8.7 PRIMARY COOLING SYSTEM INSTRUMENTATION

8.7.1 Introduction

The Primary Cooling System (PCS) instrumentation is the set of sensors and equipment responsible for acquiring and transferring to the RCMS and RPS, signals monitoring the state of the PCS. This information allows the RCMS to maintain PCS parameters within their operational limits, and allows the RPS to trigger the actuation of the shutdown systems when the PCS parameters are beyond their established safety settings.

8.7.2 Design Requirements

The PCS instrumentation complies with the following requirements according to its classification as a Safety Category 2 system:

1. PCS instrumentation provides reliable information regarding primary cooling parameters, indicating whether they are within their operational limits.
2. PCS instrumentation is able to correctly perform its functions under all normal operational conditions.
3. PCS instrumentation and control components are properly qualified such that it can fulfil its functions following abnormal occurrences.
4. PCS instrumentation is designed to properly perform its actions under all design basis environmental conditions.
5. PCS instrumentation connected to Safety Category 1 systems is Safety Category 1 qualified.
6. PCS instrumentation is designed to facilitate surveillance and maintenance of components.

8.7.3 Description

The following are the main types of PCS instrumentation:

Measuring Instrument	Signal received by:			Location of Instrument
	Local	RCMS	RPS x 3	
Flow meter			FRPS	Return pipeline outside pool
Flow meters		X		Core flushing line and line to RSPCS.
Pressure Gauges	X			Pump inlet/outlet, Heat exchangers inlet/outlet
Differential Pressure Transmitters			FRPS and SRPS	Reactor core inlet/outlet
Temperature Elements		X		Heat exchanger inlet/outlet
Temperature Elements			FRPS and SRPS	Reactor core inlet/outlet
Temperature Elements		X		Top of the chimney

Measuring Instrument	Signal received by:			Location of Instrument
	Local	RCMS	RPS x 3	
Level Switches		X	FRPS and SRPS	Pool
Limit Switch		X		Flap valves (full open and full closed) (2 additional switches for PAM indication)
Limit Switch		X		Isolation valves
Failed Fuel Detection		X		Reactor core outlet pipe (FFEM and ALMO)

Typical pump parameters received by the RCMS are:

Measured Parameter	Location of Measuring Device	Type of Measuring Device
Temperature	Drive winding	Thermistor with relays
	Drive bearings	RTD
	Bearings	RTD
	Pump bearings	RTD
Vibration		Acceleration detector
Leak Detection	Mechanical seal	Level detection switch

A detailed description of the actions and interlocks generated by the RCMS and RPS can be found in Chapter 6.

8.7.4 Conformance Analysis

8.7.4.1 Conformance to Design Requirements

8.7.4.1.1 Conformance to Design Requirements 1

Requirement 1: PCS instrumentation will provide reliable information regarding cooling parameters, indicating whether they are within their operational limits.

All PCS instrumentation has been selected to provide reliable data regarding the reactor cooling parameters. The instruments selected, cover the entire expected range of operation of the monitored parameters with appropriate accuracy. Thus the instrumentation provides reliable information that indicates if the PCS parameters are within their operational limits.

8.7.4.1.2 Conformance to Design Requirements 2

Requirement 2: PCS instrumentation will be able to correctly perform their functions under all normal operational conditions.

Operational conditions are the design bases taken into account when selecting instrumentation for each monitored parameter. All instrumentation is designed to properly function in all operational states of the system.

8.7.4.1.3 Conformance to Design Requirements 3

Requirement 3: PCS instrumentation and control components will be properly qualified such that they can fulfil their functions during and after abnormal occurrences.

All Safety Category 1 and 2 instrumentation is qualified to the requirements of their respective category. This ensures that the instrumentation will fulfil their function during and after abnormal occurrences.

8.7.4.1.4 Conformance to Design Requirement 4

Requirement 4: PCS instrumentation will be designed to properly perform their actions under all design basis environmental conditions.

PCS instrumentation is not located in the reactor pool, and is located away from harsh environments thereby reducing the possibility of equipment deterioration by corrosion, vibration or radiation. In all cases, instrumentation is provided with protection from its environment and is designed to tolerate all operational conditions and expected transients.

8.7.4.1.5 Conformance to Design Requirement 5

Requirement 5: PCS instrumentation connected to Safety Category 1 systems will be Safety Category 1 qualified.

Signals coming from Safety Category 2 systems can be shared with Safety Category 1 systems, however this imposes strict conditions on the quality of the sensors provided. In all cases where a Safety Category 2 system is connected to a Category 1 system, the sensors and instruments are qualified to Class 1E requirements and are designed with the required redundancy and physical separation.

8.7.4.1.6 Conformance to Design Requirement 6

Requirement 6: PCS instrumentation will be designed to facilitate surveillance and maintenance of components.

Where possible, instruments have been placed in locations to facilitate accessibility for surveillance and maintenance tasks by operators and maintainers.

End of Section

8.8 SECONDARY COOLING SYSTEM INSTRUMENTATION

8.8.1 Introduction

The Secondary Cooling System (SCS) instrumentation is the set of sensors and equipment responsible for acquiring and transferring to the RCMS signals monitoring the state of the SCS. This information allows the RCMS to modify operational conditions to maintain SCS parameters within operational limits.

8.8.2 Design Requirements

The SCS instrumentation fulfils the following functional requirements according to its Safety Category 2 classification:

1. SCS instrumentation provides reliable information regarding secondary cooling parameters, indicating whether they are within their operational limits.
2. SCS instrumentation is able to correctly perform its functions under all normal operational conditions.
3. SCS instrumentation and control components are properly qualified such that they can fulfil their functions during and after abnormal occurrences.
4. SCS instrumentation is designed to properly perform its functions under all design basis environmental conditions.
5. SCS instrumentation is designed to facilitate surveillance and maintenance of components.

8.8.3 Description

The following are the main types of SCS instruments:

Measuring Instrument	Signal received by:			Location
	Local	RCMS	RPS x 3	
Flow Meter	X	X		Collector – self-clean filters outlet – ventilation pump outlet
Pressure Gauges	X			Pumps inlet/outlet- Heat exchangers inlet / outlet, Cooling tower inlets
Pressure Switches		X		Water from cooling towers
Temperature Elements		X		Heat exchangers inlet / outlet collector - Downstream of main pumps
Vibration Switches		X		Cooling tower fans and pumps
Level Control Valve	X			Cooling tower basin

A detailed description of the actions and interlocks generated by the RCMS can be found in Chapter 6.

8.8.4 Conformance Analysis

8.8.4.1 Conformance to Design Requirements

8.8.4.1.1 Conformance to Design Requirements 1

Requirement 1: SCS instrumentation will provide reliable information regarding cooling parameters, indicating whether they are within their operational limits.

All SCS instrumentation is selected to indicate SCS parameters regarding the cooling characteristics. The instruments selected cover the entire expected range of operation of the monitored parameters with appropriate accuracy. The SCS instrumentation therefore provides reliable information that indicates if the SCS parameters are within their operational limits.

