SAFETY PARAMETER DISPLAY SYSTEM

FOR

COMANCHE PEAK STEAM ELECTRIC STATION

UNITS 1 AND 2

EMERGENCY RESPONSE FACILITY COMPUTER SYSTEM

SAFETY ANALYSIS REPORT

SEPTEMBER 19, 1984

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1.0 INTRODUCTION

1.1 Purpose and Scope

This report has been prepared in response to section 4 of NUREG-0737, supplement 1 (reference 1), and presents the safety analysis of the Comanche Peak Steam Electric Station (CPSES) Safety Parameter Display System (SPDS). The CPSES SPDS parameters provide sufficient information in terms of the five safety functions specified in NUREG-0737, supplement 1, to enable the plant operators to make a rapid and reliable assessment of overall plant safety status. The CPSES SPDS is responsive to a wide range of events, including the symptoms of severe accidents, and will be functional during all operating modes.

The Comanche Peak SPDS is part of the plant Safety Assessment System (SAS). The CPSES SAS has been implemented based on the generic SAS design developed by the Ad Hoc Group of the Westinghouse Owners Group Subcommittee on Instrumentation in 1981. The generic SAS design and development included a formal Verification and Validation (V&V) of the generic portions of the design, as applicable, and underwent a subsequent user's evaluation program in 1982.

The generic SAS validation provisions were essentially preserved in the Comanche Peak adaptation. The design and implementation of the CPSES SAS has been carried out in accordance with the generic SAS functional software specification and users implementation guide (references 2 and 3), subject to the Comanche Peak V&V plan for emergency response facilities data systems.

The generic SAS was originally designed to address NUREG-0696 guidelines for an SPDS. This report evaluates the adequacy of the SPDS portion of the CPSES SAS in terms of the later NUREG-0737, supplement 1 requirements.

SPDS capability to monitor a wide range of plant variables during transients and accidents was evaluated based on the analyses in the Final Safety Analysis Report (FSAR) and the critical safety function requirements of the plant technical specifications. Also, for added perspective, comparisons were made with the SPDS parameters recommended by others.

An overview of the CPSES SPDS design and installation, is presented in section 2.0. Selection and evaluation of parameters is presented in section 3.0. The 10 CFR 50.59 safety evaluation of the CPSES SPDS implementation is presented in section 4.0, and an overall summary and conclusions are presented in section 5.0.

1.2 Terminology

Key SPDS terminology used in this report is defined as follows.

1.2.1 Critical Safety Functions

Critical Safety Functions (CSF) are those safety functions that are essential to prevent a direct and immediate threat to the health and safety of the public. The critical safety functions monitored by the SPDS as required by NUREG-0737, supplement 1, are:

* Reactivity control
* Reactor core cooling and heat removal from the primary system
* Reactor coolant system integrity
* Containment conditions
* Radioactivity control

The purpose of the SPDS is to continuously display information from which to assess overall plant safety status in terms of how well the CSF's are being maintained or accomplished. However, the SPDS is not intended nor is it designed to diagnose the specific events which may be affecting CSF maintenance or accomplishment. As implemented at CPSES, the parameters displayed on the SPDS provide the reactor operator and technical advisors with continuous, unambiguous data that will enable them to make proper decisions regarding appropriate operator action to developing plant conditions. Details of the selection and evaluation process for the CPSES SPDS parameters are given in Section 3.0.

1.2.2 Parameters

Parameters are those measures of system status or performance and CSF status or performance which are obtained directly or calculated from plant signals. Plant signals are obtained from monitoring and control sensors installed in the plant systems. Each parameter is measured by one or more sensors, each of which produces a signal corresponding to the value of the parameter being measured.

1.2.3 Plant Signals

Plant signals are the electronic or electrical outputs of the monitoring and control sensing devices installed in the plant systems. These devices are calibrated so that the signals produced correspond to actual values of the process variables being measured.

1.3 Relationship of Critical Safety Functions and Barrier Concept

The definitions of critical safety functions (CSF) are based on the activities required to assess the integrity of and the potential for breach of the radioactive material barriers. The assessment of the reactor core cooling and reactivity control critical safety functions provides the information required to assess the potential for breach of fuel cladding integrity. The assessment of the coolant system integrity function provides the information required to assess the integrity of the nuclear system process barrier. The assessment of containment conditions provides the information required to access the integrity and the potential for breach of the primary containment barrier. The assessment of the radiation control function provides the information required to assess radioactive releases to the environment resulting from breaches of one or more of the radioactive material barriers. Therefore, as long as the critical safety functions are adequately maintained the radioactive barriers will remain intact and the health and safety of the public will be protected.

2.0 SPDS DESIGN AND OPERATION

2.1 System Description

The Safety Parameter Display System (SPDS) is a set of application software which provides Emergency Response Facility (ERF) function for the main control room. The SPDS software runs on the ERF Computer System (ERFCS). The ERFCS consists of two hardware/software subsystems:

* A data acquisition system
* An integrated computer system

The SPDS is available to the control room operators via dedicated CRT's in the control room (see Figure 1). The SPDS provides a concise display of critical plant information to the control room operators to aid them in rapidly and reliably determining the safety status of the plant. This information consists of the status of plant safety functions in terms of associated plant parameters. The parameters are either directly monitored or are derived using data collected via plant instrumentation systems. Derived parameters are based on algorithms consistent with those which drive other calculated parameter displays in the control room. This ensures that information protrayed for SPDS calculated parameters is consistent with that displayed by other control room instrumentation.

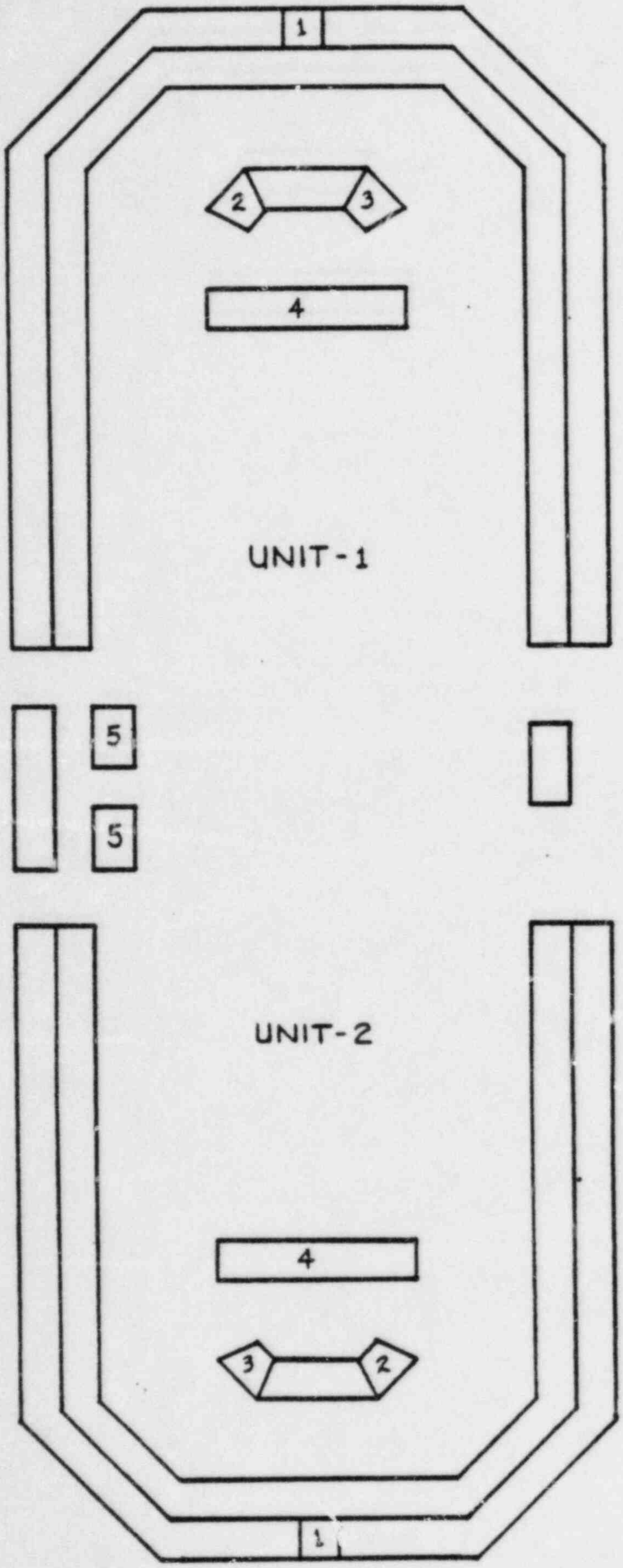
2.1.1 Data Acquisition Systems

Each unit (1 and 2) of the Comanche Peak Steam Electric Station ERFCS has its own Data Acquisition Systems (DAS). The total DAS is made up of two types of systems:

1. Remote multiplexing units (RMU's) and associated communication controllers (CC's)

2. ASCII character communication data links

Each DAS will service its respective host computer system, that is the Unit 1 DAS will serve the Unit 1 ERF Computer System and the Unit 2 DAS will serve the Unit 2 ERF Computer System.



