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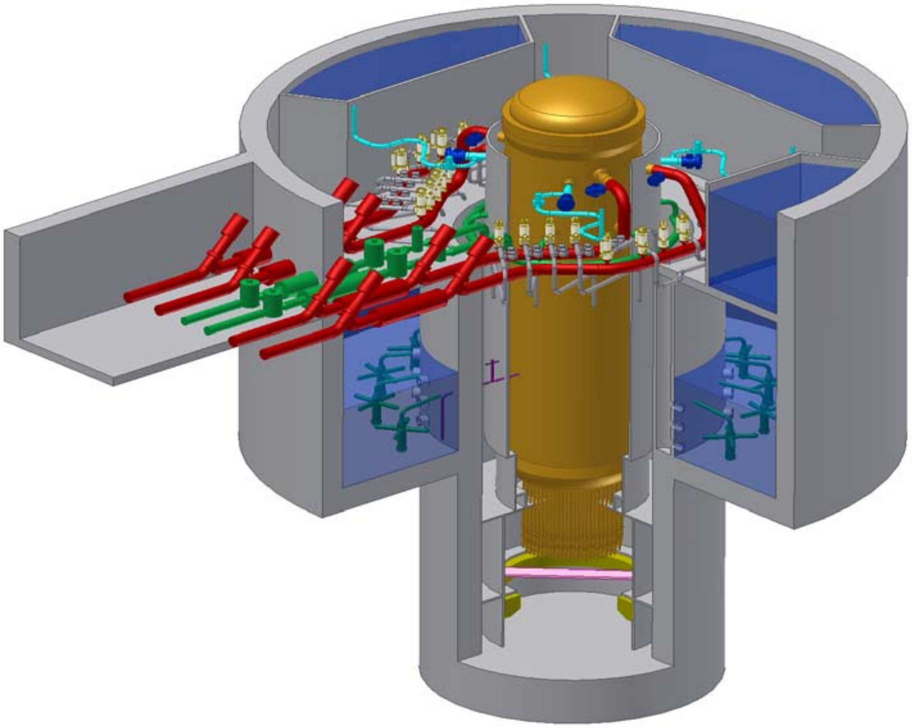

ESBWR Design Control Document
Tier 2
Chapter 18
Human Factors Engineering

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Abbreviations And Acronyms List

Term	**Definition**
10 CFR	Title 10, Code of Federal Regulations
A/D	Analog-to-Digital
AAS	Alarm and Annunciators subsystem
AASHTO	American Association of Highway and Transportation Officials
AB	Auxiliary Boiler
ABMA	Anti-Friction Bearing Manufacturers Association
ABS	Auxiliary Boiler System
ABWR	Advanced Boiling Water Reactor
ac / AC	Alternating Current
AC	Air Conditioning
ACF	Automatic Control Function
ACI	American Concrete Institute
ACS	Atmospheric Control System
AD	Administration Building
ADS	Automatic Depressurization System
AEC	Atomic Energy Commission
AFIP	Automated Fixed In-Core Probe
AGMA	American Gear Manufacturer's Association
AHS	Auxiliary Heat Sink
AHU	Air Handling Units
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AL	Analytical Limit
ALARA	As Low As Reasonably Achievable
ALWR	Advanced Light Water Reactor
AMCA	Air Movement and Control Association
ANI	American Nuclear Insurers
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
AOV	Air Operated Valve
API	American Petroleum Institute
APRM	Average Power Range Monitor
APR	Automatic Power Regulator
APRS	Automatic Power Regulator System
ARI	Alternate Rod Insertion
ARI	Air-Conditioning and Refrigeration Institute
ARMS	Area Radiation Monitoring System

Abbreviations And Acronyms List

Term	**Definition**
ASA	American Standards Association
ASA	Acoustical Society of America
ASCE	American Society of Civil Engineers
ASD	Adjustable Speed Drive
ASDC	Alternate Shutdown Cooling
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASQ	American Society for Quality
AST	Alternate Source Term
ASTM	American Society of Testing Methods
ASTM	American Society for Testing and Materials
AT	Unit Auxiliary Transformer
ATLM	Automated Thermal Limit Monitor
ATWS	Anticipated Transients Without Scram
AV	Allowable Value
AVR	Automatic Voltage Regulator
AWS	American Welding Society
AWWA	American Water Works Association
B&PV	Boiler and Pressure Vessel
BAF	Bottom of Active Fuel
BE	Best Estimate
BHP	Brake Horse Power
BiMAC	Basemat-Internal Melt Arrest Coolability
BISI	Bypass and Inoperable Status Indication
BMP	Basemat Melt Penetration
BOC	Beginning of Cycle
BOP	Balance of Plant
BOPCWS	Balance of Plant Chilled Water Subsystem
BPU	Bypass Unit
BPV	Bypass Valve
BPWS	Banked Position Withdrawal Sequence
BRE	Battery Room Exhaust
BRL	Background Radiation Level
BTP	NRC Branch Technical Position
BTU	British Thermal Unit
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CAV	Cumulative Absolute Velocity
C&FS	Condensate and Feedwater System

Abbreviations And Acronyms List

Term	**Definition**
C/C	Cooling and Cleanup
CB	Control Building
CBGAHVS	Control Building General Area
CBHVAC	Control Building HVAC
CBHVS	Control Building Heating, Ventilation and Air Conditioning System
CBP	Containment Bypass and Leakage
CCFP	Conditional Containment Failure Probability
CCI	Core-Concrete Interaction
CDF	Core Damage Frequency
CDU	Condensing Unit
CEA	Consumer Electronics Association
CET	Containment Event Tree
CFR	Code of Federal Regulations
CH	Chugging
CIRC	Circulating Water System
CIS	Containment Inerting System
CIV	Combined Intermediate Valve
CLAVS	Clean Area Ventilation Subsystem of Reactor Building HVAC
CLCH	Convection-Limited Containment Heating
CM	Cold Machine Shop
CMAA	Crane Manufacturers Association of America
CMS	Containment Monitoring System
CMU	Control Room Multiplexing Unit
CO	Condensate Oscillation
COL	Combined Operating License
COLR	Core Operating Limits Report
CONAVS	Controlled Area Ventilation Subsystem of Reactor Building HVAC
COP	Containment Overpressure Protection
COPS	Containment Overpressure Protection System
COTS	Commercial Off-the-Shelf Software
CPET	Containment System Event Tree
CPR	Critical Power Ratio
CP	Control Processor
CPS	Condensate Purification System
CPU	Central Processing Unit
CR	Control Rod
CRD	Control Rod Drive
CRDA	Control Rod Drop Accident
CRDH	Control Rod Drive Housing

Abbreviations And Acronyms List

Term	**Definition**
CRDHS	Control Rod Drive Hydraulic System
CRDS	Control Rod Drive System
CREHVAC	Control Room Envelope HVAC
CRGT	Control Rod Guide Tube
CRHA	Control Room Habitability Area
CRHAHVS	Control Room Habitability Area HVAC Sub-system
CRT	Cathode Ray Tube
CS&TS	Condensate Storage and Transfer System
CSAU	Code Scaling, Applicability, and Uncertainty
CSDM	Cold Shutdown Margin
CS / CST	Condensate Storage Tank
CT	Main Cooling Tower
CTI	Cooling Technology Institute
CTSS	Communications Continuous Tone-Controlled Squelch System
CTVCF	Constant Voltage Constant Frequency
CUF	Cumulative usage factor
CV	Containment Vessel
CWS	Chilled Water System
D-RAP	Design Reliability Assurance Program
DAC	Design Acceptance Criteria
DACS	Data Acquisition and Calibration System
DAS	Data Acquisition System
DAW	Dry Active Waste
DBA	Design Basis Accident
DBE	Design Basis Event
DB%	Dry-Basis-Percent
dc / DC	Direct Current
DCD	Design Control Document
DCH	Direct Containment Heating
DCPSS	Direct Current Power Supply System
DCS	Drywell Cooling System
DCIS	Distributed Control and Information System
DEGB	Double Ended Guillotine Break
DEPSS	Drywell Equipment and Pipe Support Structure
DF	Decontamination Factor
D/F	Diaphragm Floor
DG	Diesel-Generator
DG HVAC	DG Heating, Ventilation & Air Conditioning
DHR	Decay Heat Removal

Abbreviations And Acronyms List

Term	**Definition**
DLC	Data Logging Computer
DLF	Dynamic Load Factor
DM&C	Digital Measurement and Control
DPS	Diverse Protection System
DM&C	Digital Measurement and Control
DOF	Degree of Freedom
DOI	Dedicated Operators Interface
DORT	Discrete Ordinates Techniques
DOT	Department of Transportation
dPT	Differential Pressure Transmitter
DPS	Diverse Protection System
DPV	Depressurization Valve
DQR	Doppler Reactivity Coefficient
DRC	Dynamic Qualification Report
DR&T	Design Review and Testing
D-RAP	Design Reliability Assurance Program
DS	Independent Spent Fuel Storage Installation
DTM	Digital Trip Module
DW	Drywell
EAB	Exclusion Area Boundary
EB	Electrical Building
EBAS	Emergency Breathing Air System
EBHV/EBHVAS	Electrical Building HVAC/EB HVAC Subsystem
ECA	Electronic Components Assemblies Materials Association
ECCS	Emergency Core Cooling System
E-DCIS	Essential DCIS (Distributed Control and Information System)
EDO	Environmental Qualification Document
EFDS	Equipment and Floor Drainage System
EFPY	Effective Full Power Years
EFU	Emergency Filter Unit
EHC	Electro-Hydraulic Control (Pressure Regulator)
EIA	Electronic Industries Alliance
EMI/RFI	Electromagnetic Induction/Radio Frequency Induction
ENS	Emergency Notification System
EOC	Emergency Operations Center
EOC	End of Cycle
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedures
EPDS	Electric Power Distribution System

Abbreviations And Acronyms List

Term	**Definition**
EPG	Emergency Procedure Guidelines
EPRI	Electric Power Research Institute
EQ	Environmental Qualification
EQD	Environmental Qualification Document
EQEDC	Environmental Qualification Environmental Design Criteria
ERICP	Emergency Rod Insertion Control Panel
ERIP	Emergency Rod Insertion Panel
ERM	Engineering Review Memorandum
ESF	Engineered Safety Feature
ESP	Early Site Permit
ETD	Emergency Trip Device
ETS	Emergency Trip System
EVE	Ex-Vessel Steam Explosion
EW	East-West
EWS	Engineering Work-Station
FAA	Federal Aviation Administration
FAC	Flow-Accelerated Corrosion
FAPCS	Fuel and Auxiliary Pools Cooling System
FATT	Fracture Appearance Transition Temperature
FB	Fuel Building
FBFPHV	Fuel Building Fuel Pool HVAC
FBGAHV	Fuel Building General Area HVAC
FBHV	Fuel Building HVAC
FCI	Fuel-Coolant Interaction
FCI	Fluid Controls Institute Inc.
FCISL	Fuel Cladding Integrity Safety Limit
FCFWMD	Feedwater Control Feedwater Master Demand
FCM	File Control Module
FCS	Flammability Control System
FCU	Fan Cooling Unit
FDA	Final Design Approval
FDDI	Fiber Distributed Data Interface
FE	Finite Element
FEBAVS	Fuel Building Ventilation System
FEM	Finite Element Model
FFT	Fast Fourier Transform
FFWTR	Final Feedwater Temperature Reduction
FHA	Fire Hazards Analysis
FHA	Fuel Handling Accident

Abbreviations And Acronyms List

Term	Definition
FIV	Flow-Induced Vibration
FM	Factory Mutual
FMCRD	Fine Motion Control Rod Drive
FMEA	Failure Modes and Effects Analysis
FPC	Fuel Pool Cleanup
FPS	Fire Protection System
FO	Diesel Fuel Oil Storage Tank
FOAKE	First-of-a-Kind Engineering
FPC	Fuel Pool Cleanup
FPE	Fire Pump Enclosure
FS	Partial Full Scale
FSI	Fluid Structure Interaction
FTDC	Fault-Tolerant Digital Controller
FW	Feedwater
FWCS	Feedwater Control System
FWL	Feedwater Line
FWLB	Feedwater Line Break
FWS	Fire Water Storage Tank
GCS	Generator Cooling System
GDC	General Design Criteria
GDCS	Gravity-Driven Cooling System
GE	General Electric Company
GENE	GE Nuclear Energy
GEN	Main Generator System
GETAB	General Electric Thermal Analysis Basis
GL	Generic Letter
GLRWATBV	Generator Load Rejection With Failure of All Turbine Bypass Valves
GM	Geiger-Mueller Counter
GMAW	Gas Metal Arc Welding
GM-B	Beta-Sensitive GM (Geiger-Mueller Counter) Detector
GNF	Global Nuclear Fuel
GSI	Generic Safety Issue
GSIC	Gamma-Sensitive Ion Chamber
GSOS	Generator Sealing Oil System
GT	Gamma Thermometers
GTC	Gamma Thermometer Control Unit
GTG	General Training Guidelines
GTCAL	GT calibration module
GTM	Gamma Thermometer Monitoring Unit

Abbreviations And Acronyms List

Term	Definition
GTMON	GT monitor module
GWSR	Ganged Withdrawal Sequence Restriction
H	Horizontal
HAZ	Heat-Affected Zone
HCF	High Cycle Fatigue
HCU	Hydraulic Control Unit
HCW	High Conductivity Waste
HDVS	Heater Drain and Vent System
HEI	Heat Exchange Institute
HELB	High Energy Line Break
HELSA	High Energy Line Separation Analysis
HEP	Human Error Probability
HEPA	High Efficiency Particulate Air/Absolute
HFE	Human Factors Engineering
HFF	Hollow Fiber Filter
HGCS	Hydrogen Gas Cooling System
HI	Hydraulic Institute
HIC	High Integrity Container
HID	High Intensity Discharge
HIS	Hydraulic Institute Standards
HM	Hot Machine Shop & Storage
HP	High Pressure
HP/IP	High Pressure/Intermediate Pressure
HPME	High Pressure Melt Ejection
HPN	Health Physics Network
HPNSS	High Pressure Nitrogen Supply System
HPS	Heater Power Supply
HPT	High-Pressure Turbine
HRA	Human Reliability Assessment
HSI	Human-System Interface
HSU	Heater Switching Unit
HSSS	Hardware/Software System Specification
HTO	Tritiated Oxide (also called ‘tritiated water’)
HV	Horizontal Vent Chugging
HVAC	Heating, Ventilation and Air Conditioning
HVG	High Value Gate
HVS	High Velocity Separator
HVT	Horizontal Vent Test
HWC	Hydrogen Water Chemistry

Abbreviations And Acronyms List

Term	Definition
HWCS	Hydrogen Water Chemistry System
HWS	Hot Water System
HX	Heat Exchanger
I&C	Instrumentation and Control
I/O	Input/Output
IAS	Instrument Air System
IASCC	Irradiation Assisted Stress Corrosion Cracking
IBA	Intermediate Break Accident
IBC	International Building Code
IC	Ion Chamber
IC	Isolation Condenser
ICC	International Code Council
ICD	Interface Control Diagram
ICGT	In-core Guide Tubes
ICP	Instrument and Control Power
ICPR	Initial Critical Power Ratio
ICPSS	I&C Power Supply System
ICS	Isolation Condenser System
IDPVO	Inadvertent Depressurization Valve Opening
IE	Inspection and Enforcement
IEB	Inspection and Enforcement Bulletin
IEC	International Electrotechnical Commission
IED	Instrument and Electrical Diagram
IEEE	Institute of Electrical and Electronic Engineers
IESNA	Illuminating Engineering Society of North America
IFTS	Inclined Fuel Transfer System
IGSCC	Intergranular Stress Corrosion Cracking
IIS	Iron Injection System
ILRT	Integrated Leak Rate Test
IMC	Induction motor control
IMCC	Induction motor controller cabinet
IOP	Integrated Operating Procedure
I/O	Input/Output
IOSRV	Inadvertent Opening of a SRV
IOT	Integrated Operating Transient
IMC	Induction Motor Controller
IMCC	Induction Motor Controller Cabinet
IRM	Intermediate Range Monitor
ISA	Instrument Society of America

Abbreviations And Acronyms List

Term	Definition
ISI	In-Service Inspection
ISLT	In-Service Leak Test
ISM	Independent Support Motion
ISMA	Independent Support Motion Response Spectrum Analysis
ISRVO	Independent Safety Relief Valve Opening
ISO	International Standards Organization
ITA	Inspections, Tests or Analyses
ITAAC	Inspections, Tests, Analyses and Acceptance Criteria
ITA	Initial Test Program
IVR	In-Vessel Retention
JAPC	Japan Atomic Power Company
LANL	Los Alamos National Laboratory
LAPP	Loss of Alternate Preferred Power
LB	Lower Bound
LBB	Leak Before Break
LBL	Large Break LOCA
LCF	Low Cycle Fatigue
LCO	Limiting Conditions for Operation
LCS	Leakage Control System
LCW	Low Conductivity Waste
LD	Logic Diagram
LDA	Lay down Area
LDW	Lower Drywell
LD&IS	Leak Detection and Isolation System
LED	Light Emitting Diode
LERF	Large Early Release Frequency
LFCV	Low Flow Control Valve
LHGR	Linear Heat Generation Rate
LLRT	Local Leak Rate Test
LMU	Local Multiplexer Unit
LO	Dirty/Clean Lube Oil Storage Tank
LOCA	Loss-of-Coolant-Accident
LOFW	Loss-of-feedwater
LOOP	Loss of Offsite Power
LOPP	Loss of Preferred Power
LP	Low Pressure
LPCI	Low Pressure Coolant Injection
LPCRD	Locking Piston Control Rod Drive
LPFL	Low Pressure Flooder

Abbreviations And Acronyms List

Term	Definition
LPMS	Loose Parts Monitoring System
LPRM	Local Power Range Monitor
LPSP	Low Power Setpoint
LPZ	Low Population Zone
LUA	Lead Use Assembly
LWMS	Liquid Waste Management System
MAAP	Modular Accident Analysis Program
MAPLHGR	Maximum Average Planar Linear Head Generation Rate
MAPRAT	Maximum Average Planar Ratio
MBB	Motor Built-In Brake
MCC	Motor Control Center
MCCI	Molten Corium-Concrete Interaction
MCES	Main Condenser Evacuation System
MCOP	Manual containment overpressure protection (function)
MCM	One thousand circular mils (cross-sectional wire size)
MCPR	Minimum Critical Power Ratio
MCR	Main Control Room
MCRP	Main Control Room Panel
MELB	Moderate Energy Line Break
MFAP	Main Fire Alarm Panel
MIT	Massachusetts Institute of Technology
MLHGR	Maximum Linear Heat Generation Rate
MMI	Man-Machine Interface
MMIS	Man-Machine Interface Systems
MOC	Middle of Cycle
MOV	Motor-Operated Valve
MPC	Maximum Permissible Concentration
MPI	Balance of Plant terminology established by COL applicant
MPL	Master Parts List
MRBM	Multi-Channel Rod Block Monitor
MS	Main Steam
MSIV	Main Steam Isolation Valve
MSL	Main Steam Line
MSLB	Main Steam Line Break
MSLBA	Main Steam Line Break Accident
MSR	Moisture Separator Reheater
MSS	Manufacturers Standardization Society
MSV	Mean Square Voltage
MT	Main Transformer

Abbreviations And Acronyms List

Term	Definition
MTTR	Mean Time To Repair
MCP	Mechanical Vacuum Pump
MWS	Makeup Water System
MVD	Medium Voltage Distribution System
MVP	Mechanical Vacuum Pump
MWS	Makeup Water System
NBR	Nuclear Boiler Rated
NBS	Nuclear Boiler System
NCIG	Nuclear Construction Issues Group
NDE	Nondestructive Examination
NE-DCIS	Non-Essential Distributed Control and Information System
NEMA	National Electric Manufacturers' Code
NDRC	National Defense Research Committee
NDT	Nil Ductility Temperature
NDTT	Nil Ductility Transition Temperature
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standard Technology
NICWS	Nuclear Island Chilled Water Subsystem
NLF	Non-LOCA Fault
NIM	Network Interface Module
NMS	Neutron Monitoring System
NOAA	National Ocean and Atmospheric Administration
NOV	Nitrogen Operated Valve
NPHS	Normal Power Heat Sink
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
NRHX	Non-Regenerative Heat Exchanger
NS	Non-seismic
NSOA	Nuclear Safety Operational Analysis
NSSFC	National Severe Storms Forecast Center
NSSS	Nuclear Steam Supply System
NT	Nitrogen Storage Tank
NTSP	Nominal Trip Setpoint
NWS	National Weather Service
O&M	Operation and Maintenance
O-RAP	Operational Reliability Assurance Program
OBCV	Overboard Control Valve
OBE	Operating Basis Earthquake

Abbreviations And Acronyms List

Term	**Definition**
OELD	Office of the Executive Legal Director
OGS	Offgas System
OHLHS	Overhead Heavy Load Handling System
OIS	Oxygen Injection System
OLMCPR	Operating Limit Minimum Critical Power Ratio
OLMLHGR	Operating Limit Minimum Linear Heat Generation Rate
OLU	Output Logic Unit
OOS	Out-of-Service
OPRM	Oscillation Power Range Monitor
ORNL	Oak Ridge National Laboratory
OSC	Operational Support Center
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnect
OSTUL	One-Sided Upper Tolerance Level
P&ID	Piping and Instrumentation Diagram
PA/PL	Page/Party-Line
PABX	Private Automatic Branch (Telephone) Exchange
PAM	Post Accident Monitoring
PAR	Passive Autocatalytic Recombiner
PAS	Plant Automation System
PASS	Post Accident Sampling Subsystem of Containment Monitoring System
P/C	Power Center
PCC	Passive Containment Cooling
PCCS	Passive Containment Cooling System
PCD	Plant Configuration Database
PCF	Plant Computer Functions
PCT	Peak Cladding Temperature
PCV	Primary Containment Vessel
PDA	Piping Design Analysis
PFD	Process Flow Diagram
PG	Power Generation
PGA	Peak Ground Acceleration
PGCS	Power Generation and Control Subsystem of Plant Automation System
PH	H^+ ion concentration
PH	Pump House
PIP	Position Indicator Probe or Plant Investment Protection
PIRT	Phenomena Identification and Ranking Table
PL	Parking Lot
PLC	Programmable Logic Controller

Abbreviations And Acronyms List

Term	Definition
PM	Preventive Maintenance
PMCS	Performance Monitoring and Control Subsystem of NE-DCIS
PMF	Probable Maximum Flood
PMH	Probable Maximum Hurricane
PMP	Probable Maximum Precipitation
Ppb	parts per billion
PQCL	Product Quality Check List
PRA	Probabilistic Risk Assessment
PRDF	Pressure Regulator Downscale Failure
PROM	Programmable Read-Only Memory
PRMS	Process Radiation Monitoring System
PRNM	Power Range Neutron Monitoring
PS	Plant Stack or Pool Swell
PSA	Probabilistic Safety Assessment
PSD	Power Spectral Density
PSHA	Probabilistic Seismic Hazard Analysis
PSS	Process Sampling System
PSTF	Pressure Suppression Test Facility
PSW	Plant Service Water
PSWS	Plant Service Water System
PT	Pressure Transmitter
PWR	Pressurized Water Reactor
QA	Quality Assurance
QAPD	Quality Assurance Program Document
QA/QC	Quality Assurance/Quality Control
QG	Quality Group
RACS	Rod Action Control Subsystem
R	Difference between k_{eff} at BOC& maximum calculated strongest rod out k_{eff} at any exposure point
RAM	Reliability, Availability and Maintainability
RAPI	Rod Action and Position Information
RAT	Reserve Auxiliary Transformer
RB	Reactor Building
RBC	Rod Brake Controller
RBCC	Rod Brake Controller Cabinet
RBCWS	Reactor Building Chilled Water Subsystem
RBFB	Reactor Building Fuel Building
RBHV	Reactor Building HVAC (Heating, Ventilation and Air Conditioning)
RBHVS	Reactor Building HVAC System

Abbreviations And Acronyms List

Term	Definition
RBS	Rod Block Setpoint
RBV	Reactor Building Vibration
RC&IS	Rod Control and Information System
RCC	Remote Communication Cabinet
RCCV	Reinforced Concrete Containment Vessel
RCCW	Reactor Component Cooling Water
RCCWS	Reactor Component Cooling Water System
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RDA	Rod Drop Accident
RDC	Resolver-to-Digital Converter
REPAVS	Refueling and Pool Area Ventilation Subsystem of Fuel Building HVAC (Heating, Ventilation and Air Conditioning)
RFP	Reactor Feed Pump
RG	Regulatory Guide
RGT	Radcal Gamma Thermometer
RHR	Residual Heat Removal (function)
RHX	Regenerative Heat Exchanger
RMS	Root Mean Square
RMS	Radiation Monitoring Subsystem
RLP	Reference Loading Pattern
RMU	Remote Multiplexer Unit
RP	Report Generator (RG)
RO	Reverse Osmosis
ROAAM	Risk-Oriented Accident Analysis Methodology
ROM	Read-only Memory
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRPS	Reference Rod Pull Sequence
RRS	Required Response Spectra
RSM	Rod Server Module
RSPC	Rod Server Processing Channel
RSS	Remote Shutdown System
RSSM	Reed Switch Sensor Module
RSW	Reactor Shield Wall
RTD	Resistance Temperature Detector
RTIF	Reactor Trip and Isolation Function(s)
RTNSS	Regulatory Treatment of Non-Safety Systems
RT_{NDT}	Reference Temperature of Nil-Ductility Transition

Abbreviations And Acronyms List

Term	Definition
RTP	Reactor Thermal Power
RVs	Relief Valves
RW	Radwaste Building
RWBCR	Radwaste Building Control Room
RWBGA	Radwaste Building General Area
RWBHVAC	Radwaste Building HVAC (Heating, Ventilation and Air Conditioning)
RWCU/SDC	Reactor Water Cleanup/Shutdown Cooling
RWE	Rod Withdrawal Error
RWM	Rod Worth Minimizer
SA	Severe Accident
SACF	Single Active Component Failure
SAG	Sever Accident Guidelines
SAM	Severe Accident Management or Seismic Anchor Motion
SAR	Safety Analysis Report
SAT	Severe Accident Treatment
SAW	Submerged Arc Welding
SB	Service Building
SBA	Small Break Accident
S/C	Digital Gamma-Sensitive GM (Geiger-Mueller Counter) Detector
SC	Suppression Chamber
S/D	Scintillation Detector
S/DRSRO	Single/Dual Rod Sequence Restriction Override
S/N	Signal-to-Noise
S/P	Suppression Pool
SAS	Service Air System
SB&PC	Steam Bypass and Pressure Control System
SBL	Small Line Break
SBO	Station Blackout
SBWR	Simplified Boiling Water Reactor
SCEW	System Component Evaluation Work
SCMP	Software Configuration Management Plan
SCS	Soil Conservation Service
SCRRI	Selected Control Rod Run-in
SDC	Shutdown Cooling
SDM	Shutdown Margin
SDS	System Design Specification
SEOA	Sealed Emergency Operating Area
SER	Safety Evaluation Report
SF	Service Water Building

Abbreviations And Acronyms List

Term	Definition
SFA	Spent Fuel Assembly
SFP	Spent fuel pool
SIL	Service Information Letter
SIP	Separation Indicator Probe
SIT	Structural Integrity Test
SIU	Signal Interface Unit
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control
SLCS	Standby Liquid Control System
SLMCPR	Safety Limit Minimum Critical Power Ratio
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SMAW	Shielded Metal Arc Welding
SMU	SSLC (Safety System Logic and Control) Multiplexing Unit
SMP	Software Management Plan
SOSRV	Stuck Open Safety Relief Valve
SOT	System Operational Transient
SOV	Solenoid Operated Valve
SP	Setpoint
S/P	Suppression Pool
SPC	Suppression Pool Cooling
SPDS	Safety Parameter Display System
SPTMS	Suppression Pool Temperature Monitoring Subsystem of Containment Monitoring System
SQA	Software Quality Assurance
SQAP	Software Quality Assurance Program
SR	Surveillance Requirement
SRM	Source Range Monitor
SRNM	Startup Range Neutron Monitor
SRO	Senior Reactor Operator
SRP	Standard Review Plan or Savannah River Plant
SRS	Software Requirements Specification
SRSRO	Single Rod Sequence Restriction Override
SRSS	Square Root of the Sum of Squares
SRV	Safety Relief Valve
SRVDL	Safety Relief Valve Discharge Line
SSAR	Standard Safety Analysis Report
SS	Sub-scale
SST	Sub-scale Test
SSC(s)	Structure, System and Component(s)
SSE	Safe Shutdown Earthquake

Abbreviations And Acronyms List

Term	Definition
SSI	Soil Structure Interaction
SSLC	Safety System Logic and Control
SSP	Software Safety Plan
SSPC	Steel Structures Painting Council
SSS	Balance of Plant terminology established by COL applicant
ST	Spare Transformer
STI	Startup Test Instruction
STP	Sewage Treatment Plant
STRAP	Scram Time Recording and Analysis Panel
STRP	Scram Time Recording Panel
SV	Safety Valve
SVTP	Software Test Plan
SWH	Static Water Head
SWMS	Solid Waste Management System
SY	Switch Yard
TAF	Top of Active Fuel
TASS	Turbine Auxiliary Steam System
TB	Turbine Building
TBCE	Turbine Building Compartment Exhaust
TBAS	Turbine Building Air Supply
TBDRE	Turbine Building Decontamination Room Exhaust
TBE	Turbine Building Exhaust
TBLOE	Turbine Building Lube Oil Area Exhaust
TBS	Turbine Bypass System
TBHV	Turbine Building HVAC (Heating, Ventilation and Air Conditioning)
TBHVACS	Turbine Building HVAC System
TBV	Turbine Bypass Valve
TC	Training Center
TCCWS	Turbine Component Cooling Water System
TCS	Turbine Control System
TCV	Turbine Control Valve
TDH	Total Developed Head, Torispherical Drywell Head
TEDE	Total Effective Dose Equivalent
TEMA	Tubular Exchanger Manufacturers' Association
TFSP	Turbine First Stage Pressure
TG	Turbine Generator
TGSS	Turbine Gland Seal System
THA	Time-History Accelerograph

Abbreviations And Acronyms List

Term	Definition
TIA	Telecommunications Industry Association
TIP	Traversing In-core Probe
TLOS	Turbine Lubricating Oil System
TLU	Trip Logic Unit
TMI	Three Mile Island
TMSS	Turbine Main Steam System
TPM&D	Thermal Performance Monitor and Diagnostic
TRAC	Transient Reactor Analysis Code
TRM	Technical Requirements Manual
TS	Technical Specification(s)
TSC	Technical Support Center
TSCHVACS	TSC HVAC Subsystem
TSI	Turbine Supervisory Instrument
TSM	Tech Spec Monitoring
TSV	Turbine Stop Valve
TTWFATBV	Turbine trip with failure of all bypass valves
UAT	Unit Auxiliary Transformer
UB	Upper Bound
UBC	Uniform Building Code
UCB	University of California at Berkeley
UCSB	University of California at Santa Barbara
UHS	Ultimate Heat Sink
UL	Underwriter's Laboratories Inc.
UPS	Uninterruptible Power Supply
UPSS	Uninterruptible Power Supply System
URD	Utilities Requirements Document
USE	Upper Shelf Energy
USGS	US Geological Survey
USI	Unresolved Safety Issue
USM	Uniform Support Motion
USMA	Uniform Support Motion Response Spectrum Analysis
USNRC	United States Nuclear Regulatory Commission
USS	United States Standard
UTM	Universal Transverse Mercator system (as found on USGS topographical maps)
UV	Ultraviolet
V&V	Verification and Validation
V&VP	Verification and Validation Plans
Vac / VAC	Volts Alternating Current
Vdc / VDC	Volts Direct Current

Abbreviations And Acronyms List

Term	**Definition**
VDU	Video Display Unit or Visual Display Unit
VLU	Voter Logic Unit
VT	Vertical
VW	Vent Wall
VWO	Valves Wide Open
WD	Wash Down Bays
WH	Warehouse
WRL	Wide Range Level
WS	Water Storage
WT	Water Treatment
WW	Wetwell
XMFR	Transformer
ZPA	Zero Period Acceleration

18. HUMAN FACTORS ENGINEERING

18.1 OVERVIEW

This chapter reviews the Human Factors Engineering (HFE) programs for the ESBWR. As discussed in Subsection 1.1.2.2; 10CFR 52.45, this DCD Tier 2 supports the Final Design Approval (FDA) and standard Design Certification (DC) for the ESBWR Standard Plant. In accordance with a standard design certification under Part 52, this chapter provides technical information, which encompasses the HFE program. Because technology is continually advancing, details of the HFE design need not be complete before the NRC issuance of a design certification. The HFE focus is on the design process, which is based on 10 CFR 52.