8.8.4.1.2 Conformance to Design Requirements 2

Requirement 2: SCS instrumentation will be able to correctly perform their functions under all normal operational conditions.

Operational conditions are the design bases taken into account when selecting instrumentation for each monitored parameter. All instrumentation is designed to properly function in all operational states of the system.

8.8.4.1.3 Conformance to Design Requirements 3

Requirement 3: SCS instrumentation and control components will be properly qualified such that they can fulfil their functions during and after abnormal occurrences.

All instrumentation of the SCS is qualified according to the requirements of Safety Category 2. This ensures that the instrumentation fulfils its function during and after abnormal occurrences.

8.8.4.1.4 Conformance to Design Requirement 4

Requirement 4: SCS instrumentation will be designed to properly perform their actions under all design basis environmental conditions.

SCS instrumentation is not located in a harsh environment, thereby reducing the possibility of equipment deterioration by corrosion, vibration or radiation. In all cases, instrumentation is provided with protection from its environment and is designed to tolerate all operational conditions and expected transients.

8.8.4.1.5 Conformance to Design Requirement 5

Requirement 5: SCS instrumentation will be designed to facilitate surveillance and maintenance of components.

SCS instrumentation is placed, whenever possible in such a way as to facilitate accessibility for surveillance and maintenance tasks by operators and maintainers.

End of Section

8.9 REFLECTOR COOLING AND PURIFICATION SYSTEM INSTRUMENTATION

8.9.1 Introduction

The RCPS instrumentation is the set of sensors and equipment responsible for acquiring and transferring to the RCMS and RPS signals monitoring the state of the RCPS. This information allows the RCMS to modify the operational conditions to maintain RCPS parameters within operational limits, and allows the RPS to trigger the actuation of shutdown systems when the RCPS parameters are beyond their established safety settings.

8.9.2 Design Requirements

The RCPS Instrumentation fulfils the following functional requirements according to its Safety Class 2 classification:

1. RCPS instrumentation provides reliable information regarding reflector D_20 cooling parameters, indicating whether they are within their operational limits.
2. RCPS instrumentation is able to correctly perform their functions under all normal operational conditions.
3. RCPS instrumentation and control components are properly qualified such that they can fulfil their functions during abnormal occurrences.
4. RCPS instrumentation is designed to properly perform their actions under all design basis environmental conditions.
5. RCPS instrumentation connected to Safety Category 1 systems is Safety Category 1 qualified.
6. RCPS instrumentation is designed to facilitate the surveillance and maintenance of components.

8.9.3 Description

The main monitored parameters of the RCPS are:

a) Reflector Primary Cooling System Instrumentation:

Measuring Instrument	Signals received by:			Location
	Local	RCMS	RPS x 3	
Flow Meter		X	FRPS	Reflector vessel inlet pipe, outside of the reactor pool
Pressure Transmitter		X		Expansion tank top and heat exchanger inlet
Pressure Gauges	X			Pumps inlet/outlet - Heat exchanger outlet
Temperature Elements		X	SRPS	Reflector vessel
Temperature Elements		X		Before the pump branches; outlet of heat exchanger
Conductivity Sensor		X		Heat exchanger inlet

Measuring Instrument	Signals received by:			Location
	Local	RCMS	RPS x 3	
Level Sensor		X	FRPS	Expansion tank - Storage tank

b) Reflector Intermediate Cooling System Instrumentation:

Measuring Instrument	Signals received by:			Location
	Local	RCMS	RPS x 3	
Flow Meter		X		Heat exchanger inlet/outlet
Flow Switch	X			Filter inlet
Pressure Gauges	X			Pumps inlet/outlet - Heat exchanger outlet
Temperature Elements		X		Heat exchanger inlet/outlet
Level Sensor		X		Expansion tank

c) Deuterium Recombination System Instrumentation:

Measuring Instrument	Signals received by:			Location
	Local	RCMS	RPS x 3	
Flow Meter		X		Compressor discharge.
Pressure Indicating Transmitter	X	X		Compressor discharge
Differential Pressure Sensor		X		Gas filters
Temperature Elements		X		Electric Heaters outlet – Recombination units outlet - Gas filters outlet – compressor inlet/outlet
Conductivity Sensor		X		Gas filters outlet, heat exchanger outlet

A detailed description of the actions and interlocks generated by the RCMS and RPS can be found in Chapter 6.

8.9.4 Conformance Analysis

8.9.4.1 Conformance to Design Requirements

8.9.4.1.1 Conformance to Design Requirements 1

Requirement 1: RCPS instrumentation will provide reliable information regarding cooling parameters, indicating whether they are within their operational limits.

All RCPS instrumentation is selected to indicate reactor parameters regarding the reflector D_20 cooling and purification characteristics. The instruments are selected to cover the entire expected range of operation of the monitored parameters with the appropriate accuracy. Thus the instrumentation provides reliable information that indicates if the parameter is within its corresponding operational limit.

8.9.4.1.2 Conformance to Design Requirements 2

Requirement 2: RCPS instrumentation will be able to correctly perform their functions under all normal operational conditions.

Operational conditions are the design bases taken into account when selecting instrumentation for each monitored parameter. All instrumentation is designed to properly function in all operational states of the system.

8.9.4.1.3 Conformance to Design Requirements 3

Requirement 3: RCPS instrumentation and control components will be properly qualified such that they can fulfil their functions during and after abnormal occurrences.

All Safety Category 1 and 2 instrumentation is qualified to the requirements of their respective category. This ensures that the instrumentation fulfils its function during and after abnormal occurrences.

8.9.4.1.4 Conformance to Design Requirement 4

Requirement 4: RCPS instrumentation will be designed to properly perform their actions under all design basis environmental conditions.

The RCPS instrumentation is not located in a harsh environment, thereby reducing the possibility of equipment deterioration by corrosion, vibration or radiation. In all cases instrumentation is provided with the corresponding protection from its environment and is designed to tolerate all operational conditions and expected transients.

8.9.4.1.5 Conformance to Design Requirement 5

Requirement 5: RCPS instrumentation connected to Safety Category 1 systems will be Safety Category 1 qualified.

Signals coming from Safety Category 2 systems can be shared with Safety Category 1 systems however this imposes strict conditions on the quality of the sensors provided. In all cases where a Safety Category 2 system is connected to a Category 1 system, the sensors and instruments are qualified to Class 1E requirements and are designed with the required redundancy and physical separation.

8.9.4.1.6 Conformance to Design Requirement 6

Requirement 6: RCPS instrumentation will be designed to facilitate surveillance and maintenance of components.

Wherever possible, the instruments are placed in such a way as to facilitate accessibility for surveillance and maintenance tasks by operators and maintainers.

