abbreviations from the standard YGN 3&4 list of abbreviations are used. Abbreviations are consistent for component types, system names, and trouble types.

18.1.6.4 Multi-Input Windows

In many cases, an alarm window may have multiple inputs. The general principle governing this is that multiple inputs may be used only when the operator's response to the inputs is the same. For instance, if the operator's response to the alarm would be to dispatch someone to a local panel, regardless of what input, the inputs would be appropriate on one window. However, if the operator must perform different actions, separate windows are used. In order to limit the number of control room alarms, mult-input windows are used when appropriate.

Whenever multiple inputs are used for an alarm, the real alarm source is written out on the window, rather than "trouble". In general this is only possible if there are two or three inputs that can be verified on the main control boards. Local panel problems still utilize the word "trouble".

18.1.6.5 "Dark Board" Concept

"Dark Board" concept means that no alarms are "on" when the plant is at power and in a steady state. Alarms normally "on" therefore have their logic changed to be normally "off". The power supply for the annunciator system is designed so that, on a loss-of-offsite power, the alarms do not all actuate or go dark.

18.1.6.6 Periodic Testing and Maintenance

The annunciator system is designed to facilitate testing as needed. Tests are scheduled at regular intervals by KEPCO to discover annuncator malfunctions, burned-out bulbs, improper functioning horns, and other discrepancies. Burned-out bulbs are replaced not later than at a shift change. Hardware design facilitates ease of removal. A special ladder (to prevent stepping on control panels) is available in the control room, for changing bulbs and general access to the annunciators.

18.1.6.7 Out-of-Service and Blank Windows

Out-of-service and blank windows are designed so that the operators receive no spurious alarms. Alarms which are out-of-service are identified to the operators. When a system is permanently out-of-service or removed, the window is removed and replaced with a blank window. Blank tiles are to remain unlit. The illumination source (bulbs) is to be disabled to allow this. Blank tiles are white (uncolored).

18.1.6.8 Alarm Procedures

alarm response procedures clearly specify operator actions, component locations (if not in the control room) and time limits, if any. Up-to-date alarm response procedures are located in the control room, near the reactor operator and shift supervisor workstations.

18.1.7 Enhancements

Proper demarcation, mimic lines, and labeling significantly improve an operator's ability to use a set of controls and/or displays. Demarcation of functionally grouped controls and displays reduces operator search time. Demarcation also aids in defining or reinforcing the relationship between controls and their displays. Labeling the functionally grouped and demarcated controls/displays reduces the wordiness of individual component labels and increases information transfer. Mimics show the relationships between system components, or the directions of fluid flow or electrical distribution.

18.1.7.1 Labels

Groups of functionally similar controls and displays are enclosed by demarcation lines. The demarcated area is labeled with a descriptive title as to the system or function of the demarcated components. Each individual component is labeled with its alpha-numeric designator and/or its descriptive name. To prevent panel clutter and unnecessary repetition, a hierarchical labeling scheme is used. System or subsystem name is presented on an overall label for groups of controls and indications within these demarcated areas, and the system name is not repeated on each individual identifying label (however, each label is to have a system mnemonic displayed, which will help in system identification). As labels ascend up the hierarchy, letter height and stroke width increase. Letter size, label color, abbreviations, format, material, placement, and attachment conform to the guidelines set forth below.

a. Letter size dimensions are :

   1. Letter heights are based upon a viewing distance of 28 inches; single component (3/16 inch), small group (subgroup) of components (1/4 inch), large group of components (3/8 inch), local panel (1/2 inch), and main control panel (bilingual: Korean characters, 2 inches; English characters, 1 inch).

   2. Letter width equals 3/5 of letter height.

3. Stroke width equals 1/6 of letter height (dark letters on light background), or 1/8 inch of letter height (light letters on dark background).

b. Labels conform to the following color guidelines:

1. Caution labels are red labels with white letters. 1

2. Emergency controls or power sources (reactor trip or turbine trip) use white labels with red letters.

3. ESF manual actuation controls are located on white labels with blue letters.

4. Identification labels (device names, instrument numbers, system titles) use white labels with black letters.

5. Information labels (such as mimic sources and destinations) utilize black letters on a light grey background.

c. Labels use consistent nomenclature and abbreviations throughout the control room. Nomenclature is consistent with procedures and flow diagrams. Controls and displays are identified by a descriptive name and alpha-numeric designator where available. Only standardized symbols are to be employed.

d. Labels use a consistent identification format with the engraving centered on the label as follows:

1. Line one contains the system or subsystem name (if needed), or component name.

2. Line two contains the component (element) name and variable.

3. Line three contains the component number (which includes system mnemonic, type of equipment and its number).

e. Labels are engraved on a low-glare, rigid plastic material. The material is Gravoply II, Setonply, or reasonable equivalent, which consists of a sandwich arrangement where the outer layers are the background color and the inner layer is the letter color. The depth of the letter engraving is to the inner layer. Labels are 1/16-inch thick or greater.

f. Labels are in English and their placement on the control panel facilitates reading. The following guidelines relate to their placement:

1. Identification labels are placed above the panel component they describe.

2. Data and information labels for specific components are below or adjacent on the right side, with reference to the elements they describe. Other information labels (such as mimic destinations and sources) may be placed in any appropriate location.

3. Labels are not mounted on controls if it will cause them to be obscured by the operators hand for more than five seconds at any time.

4. Labels are placed close to or flush with panel elements they describe.

5. Labels are oriented horizontally and are non-curved.

g. Labels are attached and solidly anchored under all temperature and wear conditions, and not casually removable. They are not attached with screws or other methods which leave permanent damage on the panel metal. Labels are attached with double sided tape, covering the entire rear surface of the nameplate.

18.1.7.2 Demarcation

Demarcation is used to associate groups of controls and displays so as to enhance the operator's ability to quickly locate the needed instrumentation. Demarcation material is to be an autostriping tape. Paper-backed tape is not used as it is not durable. Width of the demarcation line is Group labels are centered on the demarcation line. The demarcation line color is medium blue 2

18.1.7.3 Mimics

Mimics integrate system components into functionally oriented diagrams that reflect component relationships and process flow. Properly designed mimics help the operator's decision making process. The following guidelines pertain to mimics:

a. Mimic lines are made of low glare material.

b. Arrows, whose base is wider than the mimic line, is used to show the direction of the fluid or electrical flow. Arrows are used only when the flow is in one direction.

c. Fluid mimic lines are black. Electrical mimic lines conform to the following convention: SY 345 kV - silver, MP 480 V - yellow, AP 13.8 kV - orange, and AP 4.16 kV - red.

d. Symbols are used to represent components in the system. Symbols match those used on related drawings.

e. The start and end of each mimic are identified; and if it connects to another mimic or extends to another panel, this is indicated. Mimics are made (cut) from the same 1/16-inch thick material as labels.

18.1.7.4 Channel Identification

The identification of redundant Class 1E components uses the following method of separating groups of channelized controls and indicators on the MCBs. This identification is in accordance with Regulatory Guide 1.75, and is consistent with KEPCO's color-coding for related plant equipment. Channels A,B,C, and D on the main control panels are identified on the lower left of a nameplate by the following color-coded tag :

a. Train A / channel A by a red circle. 2

b. Train B / channel B by a green circle.

c. Channel C by a yellow circle.

d. Channel D by a blue circle.

These tags (stick-on decals) are approximately 3/8-inch diameter, and provide operators and engineers with color coded cue which facilitate channelized instrument identification. If a component does not have a sticker, it is channel N. For Regulatory Guide 1.97, Categories 1 and 2 components are identified with a white strip on the bezel. 2

This system is significantly superior to channelized coloring of identification nameplates because such nameplates are difficult to read from a distance. Also, operators do not organize, operate, or think of components in terms of categorizing separation groups. Plants are organized and operated in terms of systems and trains. This scheme gives operators the easiest method of identifying components, while still providing a superior method of displaying channel information without channelized colored nameplates.

TABLE 18.1-1

ILLUMINATION LEVELS

Work Area or Type of Task	Task Illuminance, Footcandles		
	Minimum	Recommended	Maximum
Panels, Primary Operating Area	20	30	100
Auxiliary Panels	20	30	50
Scale Indicator Reading	20	30	50
Seated Operator Stations	50	75	100
Reading :			
. Handwritten (Pencil)	50	75	100
. Printed or Typed	20	30	50
Writing and Data Recording	50	75	100
Maintenance and Wiring Areas	20	30	50
Emergency Operating Lighting	10	As above for Area/Task	

TABLE 18.1-2

LUMINANCE RATIOS

Areas	Luminance Ratio
Task Area Versus Adjacent Darker Surroundings	3:1
Task Area Versus Adjacent Lighter surroundings	1:3
Task Area Versus More Remote Darker Surfaces	10:1
Task Area Versus More Remote Lighter Surfaces	1:10
Luminaries Versus Surfaces Adjacent to Them	20:1
Anywhere Within Normal Field of View	40:1