This chapter describes the ESBWR Human-System Interface (HSI) design goals and bases, the HSI design features, the detailed HSI design, and implementation process for the ESBWR operator interfaces. The incorporation of HFE principles into all phases of the design is described in this chapter. The overall design and implementation process is described in detail in Licensing Topical Report, titled “Man Machine Interface System and Human Factors Engineering Implementation Plan” (GEEN NEDO-33217 January 2006). This presents a comprehensive, iterative design approach for the development of human-centered control and information infrastructure for the ESBWR.

The ESBWR Emergency Procedure Guidelines (EPGs), which provide the basis for human factors evaluations of emergency operations, are contained in Appendix 18A. Appendix 18B discusses the differences between the ESBWR Emergency Procedure Guidelines and the U.S. Boiling Water Reactor Owners Group (BWROG) EPG/SAG Revision 2. The input data and results of calculations performed during the preparation of the ESBWR Emergency Procedure Guidelines are contained in Appendix 18C. Appendices A, B, and C are included for completeness in considering Human Factors in Design. The inventory and supporting analysis of emergency operation information and controls specific to ESBWR are provided in subsequent analyses.

HFE Program Goals - The general objectives of the program are stated in human-centered terms, which, as the HFE program develops, is refined and used as a basis for HFE planning, test and evaluation activities. HFE design goals include ensuring that:

- Personnel tasks are accomplished within time and performance criteria.
- HSIs, procedures, staffing/qualifications, training, management, and organizational variables support a high degree of operating crew situational awareness.
- Allocation of functions accommodates human capabilities and limitations.
- Operator vigilance is maintained.
- Acceptable operator workload is not exceeded.
- Operator interfaces do not contribute to the likelihood of human error.
- Error detection and recovery capabilities are provided.

Assumptions and Constraints - An assumption or constraint is an aspect of the design identified, such as specific staffing plans or the use of specific HSI technology, that is an input to the HFE program rather than the result of HFE analyses or evaluations.

Applicable Facilities - The HFE program addresses the Main Control Room (MCR), Remote Shutdown System (RSS), Technical Support Center (TSC), Emergency Operations Facility (EOF), and Local Control Stations (LCSs) with a safety-related function or as defined by High Level Task Analysis.

Applicable HSIs, Procedures, and Training - The applicable HSIs, procedures, and training included in the HFE program include operations, accident management, maintenance, test, inspection and surveillance interfaces (including procedures) for those systems important-to-safety. This includes monitoring the designs being presented by ESBWR suppliers, to ensure that supplier designs are consistent with the HFE requirements of the ESBWR HFE Program.

Applicable Plant Personnel - Plant personnel, both licensed and unlicensed, addressed by the HFE program are delineated in section 18.6 Staffing and Qualifications section of this chapter. The staff members include those that perform tasks that are directly related to plant safety.

The Man-Machine Interface System (MMIS) employs digital technology to implement the majority of the monitoring, control, and protection functions for the ESBWR. Standardization of hardware and software, and modularity of design is used to simplify maintenance and provide protection against obsolescence.

The HSI design implementation activities include the development of dynamic models for evaluating the overall plant response as well as individual control systems, including operator actions. These dynamic models are used to:

1) Analyze both steady state and transient behaviors,
2) Confirm the design of the advanced alarm system concepts,
3) Confirm the adequacy of control schemes,
4) Confirm the allocation of control to a system or an operator,
5) Develop and validate plant operating procedures, and
6) Incorporate, as directly as possible, into plant fullscope or limited use simulators.

Using part-task simulation an initial set of systems is identified through modeling, including the development of the graphical user interfaces (GUI). The part-task simulator will be used in preliminary ESBWR design and expanded to include ESBWR-unique design features.

As the ESBWR design progresses, the part-task simulator proceeds through a series of iterative evaluations resulting in the development of a complete control room full scope simulator. In addition, the simulator facility is the focal point for operator evaluations and feedback checkpoints throughout the MMIS design process. The general development of eleven key implementation plans, analyses, and evaluation are identified and detailed in Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan, in Section 4):

- Operating Experience Review (OER)

- Functional Requirements Analysis (FRA) and Allocation of Functions (AOF)
- Task Analysis (TA)
- Staffing and Qualifications (S & Q)
- Human Reliability Analysis (HRA)
- Human System Interface (HSI)
- Procedure Development
- Training Development
- Human Factors Verification and Validation (V & V)
- Design Implementation
- Human Performance Monitoring (HPM)

The ESBWR Defense in Depth and Diversity (D-D&D) analysis is a design input to the System FRA during each of the iterations. Important aspects of defense-in-depth are identified in RG 1.174, and include:

- Balance is preserved among prevention of core damage, prevention of containment failure, and consequence mitigation.
- Reliance on programmatic activities to compensate for possible weaknesses in plant design is minimized. This may be pertinent to changes in credited human actions (HAs).
- System redundancy, independence, and diversity are preserved commensurate with the expected frequency, consequences of challenges to the system, and uncertainties.
- Defenses against potential common cause failures are preserved, and the potential for the introduction of new common cause failure mechanisms is assessed. Caution is exercised in crediting new HAs to ensure that the possibility of significant common cause errors is avoided.
- Independence of barriers is not degraded.
- Defenses against human errors are preserved. For example, establish procedures for a second check or independent verification for risk-important HAs to determine that they have been performed correctly.
- The intent of the General Design Criteria (GDC) in Appendix A to 10 CFR Part 50 is maintained. GDC that may be relevant are: 3 - Fire Protection, 13 - Instrumentation and Control, 17 - Electric Power Systems, 19 - Control Room, 35 - Emergency Core Cooling System, 38 - Containment Heat Removal, and 44 - Cooling Water.

Safety margins used in deterministic analyses to account for uncertainty and provide an added margin to provide adequate assurance that the various limits or criteria important-to-safety are not violated. It is also possible to add a safety margin (if desired) to HAs by demonstrating that the action can be performed within some time interval (or margin) that is less than the time identified by the analysis.

Design goals and design bases for the HSI in the MCR and in other applicable facilities are established in this chapter.

18.1.1 Reference

1) GEEN NEDO-33217, Man Machine Interface System (MMIS) and Human Factors Engineering (HFE) Implementation Plan, January 2006, Rev 1

18.1.2 Design Goals and Design Bases

The primary goal for HSI designs is to facilitate safe, efficient and reliable operator performance during all phases of normal plant operation, abnormal events and accident conditions. To achieve this goal, information displays, controls and other interface devices in the control room and other plant areas are designed and implemented in a manner consistent with good human factors engineering practices. Further, the following specific design bases are adopted:

- The HSI design promotes efficient and reliable operation through application of automated operation capabilities.
- The HSI design uses only proven technology.
- Safety-related systems monitoring and control capability is provided in full compliance with regulations regarding divisional separation and independence.
- The HSI design is highly reliable and provides functional redundancy such that sufficient displays and controls are available in the MCR and remote locations to conduct an orderly reactor shutdown and to cooldown the reactor to safe shutdown conditions, even during design basis equipment failures.
- The principal functions of the Safety Parameter Display System (SPDS) as required by Supplement 1 to NUREG-0737 are integrated into the HSI design.
- Accepted human factors engineering principles are used for the HSI design in meeting the requirements of GDC 19.

The design basis for the RSS is specified in Section 7.4.2

As part of Subsection 18.2 and in detail in Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan), detailed design acceptance criteria are specified. These design acceptance criteria are used to govern and direct all ESBWR HSI design implementations. These detailed design acceptance criteria encompass the set of necessary and sufficient design implementation-related activities. These are required to maintain the implemented HSI design in compliance with accepted HFE principles and digital electronics equipment and software development methods.

Also, as part of the detailed design implementation process described in Section 18.2 and Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan), operator task analysis is performed as a basis for evaluating details of the design and specifying HSI requirements. The evaluation of the integrated control room design includes the confirmation of the ESBWR MCR standard design features.

18.1.3 Planning, Development, and Design

An integrated program plan to incorporate HFE principles and to achieve an integrated design of the instrumentation and control (I&C) systems and HSI of the ESBWR described in the License Topical Reports. The MMIS and HFE Implementation Plan presents a comprehensive, synergistic design approach with provisions for task analyses and human factors evaluations. Also included are formal decision analysis procedures to facilitate selection of design features, which satisfy top-level requirements and goals of individual systems and the overall plant.

The program plan and the associated procedures provided guidance for the conduct of the ESBWR HSI design development activities, including (1) definition of the standard design features of the control room HSI and (2) definition of the inventory of controls and instrumentation. These are necessary for the operators to follow the ESBWR Emergency Procedure Guidelines and to complete the important operator actions described in the PRA.

18.1.1.1 Standard Design Features

The ESBWR control room HSI design contains a group of standard features, which form the foundation for the detailed HSI design. The development of the control room HSI standard design features is accomplished through:

- Consideration of existing control room operating experience
- Review of trends in control room designs and existing control room data presentation methods
- Evaluation of new HSI technologies, alarm reduction, and presentation methods
- Validation testing of dynamic control room prototype.

The prototypes evaluated under simulated normal and abnormal reactor operating conditions and uses experienced nuclear plant control room operators. Following the completion of the prototype tests and result analysis, the standard control room HSI design features are finalized.

18.1.1.2 Inventory of Controls and Instrumentation

The ESBWR EPGs, presented in Appendix 18A, and the important operator actions identified in the PRA, presented in Chapter 19, provide the bases for an analysis of the information and control capability needs of the MCR operators based upon the operation strategies. This analysis defines a minimum set of controls, displays, and alarms, which allows the operators to perform the actions specified in the EOPs and the important operator actions identified in the PRA.

18.1.1.3 Detailed Design Implementation Process

The process by which the detailed equipment design implementation of the ESBWR HSI is completed is discussed in Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan, in Section 5). This process builds upon the standard HSI design features discussed in this chapter. Embedded in the process are a number of NRC conformance reviews in which various aspects and outputs of the process are evaluated against established design acceptance criteria.

18.1.4 Control Room Standard Design Features

The control room standard design features are based upon proven technologies and have been demonstrated, through broad scope control room dynamic simulation tests and evaluation, to satisfy the ESBWR HSI design goals and design bases. Validation of the implemented MCR design includes evaluation of the standard design features performed as part of the design implementation process as defined by the design acceptance criteria derived from summary results reports produced in the MMIS and HFE Implementation Plan.

18.1.5 Remote Shutdown System

The RSS provides a means to safely shut down the plant from outside the main control room. It provides control of the plant systems needed to bring the plant to hot shutdown, with the subsequent capability to attain cold shutdown, in the event that the control room becomes uninhabitable.

The RSS design is described in Section 7.4.2. Parameters that are displayed and/or controlled from Division I and Division II in the MCR are also displayed and/or controlled from the RSS Panels.

18.1.6 Systems Integration

18.1.6.1 Safety-Related Systems

The operator interfaces with the safety-related systems through a variety of methods. Dedicated switches are used for system initiation and logic reset, while system mode changes are made with other switches. Safety-related VDUs provide capability for individual safety equipment control, status display and monitoring. Nonsafety-related VDUs are used for additional safety-related system monitoring. The large fixed-position display provides plant overview information. Instrumentation and control aspects of the microprocessor-based Safety System Logic and Control (SSLC) are described in Section 7.3.4.

Divisional separation for control, alarm and display equipment is maintained. The SSLC processors provide alarm signals to their respective safety-related alarm processors and provide display information to the divisionally dedicated VDUs. The SSLC microprocessors communicate with their respective divisional VDU controllers through Essential Distributed Control and Information System (E-DCIS). The divisional VDUs have on-screen control capability and are classified as safety-related equipment. These VDUs provide control and display capabilities for individual safety systems if control of a system component is required.

Divisional isolation devices are provided between the safety-related systems and nonsafety-related communication networks so that failures in the nonsafety-related equipment will have no impact on the ability of the safety-related systems to perform their design functions. The nonsafety-related communication network is part of Non-Essential Distributed Control and Information System (NE-DCIS) described in Section 7.9.

Safety-related system process parameters, alarms and system status information from the SSLC are communicated to the NE-DCIS through isolation devices for use by other equipment connected to the communication network. Selected operator control functions are performed through dedicated control switches, which are Class 1E qualified and divisionally separated on the main control console. These switches communicate with the safety-related systems logic units.

The divisionally dedicated VDUs are classified as safety-related equipment. These VDUs provide control and display capabilities for individual safety-related systems if control of a system component is required. Normally, such control actions are performed for equipment surveillance purposes only, as the normal method of system control is through the mode-oriented master sequence switches.

18.1.6.2 Nonsafety-Related Systems

Operational control of nonsafety-related systems is accomplished using nonsafety-related, on-screen control VDUs. Nonsafety-related data is processed through the NE-DCIS, which provides redundant and distributed instrumentation and control data communications network to support the monitoring and control of interfacing plant systems.

Alarms for entry conditions into the emergency operating procedures are provided by the alarm processing units, both safety and nonsafety-related. Equipment level alarm information is presented by the computer system on the MCC VDUs.

The fixed position wide display panel (WDP) provides the critical plant operating information such as power, water level, temperature, pressure, flow and status of major equipment and availability of safety systems with mimic on the main control room during plant normal, abnormal and emergency operating conditions.

18.1.7 Detailed Design of the Operator Interface System

The standard design features of the ESBWR main control room HSI, discussed in Subsection 18.1.3.1, provide the framework for the detailed equipment hardware and software designs developed following the design and implementation process described in Section 18.2. This process is illustrated in Figure 18.1-1.

As part of Subsection 18.2 and in detail in Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan), discussion of the HSI design and implementation plan elements, detailed acceptance criteria are specified and used to govern and direct all ESBWR HSI design implementations, which reference the Certified Design. These detailed design acceptance criteria encompass the set of necessary and sufficient design implementation related activities required to maintain the implemented HSI design in compliance with accepted HFE principles and accepted digital electronics equipment and software development methods.

Also, as part of the detailed design implementation process described in Section 18.2 and Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan), operator task analysis is performed as a basis for evaluating details of the design implementation and HSI requirements are specified. The evaluation of the integrated control room design includes the confirmation of the ESBWR MCR standard design features.

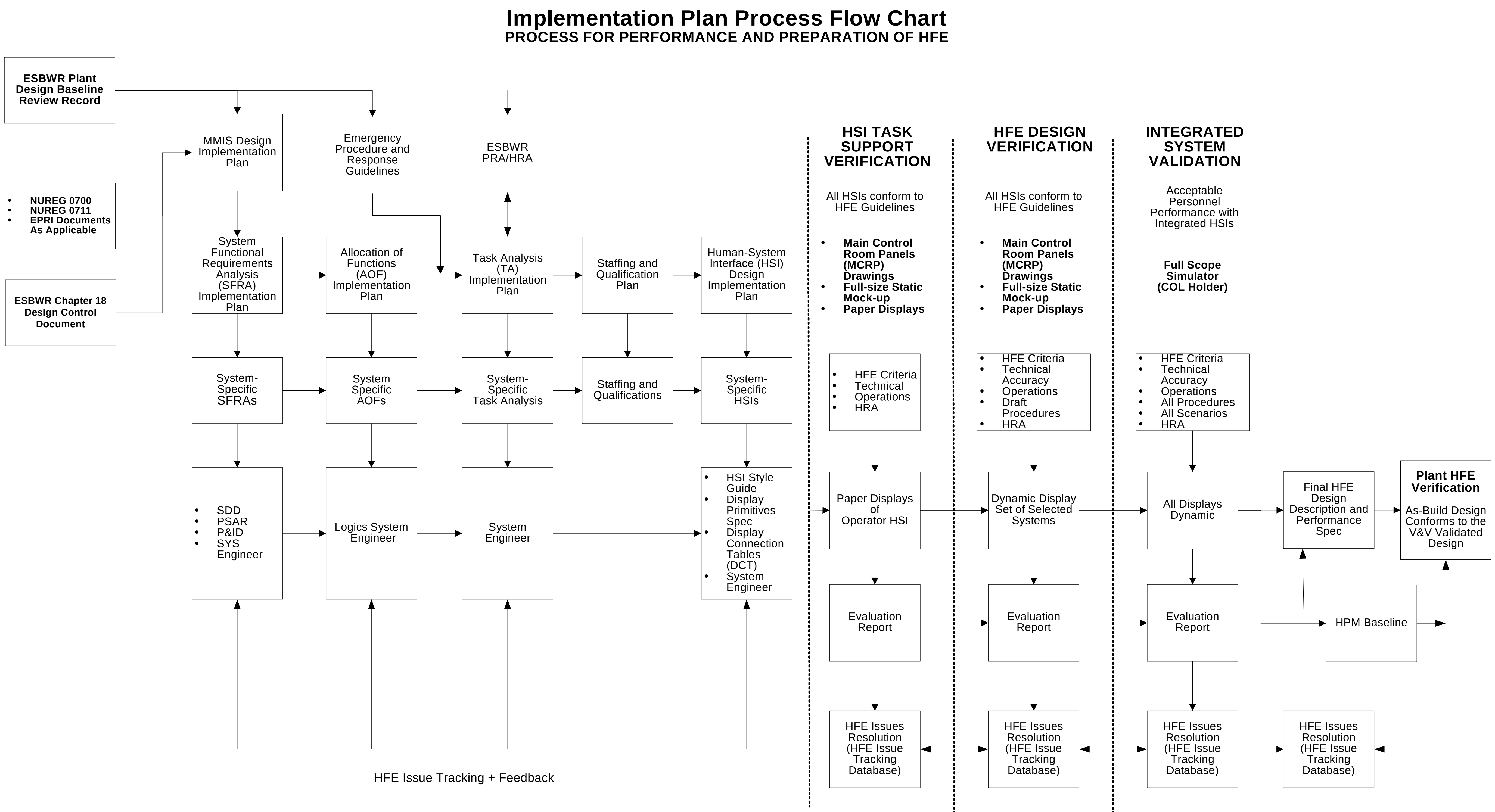

Figure 18.1-1. ESBWR MMIS Implementation Plan Process Flowchart

18.2 MMIS AND HFE PROGRAM MANAGEMENT

18.2.1 HFE Program and MMIS and HFE Implementation Plan

The HFE Design Team establishes the HFE Program and MMIS and HFE Implementation Plan that provide overall direction and integration of the HFE-related design implementation and evaluation activities for the specific HSI scope which includes the MCR, RSS, LCS, (those with a safety-related function or as identified by high level task analysis) areas of operational interface. The HFE Plan identifies the qualifications and experience of individuals who comprise the HFE Design Team and establishes the processes through which the HFE Design Team performs its functions. Included in the HFE Plan is a system for documenting human factors issues that may be identified throughout the implementation of the designs, and the actions taken to resolve those issues. The HFE Design Team also establishes the Implementation Plans for conducting each of the following HFE-related activities:

- Operating Experience Review
- Functional Requirements Analysis
- Allocation of Functions
- Task Analysis
- Staffing and Qualifications
- Human Reliability Analysis
- Human-System Interface Design
- Procedure Development
- Training Program Development
- Human Factors Verification and Validation
- Design Implementation
- Human Performance Monitoring

The Implementation Plans establish methods and criteria for the conduct of each of these HFE-related activities, which are consistent with accepted HFE practices and principles. (For additional detailed information regarding the scope and content of the HFE Program and Implementation Plans, refer to the Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan, in Section 4).

18.2.2 MMIS and HFE Implementation Plan

1) The MMIS and HFE Implementation Plan establishes:

   a. Methods and criteria for the development and evaluation of the MCR, RSS, and applicable LCSs HSI, which are consistent with accepted HFE practices and principles.

   b. The methods for addressing:

(i) Ability of the operating personnel to accomplish assigned tasks,

(ii) Operator workload levels and vigilance,

(iii) Operating personnel situational awareness,

(iv) Operator information processing requirements,

(v) Operator memory requirements, and

(vi) Potential for operator error.

c. HSI design and evaluation scope that applies to the MCR, RSS and applicable LCSs.

The HSI scope addresses normal, abnormal and emergency plant operations as well as test and maintenance interfaces that impact the function of the operations personnel. The HSI scope also addresses the development of operating technical procedures for normal, abnormal and emergency plant operations and the identification of personnel training needs applicable to the HSI design.

d. The HFE Design Team is responsible for:

– Development of HFE plans and procedures
– Oversight and review of HFE design, development, test, and evaluation activities
– Initiation, recommendation, and provision of solutions for problems identified in the implementation of the HFE activities
– Verification of resolution effectiveness
– Assurance that HFE activities comply with HFE plans and procedures
– Phasing of activities
– Methods for identification, closure, and documentation of human factors issues
- HSI design configuration control procedures

2) The HFE Plan also establishes the following items:

a. HFE issue/concerns are entered on the HFE Issue Tracking System log when first identified. Each action taken to eliminate or reduce the issue/concern is documented.

b. Final resolution of the issue/concern, as accepted by the HFE Design Team, is documented along with information regarding HFE Design Team acceptance.

c. The HFE Issue Tracking System addresses human factors issues identified throughout the development and evaluations of the MCR, RSS and applicable LCSs HSI design implementation.

d. MCR, RSS and applicable LCSs designs are implemented using HSI technologies that are consistent with those defined in Section 18.1.4.2.

e. HSI equipment technologies that are alternatively selected for application in the MCR, RSS and applicable LCSs design implementations ensure that:

(i) A review of the industry experience with the operation of selected new HSI technologies is conducted.

(ii) The OER of those new HSI equipment technologies includes both a review of literature pertaining to the human factors issues related to similar system applications of those new HSI equipment technologies and interviews with personnel experienced with the operation of those systems.

(iii) Any relevant HFE issues/concerns associated with those selected new HSI equipment technologies, identified through the conduct of the OER, is entered into the HFE Issue Tracking System for closure.

3) Reviews of HSI operating experience are conducted in accordance with Section 18.3

4) The MMIS and HFE Implementation Plan document includes:

a. Purpose and organization of the plan.

b. Relationship between the HFE program and the overall plant equipment procurement and construction program (organization and phasing).

c. Definition of the HFE Design Team and their activities, including:

(i) Description of the HFE Design Team function within the broader scope of the plant equipment procurement and construction program, including charts to show organizational and functional relationships, reporting relationships, and lines of communication.

(ii) Description of the responsibility, authority and accountability of the HFE Design Team organization.

(iii) Description of the process through which the design team resolves HFE issues.

(iv) Description of the process through which the HFE Design Team makes technical decisions.

(v) Description of the tools and techniques (e.g., review forms, documentation) utilized by the HFE Design Team in fulfilling their responsibilities.

(vi) Description of the HFE Design Team staffing, job descriptions of the individual HFE Design Team personnel and their qualifications.

(vii) Definition of the procedures that will govern the internal management of the HFE Design Team.

Definition of the HFE Issue Tracking System and its implementation, including:

(i) Individual HFE Design Team member responsibilities regarding HFE issue identification, logging, issue resolution, and issue closeout.

(ii) Procedures and documentation requirements regarding HFE issue identification: including a description of the HFE issue, effects of the issue and an assessment of the criticality and likelihood of the identified HFE issue manifesting itself into unacceptable HSI performance.

(iii) Procedures and documentation requirements regarding HFE issue resolution; including evaluation and documentation of proposed solutions, implemented solutions, evaluated residual effects and the evaluated criticality and likelihood of the implemented resolution of the HFE issue manifesting itself into unacceptable HSI performance.

Identification and description of the implementation plans defined in Section 18.1.1.

e. Definition of the phasing of HFE program activities, including:

(i) The plan for completion of HFE tasks which addresses the relationships between HFE elements and activities, the development of HFE reports and the conduct of HFE reviews

(ii) Identification of other plant equipment procurement and construction activities that are related to HFE Design Team activities but outside the scope of the team (e.g., I&C equipment manufacture)

(iii) Definition of HFE documentation requirements and procedures for retention and retrieval.

(iv) Description of the manner in which HFE Program requirements is communicated to applicable personnel and organizations, including those which are subcontracted, who are responsible for the performance of work associated with the MCR, RSS and local panels design implementation (See Figure 18.1-1).

18.2.3 HFE Design Team Composition

1) The composition of the Human Factor Engineering (HFE) Design Team includes, as a minimum, the technical skills presented in #4), below.

2) The education and related professional experience of the HFE Design Team personnel satisfies the minimum personal qualification requirements specified in #4), below, for each of the areas of required skills. In those skill areas where related professional experience is specified, qualifying experience of the individual HFE Design Team personnel includes experience with previous plants in the MCR, RSS and local panels HSI designs and design implementation activities. The required professional experiences presented in those personal qualifications of #4) are satisfied by the HFE Design Team as a collective whole. Therefore, satisfaction of the professional experience requirements associated with a particular skill area may be realized through the combination of the professional experience of two or more members of the HFE Design Team who each, individually, satisfy the other defined credentials of the particular skill area but who do not possess all of the specified professional experience. Similarly, an individual member of the HFE Design Team may possess all of the credentials sufficient to satisfy the HFE Design Team qualification requirements for two or more of the defined skill areas.

3) Alternative personal credentials may be accepted as the basis for satisfying the minimum personal qualification requirements specified in #4), below. Acceptance of such alternative personal credentials are evaluated on a case-by-case basis and approved, documented and retained in auditable plant construction files by the COL applicant or GE. The following factors are examples of alternative credentials which are considered acceptable:

   a. Professional Engineer's license in the required skill area may be substituted for the required Bachelor's degree.

   b. Related experience may substitute for education at the rate of six semester credit hours for each year of experience up to a maximum of 60 hours credit.

   c. Where course work is related to job assignments, post-secondary education may be substituted for experience at the rate of two years of education for one year of experience. Total credit for post-secondary education will not exceed two years experience credit.

4) Required Skill Area /Personal Qualification

   a. Technical Project Management
   Bachelor's degree, and five years experience in nuclear power plant design operations, and three years management experience.

   b. Systems Engineering
   Bachelor of Science degree, and four years cumulative experience in at least three of the following areas of systems engineering; design, development, integration, operation, and test and evaluation.

   c. Nuclear Engineering
   Bachelor of Science degree, and four years nuclear design, development, test or operations experience

   d. Instrumentation and Control (I&C) Engineering
   Bachelor of Science degree, and four years experience in design of hardware and software aspects of process control systems, and experience in at least one of the following areas of I&C engineering; development, power plant operations, and test and evaluation, and familiarity with the theory and practice of software quality assurance and control.

   e. Architect Engineering
   Bachelor of Science degree, and four years power plant control room design experience.

   f. Human Factors Engineering
   Bachelor's degree in Human Factors Engineering, Engineering Psychology or related science, and four years cumulative experience related to the human factors aspects of human-computer interfaces. Qualifying experience should include at least the following activities within the context of large-scale human-machine systems (e.g. process control): design, development, and test and evaluation, and four years cumulative experience

related to the human factors field of ergonomics. Qualifying experience will include experience in at least two of the following areas of human factors activities; design, development, and test and evaluation.

g. Plant Operations
Have or have held a Senior Reactor Operator license; two years experience in BWR nuclear power plant operations.

h. Computer System Engineering
Bachelor's degree in Electrical Engineering or Computer Science, or graduate degree in other engineering discipline (e.g., Mechanical Engineering or Chemical Engineering), and four years experience in the design of digital computer systems and real time systems applications

i. Plant Procedure Development
Bachelor's degree, and four years experience in developing nuclear power plant operating procedures.

j. Personnel Training
Bachelor's degree, and four years experience in the development of personnel training programs for power plants, and experience in the application of systematic training development methods.

k. System Safety Engineering
Bachelor's degree, and four years of experience in system safety engineering.

l. Maintainability/Inspectability Engineering
Bachelor's degree, and four years cumulative experience in at least two of the following areas of power plant maintainability and inspectability engineering activity: design, development, integration, and test and evaluation.

m. Reliability/Availability Engineering
Bachelor's degree, and four years cumulative experience in at least two of the following areas of power plant reliability engineering activity: design, development, integration, and test and evaluation, and knowledge of computer-based human interface systems.

18.3 OPERATING EXPERIENCE REVIEW

The operating experience review (OER) supports HFE by identifying HFE-related safety issues. The plan for the ESBWR OER is described in the ESBWR MMIS and HFE Implementation Plan NEDO-33217. An overview of the OER topics is summarized in the sections below.

18.3.1 Objectives and Scope of OER

The objectives of the OER process are to obtain information and lessons learned from past experience to support design of ESBWR systems. The scope of the analyses is to obtain, evaluate, and incorporate lessons learned from the experience into the ESBWR design. OERs related to the following areas are considered in the development of the plant system, and operational aspects of the ESBWR design:

- Predecessor plant(s) and systems
- Experience in industries with applicable systems
- Industry HSI experience
- Risk-important HAs
- Specifically-identified industry issues
- Issues identified by plant personnel.

18.3.2 OER Methodology

The OER process methodology establishes the process and procedures for evaluating operating, design, and construction experience, thus ensuring that the applicable important industry experiences are provided in a timely manner to those designing and constructing the plant, as required by 10 CFR 34 (f)(3)(I).