End of Section

8.10 REACTOR AND SERVICE POOLS COOLING SYSTEM INSTRUMENTATION

8.10.1 Introduction

The Reactor and Service Pools Cooling System (RSPCS) instrumentation is the set of sensors and equipment responsible for acquiring and transferring to the RCMS and FRPS signals monitoring the state of the RSPCS. This information allows the RCMS to modify operational conditions to maintain RSPCS parameters within operational limits, and allows the FRPS to trigger the actuation of the FSS when the RSPCS parameters are beyond their established safety settings.

8.10.2 Design Requirements

The RSPCS instrumentation fulfils the following requirements according to its Safety Class 2 classification:

1. RSPCS instrumentation provides reliable information regarding reactor and service pools cooling parameters, indicating whether it is within its operational limits.
2. RSPCS instrumentation is able to correctly perform its functions under all normal operational conditions.
3. RSPCS instrumentation and control components are properly qualified such that it can fulfil its functions during and after abnormal occurrences.
4. RSPCS instrumentation is designed to properly perform its actions under all design basis environmental conditions.
5. RSPCS instrumentation connected to Safety Category 1 systems is Safety Category 1 qualified.
6. RSPCS instrumentation is designed to facilitate surveillance and maintenance of components.

8.10.3 Description

The monitored parameters of the RSPCS are:

Measuring Instrument	Signals received by:			Location
	Local	RCMS	RPS x 3	
Flow Meter		X	FRPS	Irradiation rigs cooling branch, inlet/outlet of heat exchanger, upstream of the pumps
Limit switches		X	FRPS	RSPCS Flap Valves Position, three way valve
Pressure Differential Transmitter		X		Between the irradiation rigs plenum and the pool
Pressure Gauges	X			Pump inlet/outlet - Heat Exch. Outlet
Temperature Elements		X		Heat Exch. inlet/outlet, Pumps
Vibration elements		X		Pumps
Conductivity Sensors		X		Reactor pool outlet - Service pool outlet

A detailed description of the actions and interlocks generated by the RCMS and FRPS can be found in Chapter 6.

8.10.4 Conformance Analysis

8.10.4.1 Conformance to Design Requirements

8.10.4.1.1 Conformance to Design Requirements 1

Requirement 1: RSPCS instrumentation will provide reliable information regarding cooling parameters, indicating whether they are within their operational limits.

RSPCS instrumentation is selected to indicate the parameters regarding the cooling characteristics of the reactor and service pool. The instruments are selected to cover the entire expected range of operation of the monitored parameters with the proper accuracy. Thus the instrumentation provides reliable information that indicates if the parameters are within their corresponding operational limit.

8.10.4.1.2 Conformance to Design Requirements 2

Requirement 2: RSPCS instrumentation will be able to correctly perform their functions under all normal operational conditions.

Operational conditions are a design basis taken into account when selecting instrumentation for each monitored parameter. All instrumentation is designed to properly function in all operational states of the system.

8.10.4.1.3 Conformance to Design Requirements 3

Requirement 3: RSPCS instrumentation and control components will be properly qualified such that they can fulfil their functions following design basis fault sequences.

All Safety Category 1 and 2 instrumentation is qualified according to the requirements of their respective category. This ensures that the instrumentation will fulfil its function during and after abnormal occurrences.

8.10.4.1.4 Conformance to Design Requirement 4

Requirement 4: RSPCS instrumentation will be designed to properly perform their actions under all design basis environmental conditions.

The RSPCS instrumentation is not located in a harsh environment, thereby reducing the possibility of equipment deterioration by corrosion, vibration or radiation. In all cases instrumentation is provided with the corresponding protection from its environment and is designed to tolerate all operational conditions and expected transients.

8.10.4.1.5 Conformance to Design Requirement 5

Requirement 5: RSPCS instrumentation connected to Safety Category 1 systems will be Safety Category 1 qualified.

Signals coming from Safety Category 2 systems can be shared with Safety Category 1 systems however this imposes strict conditions on the quality of the sensors provided. In all cases, the corresponding sensors and instruments are qualified according to Class 1E requirements and have the required redundancy and physical separation.

8.10.4.1.6 Conformance to Design Requirement 6

Requirement 6: RSPCS instrumentation will be designed to facilitate surveillance and maintenance of components.

Wherever possible, the instruments have been placed in such a way as to facilitate accessibility for surveillance and maintenance tasks by operators and maintainers.

End of Section

8.11 Emergency Make-up Water System Instrumentation

8.11.1 Introduction

The Emergency Make-up Water System (EMWS) instrumentation is the set of sensors and equipment responsible for acquiring and transferring to the RCMS and PAM signals monitoring the state of the EMWS. This information allows the RCMS to modify the operational conditions to maintain the EMWS parameters within their operational limits, and reads the passive initiation of the protective action when the EMWS senses a drop in pool water level.

8.11.2 Design Requirements

The following describes the design requirements that instrumentation of the EMWS fulfils according to its Safety Category 2 classification.

1. EMWS instrumentation provides reliable information regarding EMWS parameters, indicating whether they are within their operational limits.

2. EMWS instrumentation is able to correctly perform their functions under all normal operational conditions.

3. EMWS instrumentation is properly qualified such that they can fulfil their functions during and after abnormal occurrences.

4. EMWS instrumentation is designed to properly perform their actions under all design basis environmental conditions.

5. EMWS instrumentation is designed to facilitate surveillance and maintenance of components.

8.11.3 Description

The following are the main types of EMWS instrumentation:

Measuring Instrument	Signals received by:				Location of instrument
	Local	RCMS	RPS (x3)	PAM (x2)	
Pool Water Level Switches (EMWS Actuation)				X	Detectors located close to the upper edge of the chimney
Level Switches				X	Storage Tank
Flow Switch	X	X		X	Discharge Piping Downward Flow Alarm
Flow Switch		X			Discharge Piping Ascending Flow Alarm

EMWS generates the following protection action:

a) Open valves for water injection

b) Low level in storage tanks inhibit reactor start-up

c) Manual block valve closed inhibits reactor start-up

Details of the system can be found in SAR Chapter 6.

8.11.4 Conformance Analysis

8.11.4.1 Conformance to Design Requirements

8.11.4.1.1 Conformance to Design Requirements 1

Requirement 1: EMWS instrumentation will provide reliable information regarding EMWS parameters, indicating whether they are within their operational limits.

All EMWS instrumentation has been selected to indicate the reactor parameters regarding cooling characteristics of the reactor pool and the equipment that makes up the EMWS. The instruments are selected to cover the entire expected range of operation of the monitored parameters, with the appropriate accuracy. Thus, the instrumentation provides reliable information that indicates if the parameters are within their corresponding operational limit.

8.11.4.1.2 Conformance to Design Requirements 2

Requirement 2: EMWS instrumentation will be able to correctly perform their functions under all normal operational conditions.

Operational conditions are a design basis taken into account when selecting instrumentation for each monitored parameter. All instrumentation is designed to properly function in all operational states of the system.