TABLE 18.1-3

REFLECTANCES

SURFACE	PERMISSABLE LEVELS
Ceiling	60 - 95%
Upper Wall	40 - 60%
Lower Wall	15 - 20%
Instruments/Displays	80 - 100%
Cabinets/Consoles	20 - 40%
Floor	15 - 30%
Furniture	25 - 45%

TABLE 18.1-4

ANNUNCIATOR SOUND CHARACTERISTICS

ZONE NUMBER	CHARACTERISTICS OF SOUNDS PRODUCED BY DIFFERENT GENERATORS			
	FREQUENCY AND MODULATION CODES	CENTER FREQUENCY (IN HERTZ)	SIGNAL-TO-NOISE IN PRIMARY OCTAVE BAND	SIGNAL-TO-NOISE A-WEIGHTED
1	Low Frequency Slow Modulation	500	11	8
2	Moderate Frequency Fast Modulation	2K	14	10
3	Moderate Frequency Slow Modulation	2K	17	10
4	High Frequency Fast Modulation	4K	13	7
5	High Frequency Slow Modulation	4K	12	6
6	Moderate Frequency Fast Modulation	2K	13	7

TABLE 18.1-5 HAS BEEN DELETED.

18.2 SAFETY PARAMETER DISPLAY SYSTEM DESIGN GUIDELINES

The criteria for the outline of this section are the Acceptance Criteria of NUREG-0800, NRC Standard Review Plan (SRP). The following criteria are provided from Section 18.2, Subsection II of the SRP:

a. An SPDS shall be provided that is located convenient to control room operators.

b. The SPDS shall continuously display information from which the safety status of the plant can be readily and reliably accessed by control room personnel responsible for the avoidance of degraded and damaged core events.

c. The SPDS shall provide a concise display of critical plant variables which at a minimum shall be sufficient to provide information to plant operators about the following critical safety functions:

   1. Reactivity control

   2. Reactor core cooling and heat removal from the primary system

   3. Reactor coolant system integrity

   4. Radioactivity control

   5. Containment conditions

d. The SPDS shall be designed to incorporate accepted human factors principles so that the displayed information can be readily perceived and comprehended by SPDS users.

The safety parameter display system (SPDS) functions are implemented in the critical function monitoring system (CFMS). This section will use the acronym CFMS.

The SPDS functions are met in the CFMS. The CFMS is implemeted in the plant monitoring system (PMS).

The SPDS, or CFMS, field inputs are isolated in the plant data acquisition system. The plant data acquisition system is composed of seven (7) physically separate channels (see Figure 7.7-13). Four (4) channels receive safety related inputs and three (3) channels receive non-safety related inputs. Each 1
channel receives field signals and converts these signals to a digital form which is transmitted to the non-1E plant computer system (PCS) using fiber optic cable. Separation between channels is met by using separate cabinets. Electrical isolation between the channels which receive safety related inputs and the PCS which is non-1E is provided through the use of fiber optic cable.

18.2.1 Display Location

The CFMS provides displays of the plant's safety status using cathode ray tubes (CRTs). Each CRT has its own keyboard for display selection by the viewer. Each display station is capable of providing any one of the CFMS displays.

Section 18.1 describes the human factor considerations which establish display location.

18.2.2 Information Presentation

18.2.2.1 Display Hierarchy

The CFMS presents plant information in an organized, consistently formatted manner which supports rapid, concise understanding of the plant safety status during abnormal as well as normal operating conditions. The critical functions provided by the CFMS are described in Subsection 7.7.1.3.4.1. A definition of the critical functions and key parameters are shown in Table 18.2-1.

To meet the requirements of a rapid and concise understanding of the plant safety status information, the displays are organized in a hierarchical fashion. The highest level (1) provides summary information of the plant safety status and menus of the lower level supporting displays. The middle level (2) provides mimic type graphic displays of the control loops and major components for each of the critical functions. The lowest level (3) provides detailed information of the components.

18.2.2.2 Display Access

The operator either selects displays by menu selection or is guided from one display to the next by a preprogrammed flow of logically related displays.

To access displays using the menu selection method, the operator enters a keyboard request to display the main CFMS display directory. The operator enters the desired display number to randomly access any CFMS display.