- The methods for identifying the operating experience includes identifying:
  - Operating experience for the selected HFE technology components from relevant predecessor plants and systems,
  - Risk-important human actions, recognized industry issues, and
  - Issues identified by plant personnel.
- The methods for analysis and evaluation of operating experience include:
  - Use of summarized issues from industry sources,
  - Development of insights from event reviews, and
  - Development of design solutions to reduce human error.
- The method for keeping track of the process includes the use of the HFEITS, which permits tracking, and review of the issues identified and addressed in the design.

18.3.1.1 Predecessor Plants and Systems

Experience from the entire BWR fleet of reactors is considered in the ESBWR design. The operating experience information is made available to design engineers to support development of design features that are expected to reduce human error. Likewise, positive features of previous designs are identified, evaluated, and retained. The baseline review record includes BWR experience related to the plant and systems of the ESBWR.

18.3.1.2 Risk-important Human Actions

The OER process addresses the risk important HAs from predecessor plants and other BWRs, including to:

- Identification of risk-important HAs in the predecessor plant PRAs and HRAs,
- Determination if they are still risk-important to the ESBWR design via the design level ESBWR PRA output,
- Application of HAs, identify scenarios where these actions are called for in predecessor operations,
- Noting aspects of the predecessor design that assured success for HAs,
- Identifying insights related to needed improvements in human performance if errors have occurred in task execution.

The OER process identifies and documents operational experience related to risk-important human actions for HAs in the ESBWR plant determined to be different from those of the predecessor plant.

18.3.1.3 HFE Technology

The OER associated with proposed HFE technology in the ESBWR design is described. For example, if a computer operated support system (COSS), computerized procedures, or advanced automation are planned, HFE issues associated with such use will be described.

18.3.1.4 18.3.2.4 Recognized Industry Issues

The process for recognizing how industry HFE issues are addressed in the ESBWR design includes categories identified in NUREG/CR- 6400. The categories are:

- Unresolved safety issues/generic safety issues
- TMI issues
- NRC generic letters and information notices
- Reports of the former NRC Office for analysis and evaluation of operational data,
- Low power and shutdown operations, and
- Operating plant event reports (OERs)

18.3.1.5 18.3.2.5 Issues identified by Plant Personnel

The OER plan includes the use of plant personnel interviews to supplement operating experience related to plant operations and HFE design in predecessor plants and systems. Personnel interviews include the following:

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

18.3.1.6 18.3.2.6 Issue Analysis, Tracking, and Review

Section 18.2.2 4) d. describes how OER issues are entered into the HFE issues tracking system.

18.3.3 OER Results

The results of the OER are summarized in the OER Results Summary Report (RSR). The RSR provides the OER process description along with the analyses that were used. These include:

- List of risk important HAs from the predecessor plant and their resolutions,
- List of risk important HAs from the OER requiring special attention in the design process,
- Personnel interviews conducted at predecessor plants with summarized results,
- Examples of OER issues and resolutions, and

- Reference to database containing OER issues.

Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan, in Section 3.6) provides additional details of the OER Plan.

18.4 FUNCTIONAL REQUIREMENTS ANALYSIS AND ALLOCATION OF FUNCTIONS

18.4.1 Functional Requirements Analysis Implementation Plan

1) The FRA Implementation Plan establishes:

   a. Methods for conducting the FRA consistent with accepted HFE practices and principles,

   b. Strategies to define the system functions required that determine HSI requirements,

   c. The process to identify critical safety functions (e.g., those functions required to control radionuclide release), and

   d. Function descriptions in terms of inputs, functional processes, functional operations, outputs, feedback, and interface requirements.

2) The FRA Implementation Plan includes:

   a. Methods to identify system and sub-system level functions based on the ESBWR mission and goals,

   b. Logical function sequence arrangements that can be traced from ESBWR plant level goals to specific tasks,

   c. Methods to develop function graphical descriptions starting at a "top level" and continuing to lower levels until a specific action emerges,

   d. The method to develop detailed function descriptions, which encompasses:

      (i) Identification of observable parameters that indicate system status,

      (ii) Control of processes and data required to accomplish the function, and

      (iii) Determination of the manner in which proper discharge of function is to be determined.

   e. Analysis methods that define the integration of closely related sub-functions so that they are treated as a unit, and

   f. Analysis methods that divide identified sub-functions into two groups according to whether:

      (i) Common achievement of the sub-function is an essential condition for the accomplishment of higher-level function, and

      (ii) The sub-function is an alternative supporting function to a higher-level function or the sub-function accomplishment is not necessarily a requisite for a higher-level function.

3) The results of the FRA are summarized in the FRA Results Summary Report. The RSR provides the plant functional requirements, along with an outline of the analysis that were used. A separate report will be generated following each phase of analysis: High-Level, Detailed (system), and Pre-operational. The FRA RSR may be combined with the RSR from AOF and TA.

Other RSR outputs include:

- Initial inventory of plant parameters and controls
- Emergency Procedure Guidelines (EPG) outlines
- HSI design inputs and recommendations
- Initial inventory of simulator scenarios for V&V
- Emergency Action Level (EAL) procedure outlines
- Staffing requirements and recommendations
- Outlines and inputs to System and Integrated Operating Procedures (SOPs/IOPs)
- Outlines and inputs to Annunciator Response Procedures (ARPs)
- Outlines and inputs to General Plant Procedures (GPP)
- Outlines and inputs to Abnormal Operating Procedures (AOPs)
- Outlines and inputs to Maintenance, Testing and Surveillance Procedures.

18.4.2 Allocation of Function Implementation Plan

1) The AOF Implementation Plan establishes:

   a. Methods and criteria for the execution of function allocation consistent with accepted HFE practices and principles,

   b. System and function definitions generating human performance requirements based on the expected user population,

   c. Documentation of the allocation of functions to personnel, system elements, and personnel system combinations will reflect:

      (i) Areas of human strengths and limitations,

      (ii) Sensitivity, precision, time, and safety requirements,

      (iii) Reliability of system performance, and

      (iv) Necessary personnel (numbers and skills) required for operating and maintaining the SSC.

   d. Documentation of the allocation criteria, rationale, analyses, and procedures, and

e. Analyses confirming that personnel can perform tasks allocated to them while maintaining operator situational awareness, workload and vigilance.

2) The AOF Implementation Plan includes:

a. Establishment of a structured basis and criteria for function allocation, and

b. Definition of function allocation analyses requirements, including:

(i) Objectives and requirements

(ii) Alternative function allocations

(iii) Selection criteria

(iv) Evaluation criteria

(v) Test and analysis methods

(vi) Assessments methods

3) The results of the Function Allocation are summarized in the AOF Results Summary Report. The RSR provides the plant function allocations, along with an outline of the analyses that were used. A separate report will be generated following each phase of analyses: High-Level, Detailed (system), and Pre-operational. The AOF RSR may be combined with the RSR(s) from FRA and TA.

Other RSR outputs include:

- Initial inventory of plant parameters and controls
- EPG outlines
- HSI design inputs and recommendations
- Initial inventory of simulator scenarios for V&V
- EAL procedure outlines
- Staffing requirements and recommendations
- Outlines and inputs to SOPs and IOPs
- Outlines and inputs to ARPs
- Outlines and inputs to GPPs
- Outlines and inputs to AOPs
- Outlines and inputs to maintenance, testing and surveillance procedures

18.5 TASK ANALYSIS

18.5.1 Task Analysis Implementation Plan

1) The Task Analysis (TA) Implementation Plan establishes:

   a. Methods for conduct of the TA consistent with accepted HFE practices and principles.

   b. Scope of the TA including actions performed at the MCR and at the RSS HSI.

   c. Range of plant operating conditions, including: startup, normal &, abnormal operations, transients, refueling, low power, and shutdown conditions.

   d. HSI operations during periods of maintenance, testing, and inspection of ESBWR SSCs.

   e. Links between task descriptions and safety importance, function achievement, human error potential, and impact of task failure.

   f. Descriptions of the personnel activities required for successful completion tasks.

   g. Requirements for alarms, displays, data processing, and controls.

2) The TA Implementation Plan includes:

   a. Methods and data sources used in the conduct of the task analysis,

   b. Methods for conducting the initial (high level) task analysis:

      (i) Converting functions to tasks
      (ii) Developing narrative task descriptions
      (iii) Developing the basic statement of the task functions
      (iv) Decomposition of tasks to individual activities

   c. The methods for developing detailed task descriptions that address:

      (i) Information requirements
      (ii) Decision-making requirements
      (iii) Response requirements
      (iv) Feedback requirements
      (v) Personnel workload
      (vi) Task support requirements
      (vii) Workplace factors
      (viii) Staffing and communication requirements
      (ix) Task hazards

d. Methods to identify critical tasks during postulated event scenarios of a common mode failure; including, operator actions to:

   (i) Isolate the reactor, and

   (ii) Inject water into the reactor.

e. Methods for establishing data and control requirements,

f. Methods for analyzing alarm, display, processing, and control requirements.

g. Methods through which the application of task analysis results are assembled and documented to provide input to the development of personnel training programs, and

h. Methods used to evaluate the TA results.

3) The results of the TA are summarized in the TA Results Summary Report. The RSR provides the tasks, along with an outline of the analyses that were used. A separate report will be generated following each phase of analyses: High-Level, Detailed (system), and Pre-operational. The TA RSR may be combined with the RSR(s) from FRA and AOF.

Other RSR outputs include:

- Initial inventory of plant parameters and controls
- EPG outlines
- HSI design inputs and recommendations
- Initial inventory of simulator scenarios for V&V
- EAL procedure outlines
- Staffing requirements and recommendations
- Outlines and inputs to SOPs and IOPs
- Outlines and inputs to ARPs
- Outlines and inputs to GPPs
- Outlines and inputs to AOPs
- Outlines and inputs to Maintenance, Testing and Surveillance Procedures

18.6 STAFFING AND QUALIFICATIONS

18.6.1 Background

Plant staff levels and plant staff qualifications are important considerations throughout the design process. Initial staffing level is established based on experience with ABWR Reference plants, staffing goals, initial analyses, and regulatory requirements. ESBWR staffing and qualifications plans systematically re-examine the ABWR assumptions and consider staffing reductions warranted by the use of passive safety systems.

18.6.2 Objectives and Scope of Staffing and Qualification Analyses

The objectives of the staffing and qualifications analyses and the scope of the analyses performed are provided. The scope includes the number and qualification of personnel for the full range of plant conditions and tasks including operational tasks (normal, abnormal, and emergency), plant maintenance and testing, including surveillance testing. The personnel considered are addressed in the scope and addresses licensed control room operators as defined in 10CFR Part 55 and the following categories of personnel defined by 10 CFR 50.120: non-licensed operators, shift supervisor, instrument and control technician, electrical maintenance personnel, radiological protection technician, chemistry technician, and engineering support personnel. In addition, any other plant personnel who perform tasks that are directly related to plant safety are addressed.

18.6.3 ESBWR Baseline Staffing Assumptions

The preliminary staffing assumption for ESBWR control and monitoring will consist of the following assignments:

Quantity	Qualification	Assignment
1	Control Room Supervisor[1]	Provides overall supervision of control room operations
2	Reactor Operators[2]	First operator is assigned to normal control actions at MCR HSI. Second operator is assigned to control of testing, surveillance and maintenance activities, including blocking and tagging permits.
1	Senior Reactor Operator (Shift Manager) [1]	Assigned to shift but not necessarily in the Main Control Room (MCR). Acts as manager of and relief for shift supervisor.
2	Auxiliary Operators[3]	Qualified to operate equipment in the plant.

[1]Licensed by the NRC as a Senior Reactor Operator (SRO)

[2]Licensed by the NRC

[3]Non-licensed, often called Auxiliary Equipment Operators (AEOs)

The licensed operator will remain in control of plant operation during all states of operation. During normal operations the operator will monitor the automated control functions. The operator will be able to assume manual control of those functions that have been automated for reasons other than regulatory requirements. The operating crew's training will include manual operation of an automated function that has been returned to manual monitoring and control.

18.6.4 Staffing and Qualifications Plan

The HFE team develops a staffing analysis plan to perform an iterative HFE process in accordance with Figure 18.1-1 and Section 18.1-1 reference 1 (MMIS and HFE Implementation Plan, in Figure 1.2). The basis for staffing and qualifications plan will address the following issues:

18.6.1.1 18.6.4.1 Operating Experience Review

- Operational problems and strengths that resulted from staffing levels in ABWR Reference systems
- Initial staffing goals and their bases including staffing levels of ABWR Reference plants
- Systems and a description of significant similarities and differences between ABWR Reference systems and ESBWR systems (A Baseline Review Record is developed.)
- Staffing considerations described in NRC Information Notice 95-48, "Results of Shift Staffing Study"
- Staffing considerations described in NRC Information Notice 97-78, "Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times"

18.6.1.2 18.6.4.2 Functional Requirements Analysis and Function Allocation

- Mismatches between functions allocated to personnel and their qualifications
- Changes the roles of personnel due to plant system and HFE modifications

18.6.1.3 18.6.4.3 Task Analysis

- Knowledge, skills, and abilities needed by personnel as identified by the task analysis
- Personnel response time and workload
- Personnel communication and coordination, including interactions among them for diagnosis, planning, and control activities, and interactions among personnel for administrative, communications, and reporting activities
- Job requirements resulting from the sum of all tasks allocated to each individual both inside and outside the control room
- Impact on the ability of personnel to perform their function due to plant and HFE modifications
- Availability of personnel considering other ongoing activities

- Assignment of operators to tasks outside the control room (e.g., fire brigade)
- Actions identified in 10 CFR 50.47, NUREG-0654, and procedures to meet an initial accident response in key functional areas as identified in the emergency plan
- Staffing considerations described by the application of ANSI/ANS 58.8-1994, "Time Response Design Criteria for Safety-Related Operator Actions"

18.6.1.4 18.6.4.4. Human Reliability Analysis

- Effect of overall staffing levels on plant safety and reliability
- Effect of overall staffing levels and crew coordination for risk-important HAs
- Effect of overall staffing levels and the coordination of personnel on human errors associated with the use of advanced technology

18.6.1.5 18.6.4.5 HSI Design

- Staffing demands resulting from the locations and use (especially concurrent use) of controls and displays
- Coordinated actions among individuals
- The availability or accessibility of information needed by personnel due to plant system and HFE modifications
- The physical configuration of the control room and control consoles
- The availability of plant information from individual workstations and group-view interfaces

18.6.1.6 18.6.4.6 Procedure Development

- Staffing demands resulting from requirements for concurrent use of multiple procedures
- Personnel skills, knowledge, abilities, and authority identified in procedures

18.6.1.7 18.6.4.7 Training Program Development

The training program addresses crew coordination issues that are identified during the development of training.

18.6.5 Methodology of Staffing and Qualification Analyses

This section addresses how the Staffing and Qualification Analyses methodology is coordinated with DCD Section 13.1, and is related to organization and staffing. The iterative nature of the staffing analysis and how the initial staffing goals are reviewed and modified as the analyses associated with other HFE elements are completed are addressed. The section discusses the staffing plan to address compliance with 10 CFR 50.54 (i) through (m).

Additional methodology for the staffing and qualifications element is provided in the Staffing and Qualification Implementation Plan.

18.6.6 Results of Staffing and Qualifications Analyses

The results of the Staffing and Qualification (S&Q) are summarized in the Results Summary Report. The RSR discusses in greater detail the methodology employed and provides results of the staffing analyses. The RSR includes enough detail to show the methodology implemented providing the results and the final staffing levels for all personnel identified in the above scope. This is in conjunction with compliance with all regulatory requirements as delineated in 10 CFR 50.54.

Other RSR S&Q Outputs include:

a. Demonstrated compliance with 10 CFR 50.54 (18.6.5)

b. Staffing Analysis results in detail (18.6.5)

c. Final staffing levels, including the number of personnel with a specific qualification and requirements for achieving the qualification (18.6.6)

d. Qualifications

18.7 HUMAN RELIABILITY ANALYSIS

Human reliability analysis (HRA) is performed in support of a probabilistic risk assessment (PRA) for both pre- and post-initiator human actions.

18.7.1 Objectives and Scope of Human Reliability Analysis

This section describes how the HFE program uses the Human Reliability Analysis (HRA). An initial “design level” ESBWR PRA is provided in DCD Chapter 19 to support NRC certification information requirements. The performance of the HRA quantification is addressed in DCD Chapter 19. The impact of the risk important human actions and human-error mechanisms on the HSI design is addressed in the DCD Chapter 18.

The scope for using HRA in HFE activities includes:

(1) An assessment of the potential for and mechanisms of human error that may affect plant safety, particularly the risk important HAs;

(2) A discussion of potential human errors in the design of HFE aspects of the plant to address the likelihood of personnel error, to detect errors and recover from them;

(3) Human errors identified and quantified in the PRA are further evaluated to determine if new or modified HSI design features are needed to reduce the likelihood and impact of errors and

(4) The HRA activity quantitatively integrates the HFE program into the PRA and the PRA insights into the HFE program.

18.7.2 Methodology of Human Reliability Analysis

The PRA/HRA results and the risk-important HAs are addressed by the HFE design team (through HSI design, procedural development, and training) to minimize the likelihood of operator error and provide for error detection and recovery capability. The use of passive cooling systems, increased automation and computer-based HSIs change the way that operators interact with the ESBWR compared with previous BWRs. For example, passive cooling eliminates the need for operating and controlling forced cooling systems. The operators concentrate more on monitoring and deciding on a course of action.

The PRA/HRA is used to identify the risk-important human actions for evaluation in the HFE process. The process for determining the risk-important HAs includes the use of:

- Level 1 (core damage) design level PRAs,
- Level 2 (release from containment) PRAs and post-core damage actions,
- Internal and external events portions of the PRA, and
- The low power and shutdown PRA.

The importance of each HA is determined by using an importance measure (e.g., Fussell-Vesely, achievement worth, or risk reduction worth), HRA sensitivity analyses, and threshold criteria for selecting the PRA accident scenarios (or cutsets) considered for maintaining a list of risk-important actions.

During the HFE design process HFE team verifies that HRA assumptions, such as decision-making and diagnosis strategies for dominant sequences and important actions can be performed using the MMIS for the risk important human actions. The methods include discussions and walkthrough analyses with personnel having operational experience and the use of a plant-specific control room mockup or simulator.

The HFE descriptions and analyses of operator functions and task requirements become inputs to quantification model. The HRA model updates consider previous PRA identified actions and errors, performance factors associated with the operational characteristics of HSI design, procedures for normal, startup, shutdown and emergency operations as well as training programs.

The HRA modeling for the PRA derives benefit from the HFE team descriptions and analyses of operator functions and task requirements, which are inputs to the quantification model. The HRA model consider previous PRA identified actions and errors, performance factors associated with the operational characteristics of HSI design, procedures for normal, startup, shutdown and emergency operations as well as training programs.

18.7.3 Results of Human Reliability Analysis

The results of the HRA are summarized in the results summary report. The RSR provides the list of risk important HAs and summarizes how the risk-important HAs and their associated tasks and scenarios are addressed during the various phases of the design process (e. g., in allocation of functions analyses, task analyses, HSI design, procedure development, and training). The HFE process ensures that the tasks identified are well supported by HSI design features and are within acceptable human performance capabilities. The RSR also discusses validation of the HRA assumptions.

18.8 HUMAN-SYSTEM INTERFACE DESIGN

This section describes the process by which areas of operator interfaces is established and evaluated. The primary areas of human interface are the ESBWR MCR, RSS, and LCSs with safety-related functions or identified through high-level task analysis. The HSI design implementation-related Design Acceptance Criteria (DAC), established through Rulemaking, defines a direct correspondence between the DAC entries and design activity requirements. These results are available for the NRC conformance reviews. Satisfaction of the specific requirements Section 18.1.1 reference 1 (MMIS and HFE Implementation Plan) results in full compliance with the Certified Design Commitment and the corresponding Acceptance Criteria presented in the Tier 1 (Rulemaking) DAC.

18.8.1 HSI Design Implementation Plan

1. The HSI Design Implementation Plan establishes (see Section 4.8 and 5.0 in Reference 1 for additional details):
   a. Methods and criteria for HSI equipment design and evaluation of HSI human performance, equipment design, and associated work place factors, (for example, illumination, noise, and ventilation) consistent with accepted HFE guidelines, principles, and methods,
   b. Information and control requirements, including the displays, controls, and alarms necessary for the execution of identified tasks. [See paragraph 18.8.1 2).d],
   c. Methods for comparing the consistency of the HSI human performance equipment, design, and associated workplace factors as modeled and evaluated in the completed task analysis,
   d. Equipment (hardware and software) functions as determined in the task analysis,
   e. Design criteria and guidance for control room operations during periods of maintenance, test, and inspection of control room HSI equipment and human interfaces, and
   f. Test and evaluation methods for resolving HFE/HSI design issues including the criteria to be used in selecting HFE/HSI design and evaluation tools which:
      (i) Incorporate the use of static mockups and models for evaluating access and workspace-related HFE issues, and
      (ii) Require dynamic simulations and HSI prototypes for conducting evaluations of the human performance associated with the activities in the critical tasks identified in the task analysis.
2. The HSI Design Implementation Plan includes:
   a. Identification of the specific HFE standards and guidelines documents,

b. Substantiation that selected HSI Design Evaluation Methods and Criteria are based upon accepted HFE practices and principles,

c. Definition of standardized HFE design conventions,

d. Verification that the design features, the HSI equipment technologies, and the displays, controls, and alarms are incorporated as requirements on the HSI design, and

e. Definition of the design/evaluation tools (e.g., prototypes) which are to be used in the conduct of the HSI design analyses, the specific scope of evaluations for which those tools are to be applied, and the rationale for the selection of those specific tools and their associated scope of application.

3. The results of the HSI Design Implementation are summarized in the Results Summary Report including:

   a. The style guide developed for the detailed design.

      The development and basis for the guide will be identified,

      (ii) The scope, topical contents and procedures, and

      (iii) Procedures used to maintain a style guide are described.

   b. HSI process, after the plant is in operation, by which

      (i) HSIs are modified and updated;

      (ii) Temporary HSI changes are made (such as set-point modification);

      (iii) Operator defined HSIs are created (such as temporary displays defined by operators for monitoring specific plant situations).

      (iv) The procedures governing permissible operator initiated changes to HSIs are described.

      (v) The criteria for determining that an HSI change or modification falls under the formal engineering change process will be described.

   c. The final HSI design.

18.9 PROCEDURE DEVELOPMENT

Procedures are essential to plant safety because they support and guide personnel interactions with plant systems and their response to plant-related events.

The HFE team generates the process for procedure development using applicable requirements from NUREG-0800 section 13.5. The ESBWR normal operating, abnormal operating, alarm response, test, and emergency operating procedures will be developed as an integral part of the MMIS and HSI development. The ESBWR procedures address all personnel tasks that are affected by the changes in plant systems and HSIs. The procedures will be developed or modified to reflect the characteristics and functions of the plant improvements. The same human factors principles applied to all aspects of the HSI verify complete integration and consistency.

The MMIS implementation includes steps, which provide verification that all functions and tasks assigned to the plant procedures are included in the operating procedures. The MMIS implementation process will include validation of the operating procedures using the mockup/part-task and full-scope simulator facility.

Procedures are presented electronically and meet the following requirements:

- Presented as logic or flow charts, (where practical)
- Displays include decision-making aids and requisite steps
- Checklist of prerequisites or interlocks to steps
- Allow operator access to controls
- Verification of operator decisions
- Retention of operator control and authority
- Logging of disparate decisions
- Continuous update of plant parameters and plant status
- Written to HFE best practices

18.9.1 Objectives and Scope of Procedure Development

This section describes the objectives and scope of the applicant’s procedure development program. The scope of the procedures addressed in this section is:

- EOPs including Generic Technical Guidelines (GTGs) for EOPs
- Plant and system operations (including startup, power, and shutdown operations)
- Test and maintenance
- Abnormal and emergency operations
- Alarm response

18.9.2 Methodology of Procedure Development

This section is coordinated with the procedures aspects in DCD Section 13.5 and describes the basis for procedure development including:

- Plant design bases
- System-based technical requirements and specifications
- Task analyses results
- Risk-important HAs identified in the HRA/PRA
- Initiating events to be considered in the EOPs, including those events in the design bases
- GTGs for EOPs.

The section describes how the procedures program addresses the requirements specified in 10 CFR 50.34(f)(2)(ii) and describes the Procedure Writers' Guide that establishes the process for developing technical procedures that are complete, accurate, consistent, and easy to understand and follow. In addition, this section references the ESBWR HFE Procedures Development Implementation Plan that describes further details about the following topics:

- *Writers Guide*. How the writer's guide ensures that procedures are consistent in organization, style, and content and which procedures fall within the purview of the guide.
- *Procedure Format*. The basic content and format used for procedures in the facility.
- *EOPs*. The logic used in developing the content of GTGs and EOPs, e.g., symptom-based procedures with clearly specified entry conditions.
- *Procedures V&V*. The procedure verification and validation (V&V) program including the use of simulation.
- *Computer-based Procedures*. The development, V&V, and implementation process of computer-based procedures (CBPs) includes a description of the HSI for the CBPs. An analysis of the available alternatives in the event of loss of CBPs is also provided.
- *Procedure Maintenance*. The process for procedure maintenance and control of updates is integrated across the full set of procedures. How the plant ensures that alterations in particular parts of the procedures are consistent with other parts of the full set of procedures.

  The results of the Procedure Development Results Summary Report (RSR) will provide the process for procedure maintenance and control of updates.

Procedure Access and Use. How operators access and use procedures, especially during operational events, for both hard copy and computer-based procedures.

18.9.3 Results of Procedure Development

The results of the Procedure Development are summarized in the results summary report. The RSR provides the list of the final set of procedures and procedure support equipment developed using the above methodology. The RSR includes sufficient detail to see how the methodology was implemented to provide the results.

Other RSR Procedure Development outputs include:

- Process for procedure maintenance and control of updates (18.9.2)
- Operator access and use of procedures for both hard copy and computer-based procedures (18.9.2)
- Procedure, storage and laydown area for use of hardcopies in the MCR, RSS and LCSs (with a safety-related function or as defined by high level TA).

18.10 TRAINING PROGRAM DEVELOPMENT

Training of plant personnel is an important factor in ensuring safe and reliable operation of nuclear power plants. The training program provides reasonable assurance that plant personnel have the knowledge, skills, and abilities to properly perform their roles and responsibilities. Training program development is coordinated with the other elements of the HFE design process by including for example a systematic analysis of job and task requirements.

18.10.1 Purpose

The aim of an implementation plan for training program development is to systematically incorporate information from the other HFE design tasks to support implementation of ESBWR personnel training. As minimum the training program includes the following activities:

- A systematic analysis of the tasks and jobs that are triggered by cues from the HSI or procedures, or training.
- Development of learning objectives derived from an analysis of desired performance through the training program.
- Design and implementation of training based on the learning objectives
- Evaluation of trainee mastery of the objectives during training
- Evaluation and revision of the training based on the performance of trained personnel in the job setting.

18.10.2 Objectives and Scope of Training Program Development

The objectives and scope of the training program is described. The overall scope of training includes the following:

- Categories of personnel to be trained, including the full range of positions of operational personnel including licensed and non-licensed personnel whose actions may affect plant safety
- The full range of plant conditions (normal, upset, and emergency)
- Specific operational activities (e.g., operations, maintenance, testing, and surveillance)
- The full range of plant functions and systems
- The full range of relevant HSIs (e.g., main control room, remote shutdown panel, local control stations with a safety-related function or as defined by high Level Task Analysis, TSC & EOF interface)

18.10.3 Methodology of Training Program Development

This section is coordinated with DCD Section 13.2 and describes how the training program follows a systematic approach to training and how it addresses the requirements of 10 CFR 50.120, 52.78, and 55.

The roles of all organizations, especially the HFE team, are specifically defined for the development of training requirements, development of training materials, and implementation of the training program. For example, the role of the vendor may range from merely providing input materials (e.g., GTG) to conducting portions of specific training programs. The qualifications of organizations and personnel involved in the development and conduct of training are defined.

Facilities and resources such as plant-referenced simulator and part-task training simulators needed to satisfy training design requirements and the guidance contained in ANSI 3.5 and Regulatory Guide 1.149 are defined.

The analyses approach to derive the learning objectives, including the use of:

- The licensing basis,
- Operating experience,
- Function analysis and allocation,
- Task analysis, human reliability analysis,
- The details of the HSI design,
- Plant procedures, and
- Insights from the V&V.

The development of learning objectives describes what Knowledge and Skill Attributes (KSAs) must be successfully learned.

The training program includes the use of lectures, simulators, and computer-based training; training on theory and practical applications; and schedule, timing, and arrangement of training.

18.10.4 Elements for Training Program Development

The following elements are supported by the HFE design team develop the: general approach, organization of training, learning objectives, content of training program, evaluation of training, and periodic re-training.

18.10.1.1.1 *18.10.4.1 General Approach*

A systematic approach to the training of plant personnel will be developed.

The approach follows applicable guidance in NUREG-0800 Section 13.2 ("Training"), as defined in 10 CFR 55.4, and as required by 10 CFR 52.78 and 50.120. An overall scope of training defined and supported by the HFE design team, includes the following elements:

- Categories of personnel to be trained (e.g., senior reactor operator),
- Specific plant conditions (normal, transient, and emergency),
- Specific operational activities (e.g., operations, maintenance, testing and surveillance) and,
- Key actions as required by cues from the HSIs (e.g., in the MCR, EOF, RSS and LCSs).

The training program plan provides reasonable assurance that personnel have the qualifications commensurate with the performance requirements of their jobs. The training program addresses:

- A full range of positions of operational personnel including licensed and non-licensed personnel whose actions may affect plant safety,
- A full range of plant functions and systems including those that may be different from those in predecessor plants (e.g., passive systems and functions), and

A full range of relevant HSIs (e.g., main control room, remote shutdown panel, local control stations) including characteristics that may be different from those in predecessor plants (e.g., display space navigation, operation of "soft" controls) as is appropriate for each job classification.

18.10.1.2 18.10.4.2 Organization of Training

The specific roles for development of training requirements, development of training information sources, development of training materials, and implementation of the training program are defined in a training plan. The initial role for the HFE team is expected be to provide input materials to the training program as requested to conduct specific training modules.

The qualifications of organizations and personnel involved in the development and conduct of training is defined in the training plan.

The HFE team defines the facilities and resources to be used during different phases of the design and operation. The facilities include a plant-reference simulator and part-task training simulators. The plan for these facilities will follow the guidance contained in ANSI 3.5 and Regulatory Guide 1.149.