1. Main Control Board SPDS/ Plant Process Computer CRTs
2. Operator's Console SPDS CRTs
3. Supervisor's Console SPDS CRTs
4. Plant Process Computer Consoles
5. RMS Computer Consoles

FIGURE 1

CPSES Control Room Arrangement

The primary purpose of the Data Acquisition Systems coupled with their respective host computers is to provide the Control Room SPDS, the Technical Support Center (TSC), and the Emergency Operations Facility (EOF) that make up the emergency response facilities with a highly reliable plant safety status database. This database contains the current status of all plant signals that form the basis of the overall plant safety status parameters.

2.2.1.1 Data Acquisition Via Remote Multiplexing Units (RMU)

The RMU systems are high-speed data multiplexers connected via redundant data links to a redundant set of communication controllers.

All field inputs, both 1E and non-class 1E, are connected to the remote multiplexing units (RMU's) either directly or through qualified 1E isolators as required in accordance with NUREG-0737, supplement 1 (reference 1). The RMU's transmit digitally coded information to, or receive digitally coded commands from, the redundant communication controllers (CC's) by means of redundant data links.

The redundant CC's control the interrogation of the RMU's and the transmission of data along the redundant data links. The CC's also control the allocation and transfer of data to the memories of the computer systems. The CC's likewise control commands initiated by the computers and transmit them to the appropriate RMU's.

The Remote Multiplexing Units provide the following functions:

* Analog and digital signal scanning
* Analog to digital conversion
* Class 1E isolation

2.1.1.2 Data Acquisition Via ASCII Data Links

There are three ASCII data sources that provide input to the SPDS safety status database, they are:

* Radiation Monitoring System (RMS)
* Core Cooling Monitoring System (CCM)
* Reactor Vessel Level Indicating System (RVLIS)

These systems accomplish all engineering unit conversions and data validations for each of their respective inputs. They then provide a formatted ASCII data string to the ERF Computer System. Class 1E isolation is provided by each system (RMS, CCM, and RVLIS) respectively prior to data transfer to the ERFCS.

2.1.2 Computer Systems

The Emergency Response Facility Computer System (ERFCS) consists of redundant computers designated as System A and System B for Unit 1 and an identical set for Unit 2. The other computer systems that communicate with the ERFCS are:

* Radiation Monitoring System Computers
* Meteorlogical Monitoring Computer
* Core Cooling Monitoring Microprocessor
* Reactor Vessel Level Indication System Computer
* Each Colorgraphic Display Computer

The ERFCS will transmit the time-varying portions for all of the SAS/SPDS displays to the colorgraphics display computer CRT's. Data for the static portion of the displays (termed the template) will reside in each display computer memory.

2.1.3 Availability

The CPSES SPDS has a high availability goal. A study which quantatively assesses system availability is currently underway to determine that this goal has been met. This study includes appropriate support system considerations which may impact SPDS availability such as power supply and HVAC failures.

2.2 SPDS Displays

The Safety Parameter Display System displays are divided into two main categories: Top Level and Secondary.

2.2.1 Top Level Displays

The Top Level displays provide the operator with an overview of the current plant safety status for each of the three major plant operating modes:

* Cold Shutdown
* Heatup/Cooldown
* Normal Operation

Each top-level display, except the cold shutdown display, contains a set of Critical Safety Function Monitor (CSFM) summary indications which provide information on specific critical safety function conditions. Figures 2 through 4 show typical examples of the top level displays. (NOTE: the values shown were chosen for visual reference only.) The evaluation of adequacy of the CPSES SPDS parameter set in section 3.0 addresses all of the parameters monitored and displayed on these displays.