The preprogrammed flow of displays is the more typical display access used by the operator. This flow of displays is determined by the hierarchical relationship of the displays and by the operator's choice of information needs. This flow can be described in terms of a typical path of information flow as follows:

> The normal operating mode of the CFMS is to display the level 1 overview which provides a matrix of nine color-coded boxes which represent the status of each critical function. Each box includes the name of the critical function and associated key parameters. The box borders and enclosed parameter lists exhibit color and blink behavior changes that provide a continuously updated status of all the critical functions.
>
> During alarm conditions, a single digit sector number appears next to the alarmed parameter. Depending upon the nature of the alarm, several parameters can be in alarm, each with a different sector number. The operator decides which parameter and its associated control system should be investigated first and enters the desired sector number on the keyboard. A preprogrammed display associated with the selected sector number is then shown on the CRT.

This sectoring technique permits quick maneuvering among displays on all levels of the display hierarchy. The sectoring guides the operator to more detailed displays if they are needed. The CRT's used to present CFMS displays can also be used to present non-CFMS displays. A small version of the alarm matrix is included in the margin of all displays to meet the need for continuous display of the critical function status.

18.2.3 Human Factors Principles

The CFMS displays utilize the Human Factors Engineering Guideline Document, HF-010, as described in Subsection 18.0.4.3. The displays are designed to visually support the primary function of the CFMS, which is to alert the plant operator of unsafe operating conditions. The displays are then designed to emphasize alarm conditions and to assist the operator in diagnosing the cause of the alarm(s). The displays are designed for quick and concise recognition of the alarm according to a detailed set of design rules, which provide information in an uncluttered, consistent, continuous, and timely fashion. The design rules govern the size, shape, placement, and appearance of the displayed information.

18.2.3.1 Process Symbols

Process symbols help organize information and improve operator comprehension. Process symbols represent plant components such as pumps, valves and flow lines. A standard symbol library is used for display implementation.

To aid the operator in determination of a component state, shape coding is used (hollow/solid). Hollow symbols indicate active components, whereas solid symbols indicate inactive components.

18.2.3.2 Process Mimics

Process mimics are diagrams which represent the physical relationships of the components and flow directions of the represented loop. Process mimic formats use standard information placement for similar processes and equipment. For example, fluid system piping representations are standardized, top to bottom, left to right, with avoidance of crossovers. Incoming and outgoing flow path connections are placed at the periphery.

18.2.3.3 Color Conventions

Color is used as a coding medium of provide unambiguous, discriminating information to the operator. Color coding aids in rapid operator scanning, the perception of warning signals, and the identification of functional relationships. The colors have been selected to yield satisfactory contrast.

Color usage is as follows:

Black - background color.

Green - component off/inactive, valves closed and operable.

Red - component on/activated, valves open and operable.

Blue - bad data, questionable data or out-of-range data.

Amber - low or high alarm, action may be necessary.

Magenta - low-low or high-high alarm, immediate action is necessary.

Cyan - error, advisory or information messages.

White - textual information, normal data.

Dim White - demarcation lines.

18.2.3.4 Symbol Behavior Characteristics

The displayed graphical symbols and text are static during stead-state plant operating conditions. Date and time are included in all displays to indicate a continuous update of the display. During normal transient conditions, the symbols remain static and the parameter values change to reflect plant conditions. During alarm conditions, the symbols and parameters change color and blink. Reverse video is used to indicate operator acknowledgement of the alarm conditions. Details of display behavior are provided in Subsection 7.7.1.3.4.2.2.6.

TABLE 18.2-1 (1 of 3)

KEY CRITICAL FUNCTION MONITORING PARAMETERS

CRITICAL FUNCTION	KEY PARAMETER
A. Core Reactivity Control	Start-up neutron flux Neutron logarithmic power Hot & cold leg temperatures RCS boron concentration CEA position bottom contacts CEDM power undervoltage relays
B. Core Heat Removal	Hot & cold leg temperatures Core exit temperature RCP amps RCP breakers status Reactor vessel plenum level Core exit temperature saturation margin
C. RCS Inventory Control	Pressurizer level Reactor drain tank level, reactor temperature & pressure Pressurizer safety valve position & discharge temp CEDM, ICI, S/G hot leg, cold leg, and RCP seal leakages
D. RCS Pressure Control	Cold & hot leg temperature Pressurizer pressure & water temperature
E. RCS Heat Removal	LPSI header flow & temperature Shutdown cooling valve position CEDM main power bus undervoltage relays S/G level Aux & main feedwater flow Cold & hot leg temperature Pressurizer pressure Time since reactor trip Charging pump status HPSI hot & cold leg flows Safety injection actuation system Recirculation actuation system