18.10.1.3 18.10.4.3 Learning Objectives

Learning objectives for each job description are derived from the analysis and information from the HFE team that describes desired performance after training. This analysis includes but is not limited to training needs identified in the following elements:

- Licensing Basis - Final Safety Analysis Report, system description manuals and operating procedures, facility license and license amendments, licensee event reports, and other documents identified as being important to training
- Operating Experience Review - previous training deficiencies and operational problems that can be corrected through additional and enhanced training, and positive characteristics of previous training programs.
- Function Analysis and Allocation - functions identified as new or modified by the HFE design team.
- Task Analysis - tasks identified through the HFE process as posing unusual demands including new or different tasks, and tasks requiring a high degree if coordination, high workload, or special skills are provided by the HFE team.
- Human Reliability Analysis – This analysis as part of the PRA/HRA provided by the HFE design team defines coordinated roles for the operational crew to reduce the likelihood and/or consequences of human error associated with risk-important HAs and the use of advanced technology. Generic design PRA/HRA models are plant specific.

- HSI Design – The HFE design team identifies HSI features whose purpose or operation is different from the past experience or expectations of personnel. (This is vitally important in the areas where an expanded role for passive safety systems has been incorporated into the defense in depth safety functions.)
- Procedure Development– The basic BWR symptom based emergency procedures is updated to address the impact of passive safety systems by the HFE team and modified to address plant specific issues. The HFE team addresses specific tasks that have under gone extensive revision during past procedure development to address plant safety concerns.
- Verification and Validation (V&V) –The HFE design team provides scenarios and information to support V&V testing.

Learning objectives for personnel training that address the knowledge and skill attributes associated with all relevant topics and the HFE design team develops dimensions of a trainee's job. Table 18.10-1, illustrates generic learning objectives for interactions with the plant, the HSIs, and other personnel.

18.10.1.4 18.10.4.4 Content of Training Program

- A training program based on the HFE team plan for training.
- The training plan defines specifically how learning objectives are conveyed to the trainee.

The plan will include: how lectures, simulators, and on-the-job training are used to convey particular categories of learning objectives.

- The HFE design process defines an initial listing of specific plant conditions and scenarios for training.
- Specific training scenarios incorporating lessons learned during the operational period.
- Training implementation plan developed by the HFE team are incorporated to consider the order and schedule of training segment building blocks.
- The training plan is adaptive allowing for scenario development to challenge well-trained crews.
- The training program employs factual knowledge developed by the HFE design team to teach the knowledge and skill elements within the context of actual job tasks so that trainees learn to apply knowledge and skill training in the work environment integrating theory and topical training with procedure use training.

The training plan structures training programs for developing skills so that the training topics build upon operational precepts. For example, trainees will master the manipulation of control devices through the HSI before developing coordination skills among crewmembers that require knowledge of how to manipulate the control system.

The training program employs the symptom-based procedures developed by the HFE team to support rules for decision-making related to plant systems, HSIs, and use of the procedures. The symptom-based procedures include rules for identifying cues, confirming, and interpreting information. The training program encompasses decision-making rules for interpreting symptoms of failures of systems, HSIs, and procedures that are a direct result of the passive design.

18.10.1.5 18.10.4.5 Evaluation and Modification of Training

The training program plan includes methods for evaluating the overall effectiveness of the training programs and trainee mastery of training objectives; including written tests and oral tests and observation of personnel performance during walkthrough, simulator exercises, and while on-the-job. Evaluation criteria for mastery of training objectives during individual training modules are defined in the training program plan. Methods for assessing overall proficiency are defined and coordinated with regulations, where applicable for licensed personnel.

The training program plan defines methods for verifying the accuracy and completeness of training course materials.

The training program plan establishes procedures for refining and updating the content and conduct of training. The plan includes provisions for tracking training course modifications.

18.10.1.6 18.10.4.6 Periodic Retraining

The training program plan addresses how often and which job classifications need to undergo periodic retraining. The training program plan provides for evaluating whether any changes in training are warranted following plant upgrades and other modernization programs.

18.10.5 Results of Training Program Development

The results of the Training Program Development are summarized in the Results Summary Report. The RSR describes the training program design and the use of simulator in training.

Other RSR Training Program Development outputs include:

- The Training Program Design
- The methods used for evaluating the overall effectiveness of the training programs
- Trainee mastery of training objectives, as well as overall proficiency:
  - Including written and oral tests,
  - Review of personnel performance during walkthrough,
  - Simulator exercise, and
  - On-the-job evaluation is described.
  - Descriptions of the evaluation criteria used for training objectives.
- The training simulator, its conformance with ANSI/ANS 3.5, Nuclear Power Plant Simulators for Use in Operator Training, American Nuclear Society (ANS), and its place/usage in the plant training program
- Methods for verifying the accuracy and completeness of training materials.
- Methods for refining and updating the content and conduct of training.

- Planned re-training program.

Table 18.10-1

Example Knowledge and Skill Dimensions for Learning Objectives Identification

Topic	Knowledge	Skill
Plant Interactions	Understanding of plant processes, systems, operational constraints, and failure modes.	Skills associated with monitoring and detection, situation awareness, response planning and implementation.
HSI and Procedure Interactions	Understanding of procedures and HSI structure, functions, failure modes, and interface management tasks (actions, errors, and recovery strategies).	Skills associated with interface management tasks.
Personnel Interactions (In the CR and in the plant)	Understanding information requirements of others, how actions will be coordinated with others, policies and constraints on crews' interaction.	Skills associated with crew interactions (i.e., teamwork)

18.11 HUMAN FACTORS VERIFICATION AND VALIDATION[GE78]

This section describes the following:

- The five main activities of HF V&V (in order of occurrence):
    1. Operational Conditions Sampling (per NUREG 0711r2)
    2. Design Verification
        a. Inventory and Characterization
        b. Human-System Interface (HSI) Task Support Verification
        c. Human Factors Engineering (HFE) Design Verification
    3. Integrated System Validation
    4. Human Factors Issue Resolution Verification (HED Resolution)
    5. Final Plant HFE/HSI Design Verification
- Relationship between HF V&V and hardware/software V&V
- HF V&V team
- End-users as participants and test subjects
- Documentation, reporting, performance measurement, and integration of results

Figure 18.1-1 provides an overview of the integrated HF V&V activities with their associated inputs and outputs.

18.11.1 Human Factors Verification and Validation Implementation

The ESBWR MMIS and HFE Implementation Plan, NEDO-33217, Sections 4.11 and 4.12 established:

1. Human factors V&V methods and criteria that are consistent with accepted HFE practices and principles.
2. That the scope of the evaluations of the integrated HSI includes:
    a. HSI, including both the interface of the operator with the HSI equipment hardware and the interface of the operator with the HSI equipment's software-driven functions,
    b. Plant normal and emergency operating procedures, and
    c. HSI work environment.
3. That static and/or "part-task" mode evaluations of the HSI equipment are conducted to confirm that the controls, displays, and data processing functions identified in the task analyses are designed per accepted HFE guidelines and principles.
4. The integrated system validation of HSI equipment with each other, with the operating personnel, and with the plant normal and emergency operating procedures are evaluated through the conduct of dynamic task performance testing. The dynamic task

performance testing and evaluations are performed over the full scope of the integrated HSI design using dynamic HSI prototypes (i.e., prototypical HSI equipment which is dynamically-driven using real time plant simulation computer models). When a particular HSI design implementation under consideration is referenced to a previous HSI design for which dynamic task performance test and evaluation results are available, those existing results, along with the results of limited scope dynamic task performance tests which address the areas of difference between the two subject HSI designs, are used to satisfy this requirement. The methods for defining the scope and application of the dynamic HSI prototype, past test results and other evaluation tools are documented in the ESBWR HFE V&V implementation plan, NEDO-33276.

5. Human Factors issues are included and tracked in the HFEITS.
6. Final plant HFE/HSI Design Verification completion is performed and documented as a basis to human performance monitoring.

18.11.2 Results of HFE V&V

The results of the HFE V&V activities are summarized in the results summary report including HED identification and resolutions.

18.12 DESIGN IMPLEMENTATION

The Design Implementation plan addresses the final “as-built” implementation of the HFE plant design for new plants constructed using the ESBWR standard plant. Both GE and the COL holder carry out the design implementation. The implementing organizations execute their responsibilities under the plans described in NEDO-33217. The design implementation, startup, and operation duties of the COL holder include aspects of these plans, which are transferred to the COL holder under their license obligations to ensure the integrity of the HFE infrastructure is maintained throughout the life cycle of the plant.

The HFE aspects of the ESBWR standard plant including design of the HSIs, standard plant procedures, and baseline training documentation are verified and validated using the Full Scope Simulator (FSS) during the HFE Verification and Validation (HFE V&V) process. Thereafter, each Combined Operating License (COL) holder performs the Design Implementation as described in this plan to assure that the “as-built” HFE Design conforms to the design that was used in the standard ESBWR plant V&V efforts.

18.12.1 Objectives and Scope of Design Implementation

NEDO-33278, ESBWR HFE Design Implementation Plan has the following objectives.

Confirm that the final HSIs, procedures and training (as-built) HFE design conforms to the ESBWR standard plant design resulting from the HFE design process and V&V activities.

- Verify aspects of the design and any physical or environment (e.g., noise, lighting, etc.) differences between those present at the V&V process and the “as-built” MCR.
- Verify that the resolution of Human Engineering Discrepancies (HEDs) and open HFE items are documented in the Human Factors Engineering Issue Tracking System (HFEITS).

Methodology of Design Implementation

18.12.2.1 HSI Verification (As-Built)

The Human-System Interfaces (HSIs) and their design characteristics are established in the HSI Design activity using the guidance in the Style Guide for Graphical User Interfaces and issued as the HSI Report. The HSIs are subsequently evaluated and confirmed in the HFE Verification and Validation. Following the HFE V&V, the standard plant HSI Report is revised and becomes the basis for the requirements and acceptance criteria for the fabrication/procurement of the equipment for the “as-built” installation. The process and the rationale for the HSI design are documented and managed under General Electric Energy Nuclear (GEEN) Quality Assurance (QA) and ESBWR specific design program plans.

The “as-built” confirmation for the HSIs involves an auditing of the procurement, start-up, and testing process.

18.12.2.2 Procedures and Training Confirmation (As-Built)

The standard plant procedures and training documentation are established in development activities. The HFE V&V validates the adequacy of the proposed HSIs and the standard plant procedures and training to support personnel performance.

Following the HFE V&V, the COL may choose to adapt the standard plant procedures and training to incorporate plant-specific reference information into the body of the documents. The approach to perform the "as-built" confirmation for the procedures and training is to conduct an audit of the plant-specific procedures and training, compare the "as-built" documents to the corresponding standard plant basis documents, and assess any differences.

18.12.2.3 Final HFE Design Verification Not Performed in the Simulated HFE V&V Activity

HFE design aspects that are not addressed in the simulated HFE V&V such as modifications to the standard design, and HFE aspects not feasible to perform in the simulated environment are included in the Design Implementation Report. These include:

- Communication equipment interfaces (phones, radios, intercoms, etc.),
- Lighting (normal and emergency),
- Habitability systems (HVAC, noise, lighting, etc.),
- Use of plant-specific training manuals and procedures,
- Data and video interfaces with the TSC and equipment to duplicate or link the EOF to the plant process database, and
- Procedure/P&ID drawing laydown area.

18.12.2.4 Resolution of Remaining HEDs and Open issues in HFEITS

The HFE V&V of the standard plant design addresses the issues from the HFE design and development. The Design Implementation process is used to close out remaining issues from the M-MIS/HFE Implementation Process.

18.12.3 Design Implementation Results Summary Report

The results of the Design Implementation activities are summarized in the results summary report. The RSR report provides an introduction, background, and summary of results and outputs of the activities performed.

The RSR Design Implementation Plan outputs include:

- Final "as-built" HSI verification
- Confirmation of Procedures and Training design implementation
- Verification of HFE design not performed in the HFE V&V
- Resolution to HEDs and open issues in HFEITS

18.13 HUMAN PERFORMANCE MONITORING

The Human Performance Monitoring (HPM) strategy links human factors engineering methods used during the design with methods for monitoring human performance during operation.

18.13.1 Purpose

The purposes of HPM are:

- To ensure that the high safety standards established during the HSI design are maintained even when changes are made to the plant, and
- To provide adequate assurance that the safety bases remain valid during the operational phase of the plant.

There is no intent for the MMIS designer or the COL Applicant to periodically repeat a full-integrated system validation. The strategy is to provide a monitoring plan; building upon the HFE activities during the design that can be carried forward into the operational phase, using industry accepted methods. HPM incorporates this monitoring strategy into the problem identification and corrective action program which identifies and classifies human errors, provide for evaluation of the root cause, and supports effectiveness verification and documentation of the corrective action.

18.13.2 HPM Strategy Development

The scope of the performance monitoring strategy provides reasonable assurance that:

- The HSI design is effective during:
  - Normal operations
  - Accidental Operating Occurrences (AOOs)
  - Accidents
  - Design basis events
  - Significant industry events
  - Key scenarios identified by the PRA/HRA
- Human actions, using HSI information, cues and controls can accomplish critical tasks while maintaining margin for time and performance criteria.
- Acceptable performance levels established during the integrated HSI validation are maintained. The methods for evaluation and trending established for the plant operators through INPO's HPES provides an industry-accepted approach.
- Changes made to the initial HSIs, procedures, and training does not have adverse effects on personnel performance, e.g., a change interferes with trained skills.
- The screening and processing discussed in Regulatory Guide 1.174 forms the basis of the documentation strategy and any links to the content in Chapter 18 for the FSAR.

18.13.3 Elements of HPM process

HPM strategy includes consideration of:

- Data collection
- Importance screening
- Event analysis to determine causes
- Trend analysis
- Corrective action development

The HPM process draws upon existing information sources and programs to supplement the data collection.

The HPM strategy collects data to trend human performance. The data demonstrates consistency among implemented changes and assumptions. Assumptions are a result of initial design or HSI design changes. The strategy uses existing utility or industry programs (e.g. corrective action, programs or license operator training) for data collection. The HPM strategy ensures that:

- Human actions are monitored commensurate with their safety importance,
- Feedback of information and corrective actions are accomplished in a timely manner, and
- Degradation in performance can be detected and corrected before plant safety is compromised.

This strategy is implemented through the use of a plant specific simulator during periodic training exercises. The HSI design process assumes that a simulator is maintained and upgraded to match the actual control room with good interface and dynamic response fidelity (i.e., it will meet 10 CFR 55.49 and ANSI 3.5).

The HPM maintains a database of event causes and corrective actions taken. Such data supports trending of performance anomalies.

The HPM identifies and establishes corrective actions that reduce the potential for incident recurrence. The strategy systematically identifies the cause of the failure or degraded performance. The corrective actions are derived by:

- Addressing the significance of the failure through application of PRA/HRA importance measures,
- Classifying the causes and circumstances surrounding the failure or degraded human performance,
- Illuminating the characteristics of the failure (e.g., being task specific or due to overall plant culture), and

Determining whether the failure is isolated or has generic or common cause implications.

18A. EMERGENCY PROCEDURE AND SEVERE ACCIDENT GUIDELINES

18A.1 INTRODUCTION

The EPGs/SAGs are divided into Emergency Procedure Guidelines (EPGs) and Severe Accident Guidelines (SAGs). The EPGs define strategies for responding to emergences and to events that may degrade into emergencies until primary containment flooding is required. The EPGs and SAGs have been modified based on the ESBWR system design features. The following generic symptomatic EPGs have been developed:

- RPV Control Guideline
- Primary Containment Control Guideline
- Reactor Building Control Guideline
- Radioactivity Release Control Guideline

The SAGs define strategies applicable after containment flooding is required. They comprise two guidelines:

- RPV and Containment Flooding
- Containment and Radioactivity Release Control

The RPV Control Guideline maintains adequate core cooling, shuts down the reactor, and cools down the RPV to cold shutdown conditions. This guideline is entered whenever low RPV water level, high RPV pressure, or high drywell pressure occurs, or whenever a condition that requires reactor scram exists and reactor power is above the APRM downscale trip or cannot be determined.

The Containment Control Guideline maintains containment integrity and protects equipment in the containment with respect to the consequences of all mechanistic events. This guideline is entered whenever suppression pool temperature, drywell temperature, drywell pressure, suppression pool water level, or containment hydrogen concentration is above its high operating limit or suppression pool water level is below its low operating limit. Suppression pool and drywell temperatures are determined by plant-specific procedures for determining bulk suppression pool water temperature and drywell atmosphere average temperature, respectively.

The Reactor Building Control Guideline protects the controlled areas, limits radioactivity release to the controlled areas, and either maintains controlled area integrity or limits radioactivity release from the controlled areas. This guideline is entered whenever a controlled area temperature, radiation level, or water level is above its maximum normal operating value or controlled area differential pressure reaches zero.

The Radioactivity Release Control Guideline limits radioactivity release into areas outside the containment and controlled areas. This guideline is entered whenever offsite radioactivity release rate is above that which requires an Alert.

Table 18A-1 is a list of the abbreviations used in the guidelines.

Brackets [ ] enclose plant unique setpoints, design limits, pump shutoff pressures, etc., and parentheses ( ) within brackets indicate the source for the bracketed variable. Included in these guidelines is the current state of design values for the ESBWR expressed in both SI and English units. Brackets are also used to indicate potential systems, which might be employed for those systems whose use in the indicated application is not yet well defined such as use of the fire protection system to inject water into the RPV.

At various points throughout these guidelines, a circled number in reverse type in the right margin identifies operator precautions. The number within the circle refers to a numbered "Caution" contained in the Operator Cautions section. These "Cautions" are brief and succinct red flags for the operator.

The emergency procedure guidelines for the ESBWR design address all systems that may be used to respond to an emergency.

At various points within these guidelines, limits are specified beyond which certain actions are required. The bases and calculational methods for these limits are defined in the BWROG Emergency Procedure and Severe Accident Guidelines, Revision 2, Appendices B and C, respectively. While conservative, these limits are derived from engineering analyses utilizing best-estimate (as opposed to licensing) models. Consequently, these limits are generally not as conservative as the limits specified in a plant's Technical Specifications. This is not to imply that operation beyond the Technical Specifications is recommended in any emergency. Rather, such operation is required and is now permitted under certain degraded conditions in order to safely mitigate the consequences of those degraded conditions. The limits specified in the guidelines establish the boundaries within which continued safe operation of the plant can be assured. Therefore, conformance with the guidelines does not ensure strict conformance with a plant's Technical Specifications or other licensing bases.

At other points within these guidelines, defeating safety system interlocks and initiation logic is specified. This is also required in order to safely mitigate the consequences of degraded conditions, and it is generally specified only when conditions exist for which the interlock or logic was not designed. Defeating other interlocks may also be required due to instrument failure, etc., but these interlocks cannot be identified in advance and are therefore not specified in the guidelines.

The entry conditions for these emergency procedure guidelines are symptomatic of both emergencies and events that may degrade into emergencies. The guidelines specify actions appropriate for both. Therefore, entry into procedures developed from these guidelines is not conclusive that an emergency has occurred.

Each procedure developed from these emergency procedure guidelines (EPGs) is entered whenever any of its entry conditions occurs, irrespective of whether that procedure has already been entered or is presently being executed. When RPV and Containment Flooding are required, the EPGs transition to the Severe Accident Guidelines (SAGs). The EPGs are exited and the operator returns to non-emergency procedures when either one of the exit conditions specified in the procedure is satisfied or it is determined that an emergency no longer exists. After a procedure developed from these guidelines has been entered, subsequent clearing of all entry conditions for that procedure is not, by itself, conclusive that an emergency no longer exists.

Procedures developed from these emergency procedure guidelines specify symptomatic operator actions, which will maintain the reactor plant in a safe condition and optimize plant response and margin to safety irrespective of the initiating event. However, for certain specific events (e.g., earthquake, tornado, blackout, or fire), emergency response and recovery can be further enhanced by additional auxiliary event-specific operator actions which may be provided in supplemental event-specific procedures intended for use in conjunction with the symptomatic procedures. As with actions specified in any other procedure intended for use with the symptomatic procedures, these event-specific operator actions must not contradict or subvert the operator actions specified in the symptomatic procedures and must not result in loss or unavailability of equipment the operation of which is specified in these procedures.

The ESBWR EPG/SAG was derived from Rev. 2 of the generic BWR Owners' Group Emergency Procedure and Severe Accident Guidelines. Adaptations were required to accommodate the unique design philosophy, plant configuration and specific systems and components of the ESBWR. Appendix 18B provides the bases for the modified EPG as follows:

- Section 18B.1 briefly describes the ESBWR features which greatly impacted the ESBWR EPG;
- Section 18B.2 discusses the major EPG changes arising from these features; and
- Section 18B.3 tabulates, step-by-step, the differences between EPG/SAG Rev. 2 and the ESBWR EPG and provides the bases for these differences.

18A.2 OPERATOR CAUTIONS

This section lists cautions, which are applicable at one or more specific points within the guidelines. Where a caution is applicable, a circled number in reverse type in the right margin identifies it.

❶

RPV water level indications are affected by instrument run temperatures and RPV pressure:

- If the temperature near any instrument run is above the RPV Saturation Temperature, the instrument may be unreliable due to boiling in the run.
- Each instrument in the following table may be used to determine RPV water level only when the instrument reads above the Minimum Indicated Level or the temperatures near all the instrument reference leg vertical runs are below the Maximum Run Temperature.

Instrument	Range (in.)	Maximum Run Temperature (°F) DW	Maximum Run Temperature (°F) RB	Minimum Indicated Level (in.)
[Fuel Zone	-317 to -17	324	NA	-301]

- Each instrument in the following table may be used to determine RPV water level only when the instrument reads above the Minimum Indicated Level associated with the highest temperature near an instrument reference leg vertical run:

Instrument	Highest Drywell Run Temperature (°F) Between Low	High	Minimum Indicated Level (in.)
[Narrow Range	—	278	0
(0 to +60 in.)	278	350	5
	350	450	13
	450	550	25]

Instrument	Highest Drywell Run Temperature (°F) Between Low	High	Minimum Indicated Level (in.)
[Wide Range	—	211	-150
(-150 to +60 in.)	211	250	-147
	250	350	-138
	350	450	-128
	450	550	-115]
[Shutdown Range	—	150	11
(-17 to +383)	150	250	25
	250	350	43
	350	450	67
	450	550	99]

❷

> A rapid increase in injection into the RPV may induce a large power excursion and result in substantial core damage.

❸

> A steam explosion may occur if core debris drops into the lower drywell with a drywell water level greater than [0.7 m]. Containment flooding above [0.7 m] should be prevented until the lower drywell floor thermocouples indicate that all or most of the core debris has been ejected from the RPV.

18A.3 RPV CONTROL EMERGENCY PROCEDURE GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Maintain adequate core cooling,
- Shut down the reactor, and
- Cool down the RPV to cold shutdown conditions [(120°F) 49°C <RPV water temp < 100°C (212°F) (cold shutdown conditions)].

ENTRY CONDITIONS

The entry conditions for this guideline are any of the following:

- RPV water level below [1978 cm (778.75 in) (low level scram setpoint)]
- RPV pressure above [7.72 MPa (1120 psig (high RPV pressure scram setpoint)]
- Drywell pressure above [0.01264 MPa (1.83 psig) (high drywell pressure scram setpoint)]
- A condition, which requires reactor scram, and reactor, power above [6% (APRM downscale trip)] or cannot be determined

OPERATOR ACTIONS

If while executing the following steps, Primary Containment Flooding is or has been required, enter [procedure developed from the RPV and Primary Containment Flooding Severe Accident Guideline].

RC-1 If a reactor scram has not been initiated, initiate a reactor scram.

Execute [Steps RC/L, RC/P, and RC/Q] concurrently.

RC/L Monitor and control RPV water level. ❶

RC/L-1 Initiate each of the following, which should have initiated but did not:

- Isolation
- ECCS
- All Isolation Condensers
- Standby Diesel Generator

If while executing the following step:

- Any control rod cannot be determined to be inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from Emergency Procedure Guideline Contingency #3].
- RPV water level cannot be determined, enter [procedure developed from Emergency Procedure Guideline Contingency #2].

If while executing the following step primary containment water level and suppression chamber pressure cannot be maintained below Primary Containment Pressure Limit, but only if adequate core cooling can be assured, terminate injection into the RPV from sources external to the primary containment.

If RPV water level cannot be restored and maintained above [745.3 cm (293.4 in) (top of active fuel)] enter [procedure developed from RPV and Primary Containment Flooding Severe Accident Guideline].

RC/L-2 Restore and maintain RPV water level between [1978 cm (778.75 in). (low level scram setpoint or shutdown cooling RPV water level interlock, whichever is higher)] and [2189 cm (861.8 in) (high level trip setpoint)] with one or more of the following systems:

- Condensate/Feedwater
- CRD High Pressure Makeup mode
- FAPCS LPCI mode

If RPV water level cannot be restored and maintained above [1978 cm (778.75 in). (low level scram setpoint or shutdown cooling RPV water level interlock, whichever is higher)], maintain RPV water level above [1300 cm (511.8 in) (Level 1.5)].

RPV water level control may be augmented by one or more of the following systems:

- Fire System
- [Interconnections with other units]

If RPV water level cannot be restored and maintained above [1300 cm (511.8 in) (Level 1.5)], EMERGENGY RPV DEPRESSURIZATION IS REQUIRED.

RC/L-3 Restore and maintain RPV water level above [1978 cm (778.75 in) (low level scram setpoint or shutdown cooling RPV water level interlock, whichever is higher)] with one or more of the following systems:

- Condensate/Feedwater
- CRD High Pressure Makeup mode
- FAPCS LPCI mode

RPV water level control may be augmented by one or more of the following systems:

- Fire System
- Interconnections with other units

RC/P Monitor and control RPV pressure

If while executing the following steps:

- Emergency RPV Depressurization is anticipated and either all control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, rapidly depressurize the RPV with the main turbine bypass valves and IC, irrespective of the resulting cooldown rate.
- Emergency RPV Depressurization is or has been required, enter [procedure developed from Emergency Procedure Guideline Contingency #1].
- RPV water level cannot be determined, enter [procedure developed from Emergency Procedure Guideline Contingency #2].

RC/P-1 If any SRV is cycling, initiate IC and manually open SRVs until RPV pressure drops to [6.45 MPa (935 psig) (RPV pressure at which all turbine bypass valves are fully open)].

> If while executing the following steps:
>
> - Suppression pool temperature cannot be maintained below the Heat Capacity Temperature Limit, maintain RPV pressure below the Limit, exceeding [55.55°C/hr (100°F/hr) (RPV cooldown rate LCO)] cooldown rate if necessary.
> - Suppression pool water level cannot be maintained below the SRV Tail Pipe Level Limit, maintain RPV pressure below the Limit, exceeding [55.55°C/hr (100°F/hr) (RPV cooldown rate LCO)] cooldown rate if necessary.

> If while executing the following steps:
>
> - Boron Injection is required, and
> - The main condenser is available, and
> - There has been no indication of a steam line break, open MSIVs, defeating MSL and Offgas high radiation interlocks and low RPV water level interlocks if necessary, to re-establish the main condenser as a heat sink.

RC/P-2 Stabilize RPV pressure at a pressure below [7.72 MPa (1120 psig) (high RPV pressure scram setpoint)] with the main turbine bypass valves.

RPV pressure control may be augmented by one or more of the following systems:

- IC
- SRVs, only when suppression pool water level is above [2.13 m (6.99 ft) (elevation of top of SRV discharge device)], defeating pneumatic supply isolation interlocks and restoring the pneumatic supply if necessary; open SRVs in the following sequence if possible: [(SRV opening sequence)]; if the continuous SRV pneumatic supply is or becomes unavailable, place the control switch for each SRV in the [CLOSE or AUTO] position.

- RWCU/SDC high pressure shutdown cooling mode, defeating regenerative heat exchangers and filter/demineralizers and, if necessary, defeating SLC and other isolation interlocks.
- MSL drains
- RWCU (blowdown mode), only if no boron has been injected into the RPV or it has been determined that the reactor will remain shutdown under all conditions without boron; refer to [sampling procedures] prior to initiating blowdown.

If while executing the following steps: • the reactor is not shutdown, return to [Step RC/P-2] • the RPV water temperature cannot be cooled down below 100°C {212°F} and further cooldown is required, initiate [Alternate Shutdown Cooling Procedure].

RC/P-3 When either:

- All control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- [96.8 kg (213 pounds) (Cold Shutdown Boron Weight)] of boron have been injected into the RPV, or
- The reactor is shutdown and no boron has been injected into the RPV, depressurize the RPV and maintain the cooldown rate below [55.55°C/hr (100°F/hr) (RPV cooldown rate LCO)], defeating pneumatic supply isolation interlocks and restoring the pneumatic supply if necessary.

  If one or more SRVs are being used to depressurize the RPV and the continuous SRV pneumatic supply is or becomes unavailable, depressurize with sustained SRV opening.

RC/Q Monitor and control reactor power:

If while executing the following steps:

- All control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)], enter [scram procedure].
- It has been determined that the reactor will remain shutdown under all conditions without boron, enter [scram procedure].
- The reactor is shutdown and no boron has been injected into the RPV, enter [scram procedure].

RC/Q-1 Confirm or place the reactor mode switch in SHUTDOWN.

RC/Q-2 If ARI has not initiated, initiate ARI.

Execute [Steps RC/Q-3 and RC/Q-4] concurrently.

RC/Q-3 Either:

- When periodic neutron flux oscillations in excess of [25% (Large Oscillation Threshold)] peak-to-peak commence and continue, or
- Before suppression pool temperature reaches the Boron Injection Initiation Temperature,

BORON INJECTION IS REQUIRED; inject boron into the RPV with SLC.

If boron cannot be injected with SLC, inject boron into the RPV by one or more of the following alternate methods:

- CRD
- RWCU/SDC
- Feedwater
- Hydro pump

If boron is not being injected into the RPV by RWCU/SDC and RWCU/SDC is not isolated, bypass regenerative heat exchangers and filter/demineralizers.

RC/Q-4 Insert control rods as follows:

RC/Q-4.1 Reset ARI, defeating ARI logic trips if necessary.

RC/Q-4.2 Insert control rods with one or more of the following methods:

- De-energize scram solenoids.
- Vent the scram air header.
- Reset the scram, defeating RPS logic trips if necessary, and initiate a manual scram.
- Open individual scram test switches.
- Drive control rods, defeating RC&IS and RWM interlocks if necessary.

18A.4 PRIMARY CONTAINMENT CONTROL EMERGENCY PROCEDURE GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Maintain primary containment integrity, and
- Protect equipment in the primary containment.

ENTRY CONDITIONS

The entry conditions for this guideline are any of the following:

- Suppression pool temperature above [43.3°C (110°F) (most limiting suppression pool temperature LCO)]
- Drywell temperature above [57.22°C (135°F) (drywell temperature LCO or maximum normal operating temperature, whichever is higher)]
- Drywell pressure above [0.01264 MPa (1.83 psig) (high drywell pressure scram setpoint)]
- Suppression pool water level above [5.50 m (18.05 ft) (maximum suppression pool water level LCO)]
- Suppression pool water level below [5.40 m (17.72 ft) (minimum suppression pool water level LCO)]
- Primary containment hydrogen concentration above [2% (high hydrogen alarm setpoint)]

OPERATOR ACTIONS

If while executing the following steps, Primary Containment Flooding is or has been required, enter [procedure developed from the Containment and Radioactivity Release Control Severe Accident Guideline].