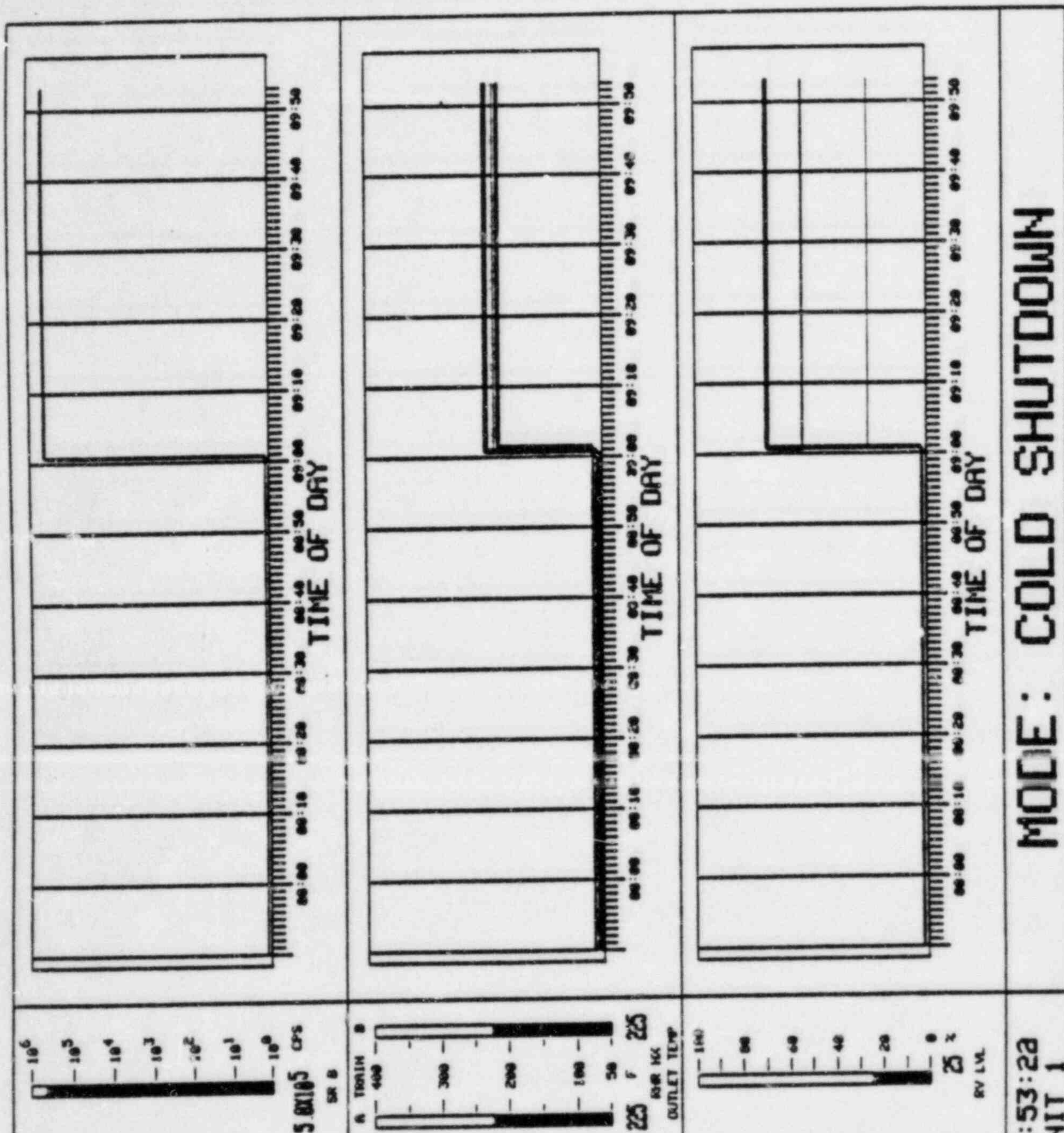


FIGURE 2
TYPICAL COLD SHUTDOWN TOP LEVEL DISPLAY

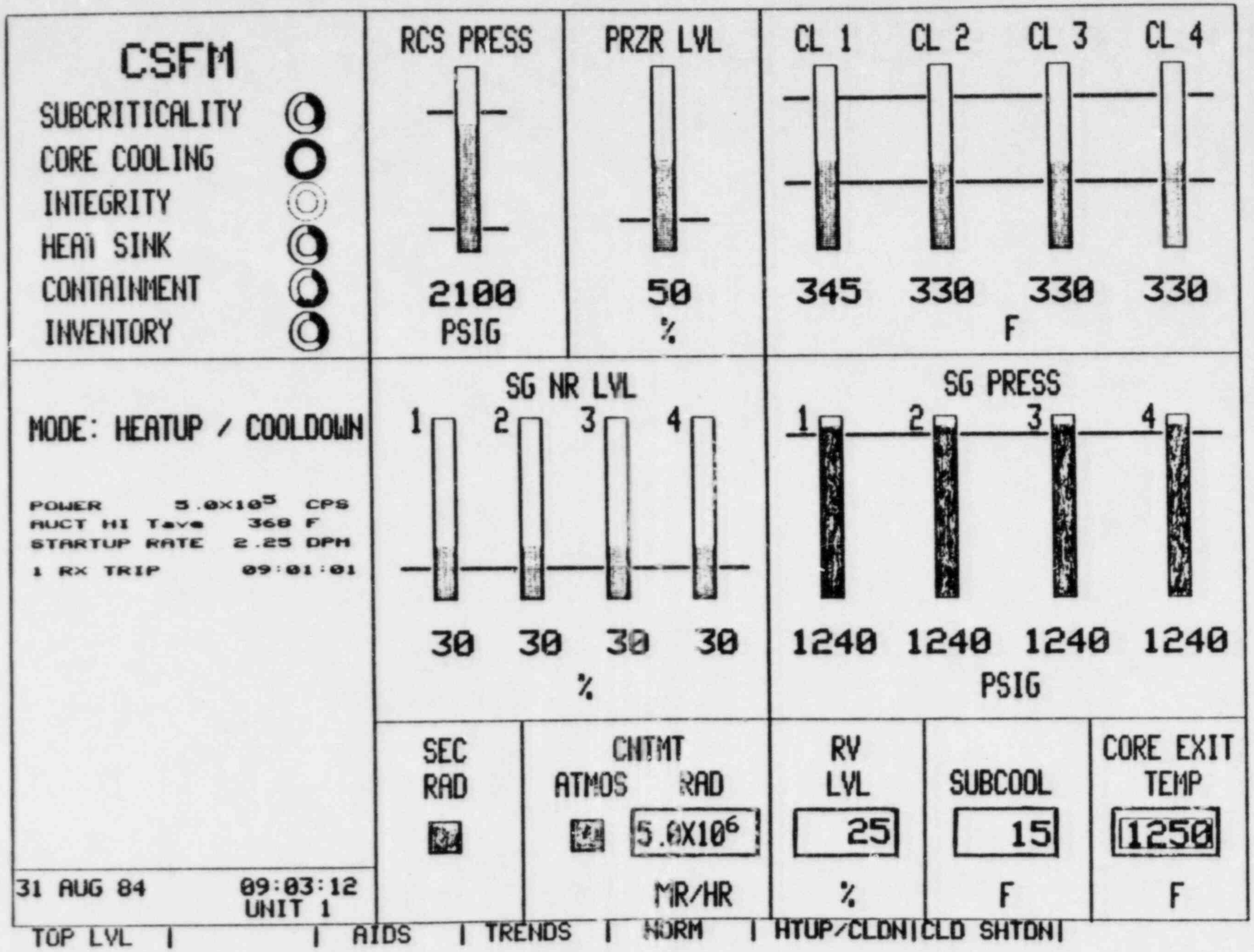


FIGURE 3

TYPICAL HEATUP/COOLDOWN TOP LEVEL DISPLAY

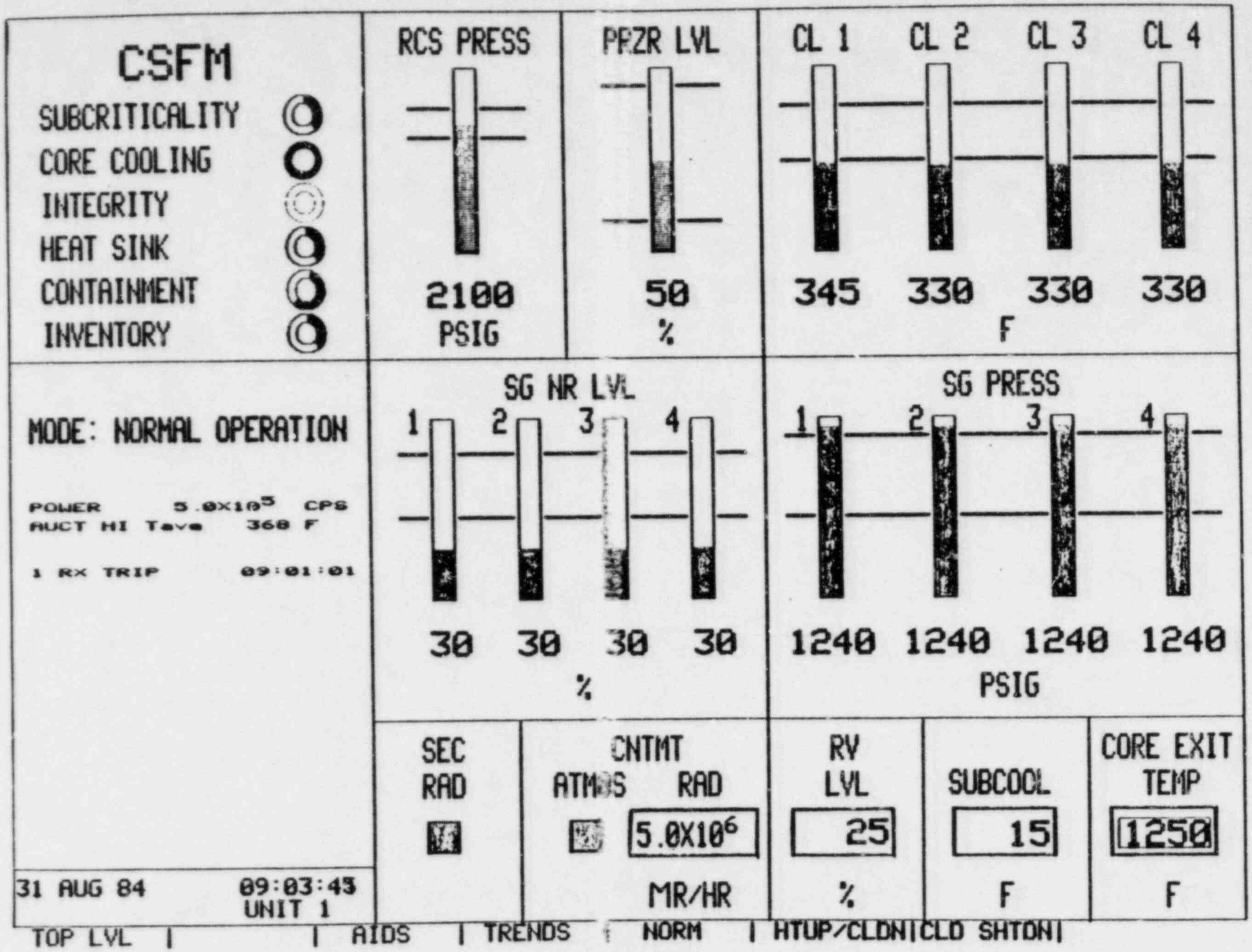


FIGURE 4

TYPICAL NORMAL OPERATION TOP LEVEL DISPLAY

2.2.2 Secondary Displays

The Secondary SPDS displays are further subdivided into two groups: four Accident Identification and Display System (AIDS) displays and fifteen Trend Graph displays.

2.2.2.1 AIDS Displays

The AIDS displays provide the operator with detailed information concerning the current status of parameters that would most likely be affected during the development and course of a particular event. A set of plant parameters was chosen (based upon CPSES design bases analyses) for each of the following four abnormal conditions:

* Loss Of Coolant Accident (LOCA)
* Steam Generator Tube Rupture (SGTR)
* Loss Of Secondary Coolant (LOSC)
* Inadequate Core Cooling (ICC)

As implemented at CPSES, AIDS does not presume to identify or predict a particular abnormal occurrence. The purpose of the CPSES AIDS is to group the current status of pertinent parameters together on a single half-page display that provides the operator and technical advisors with concise information to enable them to make an accurate assessment of the abnormality. Figures 5 and 6 show typical examples of the AIDS displays. (NOTE: any two AIDS displays can be observed simultaneously; also the values shown in figures 5 and 6 were chosen for visual reference only.)

2.2.2.2 Trend Graph Displays

The Trend Graph displays provide the operator and technical staff with a graphical indication of fifteen pre-selected groups of plant safety status parameters. These displays are also half-page and any two can be observed simultaneously. (NOTE: It is also possible to observe any one AIDS display and any one Trend Graph display simultaneously.)

Each Trend Graph display gives the current numeric value of each of its associated parameters directly beneath a vertical bar-graph depiction of the value. In addition, a time-varing plot of the value of each of the parameters during the previous thirty minutes is displayed next to the vertical bar-graphs. Figure 7 shows two typical Trend Graph displays. (NOTE: The values shown in figure 7 were chosen for visual reference only.)