8.11.4.1.3 Conformance to Design Requirements 3

Requirement 3: EMWS instrumentation will be properly qualified such that they can fulfil their functions during and after abnormal occurrences.

All Safety Category 1 and 2 instrumentation is qualified to the requirements of their respective category. This ensures that the instrumentation fulfils their function during and after abnormal occurrences.

8.11.4.1.4 Conformance to Design Requirement 4

Requirement 4: EMWS instrumentation will be designed to properly perform their actions under all design basis environmental conditions.

The EMWS instrumentation is not located in a harsh environment, thereby reducing the possibility of equipment deterioration by corrosion, vibration or radiation. In all cases, instrumentation is provided with the corresponding protection from its environment and is designed to tolerate all operational conditions and expected transients.

8.11.4.1.5 Conformance to Design Requirement 5

Requirement 5: EMWS instrumentation will be designed to facilitate surveillance and maintenance of components.

Wherever possible the instruments have been placed in such a way as to facilitate accessibility for surveillance and maintenance tasks by operators and maintainers.

End of Section

8.12 HOT WATER LAYER SYSTEM INSTRUMENTATION

8.12.1 Introduction

The Hot Water Layer System (HWLS) instrumentation is the set of sensors and equipment responsible for acquiring and transferring to the RCMS signals monitoring the state of the HWLS. This information allows the RCMS to modify the operational conditions to maintain HWLS parameters within their operational limits.

8.12.2 Design Requirements

The HWLS instrumentation fulfils the following functional requirements according to its Safety Class 2 classification:

1. HWLS instrumentation provides reliable information regarding HWLS parameters, indicating whether they are within their operational limits.

2. HWLS instrumentation is able to correctly perform their functions under all normal operational conditions.

3. HWLS instrumentation and control components are properly qualified such that they can fulfil their functions during and after abnormal occurrences.

4. HWLS instrumentation is designed to properly perform their actions under all design basis environmental conditions.

5. HWLS instrumentation is designed to facilitate surveillance and maintenance of components.

8.12.3 Description

The main types of instruments in the HWLS are:

Measuring Instrument	Signals received by:			Location
	Local	RCMS	RPS x 3	
Flow Meter	X	X		Pump discharge make-up inlet, inlet to tank
Flow Switch		X		Heater outlet
Pressure Gauges	X			Pump inlet/outlet
Pressure Safety Valve	X			Heaters
Temperature Elements		X		Heater outlet, Pump supply line
Level Switches		X		Storage tank

A detailed description of the actions and interlocks generated by the RCMS can be found in Chapter 6.

8.12.3.1 Conformance to Design Requirements

8.12.3.1.1 Conformance to Design Requirements 1

Requirement 1: HWLS instrumentation will provide reliable information regarding HWLS parameters, indicating whether they are within their operational limits.

All HWLS instrumentation has been selected to indicate reactor parameters regarding the state of the hot water layer as defined in the HWLS design basis. The instruments are selected to cover the entire expected range of operation of the monitored parameters, with appropriate accuracy. Thus, the instrumentation provides reliable information that indicates if the HWLS parameters are within their operational limits.

8.12.3.1.2 Conformance to Design Requirements 2

Requirement 2: HWLS instrumentation will be able to correctly perform their functions under all normal operational conditions.

Operational conditions are a design basis taken into account when selecting instrumentation for each monitored parameter. All instrumentation is designed to properly function in all operational states of the system.

8.12.3.1.3 Conformance to Design Requirements 3

Requirement 3: HWLS instrumentation and control components will be properly qualified such that they can fulfil their functions during and after abnormal occurrences.

All instrumentation of Safety Category 2 systems is qualified according to the requirements of this category. This ensures that the instrumentation fulfils their function during and after abnormal occurrences.

8.12.3.1.4 Conformance to Design Requirement 4

Requirement 4: HWLS instrumentation will be designed to properly perform their functions under all design basis environmental conditions.

The HWLS instrumentation is not located in a harsh environment, thereby reducing the possibility of equipment deterioration by corrosion, vibration or radiation. In all cases instrumentation is provided with the corresponding protection from its environment and is designed to tolerate all operational conditions and expected transients.

8.12.3.1.5 Conformance to Design Requirement 5

Requirement 5: HWLS instrumentation will be designed to facilitate surveillance and maintenance of components.

Wherever possible, the HWLS instrumentation has been placed in such a way as to facilitate accessibility for surveillance and maintenance tasks by operators and maintainers.

End of Section

8.13 MAIN CONTROL ROOM DESIGN

The design of the MCR takes into consideration the nuclear safety and radiological protection requirements as well as reactor utilisation for radioisotope production and neutron beam research.

The MCR is designed together with operational procedures, operator actions and information displays to allow the fulfilment of the reactor facility safety, radiological protection, and utilisation objectives.

The MCR and ECC are the main areas for reactor control. However there are other control points distributed in the plant, grouped according to functions or systems. All points have the necessary attributes and information for operators to correctly execute their tasks. The distribution of tasks is arranged to avoid overloading the MCR with information that may distract or divert operator attention from their specific function.

The MCR has three main elements:

Main Console (MC)

Supervisor Console (MCS)

Wall Panel (WP)

The operator has access to Visual Display Units (VDUs) for all the systems from which periodical or on-demand information is required. Similarly, the type of graphical presentation is defined for all parameters present in the Main Control Room or remote centres. Desks have pushbuttons, touch screens, dedicated keyboards and track balls. Information is delivered through the VDUs or hardwired instruments. In general, the horizontal section of the Main Console houses pushbuttons keyboards and keys while the vertical area houses hardwired displays and VDUs.

8.13.1 Design Requirements

8.13.1.1 General Ergonomic Design Theory

The methodology utilised for the development of an ergonomic design is presented on the flow sheet shown in Figure 8.13/1.

8.13.1.1.1 Information-Action Cycle

An operator is likely to take corrective action or execute an operation based on:

a) Training

b) Information received through the human-machine interfaces

c) Administrative procedures

The design of work sites takes into consideration the average ergonomic characteristics as indicated in Figure 8.13/2 and Figure 8.13/3.

8.13.1.1.2 Ergonomic Design

The ergonomic design concept is applied to every unit in which a human-machine interface occurs.

The main human-machine interfaces occur in the MCR at the control consoles through which the operators carry out normal and abnormal procedures.

8.13.1.1.3 Console Design Principles

In this section relevant console design principles that are applicable to the RPS dedicated console, Main Console, Supervision Console and Emergency Console are described.

8.13.1.1.3.1 Console Anthropometrics

The design of all consoles in the control centres has been based on anthropometric considerations to accommodate a broad range of the operating personnel population. The dimensions of these consoles are derived from the anthropometric data set selected for the Reactor Facility.

The controls are set back from the front edge to protect against accidental activation. Since the operator has to be able to reach the controls without having to bend or stretch significantly, all frequently used controls for an operation sequence are within the maximum extended reach of the shortest operator seated in front of the working area on a moveable chair.