Execute [Steps SP/T, DW/T, PC/P, SP/L, and PC/G] concurrently.

SP/T Monitor and control suppression pool temperature below [43.3°C (110°F) (most limiting suppression pool temperature LCO)] using available suppression pool cooling.

When suppression pool temperature cannot be maintained below [43.3°C (110°F) (most limiting suppression pool temperature LCO)]:

SP/T-1 Operate all available suppression pool cooling using only those FAPCS pumps not required to assure adequate core cooling by continuous operation in the LPCI mode.

SP/T-2 Before suppression pool temperature reaches the Boron Injection Initiation Temperature, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SP/T-3 Before the Heat Capacity Temperature Limit is reached; operate all Isolation Condensers to depressurize the RPV.

SP/T-4 When suppression pool temperature and RPV pressure cannot be maintained below the Heat Capacity Temperature Limit, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

DW/T Monitor and control drywell temperature below [57.22°C (135°F) drywell temperature LCO or maximum normal operating temperature, whichever is higher] using available drywell cooling.

When drywell temperature cannot be maintained below [57.22°C (135°F) (drywell temperature LCO or maximum normal operating temperature, whichever is higher)]:

DW/T-1 Operate all available drywell cooling, defeating isolation interlocks if necessary.

DW/T-2 Before drywell temperature reaches [171.1°C (340°F) (maximum temperature at which ADS is qualified or drywell design temperature, whichever is lower)], enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

DW/T-3 When drywell temperature cannot be restored and maintained below [171.1°C (340°F) (maximum temperature at which ADS is qualified or drywell design temperature, whichever is lower)], EMERGENCY RPV DEPRESSURIZATION IS REQUIRED;

PC/P Monitor and control primary containment pressure below [0.01264 MPa (1.83 psig) (high drywell pressure scram setpoint)] using the following systems:

- Containment Inerting System (CIS); use [CIS operating procedure].
- Reactor Building HVAC System; use [RBHVAC operating procedure]

PC/P-1 When suppression chamber pressure cannot be maintained below the Pressure Suppression Pressure, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

PC/P-2 Before suppression chamber pressure reaches Primary Containment Pressure Limit, vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary, to control pressure below Primary Containment Pressure Limit.

PC/P-3 When suppression chamber pressure exceeds Primary Containment Pressure Limit, vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary and irrespective of whether adequate core cooling is assured, to control pressure below Primary Containment Pressure Limit.

SP/L Monitor and control suppression pool water level.

SP/L-1 Maintain suppression pool water level between [5.50 m (18.05 ft) (maximum suppression pool water level LCO)] and [5.40 m (17.72 ft) (minimum suppression pool water level LCO)] using FAPCS; refer to [sampling procedure] prior to discharging water.

If suppression pool water level cannot be maintained above [5.40 m (17.72 ft) (minimum suppression pool water level LCO)], execute [Step SP/L-2].

If suppression pool water level cannot be maintained below [5.50 m (18.05 ft) (maximum suppression pool water level LCO)], execute [Step SP/L-3].

SP/L-2 SUPPRESSION POOL WATER LEVEL BELOW [5.40 m (17.72 ft) (minimum suppression pool water level LCO)]

Maintain suppression pool water level above [** m (** ft) (elevation of the downcomer openings)] [(0.61 m (2 ft) above the elevation of the top of the horizontal vents)].

If suppression pool water level cannot be maintained above [** m (** ft) (elevation of the downcomer openings)] [(0.61 m (2 ft). above the elevation of the top of the horizontal vents)], EMERGENCY RPV DEPRESSURIZATION IS REQUIRED; enter [procedure developed from the RPV Control Emergency

Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SP/L-3 SUPPRESSION POOL WATER LEVEL ABOVE [5.50 m (18.05 ft) (maximum suppression pool water level LCO)]

Execute [Steps SP/L-3.1 and SP/L-3.2] concurrently.

SP/L-3.1 Maintain suppression pool water level below the SRV Tail Pipe Level Limit.

If suppression pool water level cannot be maintained below the SRV Tail Pipe Level Limit, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

If suppression pool water level and RPV pressure cannot be maintained below the SRV Tail Pipe Level Limit but only if adequate core cooling is assured, terminate injection into the RPV from sources external to the primary containment except from systems required to shut down the reactor.

If suppression pool water level and RPV pressure cannot be restored and maintained below the SRV Tail Pipe Level Limit, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SP/L-3.2 Maintain suppression pool water level below [16.85 m (55.28 ft) (elevation of bottom of suppression chamber to drywell vacuum breaker openings [less vacuum breaker opening pressure in meters of water]).

If suppression pool water level cannot be maintained below [16.85 m (55.28 ft) (elevation of bottom of suppression chamber to drywell vacuum breaker openings [less vacuum breaker opening pressure in meters of water])] and if adequate core cooling can be assured:

Terminate injection into the RPV from sources external to the primary containment except from systems required to shut down the reactor.

PC/G Monitor and control primary containment hydrogen and oxygen concentrations.

If while executing the following steps the hydrogen or oxygen monitoring system is or becomes unavailable, sample the drywell and suppression chamber for hydrogen and oxygen in accordance with [sampling procedure].

Control hydrogen and oxygen concentrations in the drywell as follows:

		Drywell Oxygen Concentration			
		< 5%	≥ 5% or cannot be determined to be below 5%		
			Suppression Chamber Hydrogen Concentration		
			None Detected	< 6%	≥ 6% or cannot be determined to be below 6%
Drywell Hydrogen Concentration	None Detected	No action required	No action required	[PC/G-2]	[PC/G-3]
	< 6%	[PC/G-1]	[PC/G-2]	[PC/G-2]	[PC/G-3]
	≥ 6% or cannot be determined to be below 6%	[PC/G-1]	[PC/G-3]	[PC/G-3]	[PC/G-3]

Control hydrogen and oxygen concentrations in the suppression chamber as follows:

		Suppression Chamber Oxygen Concentration			
		< 5%	≥ 5% or cannot be determined to be below 5%		
			Drywell Hydrogen Concentration		
			None Detected	< 6%	≥ 6% or cannot be determined to be below 6%
Suppression Chamber Hydrogen Concentration	None Detected	No action required	No action required	[PC/G-5]	[PC/G-6]
	< 6%	[PC/G-4]	[PC/G-5]	[PC/G-5]	[PC/G-6]
	≥ 6% or cannot be determined to be below 6%	[PC/G-4]	[PC/G-6]	[PC/G-6]	[PC/G-6]

PC/G-1 Reduce drywell hydrogen and oxygen concentrations by one or both of the following methods:

- If the offsite radioactivity release rate is expected to remain below the offsite release rate specified in [Technical Specifications], vent and purge the drywell as follows, defeating isolation interlocks (except high radiation interlocks) if necessary:

If while executing the following steps the offsite radioactivity release rate reaches the offsite release rate specified in [Technical Specifications], secure vent and purge not required by other steps in the [procedures developed from the Emergency Procedure Guidelines].

(1) Refer to [sampling procedure].

(2) Vent the drywell.

(3) If the drywell can be vented, purge the drywell by injecting nitrogen into the drywell.

(4) When hydrogen is no longer detected in the drywell, secure vent and purge not required by other steps in the [procedures developed from the Emergency Procedure Guidelines].

PC/G-2 Reduce drywell hydrogen and oxygen concentrations by one or both of the following methods:

- If adequate core cooling is not assured or the offsite radioactivity release rate is expected to remain below the offsite radioactivity release rate which requires a General Emergency, vent and purge the drywell as follows, defeating isolation interlocks if necessary:

(1) Vent the drywell.

(2) If the drywell can be vented, purge the drywell by injecting nitrogen into the drywell at the maximum rate.

(3) When no hydrogen is detected in the drywell and either drywell oxygen concentration is below 5% or no hydrogen is detected in the suppression chamber, secure vent and purge not required by other steps in the [procedures developed from the Emergency Procedure Guidelines].

PC/G-3 EMERGENCY RPV DEPRESSURIZATION IS REQUIRED; enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure; vent and purge the drywell as follows, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary:

PC/G-3.1 Vent the drywell.

PC/G-3.2 If the drywell can be vented, purge the drywell by injecting air or nitrogen, whichever will more rapidly return hydrogen concentrations to below 6% or oxygen concentration to below 5%, into the drywell at the maximum rate.

PC/G-4 Reduce suppression chamber hydrogen and oxygen concentrations by one or both of the following methods:

- If the offsite radioactivity release rate is expected to remain below the offsite release rate specified in [Technical Specifications], vent and purge the suppression chamber as follows, defeating isolation interlocks (except high radiation interlocks) if necessary:

  (1) Refer to [sampling procedure].

  (2) If suppression pool water level is below [** m (** ft) (elevation of the bottom of the suppression chamber vent)], vent the suppression chamber.

  (3) If the suppression chamber can be vented, purge the suppression chamber by injecting nitrogen into the suppression chamber.

  (4) When hydrogen is no longer detected in the suppression chamber, secure vent and purge not required by other steps in the [procedures developed from the Emergency Procedure Guidelines].

PC/G-5 Reduce suppression chamber hydrogen and oxygen concentrations by one or both of the following methods:

- If adequate core cooling is not assured or the offsite radioactivity release rate is expected to remain below the offsite release rate which requires a General Emergency, vent and purge the suppression chamber as follows, defeating isolation interlocks if necessary:

  (1) If suppression pool water level is below [** m (** ft) (elevation of the bottom of the suppression chamber vent)], vent the suppression chamber.

  (2) If the suppression chamber can be vented, purge the suppression chamber by injecting nitrogen into the suppression chamber at the maximum rate.

  (3) When no hydrogen is detected in the suppression chamber and either suppression chamber oxygen concentration is below 5% or no hydrogen is detected in the drywell, secure vent and purge not required by other steps in the [procedures developed from the Emergency Procedure Guidelines].

PC/G-6 EMERGENCY RPV DEPRESSURIZATION IS REQUIRED; enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure; vent and purge the suppression chamber as follows, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary:

PC/G-6.1 If suppression pool water level is below [** m (** ft) (elevation of the bottom of the suppression chamber vent)], vent the suppression chamber.

PC/G-6.2 If the suppression chamber can be vented, purge the suppression chamber by injecting air or nitrogen, whichever will more rapidly return hydrogen concentration to below 6% or oxygen concentration to below 5%, into the suppression chamber at the maximum rate.

18A.5 REACTOR BUILDING CONTROL EMERGENCY PROCEDURE GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Protect equipment in the Reactor Building,
- Limit radioactivity release to the Reactor Building,
- and either:
- Maintain Reactor Building integrity, or
- Limit radioactivity release from the Reactor Building.

ENTRY CONDITIONS

The entry conditions for this guideline are any of the following Reactor Building conditions:

- Differential pressure at or above 0 in. of water
- An area temperature above the maximum normal operating temperature
- A HVAC cooler differential temperature above the maximum normal operating differential temperature
- A HVAC exhaust radiation level above the maximum normal operating radiation level
- An area radiation level above the maximum normal operating radiation level
- A floor drain sump water level above the maximum normal operating water level
- An area water level above the maximum normal operating water level

OPERATOR ACTIONS

If while executing the following steps, Primary Containment Flooding is or has been required, enter [procedure developed from the Containment and Radioactivity Release Control Severe Accident Guideline].

If while executing the following steps Reactor Building HVAC exhaust radiation level exceeds [20 mr/hr (Reactor Building HVAC isolation setpoint)]: • Confirm or manually initiate isolation of Reactor Building HVAC

If while executing the following steps:

- Reactor Building HVAC isolates, and,
- Reactor Building HVAC exhaust radiation level is below [20 mr/hr (Reactor Building HVAC isolation setpoint)], restart Reactor Building HVAC, defeating high drywell pressure and low RPV water level isolation interlocks if necessary.

Execute [Steps SC/T, SC/R, and SC/L] concurrently.

SC/T Monitor and control Reactor Building temperatures. ➊

SC/T-1 Operate available area coolers.

SC/T-2 If Reactor Building HVAC exhaust radiation level is below [20 mr/hr (Reactor Building HVAC isolation setpoint)], operate available Reactor Building HVAC.

SC/T-3 When an area temperature exceeds its maximum normal operating temperature, isolate all systems that are discharging into the area except systems required to suppress a fire and systems required to be operated by [procedures developed from the Emergency Procedure Guidelines].

Execute [Steps SC/T-4 and SC/T-5] concurrently.

SC/T-4 If a primary system is discharging into Reactor Building:

SC/T-4.1 Before any area temperature reaches its maximum safe operating temperature, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SC/T-4.2 When an area temperature exceeds its maximum safe operating temperature in more than one area, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SC/T-5 When an area temperature exceeds its maximum safe operating temperature in more than one area, shut down the reactor.

SC/R Monitor and control Reactor Building radiation levels.

SC/R-1 When an area radiation level exceeds its maximum normal operating radiation level, isolate all systems that are discharging into the area except systems required to suppress a fire and systems required to be operated by [procedures developed from the Emergency Procedure Guidelines].

Execute [Steps SC/R-2 and SC/R-3] concurrently.

SC/R-2 If a primary system is discharging into Reactor Building:

SC/R-2.1 Before any area radiation level reaches its maximum safe operating radiation level, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SC/R-2.2 When an area radiation level exceeds its maximum safe operating radiation level in more than one area, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SC/R-3 When an area radiation level exceeds its maximum safe operating radiation level in more than one area, shut down the reactor.

SC/L Monitor and control Reactor Building water levels.

SC/L-1 When a floor drain sump or area water level is above its maximum normal operating water level, operate available sump pumps to restore and maintain it below its maximum normal operating water level.

If any floor drain sump or area water level cannot be restored and maintained below its maximum normal operating water level, isolate all systems that are discharging water into the sump or area except systems required to suppress a fire and systems required to be operated by [procedures developed from the Emergency Procedure Guidelines].

Execute [Steps SC/L-2 and SC/L-3] concurrently.

SC/L-2 If a primary system is discharging into Reactor Building:

SC/L-2.1 Before any area water level reaches its maximum safe operating water level, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SC/L-2.2 When an area water level exceeds its maximum safe operating water level in more than one area, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SC/L-3 When an area water level exceeds its maximum safe operating water level in more than one area, shut down the reactor.

18A.6 RADIOACTIVITY RELEASE CONTROL EMERGENCY PROCEDURE GUIDELINE

PURPOSE

The purpose of this guideline is to limit radioactivity release into areas outside the primary containment and Reactor Building.

ENTRY CONDITIONS

The entry condition for this guideline is:

- Offsite radioactivity release rate above the offsite release rate which requires an Alert.

OPERATOR ACTIONS

If while executing the following steps, Primary Containment Flooding is or has been required, enter [procedure developed from the Containment and Radioactivity Release Control Severe Accident Guideline].

If while executing the following steps HVAC in the turbine building (or any other building which may be contributing to radioactive release) is shutdown, restart the HVAC as required, defeating isolation interlocks if necessary.

RR-1 Isolate all primary systems that are discharging into areas outside the primary and Reactor Buildings except systems required to be operated by [procedures developed from the Emergency Procedure Guidelines].

RR-2 If the offsite radioactivity release rate continues to increase, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC-1] and execute concurrently

RR-3 Before offsite radioactivity release rate reaches the offsite release rate which requires a General Emergency but only if a primary system is discharging into an area outside the primary containment and Reactor Building, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED

18A.7 CONTINGENCY #1 EMERGENCY RPV DEPRESSURIZATION

If while executing the following steps Primary Containment Flooding is or has been required, enter [procedure developed from the RPV and Primary Containment Flooding Severe Accident Guideline].

If while executing the following steps RPV water level cannot be determined, enter [procedure developed from Emergency Procedure Guideline Contingency #2, RPV Flooding"].

If while executing the following steps it is anticipated that primary containment water level will rise above [**m (**ft)(elevation of the inboard main steam line drain valve motor operator or elevation of the lowest SRV pneumatic solenoid, whichever is lower)], open the inboard main steam line drain valve before primary containment water level reaches [**m (**ft)(elevation of the inboard main steam line drain valve motor operator or elevation of the lowest SRV pneumatic solenoid, whichever is lower)], defeating isolation interlocks if necessary.

C1-1 When either:

- All control rods can be determined to be inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- All injection into the RPV, except from boron injection systems and CRD purge flow, has been terminated and prevented,

C1-1.1 Initiate all Isolation Condensers.

C1-1.2 Rapidly depressurize the RPV as follows, irrespective of the resulting cooldown rate:

If suppression pool water level is above [2.13 m (6.99 ft) (elevation of top of SRV discharge device)], open all SRVs, defeating isolation interlocks if necessary.

If less than [8 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open and RPV pressure is at least [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure:

(1) Rapidly depressurize the RPV using one or more of the following, defeating interlocks and exceeding offsite radioactivity release rate limits if necessary, until RPV pressure is less than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure:

- Main condenser
- [Other steam-driven equipment]
- MSL drains
- RWCU/SDCS, only if no boron has been injected into the RPV or it has been determined that the reactor will remain shutdown under all conditions without boron.
- Head vent
- IC tube side vent

(2) Maintain RPV pressure less than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure using one or more of the systems used for depressurization.

If while executing the following step:

- Less than [8 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open and RPV pressure is at least [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure, or
- The reactor is not shutdown,

return to [Step C1-1.2].

C1-2 When either:

- All control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- [96.8 kg (213 psi) (Cold Shutdown Boron Weight)] of boron have been injected into the RPV, or

- The reactor is shutdown and no boron has been injected into the RPV,

Use the RWCU/SDCS to cool down to cold shutdown conditions [49°C (120°F) <RPV water temp <100°C (212°F) (cold shutdown conditions)]

If shutdown cooling cannot be established and further cool down is required, continue to cool down to cold shutdown conditions [49°C (120°F) <RPV water temp <100°C (212°F)] using one or more of the following, defeating interlocks if necessary:

- IC
- SRVs
- Main condenser
- [Other steam-driven equipment]
- MSL drains
- Head vent
- IC tube side vent

18A.8 CONTINGENCY #2 RPV FLOODING

> If while executing the following steps RPV water level can be determined:
>
> - If any control rod cannot be determined to be inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from Emergency Procedure Guideline Contingency #3] and [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC/P].
> - If all control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Steps RC/L and RC/P].

> If while executing the following steps primary containment water level and suppression chamber pressure cannot be maintained below Primary Containment Pressure Limit, but only if RPV flooding conditions can be maintained, terminate injection into the RPV from sources external to the primary containment except from systems required to shut down the reactor.

> If while executing the following steps it is determined that core damage is occurring, PRIMARY CONTAINMENT FLOODING IS REQUIRED; enter [procedure developed from the RPV and Primary Containment Flooding Severe Accident Guideline].

C2-1 If any control rod cannot be determined to be inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, flood the RPV as follows:

> If while executing the following steps either all control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron but RPV water level cannot be determined, continue in this procedure at [Step C2-2].

C2-1.1 Terminate and prevent all injection into the RPV except from boron injection systems and CRD purge flow.

C2-1.2 If suppression pool water level is above [2.13 m (6.99 ft) (elevation of top of SRV discharge device)], open all SRVs, irrespective of the resulting RPV cooldown rate, defeating pneumatic supply isolation interlocks and restoring the pneumatic supply if necessary.

> If while executing the following steps it has been determined that the RPV has been flooded to the main steam lines, continue in this procedure at [Step C2-3].

C2-1.3 When RPV pressure is below the Minimum Steam Cooling Pressure or less than [1 (minimum number of SRVs for which the Minimum Steam Cooling Pressure is below the lowest SRV lift setpoint)] SRV[s] [is] open, commence and slowly increase injection into the RPV with the following systems, defeating high RPV water level interlocks if necessary, to establish and maintain at least [1 (minimum number of SRVs for which the Minimum Steam Cooling Pressure is below the lowest SRV lift setpoint)] SRV[s] open and RPV pressure above the Minimum Steam Cooling Pressure but as low as practicable: ❷

Minimum Steam Cooling Pressure

NUMBER OF OPEN SRVs	RPV PRESSURE MPa gauge (psig)
8 or more	0.801 (116.2)
7	0.929 (134.8)
6	1.1.02 (159.8)
5	1.342 (194.7)
4	1.703 (247.0)
3	2.304 (334.2)
2	3.507 (580.7)

- Condensate/Feedwater
- CRD high pressure makeup mode
- FAPCS LPCI mode

If required to open at least [1 (minimum number of SRVs for which the Minimum Steam Cooling Pressure is below the lowest SRV lift setpoint)]

SRV[s] or to increase RPV pressure to above the Minimum Steam Cooling Pressure, commence and slowly increase injection with the following systems, defeating high RPV water level interlocks if necessary:

- [Fire System]
- [Interconnections with other units]

If at least [8 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs can be opened or if RPV pressure can be restored and maintained above the Minimum Steam Cooling Pressure, close the MSIVs, MSL drain valves and the IC isolation valves, and isolate any of the following not needed for RPV injection:

- Main steam lines
- MSL drains
- Isolation Condensers

If less than [8 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs can be opened and RPV pressure is at least [0.345MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure but cannot be restored and maintained above the Minimum Steam Cooling Pressure, rapidly depressurize the RPV using one or more of the following, irrespective of the resulting cooldown rate, defeating interlocks and exceeding offsite radioactivity release rate limits if necessary, until RPV pressure can be restored and maintained above the Minimum Steam Cooling Pressure or is less than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure:

- Isolation Condensers
- Main condenser
- [Other steam-driven equipment]
- MSL drains
- Head vent
- IC tube side vent
- RWCU/SDC

C2-2 When all control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, flood the RPV as follows:

C2-2.1 If suppression pool water level is above [2.13 m (6.99 ft) (elevation of top of SRV discharge device)], open all SRVs, irrespective of the resulting RPV cooldown rate, defeating pneumatic supply isolation interlocks and restoring the pneumatic supply if necessary.

C2-2.2 If at least [2 (Minimum Number of SRVs Required for Decay Heat Removal)] SRVs can be opened or if CRD high pressure makeup or a feedwater pump is available, close the MSIVs, MSL drain valves, and the IC isolation valves.

> If while executing the following step it can be determined that the RPV has been flooded to the main steam lines, continue in this procedure at [Step C2-3].

C2-2.3 Flood the RPV to the elevation of the main steam lines with the follo systems, defeating high RPV water level interlocks if necessary:

- Feedwater pumps
- Condensate pumps
- CRD high pressure makeup mode
- FAPCS LPCI mode
- [Interconnections with other units]
- [Fire System]

If:

- Less than [2 (Minimum Number of SRVs Required for Decay Heat Removal)] SRVs can be opened, and
- Neither CRD high pressure makeup nor a feedwater pump is available, and
- RPV pressure is more than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure,

Rapidly depressurize the RPV using one or more of the following, irrespective of the resulting cooldown rate, defeating interlocks and exceeding offsite radioactivity release rate limits if necessary, until RPV pressure is less than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure:

- Isolation Condensers
- Main condenser
- [Other steam-driven equipment]

- MSL drains
- Head vent
- IC tube side vent
- RWCU /SDC

C2-3 When it has been determined that the RPV has been flooded to the main steam lines:

- Close the MSIVs, MSL drain valves, and the IC isolation valves.
- Control injection into the RPV to maintain the steam lines flooded with injection as low as practicable.

18A.9 CONTINGENCY #3 LEVEL/POWER CONTROL

If while executing the following steps:

- RPV water level cannot be determined, enter [procedure developed from Emergency Procedure Guideline Contingency #2].
- All control rods are inserted to or beyond position [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from the RPV Control Emergency Procedure Guideline] at [Step RC/L].
- Primary containment water level and suppression chamber pressure cannot be maintained below Primary Containment Pressure Limit, but only if adequate core cooling can be assured, terminate injection into the RPV from sources external to the primary containment except from systems required to shut down the reactor.

C3-1 If any MSL is not isolated, commence defeating [MSL and Offgas high radiation interlocks] [and] [low RPV water level interlocks] to maintain the main condenser as a heat sink.

C3-2 If reactor power is above [6% (APRM downscale trip)] or cannot be determined and RPV water level is above [1830.5 cm (720.7 in) (60.96 cm (24 in) below the feedwater sparger nozzles)], lower RPV water level to below [1830.5 cm (720.7 in) (60.96 cm (24 in) below the feedwater sparger nozzles)] by terminating and preventing all injection into the RPV except from boron injection systems and CRD purge flow, defeating interlocks if necessary.

C3-3 If:

- Reactor power is above [6% (APRM downscale trip)] or cannot be determined, and
- RPV water level is above [745.3 cm (293.4 in) (top of active fuel)], and
- Suppression pool temperature is above the Boron Injection Initiation Temperature, and
- Either an SRV is open or opens or drywell pressure is above [0.01264 MPa (1.83 psig) (high drywell pressure scram setpoint)],

Lower RPV water level, irrespective of any reactor power or RPV water level oscillations, by terminating and preventing all injection into the RPV except from boron injection systems and CRD purge flow, defeating interlocks if necessary, until either:

- Reactor power drops below [6% (APRM downscale trip)], or

- RPV water level reaches [745.3 cm (293.4 in) (top of active fuel)], or
- All SRVs remain closed and drywell pressure remains below [0.01264 MPa (1.83 psig) (high drywell pressure scram setpoint)].

If while executing the following steps Emergency RPV Depressurization is required, continue in this procedure at [Step C3-4.1].

If while executing the following step RPV water level is above [1830.5 cm (720.7 in) (60.96 cm (24 in) below the feedwater sparger nozzles)] and reactor power is above [6% (APRM downscale trip)] or cannot be determined, return to [Step C3-2].

If while executing the following step: • Reactor power is above [6% (APRM downscale trip)] or cannot be determined, and • RPV water level is above [745.3 cm (293.4 in) (top of active fuel)], and • Suppression pool temperature is above the Boron Injection Initiation Temperature, and • Either an SRV is open or opens or drywell pressure is above [0.01264 MPa (1.83 psig) (high drywell pressure scram setpoint)], return to [Step C3-2].

C3-4 Maintain RPV water level between [745.3 cm (293.4 in) (top of active fuel)] and either: ❷

- If RPV water level was deliberately lowered in [Step C3-2 or C3-3], the level to which it was lowered, or
- If RPV water level was not deliberately lowered in [Step C3-2 or C3-3], [2189 cm (861.8 in) (high level trip setpoint)],

with the following systems:

- Condensate/Feedwater
- CRD (either purge flow or high pressure makeup modes)
- FAPCS LPCI mode.

If RPV water level cannot be restored and maintained above [745.3 cm (293.4 in) (top of active fuel)], EMERGENCY RPV DEPRESSURIZATION IS REQUIRED:

C3-4.1 Terminate and prevent all injection into the RPV except from boron injection systems and CRD purge flow, defeating interlocks if necessary, until RPV pressure is below the Minimum Steam Cooling Pressure.

Minimum Steam Cooling Pressure

NUMBER OF OPEN SRVs	RPV PRESSURE MPa gauge (psig)
8 or more	0.801 (116.2)
7	0.929 (134.8)
6	1.1.02 (159.8)
5	1.342 (194.7)
4	1.703 (247.0)
3	2.304 (334.2)
2	3.507 (580.7)
1	7.116 (1032.1)

If less than [1 (minimum number of SRVs for which the Minimum Steam Cooling Pressure is below the lowest SRV lift setpoint)] SRV[s] can be opened, continue in this procedure.

C3-4.2 Commence and slowly increase injection into the RPV with the following systems to restore and maintain RPV water level above [745.3 cm (293.4 in) (top of active fuel)]: ❷

- Condensate/Feedwater
- CRD (either purge flow or high pressure makeup modes)
- FAPCS LPCI mode

If required to restore and maintain RPV water level above [745.3 cm (293.4 in) (top of active fuel)], use the following systems:

- Fire System
- [Interconnections with other units]

If RPV water level cannot be restored and maintained above [745.3 cm (293.4 in) (top of active fuel)], PRIMARY CONTAINMENT FLOODING IS REQUIRED; enter [procedure developed from the RPV and Primary Containment Flooding Severe Accident Guideline].

C3-4.3 When RPV water level can be maintained above [745.3 cm (293.4 in) (top of active fuel)], return to [Step C3-4].

18A.10 RPV AND PRIMARY CONTAINMENT FLOODING SEVERE ACCIDENT GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Submerge the core (and in-vessel core debris)
- Shut down the reactor
- Depressurize the RPV and prevent it from repressurizing.
- Submerge core debris on the lower drywell floor

ENTRY CONDITIONS

This guideline is entered whenever Primary Containment Flooding is required.

OPERATOR ACTIONS

Execute [Steps RC/F, RC/P, and RC/Q] concurrently.

RC/F Monitor and control RPV and primary containment water levels ❶❸

If while executing the following steps:

- Drywell sprays have been initiated; terminate drywell sprays before drywell pressure drops to 0 psig or if lower drywell thermocouples do not indicate the presence of core debris on the lower drywell floor.

If while executing the following steps:

- DPVs have not opened, open all DPVs

- GDCS has not initiated, initiate GDCS and open all suppression pool equalization line Squib Valves (SQVs).

Flood the primary containment as follows:

If it has been determined that core debris has breached the RPV, proceed to step RC/F-1.

If it has been determined that core debris has not breached the RPV and RPV water level can be restored to [745.3 cm (293.4 in) (top of active fuel)], proceed to step RC/F-2

RC/F-1 IT HAS BEEN DETERMINED THAT CORE DEBRIS HAS BREACHED THE RPV

If while executing the following step:

- DPVs have not opened, open all DPVs
- GDCS has not initiated, initiate GDCS and open all suppression pool equalization line SQVs,
- Lower drywell thermocouples indicate core debris on the drywell floor and the GDCS Deluge Valves have not actuated, actuate GDCS Deluge Valves.

If while executing the following step primary containment water level and suppression chamber pressure approach or exceed the Primary Containment Pressure Limit, vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rates if necessary, to maintain suppression chamber pressure below the Primary Containment Pressure Limit. If primary containment water level and suppression chamber pressure cannot be maintained below the Primary Containment Pressure Limit, but only if total injection into the RPV and drywell can be maintained greater than the Minimum Debris Retention Injection Rate, terminate injection into the RPV and primary containment from sources external to the primary containment except drywell sprays.

> If while executing the following step:
>
> - Drywell sprays are not operating, initiate drywell sprays, defeating drywell spray interlocks if necessary and irrespective of the Drywell Spray Initiation Limit or whether RPV or primary containment injection will be reduced. Use sources external to the primary containment if possible.
> - Drywell sprays are operating, maintain drywell spray flowrate greater than [3840 gpm (Minimum Drywell Spray Flow)], defeating drywell spray interlocks if necessary and irrespective of whether RPV or primary containment injection will be reduced. Use sources external to the primary containment if possible.