CSFM

SUBCRITICALITY
CORE COOLING
INTEGRITY
HEAT SINK
CONTAINMENT
INVENTORY

MODE: COLD SHUTDOWN

POWER 5.0X10^5 CPS
AUCT HI Tave 368 F

1 RX TRIP 09:01:01

31 AUG 84 09:04:38
UNIT 1

LOCA

RCS PRESS	2100	PSIG
PRZR LVL	50	%
CNTMT TEMP	150	F
CNTMT NR PRESS	27	PSIG
CNTMT HUMIDITY	0	%
CNTMT WTR LVL	812.7	EL
CNTMT RAD	$5.0X10^6$	R/HR
PRZR PORV	CLOSED	
PRZR SFTY VLV	CLOSED	
PRT PRESS	50	PSIG

SGTR

RCS PRESS	2100	PSIG
PRZR LVL	50	%
CNTMT TEMP	150	F
CNTMT NR PRESS	27	PSIG
CNTMT HUMIDITY	0	%
HIGHEST CNTMT SUMP LVL	1.5	FT
CNDSR OFF GAS RAD	$5.0X10^{-2}$	μC/ml
SG BLDN RAD	$5.0X10^{-2}$	μC/ml
HIGHEST SG NR LVL	30	%

	1	2	3	4	
SG NR LVL	30	30	30	30	%
SG AFW FLOW	275	275	275	275	GPM

TOP LVL | MODES | | TRENDS | LOCA | SGTR | LOSC | ICC

FIGURE 5
TYPICAL LOCA & SGTR AIDS DISPLAYS

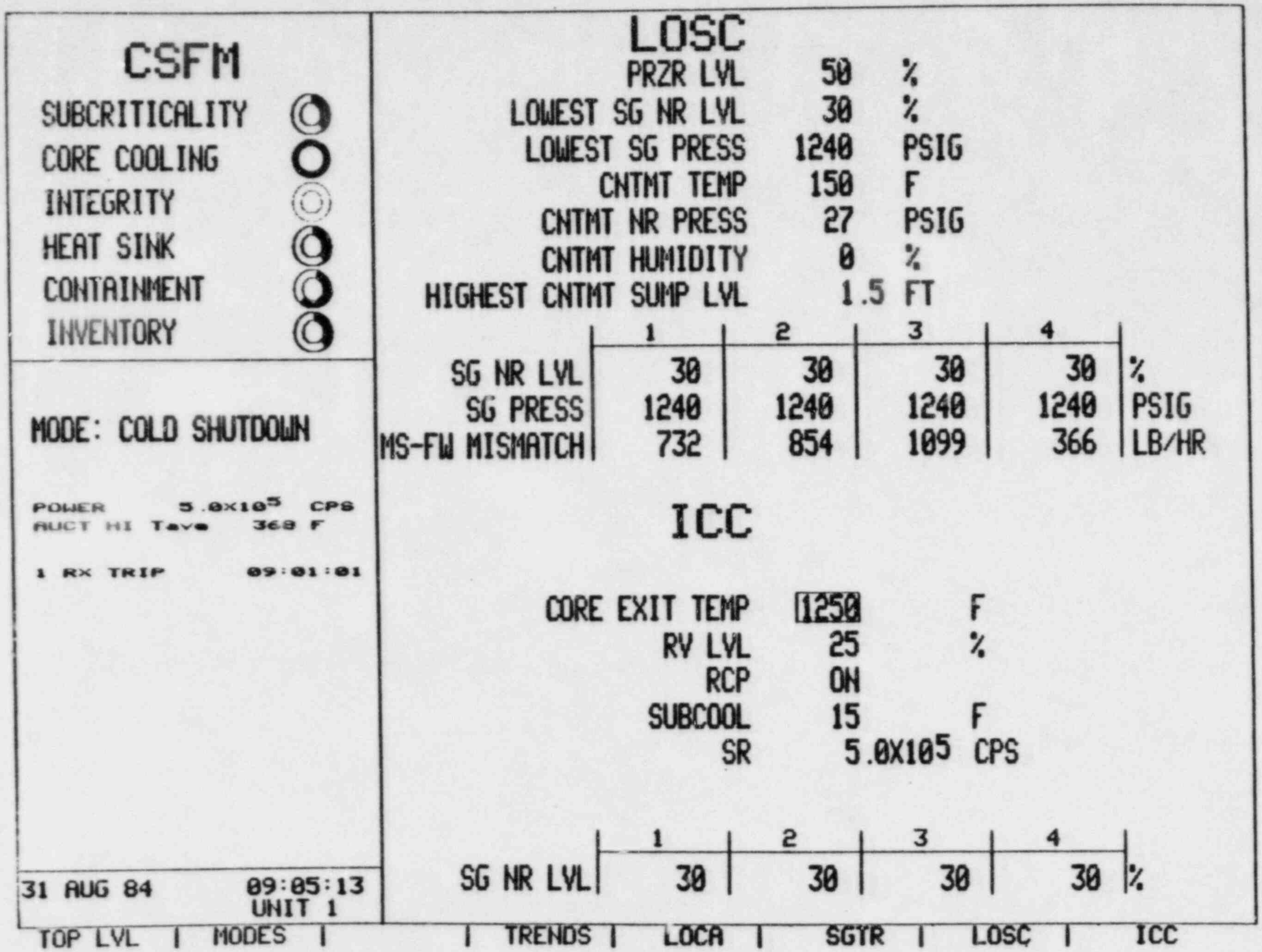


FIGURE 6

TYPICAL LOSC & ICC AIDS DISPLAYS

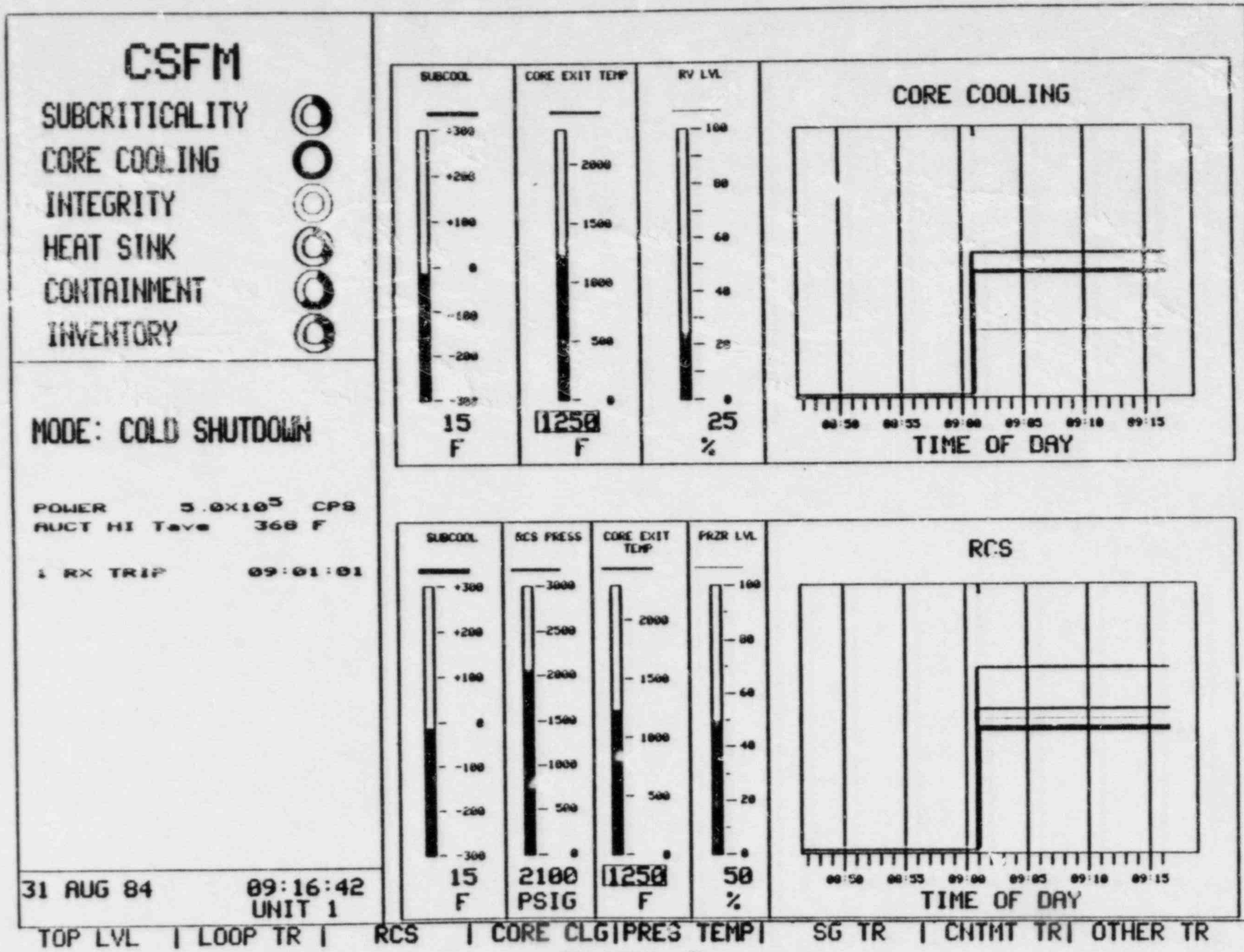


FIGURE 7
TYPICAL TREND GRAPH DISPLAYS

2.3 Human Factor Design Considerations

An interdisciplinary team of operations, control and instrumentation, and human factors engineers were involved in the definition, creation, and review of the formats to ensure a set of user-oriented displays consistent with the requirements of supplement 1 to NUREG-0737, the functional criteria of NUREG-0696, and the general human factors guidance of NUREG-0700. This program included a simulator evaluation at the Indian Point 2 power plant (Reference 5).