Sufficient leg and foot room is provided to enable operators to avoid awkward and uncomfortable seating positions.

8.13.1.1.3.2 Panel Layout

1. Modular Design

   A modular design is used for the Main and Emergency Consoles. This choice has benefits for console maintenance and construction. The coupling between the base modules defines the size and shape of each console and is determined by the operational requirements of each console.

2. Priority

   Priority principles were established and applied to the layout and arrangement of alarm signals, displays and controls. They were determined by the function of a system and the priority ranking between similar elements in the layout of the panels. The priority ranking rules derived from these principles are consistent for all panels in the plant.

3. Positioning

   The positioning of displays, indicators and controls on the panels and desks are based on the following criteria:

   a) Alarm signal displays are visible from the operator seat area.

   b) Frequently used controls are within convenient reach, and related indicators and displays are legible from the operator seat area.

   c) Controls and displays are located so that displays are not obscured during operation.

   d) The location of controls and displays within a single panel makes the most effective use of the viewing and manual operation areas.

8.13.1.1.3.3 Location Aids

a) Grouping

All displayed information and controls are logically grouped to facilitate their location and use. Particular care is taken to avoid conflicts of grouping and to be consistent with the user model of the system.

Six fundamental grouping techniques are used on the MCR and ECC console designs. These techniques group the required elements according to function, sequence of use, frequency of use, priority, operating procedures and process mimics.

b) Grouping by Function - Information and controls are grouped in relation to function or interrelationships within a system. Care is taken to identify the function in terms of what role the information plays in achieving system objectives, rather than the source of information or method of measurement.

c) Grouping by Sequence of Use - Information and controls are grouped on a sequential basis, either by considering the display as a whole or by dividing the display into parts, each of which are organised on a sequential basis. Cause and effect relationships are reflected in the display.

d) Grouping by Frequency of Use - Information most often used is collected at the top of the display with least used information at the bottom. Most used controls are nearest to the operator. This type of grouping is applied within limits, due to:

   (i) the risk of apparently illogically displayed information
   (ii) the constraints of grouping by function and sequence

e) Grouping by Priority - Information or controls are grouped by significance to the success of the system. Highest priority items are placed in prime positions within a group.

f) Grouping by Operating Procedures - Information displays and controls are grouped according to the operating procedures.

g) Mimic Grouping - Information displays and controls are grouped according to the process.

The allocation of panel positions should first ensure the integrity of the arrangement or grouping by system function and task sequence.

1. Coding

The coding system is consistent throughout the MCR and ECC. The code used for displays and associated controls is consistent. This applies to location, information, colour and illumination codes.

The coding method is determined according to the relative advantage of the five types of coding available. Five coding methods are available: physical coding, information coding, location coding, data coding and enhancement coding.

a) Physical Coding - No more than three different sizes are used for discrimination by absolute size. The number of shapes is also limited for shape coding. No more than 12 colours including black and white are used for colour coding. No more than three signals of different frequencies are used for auditory coding. No intensity coding is used in either auditory or visual displays.

b) Information Coding - Coding of displays is used to improve the usability of information by enhancing discrimination and aiding comprehension and assimilation.

c) Location Coding - Relative positioning of information is used to reinforce the intended message in addition to the information transmitted by a pointer, character, group of characters, or symbol.

d) Data Coding - Data coding is used to build a properly formulated glossary of abbreviations and acronyms. Abbreviations are used on labels and VDU displays.

e) Enhancement Coding - Techniques such as reverse video and toggling of symbol size and brightness are used to reinforce the displayed data.

f) The use of colour as a coding medium in the control rooms offers a valuable means of providing unambiguous, easily distinguishable information to the operator. The benefits of colour coding can be realised only if colour is not used indiscriminately.

2. Labelling

Controls, displays and other equipment items that must be located, identified or operated are appropriately and clearly labelled to permit rapid and accurate human response.

Adequate labelling is provided in the MCR and ECC. The labelling is consistent with other labelling in the plant and in accordance with common standards. The criteria for the labelling are as follows:

a) The hierarchy in labelling is achieved by dimensions and shape or type settings.

b) The abbreviations and acronyms are consistent in all systems and easily identified with the full names.

c) Labels provide the functional description and the identification for maintenance purposes are identical to that used in official plant documents.

d) The importance of the functional description is related to the item grouping used.

8.13.1.1.3.4 Information Systems

VDUs are provided in the MCR to provide operating personnel with information on system status and parameter values needed to meet task requirements in normal, abnormal and emergency situations.

The VDUs form the human-machine interface of the information system, considering human capabilities and characteristics.

The major functional requirements of the displays are as follows:

a) Safety-related information displays are suitably located and uniquely identified on control panels.

b) Appropriate types of displays are selected, depending on the purpose of an individual display.

c) Necessary information is available to the operators when required.

d) Information shown is clearly understood by the operators.

e) The display communicates the intended information to operators without ambiguity or loss of meaning.

f) Symbols are standardised and the range of symbol sizes limited.

g) Direction of process flow paths and the sequence of events in schematic displays are in accordance with population stereotypes.

Displays are designed considering human factors and design criteria for panel layout and location aids. Displays are compatible with both the associated controls and instrumentation and the perceptual and cognitive needs of an operator.

Adequate legibility, luminance, contrast, resolution, regeneration rate, minimum reflected glare and minimum geometric distortion are assured in order to meet the quality required for the displayed images.

The following constraints are used to determine the position of the VDUs in all consoles at the different control centres:

a) Minimum viewing distance is constrained. The minimum angle between an operator's actual line of sight and the plane of the visual display unit screen is constrained.

b) Different horizontal and vertical limits are defined for main and auxiliary VDUs. The main VDUs are those which require continuous or frequent monitoring. Other VDUs are considered auxiliary or infrequently monitored.

c) Frequently monitored VDUs are located within the shown limits.

d) Similarly, infrequently monitored VDUs are located within the shown limits

For a graphical depiction see Figure 8.13/4 and Figure 8.13/5.

8.13.1.1.3.5 Alarm System

Alarms provide the necessary information about abnormal conditions in the plant.

Because of the large number of alarm messages and the likelihood that numerous alarms may activate concurrently, logical prioritisation of alarms is implemented such that operators can differentiate the most important or serious alarms from less important ones.

8.13.1.1.3.6 Controls

Controls are designed ergonomically to ensure ease of operation and to minimise operator error.

Mechanical characteristics of control elements include; size, operating pressure or force, tactile feedback to meet human capabilities and the characteristics specified in the anthropometric data.

The controls selected are suitable for operator use in the MCR and ECC environments and match the ergonomic characteristics of the expected user population.

Controls meet the following requirements:

a) Human movement required to perform control actions conform to population stereotypes to minimise operator error.

b) Consistency is applied to colour, shape and size coding, control movements and of controls for similar control functions.

c) Categorisation of controls is commensurate with their importance to safety.