TABLE 18.2-1 (2 of 3)

CRITICAL FUNCTION	KEY PARAMETER
F. Containment Integrity	Safety injection actuation system Containment spray actuation system Containment pressure & average temperature Fan coolers status Containment spray flow Containment H2 concentration
G. Containment Isolation	Containment isolation actuation system (CIAS) CIAS - closed valve position Containment purge isolation actuation system (CPIAS) CPIAS - closed valve position Safety injection actuation system (SIAS) SIAS - closed valve position Main steam isolation system (MSIS) MSIS - closed valve position Containment spray actuation system (CSAS) CSAS - closed valve position
H. Radioactive Emissions Control	Steam-generator blowdown liquid sample radiation Condenser vacuum vent effluent radiation Deaerator vent effluent radiation Secondary aux building HVAC radiation High energy line cubicle rad Primary aux building HVAC radiation Fuel building HVAC rad Rad waste building HVAC radiation Low level lab/laundry rad Emergency core cooling system equipment room HVAC radiation Containment radiation Containment purge iodine Containment purge noble gas Containment purge particulate Liquid radwaste discharge header radiation

TABLE 18.2-1 (3 of 3)

CRITICAL FUNCTION	KEY PARAMETER
I. Maintenance of Vital Auxiliaries	4.16 kV bus voltage Class 1E dc bus voltage Component cooling water heat exchanger outlet flow Component cooling water heat exchanger outlet temperature

18.3 Remote Shutdown Panel

The remote shutdown panel (RSP) design adheres to the principles of human factors engineering. Relevant requirements of General Design Criterion (GDC) 19 are also met by assuring that man-machine interfaces are adequate for safe plant shutdown.

Human factors engineering design principles for the RSP include those outlined in Section 18.0. Specific technical details, design criteria and guidelines are found in the YGN 3&4 Human Factors Engineering (HFE) Guideline Document.

Human factors engineering addresses the efficient and safe operation of the RSP from the operator's perspective. The RSP design considered how panel design affects the operator in terms of the availability of necessary information, the adequacy of controls for the tasks to be performed, the efficiency of the overall panel layout, and the suitability of the environment.

The main body of this section contains human factors design conventions adapted from NUREG-0700, as well as plant specific design conventions which were applied to the RSP. These design conventions are to be used when performing a human factors review.

18.3.1 Remote Shutdown Panel Workspace

The layout of the RSP room is shown in Figure 18.3-1. Safety-related RSP "A" panel (RS-01JA) is located in one side of a room divided by a rated fire barrier (wall with door) and another safety-related RSP "B" panel (RS-01JB), plus the non-safety related RSP "N" panel (RS-02J), is located in the other side of the room.

The RSP is located in a limited access area under administrative control that is readily accessible from the control room. Each Safety-Related RSP is placed in a separate environmentally controlled fire area to ensure that a fire in one area does not prevent the safe shutdown of the plant from the other area. The room provides adequate space for maintenance, RSP operation, and storage of appropriate drawings on an as-needed-basis.

Both RSP "A" (RS-01JA) and "B" (RS-01JB) are free-standing, one piece, vertical panels which are approximately 90 inches high, 60 inches long and 50 inches deep, while the RSP "N" panel (RS-02J) is approximately 90 inches high, 30 inches long, and 50 inches deep. The panels are protective enclosures for the instruments and controls that are required to achieve and maintain hot shutdown of the plant.

18.3.1.1 Similarity Between Units 3 and 4

Both Unit 3 and Unit 4 RSP rooms have identical floor plans, room environments (temperature, humidity, lighting, etc.), panel component arrangement, panel size and panel shape.

Documentation, labeling, nomenclature, and abbreviations are identical. This similarity includes the Technical Specifications, plant procedures, and other written guides and the format, letter height, width nomenclature, color, and placement of labels.

18.3.1.2 Mirror Imaging

Since mirror imaging can significantly increase the chance of operator error and lead to negative transfer of training, it has been avoided in the design of the RSP.

18.3.1.3 Communications

The RSP room is equipped with sufficient communications gear to allow easy communication with the rest of the plant via sound powered phones and the plant page system. The communications system is conveniently located, easy to use, and provides for all normal and emergency needs, without interfering with the operation of the RSP. More information on the sound powered phones and plant page system can be found in Subsections 18.1.1.3 and 18.0.4.18.

18.3.1.4 Habitability

The RSP room HVAC system assures that the room is habitable under all plant conditions and is free of toxic gas, radiation and smoke.