2.3.1 Features

The display formats are designed with low information densities and include only that information required to support the task activity of the user. Further, the color scheme is designed to reduce the visual dominance of the static background information. Extensive use of demarcation lines is employed to separate classes of data or parameters. Four different colors are used on the trend graphs for differentiation and association.

Simple display formats are provided to reinforce user recognition of plant status. Vertical bar level indications are easy to associate with parameter values or magnitudes as the control boards contain mainly vertical meters. A red (off-normal)/green (normal) color is used to fill the vertical bars on top-level displays (except Cold Shutdown).

As numerous audible alarms already exist in the control room, the use of audible alarms on the SPDS display system is not provided (except for emergency computer shutdown due to adverse conditions in the computer room). However, once an alarmable parameter reaches an alarm setpoint, the parameter indication on the top-level displays (except Cold Shutdown) is set to red, i.e. the vertical bar turns red, the target turns red, and/or the numerical value is "boxed" in red. The alarm is then placed in a dead band to eliminate alarm chatter or reoccurrence should the parameter causing the alarms oscillate around the alarm setpoint.

Arrangement consistency is an important factor in display design and is a key feature of the SPDS displays. Certain data (date, time, display titles, critical safety function summary, messages, etc.) always appear in the same areas to assist user identification of data appearing on multiple displays. The data or information groups are located on the display in order of relative importance. Generally, the groups are ordered in a top-to-bottom and left-to-right ranking, with the most important data at the top or on the left of the display. Additionally, the critical safety function summary and message areas remain on all SPDS displays to prompt the user when a status change has occurred.

The quality of information being displayed to the user is also presented. Should a caution exist concerning the validity of data, the numerical value is "boxed" in yellow. If all sensors providing data for a parameter fail, or are taken out of scan, the digital value for the parameter is replaced by yellow asterisks. In no case is the display void; it is presented to the user as a system operational reference.

A predetermined set of time versus value trend graphs and a parameter versus parameter graph are provided to compare and gain historic data about functionally related sets of parameters. A 30-minute (two hours for the Cold Shutdown mode display) history is provided on each Trend Graph display.

Extensive use of graphic presentations is used on the SPDS displays. Standard or relatable symbols are used to the maximum practical extent. By using a 1024 by 1024 (780 viewable) pixel colorgraphic CRT, high-resolution color symbols and line clarity are achieved. With the high-resolution display and sharpness provided, high levels of object/background and object/object discrimination are obtained.

2.3.2 Graphic Coding

Pattern and color coding techniques are extensively used to portray status in a graphic form for rapid user recognition.

2.3.2.1 Pattern Coding

As previously mentioned, vertical bar charts were selected as the means of presenting primary status indications. This technique allowed for a range of value indication in a form comprehended by the user.

The predetermined trend graphs, mentioned in section 2.3.1, are provided for historic information over a 30-minute period. These time versus value trend graphs allow for comparison of functionally related sets of variables. Up to four variables are presented on a single graph. Each variable on a graph is assigned a specific color. To aid color-impaired users and provide a redundant coding dimension, each variable on a trend graph has a corresponding bar graph to the left of the trend graph.

Trend arrows are used on the top-level and AIDS displays in conjunction with the parameter values to provide immediate value trend direction information.

Lines are used to annotate ranges on the top-level bar charts. This provides an indication to the user as to parameter proximity to a setpoint.

2.3.2.2 Color Coding

Color coding is used to enhance changes in status and to aid parameter differentiation and association. Color use is consistent (green is always used to portray normal or acceptable conditions) and restrained (only seven colors plus a black background are used). Should a color gun fail or an operator suffer from a visual color imbalance, parameter status information is obtainable by alternate means (display location, digital values, etc.), and since no "pure" colors (i.e. color gun red, green, or blue) are used, all display contents will be retained.

The use of color on the Critical Safety Function summary employed a structured approach. To present CSF status information the following conventions are used:

* Red - off-normal, immediate action, loss of safety function
* Orange - prompt action, potential loss of safety function
* Yellow - failure or caution, loss of redundancy, action may be needed
* Green - normal, Critical Safety Function satisfied
* Yellow Asterisk - loss of indication (sensor related) Critical Safety Function unknown

Color usage on the trend graphs was used for differentiation and association to distinguish the four parameter trends on each graph and to relate a corresponding bar level to a trend line.

Beige color is used for demarcations, titles, graduations, static values, and text information. White is used for dynamic values and event/message data because of its sharp contrast value against the black background of the displays.

2.3.3 Display Access

The SPDS displays are available on two types of display terminals: the primary (SPDS console and control board) CRT's and the secondary CRT's. The primary CRTs, normally used by the reactor operators, are provided with dedicated function keypads that allow for rapid, single entry, non-ambiguous display requests. The function key access scheme--one button, one display--also provides a layout configuration reflecting the display structure or heirarchy. The type and number of SPDS displays available on the primary and secondary CRT's are discussed in detail in section 2.2. A primary display heirarchy is used to present information at three levels of detail or content:

* Top level
* AIDS
* Parameter trend graphs

The secondary CRT's are configured to access displays that are in addition to but not part of SPDS. In this capacity most functions are called up via multiple keyboard commands on a standard keyboard. These functions provide for both detailed parameter data investigation and parameter summary capability.

2.3.4 Control Room Location

The primary CRT's (two per unit) are located on the main control board and on the reactor operators console (see Figure 1). The secondary CRT's are readily accessible to the shift supervisor (at his emergency work station in the Control Room) and the technical advisory staff (in both the Technical Support Center and the Emergency Operation Facility). The shift supervisor will also have visual access to the primary CRT's. The primary CRT's will not interfere with the normal movement of the control room operations crew and will not interfere with visual access to other control room systems. The SPDS displays are readable from a minimum angle of 45° between operator line-of-sight and the plane of the display screen. The critical top-level display data is readable to a distance of 15 feet.

2.4 Verification and Validation Program

The Verification and Validation (V&V) program for the Comanche Peak safety parameter display system is in accordance with NSAC 39. The safety-related aspects of the SPDS design satisfies the requirements of ANSI N45.2.11-1974.

The SPDS is a subsystem of the emergency response facility. As such, its V&V program satisfies the objectives of NUREG-0696, "Functional Criteria for Emergency Response Facilities." All V&V activities are performed by individuals who are independent from the design effort and have sufficient experience and expertise to properly evaluate the various activities which affect the final design and installation of the SPDS. Activities covered by the V&V plan include: design verification against functional requirements and specifications, installation inspection, and overall system performance testing. The system requirements document for the ERF computer system consists of a requirements traceability matrix taken from the system requirements specifications and NUREG-0696.

2.4.1 Definitions

Verification is the demonstration of the consistency, completeness, and correctness of each stage of the development of a project on the basis of fulfillment of all requirements imposed by the previous stage. Validation is the demonstration of the correctness of the final system as determined by testing against overall functional, performance, and interface requirements.

The essential idea of verification is stage-by-stage confirmation of the design, while validation refers to overall testing of the final product. The V&V process is intended to provide an overall check that all requirements are met and that the system operates satisfactorily.

2.4.2 V&V Activities

Specific areas covered by V&V activities are:

* System requirements verification
* Hardware and software design specification verification
* System validation testing
* System verification testing

For each of the above V&V activities, qualified personnel are assigned to perform the activities required to ensure that all applicable design basis requirements are included in the design and that the design is complete, correct, and unambiguous. An interim report is issued at each phase of the V&V process, wherein all discrepancies are identified and resolved. A final V&V report summarizes the results of each activity, and documents the resolutions of all required corrective actions.

2.4.3 Relationship Between QA and V&V

The V&V efforts of the V&V program are independent of any quality assurance (QA) requirements which may be imposed elsewhere. As part of the V&V effort, the V&V team may elect to employ QA procedures, forms, or personnel. Such election would be for convenience and cost-effectiveness of the V&V effort and would not impose additional QA requirements nor compromise any QA requirements of any part of the overall system specifications.

3.0 SELECTION AND EVALUATION OF SPDS INPUT PARAMETERS

The CPSES SPDS input parameters were selected based upon their ability to comprehensively and unambiguously monitor the various plant safety functions (Reactivity Control, Reactor Core Cooling and Heat Removal, etc). Additionally, the type, number and range of each input parameter were selected to be sufficient to determine the maintenance or accomplishment status of each critical safety function for a wide variety of events, including design basis accidents for all modes of reactor operation.