To prevent an event induced by human error, erroneous activation of controls is minimised by means such as locating controls at proper positions, use of fixed protective

structures, movable covers or guards, interlocking controls, application of priority for actuation or any combinations of these, as well as ergonomic considerations.

To ensure that a pushbutton has been pressed far enough for activation, a positive indication is provided in the form of a snap feel, an audible click or an integrated light.

Computer aided functions are introduced for controls to prevent erroneous actuation by means of a sequential or logical actuation interlock, or an operator guide with a computer aided display system.

8.13.1.1.3.7 Control-Display Integration

Controls and their associated displays are correctly integrated to ensure effective operation of the plant by operators in the MCR and ECC.

Control display integration meets the following principle requirements:

a) Location criteria are followed such that controls are located near or below the associated display. Operation of a control produces a compatible change in the relevant display.

b) The form of control adopted is consistent with the form of associated information display.

c) The grouping of controls and their associated displays reflect the need to achieve system objectives and are consistent with the user's mental model of the system.

d) Where operational sequence is an essential factor, the organisation of controls and displays reflect cause and effect relationships.

e) The organisation of controls embodies user population stereotypical groupings.

f) The form of codes used for display and the associated controls are entirely consistent.

g) Engineering units are consistent with the degree of accuracy needed by the operator. All displays indicate values in a form immediately useable by the operator without requiring conversion.

8.13.2 Main Console

The Main Console is divided into areas corresponding to specific systems:

a) On the left side: shutdown actions, alarms, and RPS.

b) In the centre: nuclear and conventional process parameters, selected presentations requested by the operator and Control Rod Drive actions.

c) On the right side: PAM, graphics selected by the operator, authorisations and conventional system commands.

The operator has an integrated communication and CCTV system that enables the operator to see and communicate with any area inside and outside of the plant. Figure 8.13/6 shows the operator's view from the MCR.

8.13.3 Supervision Console

From the supervisor’s desk all operator actions may be verified but not controlled. The Shift Manager has an integral communication system allowing the Shift Manager to see and communicate with any area of the plant without interfering with the operator.

8.13.4 Hardwired Panels and Visual Display Units

The VDUs and hardwired panels allow the operator to determine the state of the facility parameters and to take actions by providing:

a) displayed parameters identified by a code

b) condition: normal condition or alarm

c) action: automatic or manual

d) position in the system

The VDUs provide the following:

a) Representation of the different systems of the plant in the form of a layout, piping and instrument, functional diagram or logic diagrams.

b) Electronic representation of measured parameter

c) Component state (on/off/maintenance)

d) Component position (up/down/on/off in case of CR or switches)

e) Component Control (on/off, open/closed).

f) Location of alarm points.

g) Outline of the relative positions of fire detectors and area monitors.

h) Use of colour coding for indication of states and alarms.

8.13.5 Visual Display Units

The VDUs include the display information related to the following areas:

a) Nuclear

   (i) CRs position

   (ii) indication of the reactor basic parameters (including power, flux readings)

b) Process Systems

   (i) main parameters (including temperatures, flows, pressures, levels etc)

   (ii) state of plant items (main pumps, valves etc)

c) Relative position of:

   (i) Radiation area monitors including alert and alarm states

8.13.6 Hardwired Panels

The hardwired panels include displays for the following:

a) RPS

   (i) state of the nuclear parameters for protection

   (ii) presentation of the protection function trigger parameters for nuclear systems

   (iii) presentation of the protection function trigger parameters for process

systems

b) PAM

(i) Value of selected PAM parameters.

8.13.7 Ergonomics

The following elements have been taken into account:

a) Ergonomics: the relationship between the psychological and physiological capacities of the operator and the working environment. The working environment includes tools, materials, methods and organisation.

b) Anthropotechnic: the interface between human and machine and the possibility to obtain the best reliable and safe design.

c) Anthropometrics: the physical characteristics of the human body both in static positions and in the different positions the operators may assume during work.

d) Architecture: defined as the art of designing and constructing aesthetic and functional spaces, volumes, structures and materials.

The interior conditions of the room include consideration of:

a) Acoustics: The noise level produced by ventilation and other equipment such as printers, alarms, and telephones are sufficiently low to enable operators to be comfortable for long periods of time.

b) Lighting: The best possible lighting levels for all areas of the plant, avoiding reflections and glare.

c) Air Conditioning: The MCR and ECC are air conditioned, taking into consideration the heat loads due to personnel working in the room, lighting and equipment.

d) Furniture: Ergonomic chairs with wheels to allow movement have been provided. Furniture is specifically designed for the tasks to be performed. Desks and consoles allow the operator to freely move his or her legs.

8.13.8 Services

The services provided in the MCR are:

a) Communications

b) Ventilation

c) Electricity

d) Further details on fire detection and fire fighting are provided in Chapter 10.

e) A CCTV system to verify operations or the presence of personnel in physical and radiological hazardous areas. This system is described in more detail in Chapter 10.

f) Seismic design provisions, as described in Chapter 2.