18.3.1.5 Access and Egress

Access to the RSP room is restricted and controlled to prevent excess traffic and noise. All plant staff not normally assigned to the RSP are considered visitors and may not enter the RSP room without shift supervisor's approval. Access to the room is through the key locked doors and access to the key is administratively controlled. Egress from the RSP room is accomplished in the reverse of access to the room. Access and egress ways are four feet wide at a minimum in order to permit two individuals to pass at all times.

18.3.1.6 Storage Space

Plant procedure, drawings, and documents are not normally or permanently stored in the RSP room. However, adequate space is provided for temporary storage of a minimum amount of procedure, documents, and drawings necessary which may be brought into the room during RSP operation.

Adequate space is also provided for keys, hardhats, coats, flash lights, etc. as well as other normal operator equipment and belongings.

18.3.1.7 Maintenance Activities

It is not expected that the RSP would need frequent or heavy maintenance activities since the panel is only to be utilized during specific plant modes of operation and periodic testing. The RSP room is not expected to be manned continuously. However, the panel design, room layout, and room environment support normal maintenance activities. The room layout provides sufficient front and back clearance space. The RSP panels and layout support normal maintenance activities and minimize disruption of operators. Panels are free standing, have access from the rear, are easy to open, have internal access to the best extent practical, and have no obstructions from fire barriers, seismic supports, and internal cable raceways. Convenience outlets are provided for powering portable temporary lighting that may be required periodically for maintenance.

18.3.2 RSP Room Environment

The RSP room environment provides comfortable, ambient surroundings for operators under all plant conditions, and is being maintained within appropriate auditory environment, comfortable humidity and temperature envelops, and sufficient illumination.

18.3.2.1 Auditory Environment

The RSP room has reduced background noise low enough to allow auditory indications and audible alarms to be clearly distinguishable, as well as allowing easy communication between operators. Sources of background noise are controlled by limiting individual access through locked doors and requiring shift supervisor's permission to enter.

18.3.2.2 Illumination

Illumination is sufficient to perform necessary tasks in a safe and accurate manner, but not so high as to cause serious glare problems. Emergency lighting is an alternate system that is activated in case of power failure, and is independent of any other plant lighting system that is available in the RSP room. Emergency lighting is activated automatically and immediately upon failure of the normal lighting system. The lighting system is similar to that of control room. Refer to Subsection 8.1.2.2 for further details.

18.3.2.3 Humidity, Temperature and Ventilation

The heating, ventilation and air conditioning (HVAC) system maintains a clean air quality, with humidity and temperature levels constantly within human comfort ranges corresponding to 65-85°F (18.3-29.4°C) for temperature and 40-60% for relative humidity.

18.3.2.4 Operator Comfort

No operators are continuously stationed in the RSP room and no amenities for operator comfort are provided.

18.3.3 Remote Shutdown Panel Design and Layout

The RSP panels are designed for stand-up operation. In positioning controls for stand-up operation, the range of suitable control heights is within the reach radius (functional reach) of most operators. The principal factors affecting the readability of displays on the RSPs are as follows:

a. Display height and orientation relative to the operator's line of sight (LOS) when he is directly in front of the display.

b. Display distance and orientation relative to the operator's straight-ahead line of sight when he must read the display from an offside position.

c. Size of the display markings relative to the reading distance.

The RSPs conform to the following dimensions:

a. The panel depth (front of backboard to rear of panel) does not exceed 127 cm (50.0 in.) for ease of maintenance.

b. Vertical section height is chosen to assure that the operators can reach the topmost controls on the panel.

c. The panel height is 229 cm (90.0 in.).

d. The RSP does not have any controls below 91 cm (36 in.) above the floor, and no indicators above 185 cm (73 in.).

The guidelines for the location of components above the floor that were followed for the remote shutdown panels were:

	Controls Min-Max	Displays Min-Max
Components used frequently or precisely	91 - 135 cm (36 - 53 in.)	127 - 170 cm (50 - 67 in.)
Components having normal usage	91 - 178 cm (36 - 70 in.)	107 - 183 cm (42 - 72 in.)

The following paragraphs discuss the internal arrangements of the panel components.

18.3.3.1 Panel Consistency and Standardization

Panels are consistently laid out to reflect system operation and function. Standardized hardware types are used on all panels. For each type of control function or indicator function, only one hardware type is used. Consistency between NSSS-supplied and BOP hardware is also maintained. The panel layout is also consistent with respect to the relationships between components. For example, banks of meters, if set up in a certain configuration in one section of the panels, are the same on other panel sections.