3.1 Selection and Evaluation Process

The CPSES Final Safety Analysis Report and the plant Technical Specifications were reviewed to determine requirements regarding the maintenance and accomplishment of each critical safety function during all modes of reactor operation; this review included:

* System design bases and performance specifications
* Transient and accident analyses
* Characteristics of the modes of operation
* Alarm setpoints and system operational limits
* Technical Specifications bases

The CPSES parameter set includes all of the minimum set of SPDS parameters selected by the Ad Hoc Group of the Westinghouse Owners Group Subcommittee on Instrumentation (1981) of which Texas Utilities is a member. The parameter set for the CPSES SPDS was also compared with the SPDS parameter sets recommended by NSAC and AIF. The NSAC (reference 6) set was derived by checking against WASH 1400 sequences and observing the number of times each parameter was a potential indicator of plant status. The indicators were classified as leading, secondary, possible misleading, or negligible response indicators for the various sequences. The AIF set (reference 7) was developed by using formal parameter selection criteria: detection, leading indicator, plant safety functions, radioactive barrier, direct measurement, reliability, and applicability under diverse plant conditions. Selected parameters were evaluated against the selection criteria in a predefined logic.

The CPSES SPDS parameter set includes all of the AIF SPDS parameters and all of the NSAC SPDS parameters which serve as leading indicators for the events analyzed except reactor coolant system flow rate, pressurizer relief tank level, volume control tank level, letdown flow rate, and control rod position. According to the NSAC study (reference 6), reactor coolant system flow rate is recommended to indicate loss of generator and subsequent failure to relay the plant loads to off site power and failure to establish conditions for natural circulation. In the case of loss of the main generator, trip of the reactor coolant pumps, which occurs on undervoltage, would provide similar indication and is monitored by the CPSES SPDS. Establishing and maintaining natural circulation and determining if adequate cooldown is occurring are accomplished without the use of RCS flow indication. Conditions which support or indicate natural circulation include reactor coolant subcooling margin greater than 10°F, steam generator pressure stable or decreasing, hot leg temperature stable or decreasing, core exit temperature stable or decreasing, and cold leg temperature near the saturation temperature for steam generator pressure. All these parameters are monitored and displayed on the SPDS.

Pressurizer relief tank level was recommended by NSAC to indicate pressurizer safety relief valve position. As an SPDS parameter, this only provides indication as to the possible cause of a reactor coolant system integrity breach. Since this is primarily used for diagnostics and because primary indicators of reactor coolant system integrity are available on the CPSES SPDS, this parameter is not displayed on the SPDS. Volume control tank level and letdown flow rate were recommended by NSAC as leading indicators of CVCS performance but are not primary indicators of CSF status. Control rod position is recommended by NSAC to indicate reactor protection system (RPS) performance. The primary indicators of RPS performance, as well as adequate core subcriticality, are neutron flux and decreasing flux (negative startup rate) both of which are monitored and displayed on the CPSES SPDS. Control rod position is not monitored by the SPDS, but is adequately displayed via the rod position indicating system display located next to the SPDS CRT on the main control board.

3.2 Parameters Required to Assess Each Critical Safety Function

The CPSES parameters selected for monitoring each of the five critical safety functions identified in NUREG-0737, supplement 1, are listed in Appendix 1. Each parameter set is discussed in terms of:

* The parameters which provide primary status indication for the critical function.
* The systems and procedures which may be used to restore or maintain the critical safety functions within safe limits, and their associated parameters.
* The parameters associated with monitoring the status or result of operator emergency actions to restore the plant to within safe operating limits.

The analog ranges of displayed parameters are listed in Appendix 2. SPDS parameter ranges were selected (see Section 3.3) to correspond with existing control room instrumentation.

3.2.1 Reactivity Control

As discussed in section 1.3, one of the critical safety functions associated with maintaining the fuel clad barrier intact is reactivity control, i.e., the control of fission in the fuel.

For all modes of normal plant operation the primary indication of core reactivity is neutron flux which is monitored and displayed on the SPDS. For normal heatup, cooldown, and power operation, neutron flux information is provided in appropriate units of counts per second or percent power. The SPDS provides neutron flux information via the Nuclear Instrumentation System (NIS) and associated electronics which monitor the entire power range identified in section 3.3. This range covers the source range (SR) in units of counts per second, intermediate range (IR) in detector amperes and power range (PR) in percent power units. For the cold shutdown display, the source range (only) is provided in a two hour trend graph format.

For off-normal or accident conditions, the primary means of assessing reactivity control is by reactor subcriticality indicators. Achievement and maintenance of subcriticality is clearly indicated by trend graphs on the SPDS Nuclear Instrumentation System (NIS) display. In addition, the CSFM status summary (located in the upper left corner of the Normal and Heatup/Cooldown Top Level displays) indicates whether or not subcriticality is being maintained.

3.2.2 Reactor Core Cooling and Heat Removal from the Primary System

Adequate core cooling and heat removal from the primary system ensures fuel cladding temperatures remain below failure limits. In order to assess adequate core cooling, the coolant inventory and temperature, the margin of subcooling, and the primary system heat sinks must be monitored.

To ensure an adequate coolant inventory exists in the primary system, the operator must be cognizant of reactor vessel and pressurizer water levels. Adequate vessel level ensures the core is covered and adequate pressurizer level ensures a total coolant inventory is properly maintained. Both of these levels are monitored and displayed by the SPDS. Reactor vessel level is monitored and displayed on all Top Level displays. Pressurizer level is monitored and displayed for all normal operating Top Level displays, except cold shutdown. In addition, both pressurizer and vessel level are given on trend graph displays.

Primary indicators of core cooling include coolant temperature and margin of subcooling. For normal power, heatup, and cooldown operations, core exit, cold leg, and hot leg temperatures are monitored to provide core exit, cold leg, and coolant average temperature indications. Margin of subcooling is also indicated in these modes. For the cold shutdown mode, only, core exit temperature is monitored. For off-normal and accident conditions, core exit temperature, margin of subcooling, vessel water level, and reactor coolant pump status are monitored for use in the ICC AIDS display and the CSFM summary on the Top Level displays (except for Cold Shutdown). These variables provide indication of the core thermodynamic state and the degree to which core cooling is accomplished. Margin of subcooling, core exit and cold leg temperatures are also given on Trend Graph displays.

The main heat sink for the primary system consists of four steam generators. If one of the four steam generators is receiving adequate flow, is not overpressurized, and has sufficient inventory, then an adequate heat sink exists. Steam generator level and pressure are monitored and displayed on the SPDS Top Level displays for normal power, heatup, and cooldown plant operating modes. Additionally, for off-normal or accident conditions, steam generator level and pressure, auxiliary feedwater flow and main steam-feedwater flow mismatch are monitored for use in the STGR and LOSC AIDS displays and the CSFM summary portion of the Top Level displays (except for Cold Shutdown). Steam generator pressure and level are also given on Trend Graph displays.

For cold shutdown, decay heat is removed using the manually initiated residual heat removal (RHR) system. RHR system flow and heat exchanger inlet and outlet temperatures which indicate the performance of this heat sink are monitored and trend graph displayed for this mode of operation.

3.2.3 Reactor Coolant System Integrity

Keeping the reactor coolant system (RCS) intact and operating within limits is necessary to ensure proper heat removal during all modes of reactor operation. Breach of reactor coolant system integrity can occur due to overpressurization or excessive thermal stress. RCS pressure and temperature combinations which may cause a breach of RCS integrity are monitored for use in the CSFM summary on the Top Level displays (except for Cold Shutdown).

Detection that a RCS breach has occurred will be indicated by various parameters depending on the location and magnitude of the breach. Decreasing reactor coolant pressure, reactor vessel level, and pressurizer level will indicate a breach. Increasing containment pressure, radiation, and water level will indicate the coolant is exiting into containment. Increasing main steam, steam generator blowdown or condenser off gas radioactivity indicate coolant is exiting through steam generator tubes into the secondary side. These parameters are monitored and displayed on the AIDS displays and are also Trend Graph displayed.

3.2.4 Containment Conditions

Containment parameters monitored which indicate a possible threat to integrity include containment pressure, sump level, water level, and radiation. The primary threat to containment is from overpressurization which could cause a breach of containment. Sump level and water level are monitored to indicate the potential for flooding which would render important containment cooling and depressurization equipment inactive. Radiation, which does not pose a threat to containment integrity directly, is monitored to assess to magnitude and potential consequences of a breach and the need to ensure proper isolation of containment. All these parameters are monitored and displayed on the LOCA AIDS display and Trend Graph displays of the SPDS.

3.2.5 Radioactivity Control

In order to assess the status of radioactivity control, all major potential release points are monitored.

The principal radioactive release point during normal, off-normal, and accident conditions is the main stack which is monitored by the SPDS. Containment radiation level is also monitored by the SPDS to enable the operators to assess the potential for radioactive releases resulting from accidents. As discussed in section 3.2.3, radioactivity that could be released through the steam generators to the secondary side is monitored by the steam generator blowdown, the condenser off gas, and the main steam line radiation monitors.