End of Section

Figure 8.13/1 General Ergonomic Design Theory

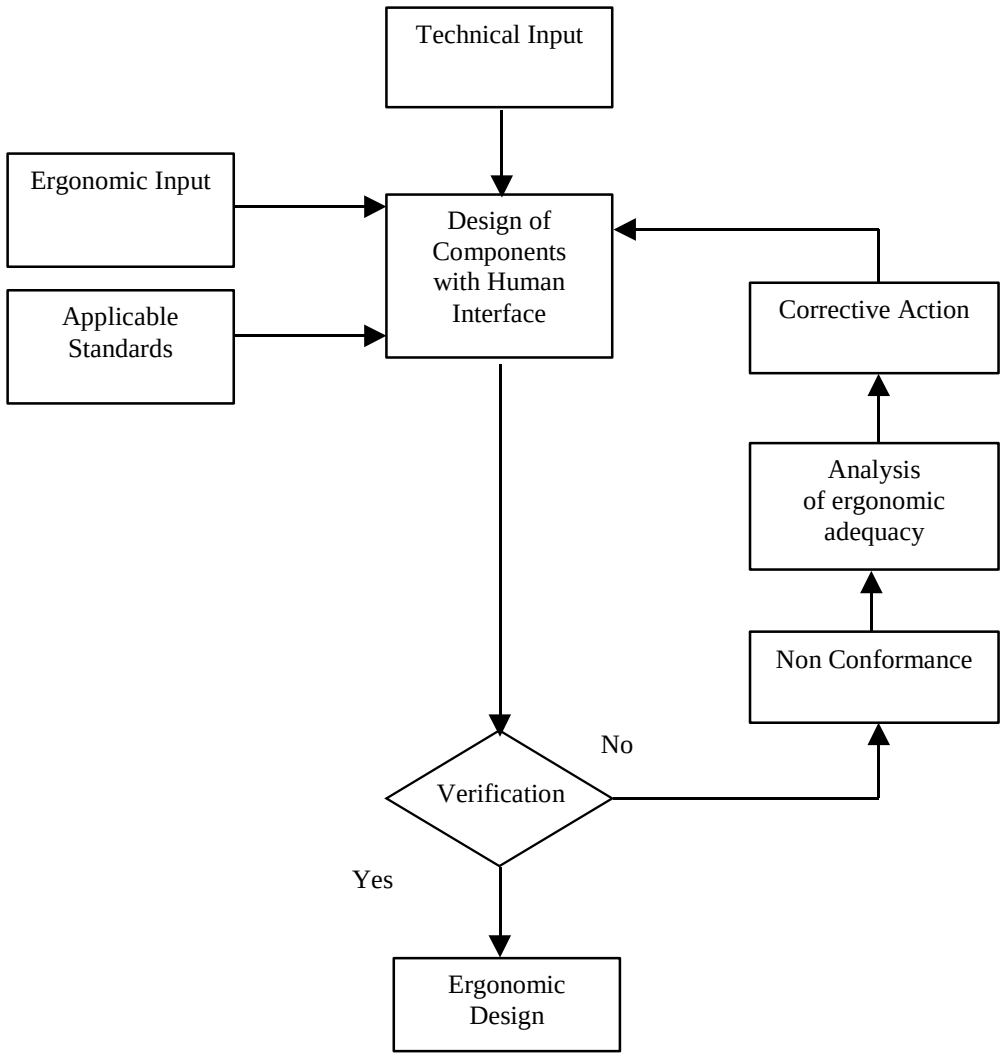
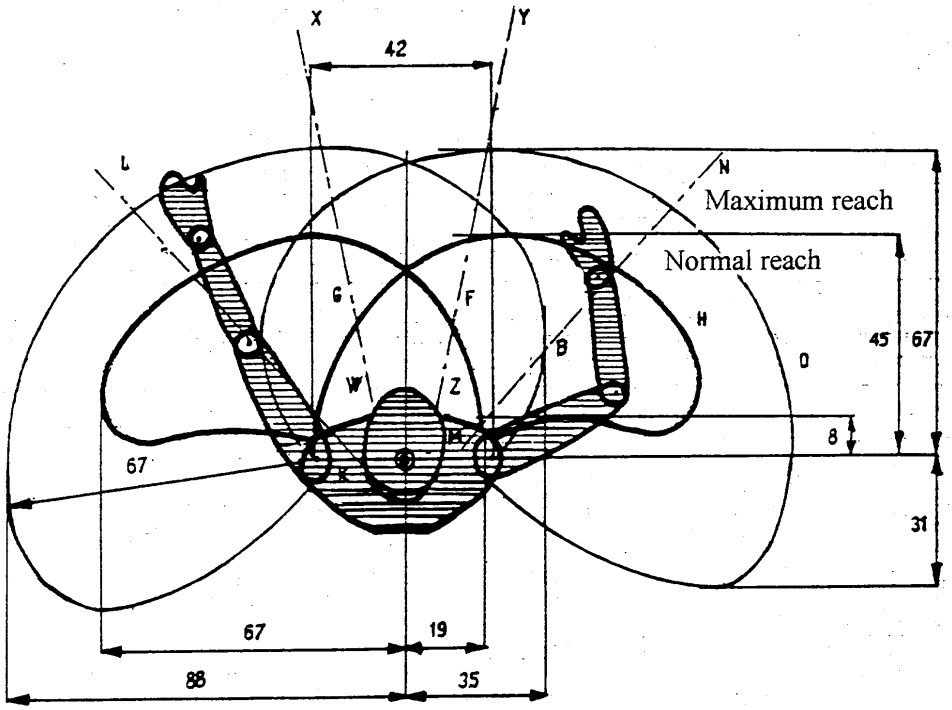
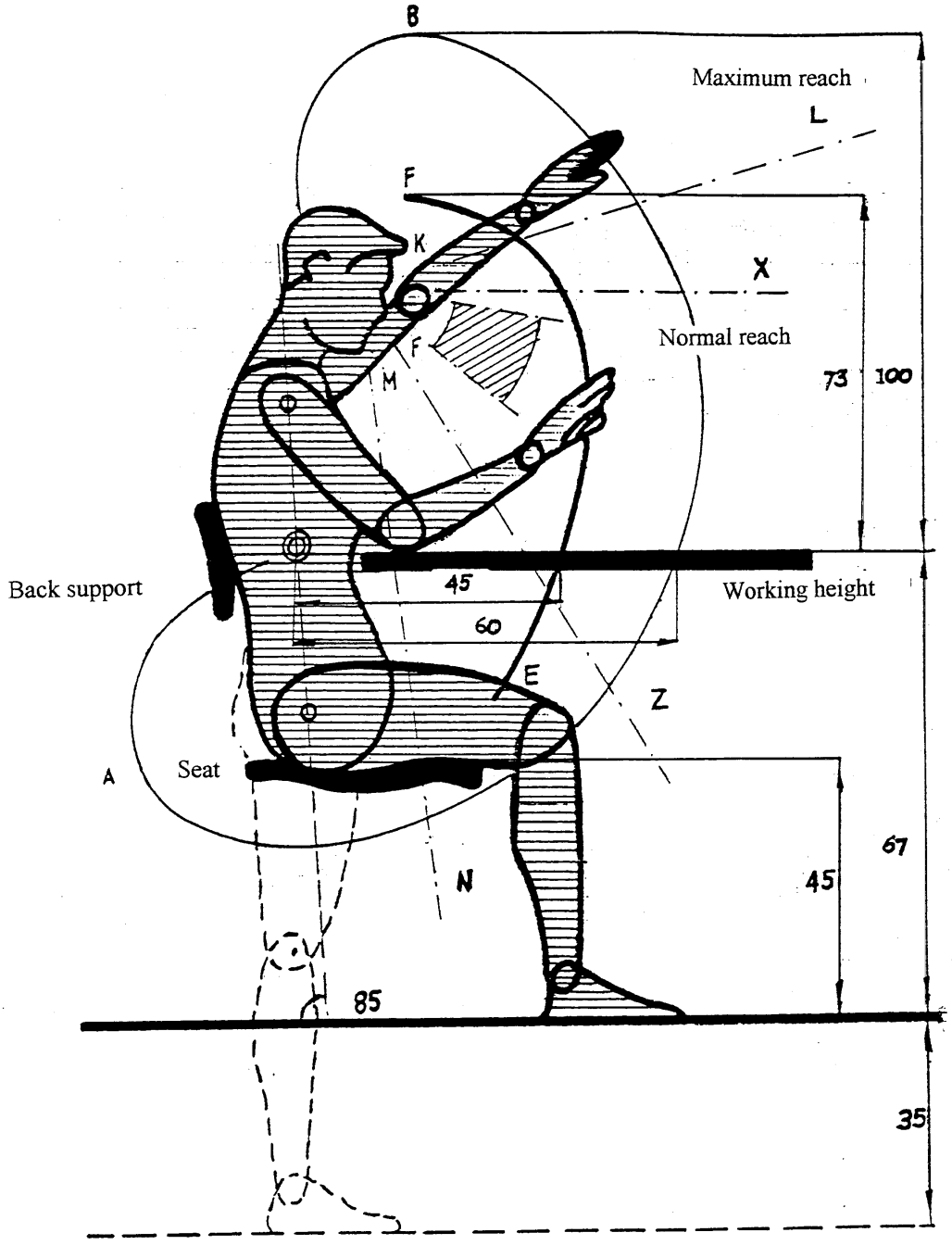