RC/F-1.1 Flood the primary containment as follows:

Maximize injection into the RPV from sources external to the primary containment using the following systems, defeating interlocks if necessary:

- Feedwater
- Condensate
- CRD High Pressure Makeup mode
- FAPCS LPCI mode
- Fire Protection System
- [Interconnections with other units]
- SLC
- [Other primary containment fill systems]

If injection into the RPV from sources external to the primary containment will not be reduced, maximize injection into the primary containment from sources external to the primary containment.

If injection into neither the RPV nor the primary containment from sources external to the primary containment will be reduced, maximize injection into the RPV from the suppression pool.

If venting the primary containment will facilitate primary containment flooding, vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary.

If while executing the following step primary containment water level and suppression chamber pressure cannot be maintained below the Primary Containment Pressure Limit restore and maintain primary containment water level and suppression chamber pressure below the Primary Containment Pressure Limit by one or both of the following methods:

- Vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary.
- Terminate injection into the RPV and primary containment from sources external to the primary containment except drywell sprays.

If while executing the following step:

- Drywell sprays are not operating and [suppression pool water level is below [16.85 m (55.28 ft) (elevation of bottom of suppression chamber to drywell vacuum breaker openings [less vacuum breaker opening pressure in feet of water])] and] drywell temperature is below the Drywell Spray Initiation Limit, initiate drywell sprays, defeating drywell spray interlocks if necessary and irrespective of whether injection into the RPV will be reduced. Sources external to the primary containment may be used only if primary containment water level and suppression chamber pressure can be restored and maintained below the Primary Containment Pressure Limit.
- Drywell sprays are operating, continue to operate drywell sprays, defeating drywell spray interlocks if necessary and irrespective of whether injection into the RPV will be reduced. Sources external to the primary containment may be used only if primary containment water level and suppression chamber pressure can be restored and maintained below Primary Containment Pressure Limit.

RC/F-1.2 When primary containment water level reaches [7.6 m (25 ft). (Minimum Debris Submergence Level)]:

Maintain primary containment water level between [7.6 m (25 ft) (Minimum Debris Submergence Level)] and [31.2 m (103 ft) (elevation of primary containment vent)] using the following systems, defeating interlocks if necessary:

- Feedwater
- Condensate
- CRD High Pressure Makeup mode
- FAPCS LPCI mode
- Fire Protection System
- [Interconnections with other units]
- SLC
- [Other primary containment fill systems]

If necessary to maintain primary containment water level above [7.6 m (25 ft). (Minimum Debris Submergence Level)], vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary.

RC/F-2 CORE DEBRIS HAS NOT BREACHED THE RPV AND RPV WATER LEVEL CAN BE RESTORED ABOVE [745.3 cm (293.4 in) (TOP OF ACTIVE FUEL)]

If while executing the following step: • DPVs have not opened, open all DPVs • GDCS has not initiated, initiate GDCS and open all suppression pool equalization line SQVs,

If while executing the following step, water level cannot be maintained above [745.3 cm (293.4 in)(top of active fuel)] then maintain water level as high as can be achieved with the available systems and maximize injection into the RPV and primary containment from sources external to the primary containment.

If while executing this step primary containment water level and suppression chamber pressure approach or exceed the Primary Containment Pressure Limit:

(1) Terminate direct injection into the primary containment from sources external to the primary containment.

(2) If primary containment water level and suppression chamber pressure cannot be maintained below the Primary Containment Pressure Limit:

- Vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary, to restore and maintain suppression chamber pressure below the Primary Containment Pressure Limit.
- If primary containment water level and suppression chamber pressure reach the Primary Containment Pressure Limit, but only if RPV water level can be maintained above [745.3 cm (293.4 in) (top of active fuel)], terminate injection into the RPV from sources external to the primary containment, except boron injection from SLC.

Restore and maintain RPV water level between [745.3 cm (293.4 in) (top of active fuel)] and [2189 cm (861.8 in) (high level trip setpoint)] using the following systems, taking suction from sources external to the primary containment only when required, defeating interlocks if necessary:

- Feedwater
- Condensate
- CRD High Pressure Makeup mode
- FAPCS LPCI mode

If required to restore and maintain RPV water level above [745.3 cm (293.4 in) (top of active fuel)], use the following systems, taking suction from sources external to the primary containment only when required, defeating interlocks if necessary:

- Fire Protection System
- [Interconnections with other units]
- SLC
- [Other primary containment fill systems]

If necessary to restore and maintain RPV water level above [745.3 cm (293.4 in) (top of active fuel)]:

- Vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary.
- If no DPV can be opened, vent the RPV with one or more of the following, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary:
  [
  - MSIVs
  - MSL drains
  - IC tube side vents
  ]

RC/P Monitor and control RPV pressure.

> If while executing the following steps it is anticipated that primary containment water level will rise above [**m (**ft) (elevation of the inboard main steam line drain valve motor operator or elevation of the lowest SRV pneumatic solenoid, whichever is lower)], open the inboard main steam line drain valve before primary containment water level reaches [**m (**ft) (elevation of the inboard main steam line drain valve motor operator or elevation of the lowest SRV pneumatic solenoid, whichever is lower)], defeating isolation interlocks if necessary.

RC/P-1 Initiate all Isolation Condensers.

RC/P-2 Rapidly depressurize the RPV as follows, irrespective of the resulting cooldown rate:

If suppression pool water level is above [2.13 m (6.99 ft) (elevation of top of SRV discharge device)], open all ADS SRVs and DPVs, defeating pneumatic supply isolation interlocks and restoring the pneumatic supply if necessary.

If any ADS valve cannot be opened, but only if suppression pool water level is above [2.13 m (6.99 ft) (elevation of top of SRV discharge device)], open other SRVs, defeating pneumatic supply isolation interlocks and restoring the pneumatic supply if necessary, until [10 (number of SRVs dedicated to ADS)] valves are open.

If DPVs did not open and less than [8 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open and RPV pressure is at least [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure:

(1) Rapidly depressurize the RPV using non-ADS SRVs and one or more of the following, defeating interlocks and exceeding offsite radioactivity release rate limits if necessary, until RPV pressure is less than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure:

- Main condenser
- [Other steam-driven equipment]
- MSL drains
- Head vent
- IC tube side vent
- RWCU/SDCS, only if no boron has been injected into the RPV or it has been determined that the reactor will remain shutdown under all conditions without boron.

(2) Maintain RPV pressure less than [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure using one or more of the systems used for depressurization.

If while executing the following step:

- Less than [8 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open and RPV pressure is at least [0.345 MPa (50 psig) (Decay Heat Removal Pressure)] above suppression chamber pressure, or

- The reactor is not shutdown, return to [Step RC/P-2].

RC/P-3 If further cooldown is required, continue to cool down to cold shutdown conditions ((120°F) 49°C <RPV water temp < 100°C (212°F) (cold shutdown conditions)]) using one or more of the following, defeating interlocks if necessary:

- ICs
- RWCU/SDC
- SRVs
- Main condenser
- [Other steam-driven equipment]
- MSL drains
- Head vent
- IC tube side vent

RC/Q Monitor and control reactor power.

RC/Q-1 Confirm or place the reactor mode switch in SHUTDOWN.

RC/Q-2 If ARI has not initiated, initiate ARI.

Execute [Steps RC/Q-3 and RC/Q-4] concurrently.

RC/Q-3 Inject boron into the RPV with SLC

RC/Q-4 Insert control rods as follows until it has been determined that core debris has breached the RPV:

RC/Q-4.1 Reset ARI, defeating ARI logic trips if necessary.

RC/Q-4.2 Insert control rods with one or more of the following methods:

- De-energize scram solenoids.
- Vent the scram air header.

- Reset the scram, defeating RPS logic trips if necessary, drain the scram discharge volume, and initiate a manual scram.
- Open individual scram test switches.
- Drive control rods, defeating RC&IS and RWM interlocks if necessary.

18A.11 CONTAINMENT AND RADIOACTIVITY RELEASE SEVERE ACCIDENT GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Protect equipment in the primary containment and Reactor Building,
- Maintain primary containment and Reactor Building integrity, and
- Limit radioactivity release into areas outside the primary containment and Reactor Building.

ENTRY CONDITIONS

This guideline is entered whenever Primary Containment Flooding is required.

OPERATOR ACTIONS

If while executing the following steps Reactor Building HVAC exhaust radiation level exceeds [20 mr/hr (Reactor Building HVAC isolation setpoint)]:

- Confirm or manually initiate isolation of Reactor Building HVAC.

If while executing the following steps:

- Reactor Building HVAC isolates, and,
- Reactor Building HVAC exhaust radiation level is below [20 mr/hr (Reactor Building HVAC isolation setpoint)], restart Reactor Building HVAC, defeating high drywell pressure and low RPV water level isolation interlocks if necessary.

If while executing the following steps HVAC in the turbine building (or any other building which may be contributing to radioactive release) is shutdown [or isolated due to high radiation], restart the HVAC as required, defeating isolation interlocks if necessary.

Execute [Steps SP/T, DW/T, PC/P, PC/R, PC/G, SC/T, SC/R, SC/L, and RR] concurrently.

SP/T Monitor and control suppression pool temperature.

If injection into neither the RPV nor the primary containment will be reduced or if RPV water level can be maintained above [745.3 cm (293.4 in) (top of active fuel)], control suppression pool temperature below [43.3°C (110°F) (most limiting suppression pool temperature LCO)] using available suppression pool cooling.

DW/T Monitor and control drywell temperature. ❶❸

Control drywell temperature below [57.22°C (135°F) (drywell temperature LCO or maximum normal operating temperature, whichever is higher)] using available drywell cooling, defeating isolation interlocks if necessary.

Before drywell temperature reaches [171.1°C (340°F) (maximum temperature at which ADS is qualified or drywell design temperature, whichever is lower)], drywell spray can be utilized if drywell water level is less than [0.7 m] or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor. If drywell water level is greater than [0.7 m] and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized.

PC/P Monitor and control primary containment pressure. ❶❸

When suppression chamber pressure exceeds [0.095 MPa (13.8 psig) (Drywell Spray Initiation Pressure)] drywell spray can be utilized if drywell water level is less than [0.7 m] or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor. If drywell water level is greater than [0.7 m] and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized.
Before suppression chamber pressure reaches the Primary Containment Pressure Limit, vent the primary containment, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary, to control pressure below the Primary Containment Pressure Limit.

PC/R Monitor and control [drywell] [suppression chamber] radiation level. ❸

Before [drywell] [suppression chamber] radiation level reaches [14,000 R/hr (drywell or suppression chamber radiation level which requires a General Emergency)], drywell spray can be utilized if drywell water level is less than [0.7 m] or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor. If drywell water level is greater than [0.7 m] and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized.

PC/G Monitor and control primary containment hydrogen and oxygen concentrations.

> If while executing the following steps the hydrogen or oxygen monitoring system is or becomes unavailable, sample the drywell and suppression chamber for hydrogen and oxygen in accordance with [sampling procedure].

Control hydrogen and oxygen concentrations in the drywell as follows:

		Drywell Oxygen Concentration			
		< 5%	≥ 5% or cannot be determined to be below 5%		
			Suppression Chamber Hydrogen Concentration		
			None Detected	< 6%	≥ 6% or cannot be determined to be below 6%
Drywell Hydrogen Concentration	None Detected	No action required	No action required	[PC/G-2]	[PC/G-3]
	< 6%	[PC/G-1]	[PC/G-2]	[PC/G-2]	[PC/G-3]
	≥ 6% or cannot be determined to be below 6%	[PC/G-1]	[PC/G-3]	[PC/G-3]	[PC/G-3]

Control hydrogen and oxygen concentrations in the suppression chamber as follows:

		Suppression Chamber Oxygen Concentration			
		< 5%	≥ 5% or cannot be determined to be below 5%		
			Drywell Hydrogen Concentration		
			None Detected	< 6%	≥ 6% or cannot be determined to be below 6%
Suppression Chamber Hydrogen Concentration	None Detected	No action required	No action required	[PC/G-5]	[PC/G-6]
	< 6%	[PC/G-4]	[PC/G-5]	[PC/G-5]	[PC/G-6]
	≥ 6% or cannot be determined to be below 6%	[PC/G-4]	[PC/G-6]	[PC/G-6]	[PC/G-6]

PC/G-1 Reduce drywell hydrogen and oxygen concentrations by one or both of the following methods:

- If the offsite radioactivity release rate is expected to remain below the offsite release rate specified in [Technical Specifications], vent and purge the drywell as follows, defeating isolation interlocks (except high radiation interlocks) if necessary:

If while executing the following steps the offsite radioactivity release rate reaches the offsite release rate specified in [Technical Specifications], secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

(1) Refer to [sampling procedure].

(2) Vent the drywell.

(3) If the drywell can be vented, purge the drywell by injecting nitrogen into the drywell.

(4) When hydrogen is no longer detected in the drywell, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

PC/G-2 Reduce drywell hydrogen and oxygen concentrations by one or both of the following methods:

- If RPV water level cannot be maintained above [745.3 cm (293.4 in) (top of active fuel)] or the offsite radioactivity release rate is expected to remain below the offsite radioactivity release rate which requires a General Emergency, vent and purge the drywell as follows, defeating isolation interlocks if necessary:

If while executing the following RPV water level can be maintained above [745.3 cm (293.4 in)(top of active fuel)] and it has been determined that the offsite radioactivity release rate has reached the offsite radioactivity release rate which requires a General Emergency, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

(1) Vent the drywell.

(2) If the drywell can be vented, purge the drywell by injecting nitrogen into the drywell at the maximum rate.

(3) When no hydrogen is detected in the drywell and either drywell oxygen concentration is below 5% or no hydrogen is detected in the suppression chamber, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

PC/G-3 Vent and purge the drywell as follows, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary:

PC/G-3.1 Vent the drywell.

PC/G-3.2 If the drywell can be vented, purge the drywell by injecting air or nitrogen, whichever will more rapidly return hydrogen concentrations to below 6% or oxygen concentration to below 5%, into the drywell at the maximum rate.

PC/G-3.3 If drywell water level is less than [0.7 m] or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor, drywell sprays can be utilized. If drywell water level is greater than [0.7 m] and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized. ❸

PC/G-4 Reduce suppression chamber hydrogen and oxygen concentrations by one or both of the following methods:

- If the offsite radioactivity release rate is expected to remain below the offsite release rate specified in [Technical Specifications], vent and purge the suppression chamber as follows, defeating isolation interlocks (except high radiation interlocks) if necessary:

If while executing the following steps the offsite radioactivity release rate reaches the offsite release rate specified in [Technical Specifications], secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

(1) Refer to [sampling procedure].

(2) If suppression pool water level is below [** m (** ft) (elevation of the bottom of the suppression chamber vent)], vent the suppression chamber.

(3) If the suppression chamber can be vented, purge the suppression chamber by injecting nitrogen into the suppression chamber.

(4) When hydrogen is no longer detected in the suppression chamber, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

PC/G-5 Reduce suppression chamber hydrogen and oxygen concentrations by one or both of the following methods:

- If RPV water level cannot be maintained above [745.3 cm (293.4 in) (top of active fuel)] or the offsite radioactivity release rate is expected to remain below the offsite release rate which requires a General Emergency, vent and purge the suppression chamber as follows, defeating isolation interlocks if necessary:

If while executing the following steps RPV water level can be maintained above [745.3 cm (293.4 in) (top of active fuel)] and it has been determined that the offsite radioactivity release rate has reached the offsite release rate which requires a General Emergency, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

(1) If suppression pool water level is below [** m (** ft) (elevation of the bottom of the suppression chamber vent)], vent the suppression chamber.

(2) If the suppression chamber can be vented, purge the suppression chamber by injecting nitrogen into the suppression chamber at the maximum rate.

(3) When no hydrogen is detected in the suppression chamber and either suppression chamber oxygen concentration is below 5% or no hydrogen is detected in the drywell, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

PC/G-6 Vent and purge the suppression chamber as follows, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary:

PC/G-6.1 If suppression pool water level is below [** m (** ft) (elevation of the bottom of the suppression chamber vent)], vent the suppression chamber.

PC/G-6.2 If the suppression chamber can be vented, purge the suppression chamber by injecting air or nitrogen, whichever will more rapidly return hydrogen concentration to below 6% or oxygen concentration to below 5%, into the suppression chamber at the maximum rate.

SC/T Monitor and control Reactor Building temperatures. ❶

Operate available area coolers.

If Reactor Building HVAC exhaust radiation level is below [20 mr/hr (Reactor Building HVAC isolation setpoint)], operate available Reactor Building HVAC.

When an area temperature exceeds its maximum normal operating temperature, isolate all systems that are discharging into the area except systems required to suppress a fire and systems required to be operated by [procedures developed from the Severe Accident Guidelines].

SC/R Monitor and control Reactor Building radiation levels.

When an area radiation level exceeds its maximum normal operating radiation level, isolate all systems that are discharging into the area except systems required to suppress a fire and systems required to be operated by [procedures developed from the Severe Accident Guidelines].

SC/L Monitor and control Reactor Building water levels.

When a floor drain sump or area water level is above its maximum normal operating water level, operate available sump pumps to restore and maintain it below its maximum normal operating water level.

If any floor drain sump or area water level cannot be restored and maintained below its maximum normal operating water level, isolate all systems that are discharging water into the sump or area except systems required to suppress a fire and systems required to be operated by [procedures developed from the Severe Accident Guidelines].

RR Isolate all primary systems that are discharging into areas outside the primary containment and Reactor Building except systems required to be operated by [procedures developed from the Severe Accident Guidelines].

Table 18A-1

EPG Abbreviations

ADS	Automatic Depressurization System
APRM	Average Power Range Monitor
ARI	Alternate Rod Insertion
CRD	Control Rod Drive
DPV	Depressurization Valve
ECCS	Emergency Core Cooling Systems
FAPCS	Fuel and Auxiliary Pools Cooling System
GDCS	Gravity-Driven Cooling System
HVAC	Heating, Ventilating and Air Conditioning
IC	Isolation Condenser
LCO	Limiting Condition for Operation
LPCI	Low Pressure Coolant Injection
MSIV	Main Steamline Isolation Valve
RC&IS	Rod Control and Information System
RWCU/SDC	Reactor Water Cleanup/Shutdown Cooling System
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RWM	Rod Worth Minimizer
SLC	Standby Liquid Control
SQV*	Squib Valve
SRV	Safety Relief Valve

*NOTE: Currently not included in Abbreviation Listing.

Table 18A-2

Reactor Building Temperature Operating Values for EPGs and SAGs

Area	**Maximum Normal Temperature** (°C)(°F)	**Maximum Safe Temperature** (°C)(°F)
RWCU A Pump Room	*	*
RWCU B Pump Room	*	*
RWCU HX Room	*	*
RWCU HX Room at Hotwell Discharge	*	*
Main Steam Tunnel	*	*
Reactor Area A	*	*
Reactor Area B	*	*
	Maximum Normal delta T (°C)(°F)	**Maximum Safe delta T** (°C)(°F)
HVAC Cooler	*	*
RWCU A Pump Room	*	*
RWCU B Pump Room	*	*
RWCU HX Room at HX	*	*
RWCU HX Room at Hotwell Discharge	*	*
Main Steam Tunnel Cooler	*	*
* Plant Specific Data – COL Applicant		

Table 18A-3

Reactor Building Radiation Level Operating Values for EPGs and SAGs

Area	**Maximum Normal Radiation Level** (Sv)(Rem)	**Maximum Safe Rad Level** (Sv)(Rem)
Equipment Hatch	*	*
Drywell Personnel Lock	*	*
Clean-up System Room	*	*
Clean-up Filter Demin Area	*	*
SLC Room	*	*
Chem Lab	*	*
Fuel Pool HX	*	*
Refueling Floor Laydown Area	*	*
Refueling Floor Change Area High	*	*
HVAC Exhaust	*	*
Safety Envelope	*	*
Refuel Floor	*	*
* Plant Specific Data – COL Applicant		

Table 18A-4

Reactor Building Water Level Operating Values for EPGs and SAGs

Area	**Maximum Normal Water Level** (m)(ft)	**Maximum Safe Water Level** (m)(ft)
Floor drain sump	*	NA
CRD Compartment	*	*
RB NE Corner Room	*	*
RB SE Corner Room	*	*
* Plant Specific Data – COL Applicant		

18B. ESBWR EPG/SAG COMPARED TO GENERIC BWR EPG

The ESBWR design has incorporated many desirable features and systems characteristic of earlier generation BWRs. Some common BWR systems have been eliminated or modified and some unique systems and configurations have been added to improve safety or operational characteristics in the ESBWR.

The purpose of this document is to provide information about the ESBWR design philosophy and features relative to other BWRs in limited, but sufficient detail to explain the rationale behind the adaptation of the generic EPG/SAG for use in the ESBWR. BWROG EPG/SAG Rev. 2 is used as the standard for comparison.

Section 18B.1 contains summary descriptions of ESBWR systems or features requiring changes from the generic EPG/SAG. Section 18B.2 describes the major changes to the ESBWR EPG/SAG and the bases for these changes. Section 18B.3 compares the ESBWR EPG/SAG step-by-step to EPG/SAG Rev. 2 and documents the basis for each modification made.

18B.1 ESBWR DESIGN FEATURES AFFECTING THE EPG/SAG

The ESBWR design is described elsewhere in detail, but a brief summary of those features, which have had significant impact on the development of the ESBWR EPG/SAG is described below.

18B.1.1 ESBWR RPV and Related Features

The ESBWR is a natural circulation plant and has neither jet pumps nor external or internal recirculation pumps. Thus, there will be no operator actions specified regarding control of recirculation flow. The reactor core is shorter in height than most of the earlier BWR designs and the reactor pressure vessel (RPV) is much taller, resulting in a much larger vessel volume to core power ratio. As a result, level transients would be slower allowing more time for operator recovery actions. The ESBWR also has fine motion control rod drives, so specific operator actions to manually scram the reactor are different from those for the hydraulic locking-piston drives in earlier BWRs. The CRD system in the ESBWR can be operated in the usual (purge) mode or can inject flow into the RPV via the feedwater line (high pressure makeup mode). Where appropriate, a distinction between modes is made in the ESBWR EPG/SAG.

18B.1.2 Isolation Condenser

Most operating plants have no isolation condenser and the relative capacities of those plants that have isolation condensers are much smaller than the ESBWR design. Thus, the ESBWR isolation condensers play a larger role for reactor pressure and level control in the ESBWR.

18B.1.3 Emergency Core Cooling Systems

Operating BWRs typically have a full compliment of automatically initiated Emergency Core Cooling Systems (ECCS) for both high and low pressure injection, plus an ADS for vessel depressurization. High-pressure systems are typically steam driven (HPCI or RCIC). ESBWR has no steam driven or other high pressure ECC related injection systems.

In contrast, ESBWR has the capacity to gravity reflood the RPV using the ADS and the Gravity Driven Cooling System (GDCS). These two systems comprise the ECCS for ESBWR. The function of ADS is to depressurize the reactor pressure vessel (RPV) sufficiently so that the GDCS can re-flood at very low RPV pressure. Gravity re-flooding of the RPV can be accomplished by draining the GDCS pools and by draining the suppression pool through the equalizer line. The RPV must be at essentially the same pressure as the containment for gravity re-flooding to be accomplished.

The ADS in ESBWR consists of 10 SRVs piped to the suppression pool and a set of 8 depressurization valves (DPVs) which discharge directly to the drywell. ESBWR ADS has no start time delay timer, but stages first the SRV openings in two groups of five with a delay in between; then after a further time delay, stages the DPV openings in groups with time delays between the groups.

Significant variations in EPG/SAG strategy arise from these basic ECC concept differences.

18B.1.4 ATWS Mitigation Systems

Operating plant SLC systems are typically pump driven with borated water taken from a supply tank. The ESBWR SLC system is accumulator driven, necessitating that somewhat different directions be specified to the operator. ESBWR has an automatic ADS inhibit feature in contrast to earlier BWRs where manual action is required to inhibit, if needed. In contrast, ESBWR has no manual inhibit feature.

18B.1.5 Containment Features

ESBWR has a unique natural circulation driven Passive Containment Cooling System (PCCS). This system condenses steam in the containment and has a vent for transport of non-condensable gases to the suppression pool which is driven by any pressure difference between the drywell and suppression pool. There are no valves or any other device requiring activation and thus no operator actions are specified in the EPG/SAG. The PCCS is mentioned here because of its inherent ability to control containment pressure and remove energy and its high likelihood of being in operation during any event without operator action.

18B.2 MAJOR DIFFERENCE BETWEEN ESBWR AND BWROG EPG/SAG REV. 2

The major strategy differences between ESBWR EPG/SAG and BWROG Rev. 2 EPG/SAG arise from the fundamental design differences described below. It is recognized that many systems would be initiated automatically and may be in operation during a given transient. However, when it is time for a system to be placed into operation during the EPG/SAG evolution, direction is given to operate the system in case it did not initiate on an automatic signal, or if the system was prevented from operation or bypassed earlier by the operator. This is the same approach generally used in BWROG EPG/SAG Rev. 2, but is noted here as a reminder because of the many automatically initiated systems in ESBWR.

18B.2.1 Level Control

The operator is directed to depressurize the RPV manually using SRVs and attempt to restore level in the event of a failure of the automatic ADS initiation on Level 1.5. If level reaches the top of the active fuel, then direction is given to enter the RPV and Containment Flooding procedure and initiate DPVs and actuate the GDCS. This provides some additional time to allow for recovery. Normally, however, the ADS would initiate automatically on Level 1.5. The Isolation Condensers will be automatically (or manually) initiated and will remove decay heat and return condensate to the RPV.

In the ESBWR EPG/SAG, Level 1.5 is chosen as the control level if RPV water level cannot be restored and maintained in the preferred range (low level scram to high level trip). Level 1.5 is chosen primarily because the GDCS is automatically initiated at Level 1.5. If Level 1.5 cannot be maintained and the GDCS fails to initiate, a further effort is provided to maintain level at top-of-active-fuel (TAF). This control method is not consistent with the BWROG EPG/SAG Rev 2, Contingency 1, Alternate Level Control, control strategy and has thus been eliminated from the ESBWR EPG/SAG. If level cannot be maintained at TAF, then the RPV and Containment Flooding procedure is entered.

ESBWR has a very limited number of ECC injection systems, depending primarily on the alternate strategy of depressurization and gravity re-flooding, thus there is no need for pump lineup and starting as directed in Contingency 1 of BWROG EPG/SAG Rev. 2. The emergency depressurization action and the final measure of containment flooding in BWROG EPG/SAG Rev. 2, Contingency 1 are incorporated in the ESBWR EPG/SAG in the level control section.

If level cannot be maintained above the preferred control point (low level scram set point or shutdown cooling RPV water level interlock, whichever is higher), then emergency depressurization is required. Once emergency depressurization has been started, the operator is directed to again attempt level recovery using the available injection systems at lower pressure.

At this point, if level cannot be maintained above TAF at the lower RPV pressure, entry into RPV and Containment Flooding is directed. The first action is to initiate GDCS.

RPV Flooding also calls for use of DPVs and GDCS. Initiation of DPVs will assure complete blow down of the RPV so that gravity re-flooding can be achieved. GDCS first drains the GDCS pools, which likely would be adequate to cover the core. The operator is also instructed to open the squib valves (SQVs) in the equalizer lines to flood the RPV from the suppression pool.

Level control steps and re-flood evolutions similar to those described above in RPV level control have been incorporated into Contingency 3, Level/Power Control of the EPG/SAG for the ESBWR.

18B.2.2 Steam Cooling and Alternate Level Control

In Contingency 1 of BWROG EPG/SAG Rev. 2, steam cooling is required if no injection or alternate injection pumps are running as noted above in Section 18B.2.1. The purpose of steam cooling is to allow the operator more time to get injection systems lined up with pumps running prior to depressurization. Once injection systems are available, depressurization can be accomplished with assurance of injection capability. For the ESBWR, gravity re-flooding is the principal mode of assuring adequate core cooling which can only be accomplished after blow down, so there is no need to delay blow down to get injection systems lined up with pumps running and thus no need for steam cooling.

As discussed in Section 18B.2.1 and directly above, the Alternate Level Control actions of injection system lineup and pump starting and potential need for steam cooling are not appropriate for the ESBWR so these steps have been eliminated. Additionally, the emergency depressurization and containment flooding steps of Contingency 1 of BWROG EPG/SAG Rev. 2 have been incorporated into the ESBWR EPG/SAG various level control sections, so the ESBWR EPG/SAG has no Alternate Level Control or Steam Cooling Contingencies.

18B.2.3 Emergency Depressurization

Emergency depressurization in BWROG EPG/SAG Rev. 2 following initiation of the isolation condenser, directs the operator to open all ADS valves or if any ADS valves can't be opened, to open an equivalent number of SRVs. For the ESBWR direction is given to open all SRVs. The operator is not instructed to take action to open the DPVs until other means of depressurization have been attempted and other level recovery actions were attempted and found to be unsuccessful.

Should this be the case, the next evolution specified in ESBWR EPG/SAG is to re-flood using the GDCS. Complete depressurization is required for re-flooding so opening the DPVs is necessary. Note that the action to open the DPVs is contained in RPV and Containment Flooding rather than in the Emergency Depressurization Contingency for the ESBWR EPG/SAG.

Delayed use of the DPVs is directed because the DPVs discharge RPV effluents directly to the drywell, whereas other paths are preferred from energy and fission product retention considerations.

18B.3 SPECIFIC DIFFERENCES BETWEEN ESBWR AND BWROG EPG/SAG REV. 2

The accompanying table 18B-1 delineates changes made to the EPG/SAG Rev. 2 for adaptation to the ESBWR EPG/SAG. Comparisons are made step-by-step for every change and the basis is provided for the differences. The table is divided into sections corresponding to the major EPG/SAG control sections and contingencies.

Table 18B-1

RPV Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
RC/L	RC/L	No reference to Caution #2	ESBWR has no heated reference leg instruments.
RC/L-1	RC/L-1	Isolation condenser is added to list of equipment to be initiated	The isolation condenser provides a significant heat sink and would normally be automatically initiated at Level 2.
RC/L-2	RC/L-2	No reference to Cautions #3, #4 and #5	These cautions are no longer applicable to ESBWR. See Table 18B-9.
RC/L-2	RC/L-2	RCIC, HPCI, HPCS, LPCS and RHR were eliminated from the list of injection systems for possible use.	ESBWR has none of these injection systems.
		FAPCS LPCI mode is included in the list of systems.	ESBWR has low pressure injection capability using FAPCS in the LPCI mode which can be manually initiated.
RC/L-2	RC/L-2	Shorter list of alternate injection systems for possible use.	ESBWR has no RHR or ECCS keep full systems nor any SLC tanks.
RC/L-2	RC/L-2	Preventing automatic RPV depressurization by resetting ADS is eliminated.	ESBWR has no reset or manual inhibit of ADS.
RC/L-2	RC/L-2	Emergency depressurization and continuance in RC/L is specified; EBG/SAG Rev. 2 direction is to exit RC/L and enter the original Contingency #1, Alternate Level Control (which has been removed from the ESBWR EPGs.	The original EPG/SAGs employ a large complement of ECC injection systems which are first employed in the original Contingency #1 before requiring emergency depressurization. ESBWR has the gravity reflood system (GDCS) in place of these systems (refer to additional discussion in Section 18B.1.3).