Containment, steam generator blowdown, condenser off gas, and highest main steam line activities are all indicated on the SPDS Top Level displays for the normal and heatup/cooldown modes of operation. Additionally, containment radiation is displayed on the LOCA AIDS display while steam generator blowdown and condenser off gas radiation is displayed on the SGTR AIDS display. All of these radioactivity parameters are also given on a Trend Graph display.

3.3 Parameter Ranges

The SPDS parameter ranges are presented in Appendix 2. Analog signals which provide input to the SPDS are identified with their corresponding ranges. In general, all ranges monitored by the SPDS are identical to those in the control room and envelope system design criteria, plant responses to design basis accidents, transients, and ATWS responses.

Neutron flux (reactor power) information is provided in the range of one count per second to 150 percent of full reactor power. Full range monitors that include source range (SR), intermediate range (IR), and power range (PR) outputs are used with sufficient overlap of ranges to provide this information. Additionally, SR startup rate is monitored from -.5 to 5 decades per minute (dpm). These ranges correspond with the nuclear instrumentation system (NIS) indicators located in the control room.

Pressurizer level and reactor vessel level are monitored and displayed from 0 to 100 percent of capacity which corresponds with control room indication.

Core exit temperature is monitored and displayed over the range of 0 to 2,300°F. This range corresponds with the Core Cooling Monitor indications located in the control room. The RCS subcooling margin is monitored and displayed over the range of -300 to +300 °F which corresponds with the Core Cooling Monitor control room indications.

Cold and hot leg temperatures are monitored from 0 to 700°F which corresponds with the RCS temperature indicators located in the control room.

Steam generator level is monitored and displayed over its entire capacity of 0 to 100 percent. Steam generator pressure is monitored and displayed from 0 to 1,300 psig. These ranges correspond with the steam generator indicators located in the control room.

Steam generator steam flow and auxiliary feedwater flow are monitored from 0 to 5×10^6 lbm/hr and 0 to 550 gpm, respectively. These flow rates are on a per-loop basis for each of the four loops. Both the auxiliary feedwater and steam flow rates monitored and displayed correspond with the control room indicators.

RHR system flow is monitored and displayed from 0 to 5,500 gpm which correspond with the indications located in the control room.

RHR heat exchanger inlet and outlet temperatures are monitored from 50 to 400°F which correspond with indications located in the control room.

Pressurizer pressure and reactor coolant loop pressure are monitored from 1,700 to 2,500 psig and 0 to 3,000 psig, respectively. These are combined to provide a reactor coolant system (RCS) pressure display of 0 to 3,000 psig. This display corresponds with indications located in the control room.

Containment pressure is monitored and displayed over the range of -5 to 60 psig which corresponds with indications located in the control room.

Containment water level is monitored and displayed with respect to site elevation and containment sump level is monitored and displayed from 0 to 3 feet. These displays correspond with indications located in the control room. Additionally, containment humidity is derived from containment temperatures (wet and dry bulb) and pressure and is displayed over the full range of 0 to 100 percent.

Containment radiation is monitored and displayed over the range of 10^3 to 10^{10} mR/hr which corresponds with the Radiation Monitoring System (RMS) indications located in the control room.

Containment hydrogen (H_2) concentration is monitored and displayed over the range of 0 to 10 percent which corresponds with the Hydrogen Analyzer indications located in the control room.

Steam generator blowdown radiation and condenser off gas radiation are monitored and displayed from 10^{-5} to 10^{-1} μC/ml which corresponds with the Radiation Monitoring System (RMS) indications for these parameters. Additionally, all four Main Steam line radiation levels are monitored and the highest is displayed from 10^{-1} to 10^3 μC/ml which also corresponds with the RMS indications in the control room.

3.4 Selection of SPDS Alarm Setpoints

Alarm setpoints for SPDS input parameters were selected to provide indications consistent with existing plant alarm setpoints.

3.5 Reactor Mode Indication

The SPDS will be operational during all reactor operation modes, i.e., normal power operation, startup operation, hot shutdown, cold shutdown, and refueling shutdown. Three dedicated top-level displays are provided to cover the above operating modes they are: normal power operation, heatup/cooldown, and cold shutdown.

3.6 Provisions for Validation of SPDS Data

The displayed value of each SPDS parameter is determined by processing one or more plant signals. Valid/invalid indications are provided for SPDS parameters and are determined through systematic consideration of the type and number of signals available for each parameter. A displayed variable which consists of a single analog input signal is generally determined to be valid or invalid based on a validation table comparison check of the high and low limits. If the data is out of range, the parameter is failed, and the digital value on the display is replaced by yellow asterisks.

For a parameter with two sensor inputs, the sensor input data are checked against the validation table limits. Three different situations can occur:

1. One sensor is rejected in range checking. The data for the remaining one sensor is taken as the parameter data. Since only one sensor data is left, it is defined to be in a "Suspect" condition and the parameter data is displayed in a yellow box.

2. Both sensors are rejected in range checking. The parameter will be displayed as a failed parameter, i.e., displayed as yellow asterisks.

3. No sensor has been rejected. The average of the two sensor's data will be displayed as the parameter data. If the two sensor data are divergent by more than 10%, the parameter value is considered as "Suspect" and is displayed in a yellow box.

For SPDS parameters utilizing three or more sensor inputs, the inputs are first checked against validation table range limits. If the unrejected sensors are less then three, the remaining sensor inputs will be treated as described above for one or two sensor inputs. If three or more sensors are left unrejected, these inputs will be validated with Chauvenet's criteria. If Chauvenet's criteria rejects an input, the remaining inputs (there will be at least two) will be averaged and the average will be used as the SPDS parameter value. If no other inputs are rejected by Chauvenet's criteria, all these inputs will be averaged and the average will be used as the SPDS parameter value.

Chauvenet's criteria is a simple rejection criteria that accounts for affects of sample size, N, and the deviation of a sample from the mean (reference 2). Chauvenet's criteria allows a sample to be rejected if the probability is less than 1/(2N) that deviations from the mean equal to or greater than the sample deviation can occur. This probability is computed by integrating the normal distribution from the negative difference of the sample value and mean value to the positive difference of the sample value and mean value. If a sample is rejected, an new mean is recalculated, the the criteria applied again to the remaining valid data.

If all SPDS input sensor signals for a parameter are rejected, the failed parameter is displayed on the Channel Malfunction Monitor display which provides information in text identifying the parameter. Additionally, all failed plant input sensors are tabulated and displayed on the Failed Point Summary display. These displays are available only on the supervisor's, TSC's, and EOF's CRT displays, and are not a part of the SPDS. They do, however, provide for rapid diagnosis of signal malfunctions affecting the SPDS.

4.0 SAFETY EVALUATION PER 10CFR50.59

This evaluation analyzes the function, design, installation, and operation of the Safety Parameter Display System (SPDS) to ensure that SPDS implementation does not involve an unreviewed safety question. The objective of the evaluation is to verify that: 1) the probability of occurrence or the magnitude of the consequences of an accident or malfunction of equipment important to safety, previously evaluated in the FSAR will not be increased, 2) the possibility for an accident or malfunction of a different type than any evaluated previously in the FSAR has not been created, and 3) the margin of safety as defined in the basis for any technical specification will not be reduced by the addition of the SPDS.

4.1 SPDS Function and Design

The SPDS provides a concise display of critical plant safety parameters to the control room personnel to aid them in rapidly and reliably determining the safety status of the plant. The SPDS will be operable during normal and abnormal plant conditions. The principal purpose and function of the SPDS is to aid the control room personnel during abnormal and emergency conditions in determining the current safety status of the plant. The SPDS will continuously display real-time information in the control room from which the plant safety status can be readily and reliably assessed by control room personnel.

The SPDS, however, is not a safety system and will perform no active safety function. The existing control room instrumentation provides the operators with the information necessary for safe reactor operation under normal, transient, and accident conditions. The SPDS will be used in addition to the existing instrumentation and will serve to aid and augment it. For these reasons, Supplement 1 to NUREG-0737 directs that the requirements applicable to control room instrumentation are not needed for this augmentation. The SPDS need not meet the requirements of the single-failure criteria and it need not be qualified to meet Class 1E requirements.

4.2 SPDS Installation and Safety System Interface

The installation of the CPSES SPDS does not compromise any safety system or involve an unreviewed safety question for the following reasons:

* All SPDS displays located in the control room are mounted per seismic category II specifications so that they will not affect any safety system instrumentation or control in the event of a design basis seismic disturbance.

* The ERF/SPDS supporting computers are located in a separate, seismic category I, fire protected room ajacent to the control room and will not affect any safety system instrumentation or control in the event of a fire or design basis seismic disturbance.

* The SPDS is electrically and electronically isolated from all CPSES safety related devices and complies with Class 1E isolation criteria.

4.3 SPDS Operation

The SPDS operational safety evaluation encompasses three major areas: functional requirements as specified by Federal Regulations and CPSES procurement specifications, input sensor verification, and control room operator influence.