Figure 8.13/2 Average Dimensions of a Work Bench (Top View)



Average dimensions of a work bench, (top view)

Figure 8.13/3 Average Dimensions of a Work Bench (Sectional View)



Average dimensions of a work bench, (sectional view)

Figure 8.13/4 Minimum Viewing Angle

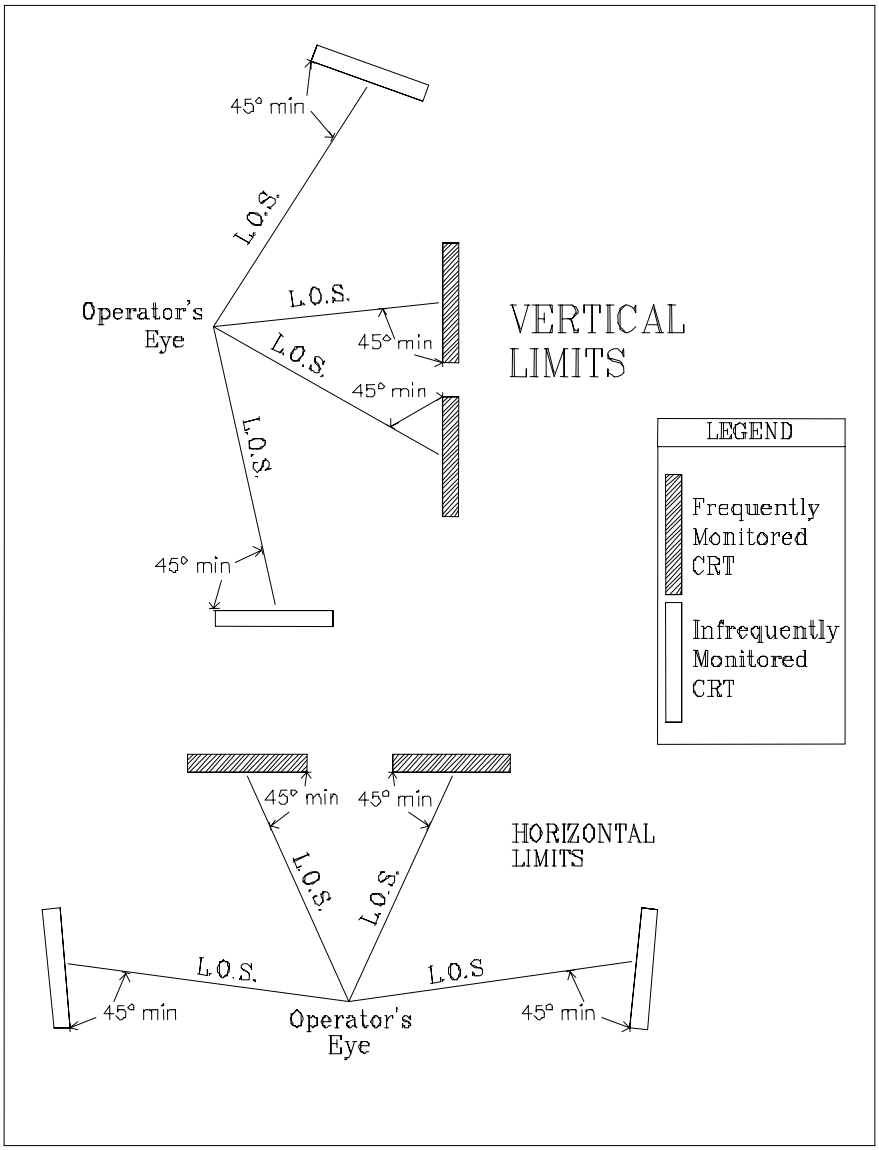


Figure 8.13/5 Screen Location Limits - Seated Operator

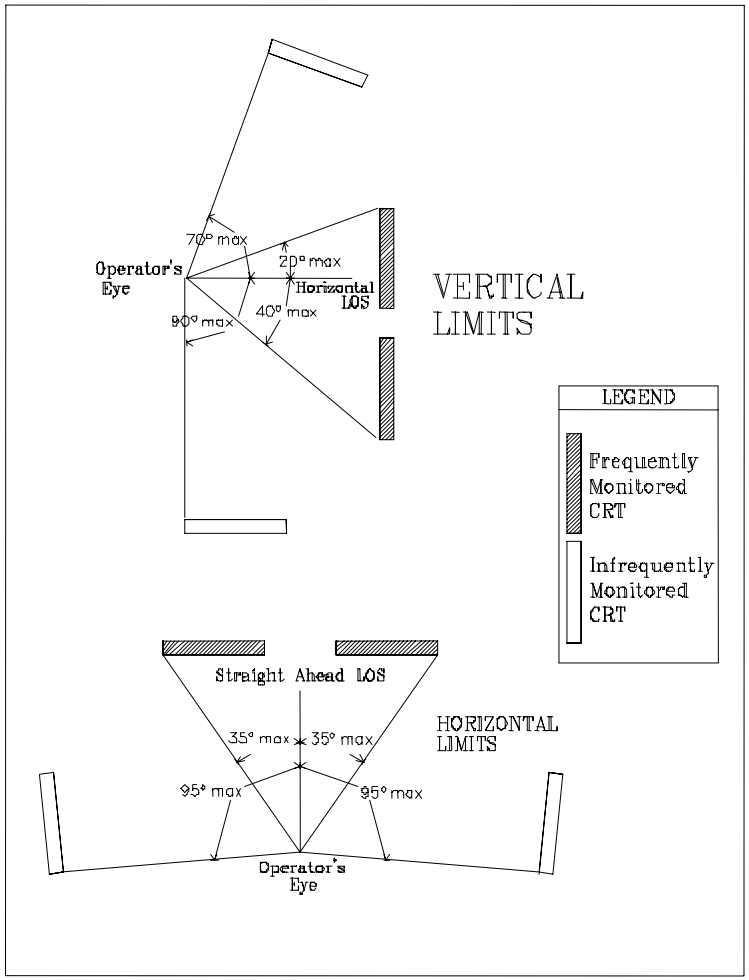


Figure 8.13/6 Operators Viewpoint from the Main Control Room

Figures

8.14 EMERGENCY CONTROL CENTRE DESIGN

The purpose of the ECC is to act as an alternative control room for the purpose of shutting down or maintaining the facility in a safe shutdown state when the MCR is uninhabitable.

End of Section