18.3.3.2 Display and Control Groups

Related instruments and controls are grouped together on all panels. These components use spacing and clustering to represent functional and operational groups. Related indicators are placed adjacent and related process controls are in proximity to each other.

18.3.4 Visual Displays

Visual displays are easy to read, unambiguous, easy to maintain and they provide needed, relevant information. Displays are selected using the criteria outlined below:

a. The capability is provided to distinguish significant levels of controlled system parameters.

b. Actual system/equipment status is displayed for all important parameters.

c. Displays identify whether they reflect demand or actual status.

d. The required level of reading accuracy is provided.

e. The operator receives feedback for any deliberate movement of a control.

When banks of indicators are used, they reflect an organization which is clear to the operators, such as all indicators for one tank or multiple indications of the same variable. Banks of indicator lights are arranged to accurately reflect system or operation sequence.

18.3.4.1 Indicating Lights

Indicator lights are easy to maintain, and easy to see against background lighting and glare. The indicating lights are at least 10% brighter than the surrounding panel, which can be clearly recognizable under the highest predicted ambient light conditions.

Color coding provides clear status information on lights and is derived from lens color and not by a layer of colored material inside the cover. Color coding for indicator lights is as follows: Red connotes equipment or process operating, or the flow of energy (open, running, on); Green means the equipment or process not operating, or the non-flow of energy (close, stop, off); White or Yellow represents a trouble/disable condition or an abnormal 2
operating situation.

Lettering and wording are clear, consistent, and readable under all conditions. The letters are sized so as to subtend a sufficient number of degrees of visual arc for ready comprehension. Nomenclature is consistent for standard words or all indicators. Legends and component names are engraved on indicators and on labels so that the control name is visible even when the bulbs are burned out or power is lost.

18.3.4.2 Meters and Recorders

Meters are easy to use, and they are accurate and unambiguous under all conditions. Meter scales have clear divisions, and utilize major, intermediate and minor scale divisions. Scales are in units preferred by operators for interpreting the variable. Metric units are used on all meters and indicators. Scales begin and end at major scale divisions and are consistent with range limits. Log scales are provided for power level indication.

In the event of power loss, meters fail to zero or offscale.

Other pertinent information relating to meters is described below:

a. Meters are equipped with red pointers for easy viewing and contrast with the meter scale. Bright green as a second pointer on dual meters is also used.

b. Multiscale meters (including dual) may be applied where such devices have operational benefits, such as data comparison.

c. Meters are designed for easy calibration and maintenance.

18.3.5 Controls

All controls are easily discriminated, standardized across function, grouped according to function and generally within system, and chosen with good human factors incorporated into the hardware. In addition, they are chosen and located in order to facilitate rapid, easy, and error-free use.

Controls are arranged to avoid operator confusion. The number of controls and their use are chosen to support the hot shutdown of the plant and to accurately reflect genuine process control needs. Primary controls (such as frequently used controls and safety system controls) are in easy-to-reach locations on the panel.

18.3.5.1 Coding and Types of Controls

Controls are functionally coded such that valve, pump, breaker trip and actuation controls are all readily discriminated. A combination of methods such as hardware types, location, and color coding are used to accomplish this. For example, fan and pump controls have blue bezels, while other controls (such as breakers and valves) have black bezels. All control types are standardized to function. That is, if a pushbutton control switch is used for one type of task, such as valve operation, it is used for that task in all instances.

Specific information relating to the different types of controls are described below:

a. Pushbutton controls have easily removable covers for bulb or LED replacement. As a general practice, pushbutton controls are vertically aligned. Legends are readable under ambient light conditions, regardless of internal illumination.

b. All rotary control knobs incorporate the following features: good control resistance, grooved or textured edge, a 2.5 cm minimum diameter, and clear linear scale markings (a detent at each position if possible).

c. Toggle switches, levers, partial rotation controls, slide switches and rocker switches (as well as pushbuttons, rotary controls, and J-handle controls) conform to human factors criteria for size and shape.

Except for the main control, the remote shutdown, and AAC control panels no other controls in the two units are in the scope of Chapter 18 or NUREG-0800.