Table 18B-1

RPV Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
RC/L-3	—	Additional action in ESBWR guideline (similar to RC/L-2 actions at lower pressure).	Since ESBWR RPV depressurization is initiated at Level 1.5 vs TAF in BWROG EPG/SAG Rev. 2, additional flexibility is given to attempt level restoration using step RC/L-2 systems but at lower RPV pressure (refer to additional discussion in Section 18B.2.
RC/L-3	—	Exit to RPV flooding contingency if no way was found to maintain RPV water level above TAF.	This is different from BWROG EPG/SAG Rev. 2 only in that it appears in RC/L rather than in Contingency #1. In both guidelines, all other level recovery possibilities are exhausted before this action is taken.
RC/P	RC/P	First override in BWROG EPG/SAG Rev. 2 calling for prevention of low pressure ECCS injection by a high drywell pressure is omitted for the ESBWR.	ESBWR has no LPCS; FAPCS LPCI mode has no automatic initiation, so no prevention action is necessary.
RC/P	RC/P	Remove reference to Caution #2 in second override.	ESBWR has no heated reference leg instruments.
RC/P-1	RC/P-1	Third override when steam cooling is required is deleted for ESBWR.	ESBWR has no Steam Cooling Contingency. Steam Cooling is an action taken in operating BWRs to delay blow down in situations when ECC pumps are not available.

Table 18B-1

RPV Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
RC/P-2	RC/P-2	Delete reference to Cautions #3, 4 and 5.	These Cautions are not applicable to ESBWR.
		HPCI, RCIC and other steam driven equipment options are deleted from the list of pressure control augmentation systems.	These equipment options are not available in ESBWR.
		RWCU/SDC high pressure shutdown cooling mode is called for rather than "RWCU (re-circulation mode)"	Alternate name and mode for this function in the ESBWR.
		No brackets enclosing "regenerative heat exchangers and"	Bypassing the heat exchangers can be done in ESBWR and is so directed.
RC/P-2	RC/P-2	A second override is added to use alternate shutdown cooling procedures, if required.	ESBWR shutdown cooling, initiated as an augmentation to pressure control in the same step, can operate over the full pressure range. The override calls for alternate shutdown cooling, if required. These changes are made along with deletion of BWROG EPG/SAG Rev. 2 Step RC/P-4 for a consistent set of instructions (refer to discussion below).
—	RC/P-4	This step is not included for the ESBWR.	RWCU/SDC high pressure shutdown cooling mode can operate at high pressure so there is no need to wait for pressure interlocks to clear. Use of alternate methods for further cool down is called for in the RC/P-2 second override (refer to discussion above).

Table 18B-1

RPV Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
RC/Q	RC/Q	First and second overrides for ESBWR omit the instruction to “terminate boron injection”	Accumulator driven boron injection for the ESBWR cannot be terminated once initiated.
RC/Q-1	RC/Q-1	Brackets encompassing the actions are deleted.	Brackets indicate system use or action may not be appropriate. Deleted because this action is the best means of providing diverse and redundant scram signals for ESBWR.
RC/Q-2	RC/Q-2	Brackets encompassing the entire step are deleted.	This step is applicable to ESBWR.
—	RC/Q-3	Deleted	Re-circulation flow runback is not an option in ESBWR since there are no re-circulation pumps.
—	RC/Q-4	Deleted	Re-circulation pump trip is not an option in ESBWR since there are no re-circulation pumps.
—	RC/Q-5	Deleted	This instruction already given in previous step, RC/Q-2.
RC/Q-2	RC/Q-5	Same instructions are given in the override; only step numbers are changed.	Required renumbering because of RC/Q-3, 4 and 5 deletions.
RC/Q-3	RC/Q-6	Same instruction; only a step number change.	Required because of step deletions.
RC/Q-3	RC/Q-6	Shorter list of alternate boron injection methods; alternate name for RWCU.	HPCS, HPCI and RCIC not available in ESBWR; RWCU/SDC is the system designation in ESBWR.
RC/Q-3	RC/Q-6	Deleted override to trip SLC pumps when SLC tank level reaches low level trip.	There are no SLC pumps or SLC tank in ESBWR.

Table 18B-1

RPV Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
RC/Q-3	RC/Q-6	Identical action; steps renumbered and RWCU designation changed.	Renumbered and renamed for consistency (refer to previous discussions).
RC/Q-4	RC/Q-7	Number change	Consistency with deleted step and renumbering.
RC/Q-4.1	RC/Q-7.1	Number change	Numbering consistency
RC/Q-4.2	RC/Q-7.2	Number change.	Numbering consistency
		The text “drain the scram discharge volume” has been deleted for ESBWR in the third method	There is no scram discharge volume feature in the ESBWR CRD.
		Deleted “Increase CRD cooling water differential pressure” and “Vent control rod drive over piston volumes”.	These methods are not applicable to the FMCRDs used in the ESBWR.
		Changed “RSCS” to “RC&IS”	ESBWR has no RSCS but the RC&IS provides a similar function.

Table 18B-2

Primary Containment Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG EPG/SAG REV 2 EPG EPG Step	Difference	Basis For Difference
All steps in the BWROG EPG/SAG REV 2 column below refer to the Mark I and II Containment. Procedures. These more closely approximate the ESBWR design			
Entry Condition	Entry Condition	No containment temperature entry condition in ESBWR EPG.	This entry condition is applicable only to plants with Mark III containments.
Operator Action PC Overrides	Operator Action PC Overrides	Deleted 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} overrides.	These overrides referred specifically to drywell or suppression pool sprays which are not included in the ESBWR design.
Branch before Step SP/T	Branch before Step SP/T	“CN/T” deleted from concurrent execution	CN/T is for Mark III containments only.
SP/T-1	SP/T-1	Brackets removed; reference to “RHR” pumps replaced by “FAPCS”.	ESBWR has no RHR system but FAPCS can be used for suppression pool cooling if not needed to assure adequate core cooling.
SP/T-3	SP/T-3	Added “Before the Heat Capacity Temperature Limit is reached; operate all available Isolation Condensers to depressurize the RPV”	ICs can be used to avoid the HCTL and prevent the need for emergency depressurization. It was decided to highlight this as a separate step, even though the ICs are called out in RPV Control.
SP/T-4	SP/T-3	Separated the emergency depressurization requirement into a separate step	This is an editorial change to avoid having two actions in a single step

Table 18B-2

Primary Containment Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG EPG/SAG REV 2 EPG EPG Step	Difference	Basis For Difference
DW/T-2	DW/T-2	Deleted “DRYWELL SPRAY IS REQUIRED”	ESBWR does not use drywell spray in the EPGs
		Additional direction is given to enter RPV control and execute it concurrently.	Entry to RPV control is given earlier because earlier entry to RPV control would allow operator a chance to depressurize through the main condenser or ICs before emergency depressurization as required at Step DW/T-3
DW/T-3	DW/T-3	Direction to enter RPV control deleted.	Same direction given in earlier step (see Step DW/T-2 for discussion of the basis).
—	CN/T	This section eliminated from ESBWR EPG.	Applies only to BWRs with Mark III containments.
PC/P	PC/P	Added Containment Inerting System (CIS) and RBHVAC system.	The system called for in the ESBWR EPG to control containment pressure is the Containment Inerting System (CIS). It operates in conjunction with the RBHVAC system.
		Deleted “When primary containment pressure cannot be maintained below [13.8 KPA (2.0 psig) (high drywell pressure scram set point)]:”	No additional actions are available that are not already being done. There are no suppression pool sprays or use of drywell sprays in this mode for the ESBWR.
—	PC/P-1	Deleted Suppression Pool Spray Requirement	ESBWR does not have Suppression Pool Sprays.
—	PC/P-2	Deleted Drywell Spray Requirement	ESBWR does not use Drywell Sprays in the EPGs.

Table 18B-2

Primary Containment Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG EPG/SAG REV 2 EPG EPG Step	Difference	Basis For Difference
PC/P-1	PC/P-3	PC/P-3 was renumbered to PC/P-1	PC/P-1 and 2 were deleted
PC/P-2	PC/P-4	Step renumbered	Deletion of EPG/SAG steps PC/P-1 and 2 required renumbering
PC/P-3	PC/P-5	Step renumbered	Deletion of EPG/SAG steps PC/P-1 and 2 required renumbering
SP/L-1	SP/L-1	In ESBWR direction is given to use FAPCS.	No specific systems are specified in EPG/SAG because of plant variability. In ESBWR FAPCS is appropriate.
		References to SPMS have been eliminated.	ESBWR has no SPMS.
SP/L-2	SP/L-2	Eliminated override to execute following two sub steps concurrently.	Only one sub step follows in the ESBWR EPG.
SP/L-2	SP/L-2.1	Sub step number eliminated.	Sub step is not needed for ESBWR (See SP/L-2.2 discussion)
—	SP/L-2.2	Sub step eliminated.	No concern regarding HPCI exhaust since ESBWR does not have HPCI.
SP/L-3	SP/L-3	Reference to SPMS deleted.	No SPMS in ESBWR.
SP/L-3.2	SP/L-3.2	"feet" changed to "meters" in two places.	Units change.
		Removed requirement to terminate drywell sprays.	ESBWR does not use Drywell Sprays in the EPGs.
PC/G-1	PC/G-1	Removed sub steps associated with hydrogen re-combiner operation	ESBWR does not utilize hydrogen re-combiners for hydrogen concentration control

Table 18B-2

Primary Containment Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG EPG/SAG REV 2 EPG EPG Step	Difference	Basis For Difference
PC/G-2	PC/G-2	Removed sub steps associated with hydrogen re-combiner operation	ESBWR does not utilize hydrogen re-combiners for hydrogen concentration control
PC/G-3	PC/G-3	Deleted reference to hydrogen mixing system and hydrogen re-combiners	ESBWR does not have a hydrogen mixing system or hydrogen re-combiners
-------	PC/G-3.3	Deleted this step which initiates drywell sprays	ESBWR does not use Drywell Sprays in the EPGs.
PC/G-4	PC/G-4	Removed sub steps associated with hydrogen re-combiner operation	ESBWR does not utilize hydrogen re-combiners for hydrogen concentration control
PC/G-5	PC/G-5	Removed sub steps associated with hydrogen recombiner operation	ESBWR does not utilize hydrogen re-combiners for hydrogen concentration control
PC/G-6	PC/G-6	Removed words “secure all re-combiners taking suction on the suppression chamber “	ESBWR does not utilize hydrogen re-combiners for hydrogen concentration control
-------	PC/G-6-1	Deleted this step which requires suppression pool sprays	ESBWR does not have suppression pool sprays
PC/G-6-1	PC/G-6-2	Renumbering required	Deletion of earlier step
PC/G-6-2	PC/G-6-3	Renumbering required	Deletion of earlier step

Table 18B-3

Reactor Building Control Emergency Procedure Guidelines

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
Title	Title	"Secondary Containment" changed to "Reactor Building"	The building which surrounds the primary containment in the ESBWR is referred to as the Reactor Building
RB-1 2nd Override	RB-1 2nd Overrides	"Confirm initiation of or manually initiate SBGT" eliminated.	ESBWR has no Standby Gas Treatment System.
Tables 18A-2 thru 18A-4	Table SC-1	This table was generalized for the ESBWR EPG/SAGs	Detailed information will be provided under the plant specific implementation of the EPGs

Table 18B-4

Radioactivity Release Control Emergency Procedure Guideline

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
Override	Override	Deleted "[or isolated due to high radiation]" and "defeating isolation interlocks if necessary".	HVAC is not isolated on high radiation in buildings other than the reactor building.
RR-2&3	RR-2	Separated BWROG step actions into two steps.	Allow attempt at normal depressurization thereby reducing containment heat load prior to emergency depressurization.

Table 18B-5

Contingency 1 - Emergency Depressurization

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
Note: Contingency 1 in EPG/SAG Rev 2 is “Alternate Level Control”. This contingency involves the control of RPV level below the top of the active fuel. It is not applicable to the ESBWR and has been deleted.			
C1-1	C2-1	Reference to RCIC has been deleted and “purge flow” has been added to CRD.	ESBWR has no RCIC. ESBWR CRD can be operated in the injection mode, but operating in the purge mode characterizes this entry condition for an ATWS situation.
C1-1	C2-1	Removed original Caution #2	Original Caution #2 referred to heated reference leg instruments which are not used in the ESBWR
—	C2-1.1	Deleted.	ESBWR has no automatic ECCS initiation on a high drywell pressure signal.
C1-1.1	C2-1.2	Step number change. Changed to “initiate all ICs”.	Renumbered because of deleted step. Effects subsequent steps also. ESBWR has 4 ICs.
C1-1.2	C2-1.3	Step number change. Direction to open all SRVs vs. equivalent number dedicated to ADS. Minimum number of SRVs changed from 4 to 8	All SRVs are used to maximize depressurization. Minimum number of SRVs for ESBWR has yet to be determined. Current number is assumed to be 8.
		Cautions #3, #4 & #5 were deleted	Cautions #3, #4, #5 referred to systems not available in ESBWR (HPCI, RCIC, HPCS, LPCS, RHR).
		Shortened list of options for depressurizing.	No HPCI, RCIC or RHR systems in ESBWR.
C1-2	C2-2	Replaced Shutdown Cooling with RWCU/SDCS.	ESBWR uses RWCU/SDCS to achieve cold shutdown. System

Table 18B-5

Contingency 1 - Emergency Depressurization

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
		Eliminated reference to pressure interlock Removed reference to RHR	operates at full reactor pressure. ESBWR has no RHR system.
C1-2	C2-2	Original Cautions #3, #4 & #5 were deleted	Cautions #3, #4, #5 referred to systems not available in ESBWR (HPCI, RCIC, HPCS, LPCS, RHR).

Table 18B-6

Contingency 2 - RPV Flooding

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
This was Contingency #4 in EPG/SAG Rev 2. Contingency #3 in EPG/SAG Rev 2 was "Steam Cooling" which is not applicable to the ESBWR and was eliminated. Thus, "RPV Flooding" became Contingency #2.			
C2-1	C4-1	Renumbering all steps from C4 to C2	Deletion of earlier contingencies necessitated renumbering of subsequent contingencies
C2-1.1	C4-1.1	"purge mode" has been added to CRD to specify the operation mode. RCIC was removed.	CRD flow injection through the feedwater line is not desirable when it is not certain that the reactor is or will remain shutdown. ESBWR has no RCIC system.
C2-1.2	C4-1.2	Removed discussion regarding ADS valves.	ESBWR direction is to use all SRVs for emergency manual depressurization rather than the subset of these identified as ADS valves.
C2-1.3	C4-1.3	Shortened list of injection systems.	No RCIC, HPCI, LPCI or RHR systems in ESBWR.
		Shortened list of alternate injection systems.	No HPCS, HPCS, LPCI, LPCS, or ECCS keep-full system in ESBWR.
		Shortened list of valves to close.	Fewer systems for ESBWR
		List of alternate depressurization systems shortened Original Cautions #3,#4,#5,#6 were replaced with new Caution #3	ESBWR has no HPCI, RCIC or RHR systems Original Cautions #3, #4, #5 are not applicable to ESBWR. Original Caution #6 was renumbered to Caution #3.
C2-2.1	C4-2.1	Removed discussion regarding ADS valves.	ESBWR direction is to use all SRVs for emergency manual depressurization rather than the subset of these identified as ADS valves.

Table 18B-6

Contingency 2 - RPV Flooding

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
C2-2.2	C4-2.2	Removed HPCS and "motor driven". Added CRD high pressure makeup	ESBWR has no HPCS. All FW pumps are motor driven. CRD provides high pressure makeup in ESBWR.
		Shortened list of systems to isolate	No HPCI, RCIC or RHR in ESBWR
C2-2.3	C4-2.3	Shortened list of systems to use for flooding. Removed "motor drive" from feed pump. Added "high pressure makeup mode" to CRD system.	No HPCS, LPCS, LPCI, RHR or ECCS Keep-Full systems in ESBWR. All feed pumps in ESBWR are motor driven.
		Original Cautions #3, #4 & #5 were deleted	Original Cautions #3, #4, #5 referred to systems not available in ESBWR (HPCI, RCIC, HPCS, LPCS, RHR).
		Removed "motor drive" from feed pump. Removed HPCS and added "CRD high pressure makeup mode". Changed list of systems to use for depressurization if insufficient number of SRVs can be opened.	No HPCS, HPCI, RHR or RCIC systems in ESBWR. All feed pumps in ESBWR are motor driven. ESBWR has RWCU/SDC system and uses CRD in high pressure makeup mode.
C2-3	C4-3	Removed RCIC, HPCI, and RHR systems.	ESBWR has no RCIC, HPCI and RHR systems

Table 18B-7

Contingency 3 - Level/Power Control

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
The deletion of Contingencies 1 & 3 from the BWROG EPGSAG results in the renumbering of this Contingency for #5 to #3.			
-------	C5-1	The text “prevent automatic initiation of ADS” has been eliminated.	Operator prevention of ADS is not possible in ESBWR. ATWS logic automatically inhibits ADS without need for operator action.
C3-1	C5-2	Renumbering of step	Deletion of original step C5-1. This also applies to all subsequent steps.
C3-2	C5-3	Eliminated RCIC and added CRD “purge flow”	ESBWR has no RCIC. CRD has two modes, purge mode and high pressure makeup mode. Purge mode is applicable here.
C3-3	C5-4	Eliminated RCIC and added CRD “purge flow”	ESBWR has no RCIC. CRD has two modes, purge mode and high pressure makeup mode. Purge mode is applicable here.
C3-4	C5-5	Changed low level control from Minimum Steam Cooling RPV Water Level to Top of Active Fuel. Original Cautions #3, #4, #5, #6 were replaced with new Caution #3	Minimum Steam Cooling RPV Water Level control is not being utilized in the ESBWR EPGs. Original Cautions #3, #4, #5 are not applicable to ESBWR. Original Caution #6 was renumbered to Caution #3.
C3-4	C5-5	Shortened list of injection systems. Added, “either purge flow or high pressure makeup modes” to CRD.	RCIC LPCI, HPCI and RHR are not systems in the ESBWR; water can be injected using the FAPCS LPCI mode.
C3-4.1	C5-5.1	“purge mode” added to CRD and “RCIC” deleted.	Same basis as given in C3-2; ESBWR has no RCIC.

Table 18B-7

Contingency 3 - Level/Power Control

ESBWR EPG/SAG EPG Step	BWROG Rev. 2 EPG/SAG EPG Step	Difference	Basis For Difference
C3-4.2	C5-5.2	Shortened list of injection systems. Added, "either purge flow or high pressure makeup modes" to CRD.	RCIC LPCI, HPCI and RHR are not systems in the ESBWR; water can be injected using the FAPCS LPCI mode.
		Changed low-level control from Minimum Steam Cooling RPV Water Level to Top of Active Fuel. Original Cautions #3, #4, #5, #6 were replaced with new Caution #3	Minimum Steam Cooling RPV Water Level control is not being utilized in the ESBWR EPGs. Original Cautions #3, #4, #5 are not applicable to ESBWR. Original Caution #6 was renumbered to Caution #3.
Override following C3-4.2	Override following C5-5.2	Changed level for entry to Primary Containment Flooding from "Minimum Steam Cooling RPV Water Level" to "Top of Active Fuel."	Minimum Steam Cooling RPV Water Level control is not being utilized in the ESBWR EPGs. Top of active fuel is the minimum level for action.
C3-4.3	C5-5.3	Changed low level control from Minimum Steam Cooling RPV Water Level to Top of Active Fuel.	Minimum Steam Cooling RPV Water Level control is not being utilized in the ESBWR EPGs.
—	C5-6	Step C5-6 and its preceding override are eliminated.	This step and override apply to plants with SLC injection location below the core in the lower plenum. The purpose was to raise level and promote mixing into the core. ESBWR SLC injects directly into the core so this action is not required.

Table 18B-8

RPV and Primary Containment Flooding Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
Purpose	Purpose	First purpose changed to “Submerge the core (and in-vessel core debris)” Added an additional purpose “Submerge core debris on the lower drywell floor	More descriptive of purpose of this SAG
RC/F	RC/F	Removed original Caution #2 and added new Caution #3. Modified drywell spray override to include a shutoff of sprays unless core debris is on drywell floor. Deleted suppression pool sprays from override	Original Caution #2 is not applicable to ESBWR design New Caution #3 is applicable to this step. This is directly related to new Caution #3 to avoid possible steam explosion ESBWR has no suppression pool sprays
RC/F-1	RC/F-1	Added override to depressurize with DPVs, initiate passive cooling system and drywell deluge.	ESBWR systems used for post accident RPV and containment flooding
------	RC/F-1.1	Removed override regarding suppression pool sprays	ESBWR has no suppression pool sprays
-------	RC/F-1.1	Step deleted	ESBWR passive systems require RPV venting.
RC/F-1.1	RC/F-1.2	Renumbering of steps	Required because RC/F-1.1 was deleted

Table 18B-8

RPV and Primary Containment Flooding Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
RC/F-1.1	RC/F-1.2	Deleted “Initiate SPMS” from ESBWR EPG.	ESBWR has no SPMS.
		Modified list of systems.	ESBWR has no HPCS, LPCS, RCIC, RHR or ECCS keep-full systems. LPCI is possible using FAPCS in the LPCI mode. Other containment fill systems in the ESBWR are the Makeup Water System and the Condensate Storage and Transfer System.
		Removed original Cautions #3, #4, #5	Original Cautions #3, #4, #5 involved non – ESBWR systems
		Removed override regarding suppression pool sprays	ESBWR has no suppression pool sprays
RC/F-1.2	RC/F-1.3	Renumbering of steps	Required because RC/F-1.1 was deleted
RC/F-1.2	RC/F-1.3	Removed requirement to operate HPCS and LPCS	ESBWR has no HPCS or LPCS.
		Modified list of systems.	ESBWR RHR or ECCS keep-full systems. LPCI is possible using FAPCS in the LPCI mode. Other containment fill systems in the ESBWR are the Makeup Water System and the Condensate Storage and Transfer System.
RC/F-2	RC/F-2	Changed title	The new title reflects the condition in which water level can be restored up to and beyond TAF. This is associated with the simplification of RC/F for the ESBWR.

Table 18B-8

RPV and Primary Containment Flooding Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
		Added override to open DPVs, initiate GDCS and open SP equalization line	ESBWR passive system for RPV depressurization / venting to drywell and core cooling by gravity drain to RPV
		Added override to maintain level as high as possible if it cannot be restored and maintained above TAF and to maximize injection from external sources	All available systems are already being used to restore level and attempt to maintain it above TAF. If TAF cannot be achieved, there are no additional actions that can be taken.
		Removed override for suppression pool sprays.	ESBWR has no suppression pool sprays
		Removed override for drywell sprays	Drywell sprays will only be used if lower drywell floor thermocouples indicate core debris on the drywell floor.
		System list to restore and maintain level has been modified	ESBWR has no RCIC and RHR. Added CRD high pressure makeup mode and FAPCS LPCI mode.
		Backup system list to restore and maintain RPV level has been modified	ESBWR has no HPCS, LPCS, RHR or ECCS Keep-Full system
		Removed original Cautions #3, #4, #5	Original Cautions #3, #4, #5 involved non – ESBWR systems
		Shortened list of alternate methods to use to vent the RPV	ESBWR does not have flood vent valves, HPCI, RCIC or RHR. The primary means of RPV venting in the ESBWR are the DPVs.
		RPV venting with alternate systems is only required if no DPVs can be opened	One or more open DPVs is the most desirable manner of venting the RPV in this step
--------	RC/F-3	This step was deleted	Steps RC/F-3 thru RC/F-6 are not

Table 18B-8

RPV and Primary Containment Flooding Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
--------	RC/F-4	This step was deleted	directly applicable to the ESBWR because if the DPVs and GDCS function as designed then a core melt is not credible. If the GDCS fails then the ESBWR severe accident assumption that core melt is not arrested in vessel applies. Actions in earlier steps will provide in vessel core debris cooling.
--------	RC/F-5	This step was deleted	
--------	RC/F-6	This step was deleted	
RC/P-1	RC/P-1	Changed to initiate all available Isolation Condensers	ESBWR design has 4 Isolation Condensers
RC/P-2	RC/P-2	Removed original Caution #2	The original Caution #2 is not applicable to ESBWR because it does not utilize heated reference legs.
		Changed open all “ADS valves” to open all “ADS SRVs and DPVs”.	ESBWR depressurization system consists of 10 ADS SRVs and 8 DPVs.
		Modified list of systems for further depressurization	ESBWR does not have HPCI, RCIC & RHR. ESBWR has RWCU/SDC system.
RC/P-3	RC/P-3	Modified list of systems for further cool down	ESBWR does not have HPCI, RCIC & RHR. ESBWR has RWCU/SDC system.
		Removed original Cautions #3, #4, #5	These original Cautions are not applicable to ESBWR
RC/Q-3	RC/Q-3	Removed “until SLC tank water level drops to [0% (low SLC tank water level trip)]”.	ESBWR has no SLC tank or pump, only accumulators. Operator has no control of SLC level in the accumulator and there is no low SLC tank water level trip.

Table 18B-8

RPV and Primary Containment Flooding Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
RC/Q-4.2	RC/Q-4.2	Deleted “Increase CRD cooling water differential pressure” and “Vent control rod drive over piston volumes”.	These methods are not applicable to the FMCRDs used in the ESBWR.

Table 18B-9

Cautions

ESBWR EPG/SAG Caution	BWROG Rev. 2 EPG/SAG Caution	Difference	Basis For Difference
1	1	No Difference	
-	2	Deleted for ESBWR	ESBWR has no heated reference leg instruments.
-	3	Deleted for ESBWR	ESBWR does not have these systems, so their NPSH and vortex limits are not applicable.
-	4	Deleted for ESBWR	ESBWR does not have RCIC system.
-	5	Deleted for ESBWR	ESBWR does not have HPCI or RCIC turbines.
2	6	No Difference	
-	7	Deleted for ESBWR	No NPSH issues for ESBWR because the FAPCS design requires operability without pump cavitations with conditions down to saturation at the suppression pool source.
3	-	Added a caution to identify that if core debris interacts with a water level in the lower plenum that is greater than 0.7 m, a steam explosion may occur.	This phenomenon is documented in the ESBWR severe accident analyses and is added here to prevent actions that will lead to high water level in the lower drywell prior to core melt ejection.

Table 18B-10

Containment and Radioactivity Release Control Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
OPERATOR ACTIONS	OPERATOR ACTIONS	Deleted "Confirm initiation of or manually initiate SBGT" in first override	ESBWR does not have a SBGT system
		Removed CN/T from steps to execute concurrently	CN/T refers to Mark III containments
SP/T	SP/T	Removed original Caution #3	Original Caution #3 does not apply to ESBWR
DW/T	DW/T	Removed "DRYWELL SPRAY IS REQUIRED" and added "Drywell spray can be utilized if drywell water level is less than 0.7m or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor. If drywell water level is greater than 0.7m and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized."	There is no requirement to initiate drywell sprays in the ESBWR. They may be used under the conditions cited.
		Added new Caution #3	New Caution #3 refers to use of drywell sprays in a manner to preclude steam explosions
---------	CN/T	Removed this step	CN/T applies only to Mark III containments
PC/P	PC/P	Removed requirement to initiate suppression pool sprays	ESBWR does not have suppression pool sprays

Table 18B-10

Containment and Radioactivity Release Control Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
PC/P	PC/P	Removed “DRYWELL SPRAY IS REQUIRED” and added “Drywell spray can be utilized if drywell water level is less than 0.7 m or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor. If drywell water level is greater than 0.7 m and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized.”	There is no requirement to initiate drywell sprays in the ESBWR. They may be used under the conditions cited.
		Added new Caution #3	New Caution #3 refers to use of drywell sprays in a manner to preclude steam explosions
		Changed “Primary Containment Pressure Limit C “ to “Primary Containment Pressure Limit”	Primary Containment Pressure Limits A, B, C do not apply to ESBWR because there is one limit that encompasses the limits associated with A, B & C. The Primary Containment Pressure Limit is the ultimate pressure capability for the ESBWR.
PC/R	PC/R	Removed requirement to initiate suppression pool sprays	ESBWR does not have suppression pool sprays

Table 18B-10

Containment and Radioactivity Release Control Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
		Removed “DRYWELL SPRAY IS REQUIRED” and added “Drywell spray can be utilized if drywell water level is less than 0.7 m or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor. If drywell water level is greater than 0.7 m and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized.”	There is no requirement to initiate drywell sprays in the ESBWR. They may be used under the conditions cited.
		Added new Caution #3	New Caution #3 refers to use of drywell sprays in a manner to preclude steam explosions
PC/G associated with Mark I and II containments was used since it was more applicable. PC/G associated with Mark III containments was deleted.			
PC/G-1	PC/G-1	Removed requirement for hydrogen re-combiner operation	ESBWR does not have a hydrogen re-combiner
PC/G-2	PC/G-2	Removed requirement for hydrogen re-combiner operation	ESBWR does not have a hydrogen re-combiner
PC/G-3	PC/G-3	Removed requirement for securing hydrogen re-combiner and hydrogen mixing system	ESBWR does not have a hydrogen re-combiner or mixing system

Table 18B-10

Containment and Radioactivity Release Control Severe Accident Guideline

ESBWR EPG/SAG SAG Step	BWROG Rev. 2 EPG/SAG SAG Step	Difference	Basis For Difference
PC/G-3-3	PC/G-3-3	Removed "DRYWELL SPRAY IS REQUIRED" and added "If drywell water level is less than 0.7 m or lower drywell floor thermocouples indicate the presence of core debris on the drywell floor, drywell sprays can be utilized. If drywell water level is greater than 0.7 m and lower drywell floor thermocouples do not indicate the presence of core debris on the drywell floor, drywell sprays should not be utilized."	There is no requirement to initiate drywell sprays in the ESBWR. They may be used under the conditions cited.
PC/G-4	PC/G-4	Removed requirement for hydrogen re-combiner operation	ESBWR does not have a hydrogen re-combiner
PC/G-5	PC/G-5	Removed requirement for hydrogen re-combiner operation	ESBWR does not have a hydrogen re-combiner
PC/G-6	PC/G-6	Removed requirement for securing hydrogen re-combiner and hydrogen mixing system	ESBWR does not have a hydrogen re-combiner or mixing system
--------	PC/G-6-1	Deleted step requiring suppression pool sprays	ESBWR does not have suppression pool sprays
PC/G-6-1	PC/G-6-2	Renumbering required	Deletion of step required renumbering of subsequent steps
PC/G-6-2	PC/G-6-3	Renumbering required	Deletion of step required renumbering of subsequent steps
Tables 18A-2 thru 18A-4	Table SC-1	This table was generalized for the ESBWR	More detailed information will be provided when plant specific ESBWR EOPs are developed.