4.3.1 SPDS Functional Requirements

The CPSES SPDS implementation was subject to an extensive verification and validation (V&V) program which followed the guidance of NSAC 39. The verification (V&V) program provided an independent review to verify that:

* All interfaces with existing safety-related and non-safety related equipment have been properly identified.
* The proper design standards have been invoked.
* The applicable design requirements have been properly implemented in the design, functional, and procurement specifications.

Additionally, an extensive validation testing program was employed to ensure proper functioning of the total integrated SPDS data acquisition, manipulation, and display systems per the verified design specifications.

4.3.2 SPDS Input Sensor Verification

Each plant system sensor that has input to the SPDS was simulated through the actual sensor field cables to ensure a one-to-one correspondence between the input sensor signal and the SPDS displayed value. This input/output (IO) verification process assured accurate, non-ambiguous sensor input recognition by the SPDS and it also determined that no input data was "lost" or "shuffled".

4.3.3 SPDS Control Room Operator Influence

The SPDS will not degrade control room operators' performance or ability to respond to plant operational requirements for either normal or accident conditions. In addition to the human factors design considerations discussed in Section 2.3, the operators will be trained in the use of the SPDS.

Control room operators are trained in procedures which describe the timely and correct safety status assessment when the SPDS is and is not available. Operating procedures are written to preclude the operator from taking actions based solely on SPDS display information. The operating procedures require that all operator actions affecting the safety of the plant be based on information which has been confirmed using the existing control room indicators. Therefore, no transient or accident analyzed in the FSAR are affected by either the operation or the failure of the SPDS, nor is the potential increased for a malfunction or accident of a different type than those previously described in the FSAR.

5.0 SUMMARY AND CONCLUSIONS

This safety analysis report was prepared in response to section 4 of supplement 1 to NUREG-0737 (reference 1). This SAR describes the methodology and basis on which the plant parameters selected for monitoring on the CPSES SPDS have been determined to be sufficient to assess the overall safety status of the plant in terms of the following five critical safety functions:

* Reactivity control
* Reactor core cooling and heat removal from the primary system
* Reactor coolant system integrity
* Containment conditions
* Radioactivity control

The CPSES SPDS parameter set was evaluated against the CPSES FSAR, technical specifications, SAS simulator-tested parameter set, NSAC-recommended parameter set, and the AIF-recommended set for sufficiency in terms of the type and number of parameters set for sufficiency in terms of the type and number of parameters monitored to assess each safety function, and the range of plant conditions covered by the parameters. The final parameter set covers all Function Restoration Guidelines (FRG) entry conditions associated with critical safety function assessment, and includes all variables recommended by the SAS group for the SPDS. On the basis of this review and evaluation process, the CPSES parameters are sufficient to assess plant safety status over a wide range of conditions, including the symptoms of severe accidents and all modes of reactor operation. The function, design, installation, and operation of the CPSES SPDS were also analyzed in accordance with the provisions of 10 CFR 50.59, and it was concluded that no unreviewed safety question is involved with the SPDS implementation at CPSES.

6.0 REFERENCES

1. NRC Letter, supplement 1 to NUREG-0737 "Requirements for Emergency Response Capability" (Generic letter no 82-33), December 17, 1982.

2. "Functional Design Specification for SAS Software (Proprietary)," prepared by Quadrex Corporation for the Ad Hoc Committee on Instrumentation Systems, Safety Assessment System Project, revision 2, May 1982.

3. "Safety Assessment System User Implementation Guide," QUAD-7-82-010 revision 0, prepared by Quadrex Corporation for the Ad Hoc Group of the Westinghouse Owners Group (WOG) Subcommittee on Instrumentation, May 1982.

4. Comanche Peak Steam Electric Station Final Safety Analysis Report (FSAR).

5. "Safety Assessment System Evaluation Program Report", prepared by Quadrex Corporation and Inpsych for the Ad Hoc Committee on Instrumentation Systems, Safety Assessment System Project, May 20, 1982.

6. A. R. Buhi, et al., "Nuclear-Plant Safety-Parameter Evaluation by Event Tree Analysis", NSAC-8, October 1980.

7. Letter from David G. Cain, NSAC, to AIF subcommittee on safety parameter integration, Parameter Selection Work Group, subject: SPDS Minimum Parameter Set, July 3, 1980.

APPENDIX 1

SPDS CRITICAL SAFETY FUNCTIONS AND ASSOCIATED MONITORED AND DISPLAYED PARAMETERS

CRITICAL SAFETY FUNCTION	MONITORED PARAMETER	DISPLAYED PARAMETER	TREND GRAPHED
Reactivity Control	(SR, IR, & PR Monitor) Power	(SR, IR, & PR Monitor) Power	X
	SR Startup Rate	SR Startup Rate	
	Reactor Trip Status	Reactor Trip Status	
Reactor Core Cooling and Heat Removal From the Primary System	Reactor Vessel Level	Reactor Vessel Level	X
	Pressurizer Level	Pressurizer Level	X
	Core Exit Temperature	Core Exit Temperature	X
	Cold Leg Temperature	Cold Leg Temperature	X
	Hot Leg Temperature and	Hot Leg Temperature	X
	Cold Leg Temperature	Reactor Coolant Average Temp.	
	Reactor Coolant Pump Status	Reactor Coolant Pump Status	
	Core Exit Temperature and	Subcooling Margin	X
	Reactor Coolant Pressure		
	Steam Generator Level	Steam Generator Level	X
	Steam Generator Pressure	Steam Generator Pressure	X
	Auxiliary Feedwater Flow	Auxiliary Feedwater Flow	
	Steam Generator Steam Flow	Steam Generator Steam Flow	X
	RHR System Flow	RHR System Flow	X
	RHR Heat Exchanger Inlet Temp.	RHR Heat Exchanger Inlet Temp.	X
	RHR Heat Exchanger Outlet Temp.	RHR Heat Exchanger Outlet Temp.	X
Reactor Coolant System Integrity	Reactor Coolant Loop Pressure	Reactor Coolant System Pressure	X
	and Pressurizer Pressure		
	Cold Leg Temperature and	Reactor Coolant Average Temperature	
	Hot Leg Temperature	Hot Leg Temperature	X
	Cold Leg Temperature	Cold Leg Temperature	X
	Reactor Vessel Level	Reactor Vessel Level	X
	Pressurizer Level	Pressurizer Level	X
	Containment Radiation	Containment Radiation	X
	Containment Pressure	Containment Pressure	X
	Containment Water Level	Containment Water Level	X
	Containment Sump Level	Containment Sump Level	X
	Steam Generator Blowdown Rad.	Steam Generator Blowdown Rad.	X
	Condenser Off Gas Radiation	Condenser Off Gas Radiation	X
	Main Steam Line Radiation	Main Steam Line Radiation	X
Containment Conditions	Containment H_2 Concentration	Containment H_2 Concentration	X
	Containment Water Level	Containment Water Level	X
	Containment Pressure	Containment Pressure	X
	Containment Radiation	Containment Radiation	X
	Containment Temperature	Containment Temperature	X
	Containment Pressure and	Containment Humidity	X
	Temperatures		
Radioactivity Control	Main Steam Line Radiation	Main Steam Line Radiation	X
	Containment Radiation	Containment Radiation	X
	Steam Generator Blowdown Rad.	Steam Generator Blowdown Rad.	X
	Condenser Off Gas Radiation	Condenser Off Gas Radiation	X

APPENDIX 2

SPDS PARAMETER RANGES

DISPLAYED PARAMETER	DISPLAYED RANGE
Reactor Power (SR, IR, and PR Monitor)	.1 to 10^5 cps (SR) 10^{-11} to 10^{-3} amp (IR) 0 to 150% (PR)
SR Startup Rate	-.5 to 5 dmp
Reactor Vessel Level	0 to 100%
Pressurizer Level	0 to 100%
Core Exit Temperature	0 to 2,300°F
RCS Subcooling Margin	-300 to +300°F
Cold Leg Temperature	0 to 700°F
Hot Leg Temperature	0 to 700°F
Steam Generator Level	0 t0 100%
Steam Generator Pressure	0 to 1,300 psig
Steam Generator Steam Flow	0 to 5 x 10^6 lbm/hr
Auxiliary Feedwater Flow	0 to 550 gpm
RHR System FLow	0 to 5,500 gpm
RHR Heat Exchanger Inlet and Outlet Temperatures	50 to 400°F
Reactor Coolant System Pressure	0 to 3,000 psig
Containment Temperature	0 to 300°F
Containment Pressure	-5 to 60 psig
Containment Water Level	808' to 816.5' elevation
Containment Sump Level	0 to 3 ft.
Containment Humidity	0 to 100%
Containment Radiation	10^3 to 10^{11} mR/hr
Containment H_2 Concentration	0 to 10%
Steam Generator Blowdown Radiation	10^{-5} to 10^{-1} μC/ml
Condenser Off Gas Radiation	10^{-5} to 10^{-1} μC/ml
Main Steam Line Radiation	10^{-1} to 10^3 μC/ml