18.3.5.2 Prevention of Inadvertent Activation

Restricted use controls have barriers to prevent inappropriate actuation. These controls use either protective housings or hinged shields in order of preference. The method utilized depends on the need for rapid operator access and the seriousness of consequences following an accidental activation. The following devices are used on the RSP:

a. Protective housings are a type of control in which a round pushbutton has a guard on its side but not on its top. This prevents inadvertent actuation, but does not cause the operator to take extra action or pause. These housings are used on the manual trip buttons for MSIS actuation.

b. Hinged shields are transparent plastic covers, which are placed over a control for the purpose of causing the operator to pause and to think, as well as to prevent accidental actuation. This type of switchguard is used only when called out by administrative procedure. These guards have the hinged shield anchored so that the operator does not have to hold the shield up while operating the control.

18.3.6 Annunciators

Audible annunciators are provided as a subfunction of the pressurizer and steam generator pressure pretrip/reset features to alert the operator to pretrip conditions for these parameters. These annunciators are provided as an aid for the plant cooldown and depressurization evolution. They do not require the full complement of generic alarm control features. Acknowledgment/reset of annunciators is integral with the reset of the actual setpoints; 2

no separate acknowledgement of the annunciators is required. Testing of the audible annunciators should be accomplished as part of the scheduled PPS Cabinet surveillance. 2

Alarm signals have an adequate decibel (dB) level to be heard above the mean background noise level. Alarm signals are coded by tone to indicate which process parameter is in a pretrip condition.

18.3.7 Enhancements

Proper demarcation and labeling are used to significantly improve an operator's ability to use a set of controls and/or displays. Demarcation of functionally grouped controls and displays reduces operator search time. Demarcation also aids in defining or reinforcing the relationship between controls and their displays. Labeling the functionally grouped and demarcated controls/displays reduces the wordiness of individual component labels and increases information transfer.

18.3.7.1 Labels

Groups of functionally similar controls and displays are enclosed by demarcation lines. The demarcated area is labeled with a descriptive title as to the system or function of the demarcated components. Each individual component is labeled with its alpha-numeric designator and its descriptive name. Label color, abbreviations, format, material, placement, and attachment conform to the guidelines set forth below.

a. Labels conform to the following color guidelines:

   1. Caution labels are red labels with white letters.

   2. ESF manual actuation controls are located on white labels with blue letters.

3. Identification labels (device names, instrument numbers, system titles) use white labels with black letters.

b. Labels use consistent nomenclature and abbreviations. Nomenclature is consistent with procedures and flow diagrams. Controls and displays are identified by a descriptive name and alpha-numeric designator where available.

c. Labels use a consistent identification format with the engraving centered on the label as follows:

1. Line one contains the system or subsystem name (if needed), or component name.

2. Line two contains the component (element) name and variable.

3. Line three contains the component number. (which includes system mnemonic, type of equipment and its number).

d. Labels are engraved on a low-glare, rigid plastic material. The material is Gravoply which consists of a sandwich arrangement where the outer layers are the background color and the inner layer is the letter color. The depth of the letter engraving is to the inner layer. Labels are 1/16 inch thick or greater.

e. Labels are in English and their placement on the control panel facilitates reading. The following guidelines relate to their placement:

1. Identification labels are placed above the panel component they describe.

2. Labels are not mounted on controls.

3. Labels are oriented horizontally and are non-curved.

f. Labels are attached and solidly anchored under all temperature and wear conditions, and not casually removable. They are not attached with screws or other methods which leave permanent damage on the panel metal. Labels are attached with double sided tape, covering the entire rear surface of the nameplate.

18.3.7.2 Demarcation

Demarcation is used to associate groups of controls and displays so as to enhance the operator's ability to quickly locate the needed instrumentation. Demarcation material is gravoply. The width of the demarcation line is Group labels are centered on the demarcation line. The demarcation lines utilize different colors based on the system being grouped. These demarcation line colors are depicted in Table 18.1-5.

18.3.7.3 Channel Identification

The identification of redundant Class 1E components uses the following method of separating groups of channelized controls and indicators on the RSPs. This identification is in accordance with Regulatory Guide 1.75, and is consistent with KEPCO's color-coding for related plant equipment. Channels A,B,C, and D on the RSPs are identified on the lower left of a bezel by a shape and color-coded tag as follows:

a. Train A / channel A by a red triangle.

b. Train B / channel B by a green octagon.

c. Channel C by a yellow circle.

d. Channel D by a blue square.

These tags (stick-on decals) are approximately 1/8-inch diameter, and provide operators and engineers with two cues (shape and color) which facilitate channelized instrument identification. If a component does not have a sticker, it is channel N.

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

RSP WORKSPACE LAYOUT

Figure 18.3-1