18C. ESBWR EPG/SAG INPUT DATA

18C.1 INTRODUCTION

The Emergency Procedure Guidelines (EPGs) provided in Appendix 18A refer to various limits for emergency plant operation. These operation limits are based upon plant specific design parameters. This appendix identifies the plant parameters that are used for calculation of operation limits. The input parameters provided are in accordance with those in Appendix C of the BWROG EPG/SAG Revision 2.

The parameter input values used for calculation of operation limits are given in Section 18C.2. The input parameters will be provided throughout the design phase when specific installation details become available. [The COL applicant is required to input the parameters and calculate the plant specific operation limits (Subsection 18B.2).] In addition, the EPG/SAGs in Appendix 18A will incorporate the results of these calculations.

18C.2 INPUT PARAMETERS

Tables 18C-1 through 18C-9 list all plant parameters that are used for calculation of operation limits. The parameter definitions are in accordance with Appendix C of the BWROG EPG/SAG, Revision 2. Generic parameter values are provided where appropriate. When detailed plant design is completed and specific plant installation details are known, all parameter values can be determined.

18C.3 CALCULATION RESULTS

Figures 18C-1 through 18C-9 contain typical limit curves and are provided for illustrative purposes only. Calculation of these limit curves would be performed at the COL stage in accordance with the methods revised/updated for the ESBWR given in Appendix C of the BWROG EPG/SAG, Revision 2 using the input data discussed above (subsection 18.C.2).

Table 18C-1

BWROG EPG/SAG Rev. 2 Appendix C: FAPCS Suction Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
FAPCS Suction Data		
SuctionID1	Suction identification	FAPCS
Dsuct1	Diameter of suction inlet (in.)	
Hsuct1	Elevation of center of suction inlet [m (ft)]	
WsuctMax1	Flow (maximum) through suction (gpm)	
FAPCS Tabular Data		
Wfapcs-lpci Table	Flow rate (gpm) pf the FAPC LPCI as a function of RPV pressure (psig). Run out to shutoff.	

Table 18C-2

BWROG EPG/SAG Rev. 2 Appendix C: Primary Containment Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
Primary Containment Data		
PCDesign	BWR primary containment design (Mark I, II, or III)	ESBWR
Hhorvent	Elevation of top of horizontal vents (ft)	
HscTap	Elevation of suppression chamber pressure instrument tap (ft))	
HspRef	Elevation of suppression pool water level instrument zero (ft)	
HvbInt	Elevation of bottom of internal Mark II containment wetwell-to-drywell vacuum breakers (ft)	
HventPC	Elevation of containment vent capable of removing all decay heat and located above TAF (ft)	
PdwMaxop	Pressure (maximum normal operating), drywell (psig)	
PdwMinop	Pressure (minimum normal operating), drywell (psig)	
PdwScram	Pressure setpoint for high drywell pressure scram (psig)	
PpcVent	Pressure (maximum) in airspace at which containment vent located above TAF can be opened and closed (psig)	
PscMaxop	Pressure (maximum normal operating), suppression chamber (psig)	
PscMinop	Pressure (minimum normal operating), suppression chamber (psig)	
PspDes	Load (design), suppression pool boundary (psi)	
PspSRV	Load (maximum) on suppression pool boundary resulting from SRV actuation (psi)	
Tcst	Temperature (maximum normal operating) of condensate storage tank water (°F)	
TdwMaxop	Temperature (maximum normal operating), drywell (°F)	
TdwMinop	Temperature (minimum normal operating), drywell (°F)	
TscMax	Temperature capability (maximum) of the suppression	

Table 18C-2

BWROG EPG/SAG Rev. 2 Appendix C: Primary Containment Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
Primary Containment Data		
	chamber and equipment within the suppression chamber which may be required to operate when the RPV is pressurized (°F)	
TscMaxop	Temperature (maximum normal operating), suppression chamber airspace (°F)	
TscMinop	Temperature (minimum normal operating), suppression chamber airspace (°F)	
TspFlood	Temperature (minimum) of suppression pool when containment flooded (°F)	
TspMinop	Temperature (minimum normal operating), suppression pool (°F)	
TspScram	Temperature of suppression pool at which reactor scram is required (°F)	
Vdw	Volume (free) of drywell and vent system (ft^3)	
VscLCO	Volume (free) of suppression chamber above minimum suppression pool water level LCO (ft3)	
WLspMaxLCO	Water level LCO (maximum) of suppression pool (ft)	
WLspMinLCO	Water level LCO (minimum) of suppression pool (ft)	
Parameters for components which are limiting at high containment pressures		
CompID1	Identification	DRYWELL HEAD
Elevation1	Elevation (m (ft))	
Location1	Location (DW or WW)	DW
Material1	Material type	
Strength1	Strength type (yield or tensile)	
Pcalc1	Pressure capability (maximum) (psig)	
Tcalc1	Temperature used to determine Pcalc (°F)	
CompID2	Identification	WETWELL BOTTOM

Table 18C-2

BWROG EPG/SAG Rev. 2 Appendix C: Primary Containment Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
Primary Containment Data		
Elevation2	Elevation (m (ft))	
Location2	Location (DW or WW)	WW
Material2	Material type	
Strength2	Strength type (yield or tensile)	
Pcalc2	Pressure capability (maximum) (psig)	
Tcalc2	Temperature used to determine Pcalc (°F)	
Primary Containment Tabular Data		
Nnzl(n) Wnzl(n)	Table: Nnzl : Wnnzl -- The minimum number of spray nozzles of size "n" through which a single Drywell Spray division can deliver flow to the drywell. (n = 1, 2, 3, etc) The minimum flow that provides a full cone spray pattern for Nnzl (n) (gpm)	
WLsp Vsp Vsc-air	Table WLsp: Vsp: Vsc-air -- Volume of water and airspace in the suppression chamber as a function of suppression pool water level bottom to top of suppression chamber: Suppression pool water level (ft) Volume (ft3) of water in suppression pool for a given height WLsp Volume (ft3) of airspace in suppression chamber for a given water height WLsp	

Table 18C-3

BWROG EPG/SAG Rev. 2 Appendix C: Fuel Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
Fuel Data		
c-clad	Specific heat of clad and channels (BTU/lbm-°F)	
c-fuel	Specific heat of fuel (BTU/lbm-°F)	
Mclad	Mass of clad and channels (lbm)	
Mfuel	Mass of fuel (lbm)	
Nbuns	Number of fuel bundles	1132
Qrx-rated	Power (rated) (MWt)	4500
Lfuel	Length of active fuel (in)	120
	Fuel Type	GE-14
Fafl-15	Minimum active fuel length fraction, which must be covered to maintain PCT<1500°F with injection (%)	
Fafl-18	Minimum active fuel length fraction which must be covered to maintain PCT<1800°F without injection (%)	
FQdh-10	Decay heat fraction 10 minutes after shutdown	0.0221
Fuel Data Tables		
Wg-1500 (Wg-1500Table)	Fuel-n: Wg-1500-n -- Minimum bundle steam flow required to maintain PCT<1500°F at peak LHGR (lbm/hr) Fuel-n Wg-1500-n (lbm/hr) 1 -------- 2 -------- 3 --------	

Table 18C-3
BWROG EPG/SAG Rev. 2 Appendix C: Fuel Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
Qdh (Table)	Time (min): Qdh (%) -- Decay heat after reactor shutdown: Time (min.) Qdh-% Time Qdh 2 3.038 120 1.057 4 2.658 150 0.9901 6 2.458 200 0.9661 8 2.320 300 0.8673 10 2.212 450 0.7863 15 2.009 600 0.7255 20 1.862 900 0.6509 25 1.747 1200 0.6002 30 1.653 1500 0.5622 35 1.574 1800 0.5331 40 1.507 45 1.450 50 1.400 60 1.318 90 1.155	

Table 18C-4

BWROG EPG/SAG Rev. 2 Appendix C: RPV Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
RPV Data		
dPvent-rpv	Differential pneumatic pressure (minimum) required to operate RPV vent valve(s) (psid)	
Hvent-rpv	Elevation of lowest RPV vent valve pneumatic solenoid (ft)	
Mf-rpv-cld	Mass of water in shutdown cooling, and RWCU loops and in RPV with water level at high level trip setpoint and water temperature at 68°F (lbm)	
Mf-rpv-hot	Mass of water in RWCU loops and in RPV with water level at high level trip setpoint and water temperature at saturation temperature for minimum pressure at which an SRV is set to lift (lbm)	
Mg-rpv-hot	Mass of saturated steam in RPV and main steam lines inboard of outboard MSIVs with water level at high level trip setpoint and pressure at minimum at which an SRV is set to lift (lbm)	
Mrpv	Mass of RPV, internals and main steam lines inboard of outboard MSIVs (lbm)	
Psup-rpv	Pressure (minimum normal operating), pneumatic supply system for RPV vent valve(s) (psig)	
WLrpv-baf	Water level at bottom of active fuel (in.)	

Table 18C-5

BWROG EPG/SAG Rev. 2 Appendix C: RPV Level Instrument Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
RPV Water Level Instrument Data		
Provide the following information for each RPV water level instrument range		
Fhtc	Heat transfer coefficient (zero unless instrument has heated reference leg) (dimensionless)	
Hrange-lo	Elevation of instrument range low end (ft)	
Href-dw	Elevation of reference leg drywell penetration (ft)	
Href-surf	Elevation of condensing chamber water surface (ft)	
Hvar-dw	Elevation of variable leg drywell penetration (ft)	
Hvar-tap	Elevation of variable leg RPV tap (ft)	
Prpv-cal	Pressure in RPV at calibration (psig)	
Tdw-cal	Temperature in drywell at calibration (°F)	
Trb-cal	Temperature in reactor building or containment at calibration (°F)	
WLrpv-hi	Water level at instrument range high end (in.)	
WLrpv-lo	Water level at instrument range low end (in.)	

Table 18C-6

BWROG EPG/SAG Rev. 2 Appendix C: SLC System Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
SLC System Data		
FB10-slc	Atomic abundance of B10 isotope (i.e., boron enrichment) as a fraction of all boron in the SLC Accumulator (0.1978 if naturally occurring boron is used)	
Tslc	Temperature (maximum normal operating) of water in SLC Accumulator (°F)	
Wslc	SLC injection flowrate for boron injection under 10CFR50.62, the ATWS rule (gpm)	
XB-cld-nat	Cold shutdown boron concentration requirement for naturally occurring boron (ppm)	
XB-hot-nat	Hot shutdown boron concentration requirement for naturally occurring boron (ppm)	
XB-slc	Concentration (minimum normal operating) of boron in SLC Accumulator (ppm)	

Table 18C-7

BWROG EPG/SAG Rev. 2 Appendix C: SRV System Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
dPsrv	Differential pneumatic pressure (minimum) required to open SRVs (psid)	
Hsrv	Elevation of lowest SRV pneumatic solenoid (ft)	
Nsrv-ads	Number of SRVs dedicated to ADS	10
Pq-code	Stress (code allowable) for SRV quencher (kpsi)	
Pq-des	Stress (design basis) for SRV quencher (kpsi)	
Pqs-code	Stress (code allowable) for SRV quencher support (kpsi)	
Pqs-des	Stress (design basis) for SRV quencher support (kpsi)	
Prpv-tp	Pressure in RPV used for SRV tail pipe design calculations (psig)	
Psrv-lift	Pressure (minimum) in RPV at which an SRV is set to lift (psig)	
Psrv-name	Pressure for SRV per nameplate (psig)	
Psup-srv	Pressure (minimum normal operating), pneumatic supply system for SRVs (psig)	
Ptp-code	Stress (code allowable) for SRV tail pipe (kpsi)	
Ptp-des	Stress (design basis) for SRV tail pipe (kpsi)	
Ptps-code	Stress (code allowable) for SRV tail pipe support (kpsi)	
Ptps-des	Stress (design basis) for SRV tail pipe support (kpsi)	
Type of SRV (Name, Model#)	Dresser Crosby Target Rock Dikkers Sebim	
WLsp-srv	Water level of suppression pool used to determine maximum suppression pool boundary load resulting from SRV actuation (ft)	
WLsp-tp	Water level of suppression pool used for SRV tail pipe	

Table 18C-7

BWROG EPG/SAG Rev. 2 Appendix C: SRV System Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
	design calculations (ft)	
Wsrv-name	Flowrate through SRV per nameplate (lbm/hr)	
WLL-n (Tables)	WLsp: WLL-n --- Water leg length (*WLL-n*) in tail pipe (for discharge line "n") as a function of suppression pool water level (*WLsp*) referenced to 0 for *WLsp* at level used for SRV tail pipe design calculations. One table for each SRV discharge line (SRVDL 1…n)).	

Table 18C-8

BWROG EPG/SAG Rev. 2 Appendix C: Generic Input Data

PARAMETER	PARAMETER DEFINITION	VALUE
c-steel	Specific heat of steel (BTU/lbm-°F)	0.128
dPtp-dPrpv	SRV tail pipe system load variation with RPV pressure (%/psig)	0.10
dPtp-dWLL	SRV tail pipe system load variation with SRVDL water leg length (%/ft)	5.00
F-vortex	Air entrainment threshold Froude Number	0.80
FB10-nat	Nuclidic abundance of B10 isotope as a fraction of naturally occurring boron	0.1978
FB11-nat	Nuclidic abundance of B11 isotope as a fraction of naturally occurring boron	0.8022
K1	Conversion constant (BTU/hr-MWt)	3,412,000
K2	Conversion constant (BTU/min.-MWt)	56,868
K3	Conversion constant (gal/ft3)	7.48
M-B10	Nuclidic mass of B10 isotope	10.01
M-B11	Nuclidic mass of B11 isotope	11.01
M-B-nat	Atomic mass of natural boron (B)	10.81
M-H	Atomic mass of hydrogen (H)	1.01
M-Na	Atomic mass of sodium (Na)	22.99
M-O	Atomic mass of oxygen (O)	16
Material Strength	Temp (°F): Fyield –n: Ftens –n -- Normalized material strengths. Information to be provided for each material (1…n). Temp (°F) / Yield Strength Fyield-1 / Tensile Strength Ftens-n	
SRV Re-opening Pressure Table:	SRV Type: Re-opening Pressure (Psid)	

Table 18C-9

BWROG EPG/SAG Rev. 2 Appendix C: Assumed and Supplemental Data

PARAMETER	PARAMETER DEFINITION	VALUE
Assumed Data		
TdwMinX	Minimum drywell temperature (°F)	
TdwMaxX	Maximum drywell temperature (°F)	
TscMinX	Minimum suppression chamber temperature (°F)	
TscMaxX	Maximum suppression chamber temperature (°F)	
Supplemental Data		
Primary Containment Supplemental Data		
Hsc0	Elevation of bottom of suppression chamber (ft)	
HpcRef	Elevation of primary containment water level instrument zero (ft)	
nSRV	Total number of SRVs	18
TdwMaxInd	Maximum indicated drywell temperature (°C)	
SLC Supplemental Data		
FB10_spb	Atomic abundance of B10 isotope (boron enrichment) as a fraction of all boron in enriched boron used for alternate boron injection (needed only if enriched boron is used for alternate boron injection)	
Kslc_wl	SLC Accumulator volume conversion factor (gal/unit)	
MbxUnit	Borax container capacity (lbm borax) (needed only if borax and boric acid are used for alternate boron injection)	
MbaUnit	Boric acid container capacity (lbm boric acid) (needed only if borax and boric acid are used for alternate boron injection)	
MspbUnit	Sodium pentaborate container capacity (lbm sodium pentaborate (needed only if enriched sodium pentaborate is used for alternate boron injection)	
rhoCal	Density of solution in the SLC Accumulator assumed for calibration of SLC Accumulator level instrument (lbm/ft3) (needed only if SLC Accumulator level indication is affected by solution density)	

Table 18C-9

BWROG EPG/SAG Rev. 2 Appendix C: Assumed and Supplemental Data

PARAMETER	PARAMETER DEFINITION	VALUE
rhoSLC	Density of solution in the SLC Accumulator with boron concentration at XB-slc and temperature at Tslc (lbm/ft3)	
WLslcMin	Water level (minimum normal operating) in SLC tank	
WLslcUnits	SLC Accumulator level indicator units	
WLslcErr	Is the SLC Accumulator level indication affected by changes in solution density?	
AltBoronMethod	Alternate boron injection method:	
Pump NPSH Supplemental Data		
	Provide information for all pumps (1….n)	
Pump-n	Pump identification	
HminNPSH-n	Elevation of minimum suppression pool water level for pump operation within NPSH and vortex limits	
WloopMax-n	Maximum loop flow (gpm)	
hLRefTable-n	Suction piping reference head loss: % Loop Flow In Segment / Head Loss (ft) / Reference Flow (gpm) Strainer: Segment 1: Segment 2:	
NPSHTable-n	Required net positive suction head (ft) as a function of pump flow—maximum ten data points, from zero to maximum flow: Wpump (gpm) / NPSHreq (ft)	

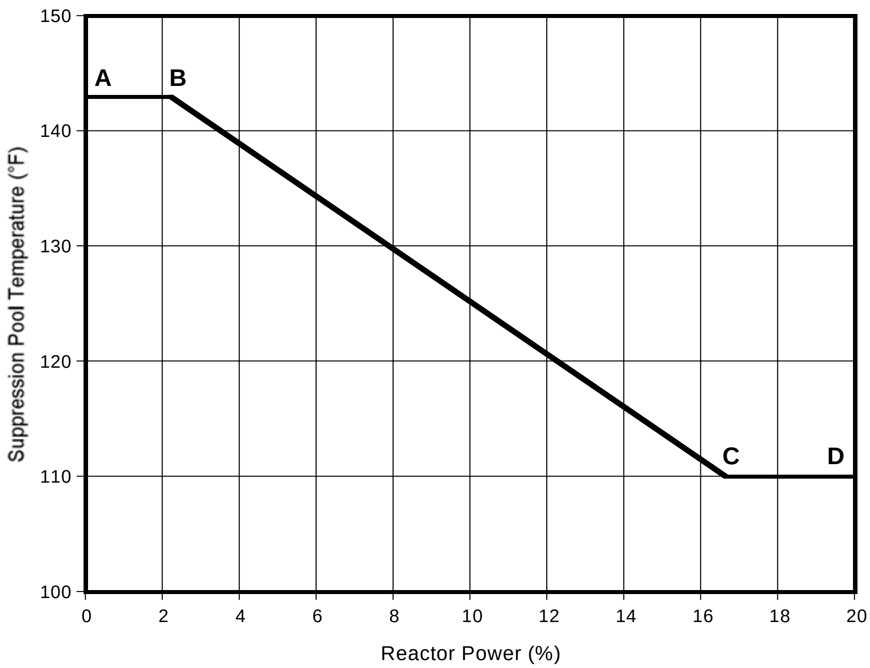

Figure 18C-1. Typical Boron Injection Initiation Temperature
(Plant Specific Operating Limit to be provided at COL)

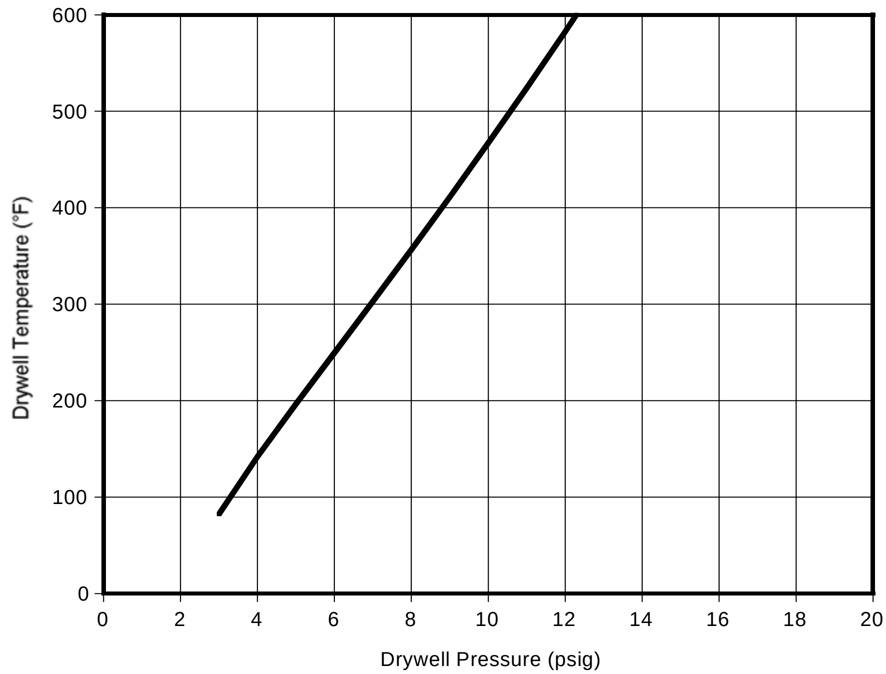

Figure 18C-2. Typical Drywell Spray Initiation Limit
(Plant Specific Operating Limit to Be Provided at COL)

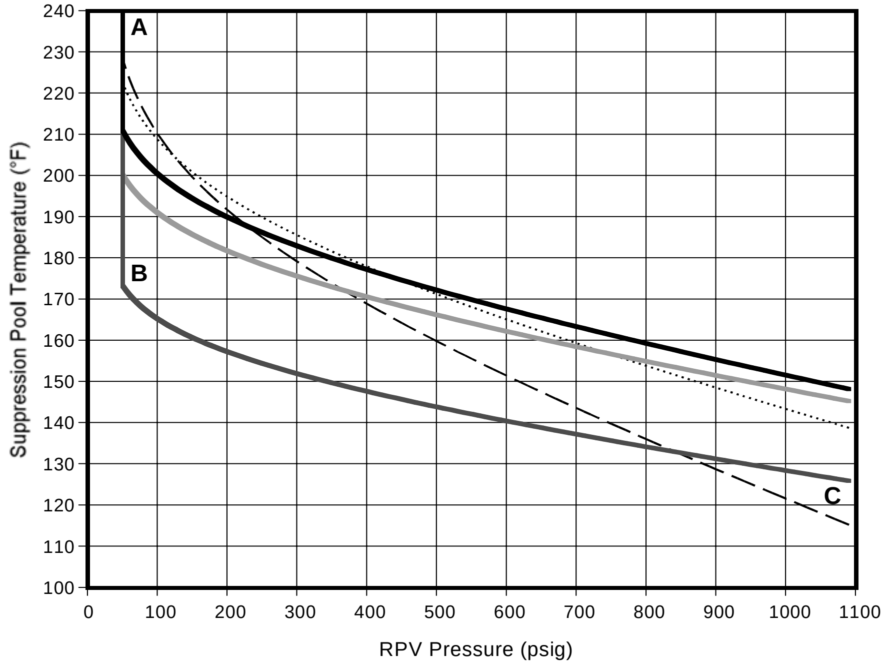

Figure 18C-3. Typical Heat Capacity Temperature Limit
(Plant Specific Operating Limit to Be Provided at COL)

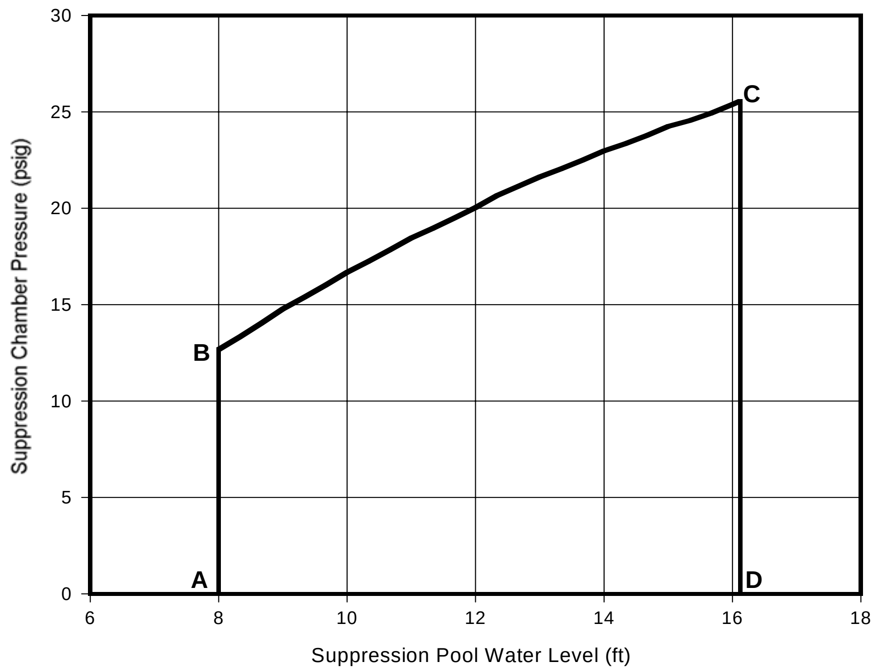

Figure 18C-4. Typical Pressure Suppression Pressure Curve
(Plant Specific Operating Limit to Be Provided at COL)

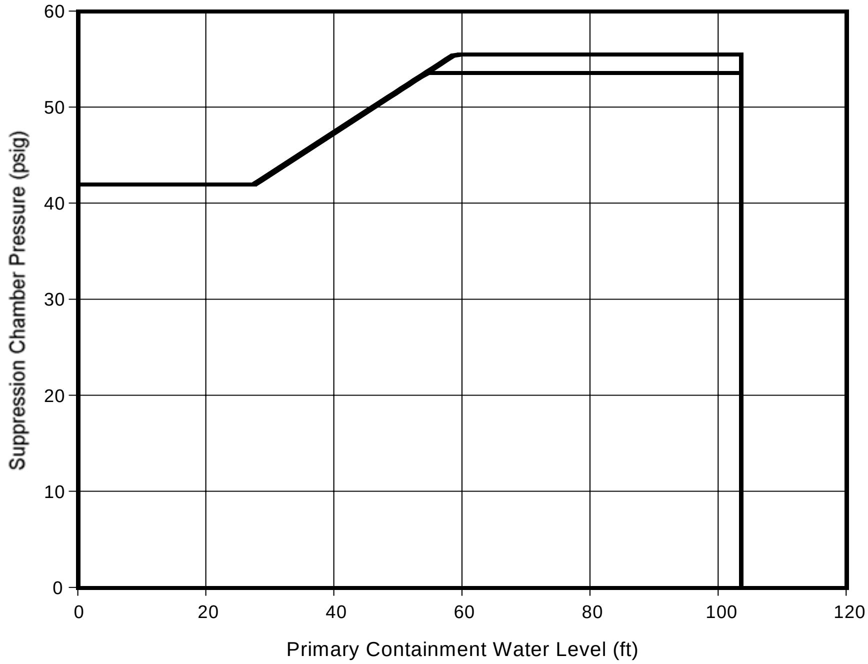

Figure 18C-5. Typical Containment Pressure Limit
(Plant Specific Operating Limit to Be Provided at COL)

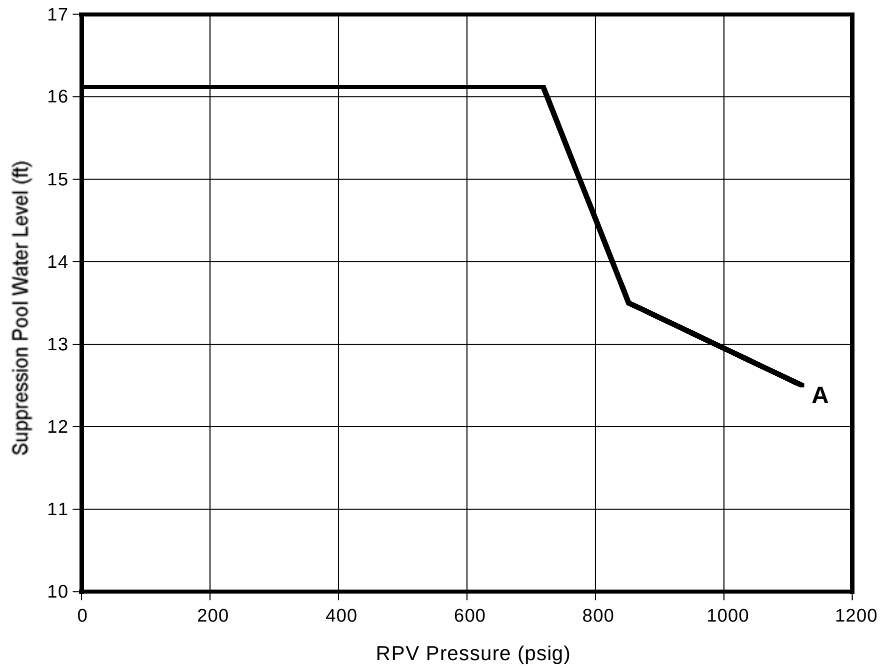

Figure 18C-6. Typical SRV Tail Pipe Level Limit
(Plant Specific Operating Limit to Be Provided at COL)

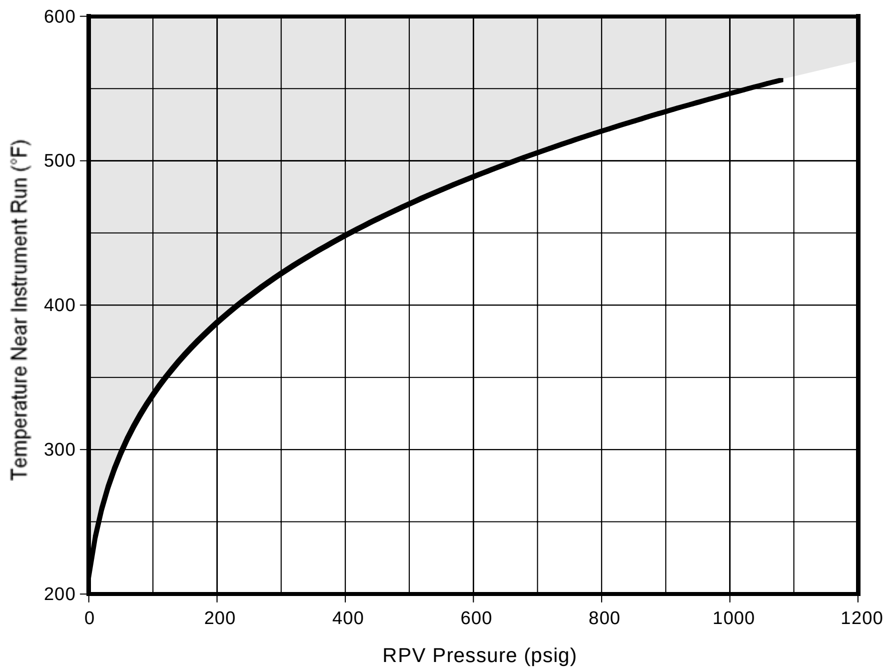

Figure 18C-7. Typical RPV Saturation Temperature