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ASEA BROWN BOVERI

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LD-92-029

Docket No. 52-002

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: Human Factors Engineering - Revised RAI Responses

Dear Sirs:

Enclosure I to this letter provides revised responses to RAIs 620.5, 620.13, 620.16, 620.24, and 620.25, as agreed at the December 4, 1991, meeting with NRC staff. Other revised responses will be provided in the near future.

Should you have any questions on the enclosed material, please contact me or Mr. Stan Ritterbusch of my staff at (203) 285-5206.

Very truly yours,

COMBUSTION ENGINEERING, INC.

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gdh:lw

Enclosures: As Stated

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Enclosure I to
LD-92-029

REVISED RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION
I&C AND HUMAN FACTORS RAIs

Question 620.5:

Chapter 18 Section 17.7.1.1.2 describes the use of 11 colors; TE 790-01 Paragraph 3.1.2, Point 1, identifies another two colors; and SD640 Paragraph 6.1.4.1 identifies two or more colors. There is no clear and concise presentation of the information coding scheme used in the System 80+ control room.

Provide a matrix of all the information coding methods and their meanings used in the control room. This would include, at a minimum, the colors, the symbols, changes to alphanumeric and symbols such as case or size, any patterns, position/location/denotation of data that would convey information, flash, flash rate, figure-background changes, reverse video, color changes (include contrast ratios), changes in intensity, etc., or any combinations thereof that are used on software driven and hardwired displays that provide some kind of quantitative or qualitative information to operators or maintenance personnel.

Response to 620.5 (Revision 1):

The issue of Nuplex 80+ coding was one of the seven technical issues addressed in detail during meetings with the NRC Human Factors Branch on 11/17/91 and 12/4/91) as well as in the supplemental response to RAI 620.13. This response is being provided to Question 620.5 to further clarify the matter and provide details requested in the 12/4 meeting. The following issues will be addressed:

a) The Nuplex 80+ coding scheme and the identification of the documents that the details reside are provided below

b) Examples of rationale (including Human Factors Engineering rationale) for selection and assignment of individual code dimensions

c) Differences in coding as they pertain to different equipment (such as CRTs, flat panel displays, etc.)

The revised coding scheme matrix was provided in the table presented at the 12/4 meeting and attached here for reference. Example tables and figures are also attached for reference, to demonstrate and provide examples of systematic use of human factors

engineering in the application of information coding.

Descriptions of coding and symbology may be found in several documents which have previously been provided. In addition to the Information Systems document excerpted here, the Human Factors Standards and Guidelines Document provides such information. Although coding and symbology may be addressed in other project documents, such as other system descriptions, all coding conventions are defined in the two aforementioned ones, and are standard throughout the design.

Coding conventions do not vary across hardware or software types in Nuplex 80+. The same type of line (e.g.-thickness, style), nomenclature, color code, flash rates, and other aspects of coding are used regardless of hardware type. For example, red has the same meaning on the Integrated Process Status Overview display (the 'big screen') as on CRT displays, pushbutton switches, and other places where it is used as a coding tool. Thus, the coding matrix provided in this response is applicable to all types of hardware. The only variance to this coding standardization is that the flat panel displays are monochromatic (this was necessary in order to provide alarms, indicators, and process controllers on qualified hardware). However, this variance does not adversely affect the man-machine interface since, in all cases, color is a secondary coding mechanism. That is, anywhere where color conveys information, such as red for an open valve, it is redundant with another coding mechanism (in this case whether the valve symbol is filled or hollow).

The fact that color is only a secondary coding technique assures that on monochromatic displays, there is no contradictory coding technique, merely the absence of the redundant information coding method. This assures positive transfer of training from hollow fill and that the man-machine interface will be consistent throughout the control complex.

Operator error due to equipment failure causing coding confusion is not considered a concern in Nuplex 80+. The man-machine interface is resistant to hardware failures which would cause coding methods to be mistaken, as explained below:

CRTs: Degradation would be caused by gun failure or gun calibration. Either would cause a failure of color, not shape coding. Color coding is a redundant, secondary coding method and is easily detectable. Further, any display can be called up on any of the numerous CRTs in the control complex, so backup hardware is always available.

Flat Panel Displays: Degredation would take the form of pixel failure. Pixel failures are unlikely to confuse the operator because all symbols/lines use multiple pixel widths. Further, there is always a second source of flat panel display control (i.e.-if one process controller fails, an operator's module can be used while replacement is made).

Switch Indications: There will be two or more light sources in each lens. Hence the failure of one source will not eliminate indication but will immediately alert the user to a maintenance need.

Further, periodic tests will be performed and hardware will meet testing requirements set forth by the NRC. Hardware which shows signs of failure will be immediately replaced or repaired, as it is in conventional plants today.

Coding Examples and Rationale:

It is beyond the scope of this response to explain the source of every coding technique (note that main coding methods alone fill a 20 x 25 grid on the attachment). Some examples are provided below to illustrate the process used in choosing coding techniques based on human factors rationale. Similar methods were used to develop all coding types and the source materials cited below were utilized as were other standard human factors publications such as Salvendy, Van Cott & Kincade, pertinent NUREGs, et. al. A full listing of main source materials may be found in CESSAR/DC and in the original response to RAI 620.31. The Design Bases Document for System 80+ Human Factors Standards and Guidelines lists all HF bases used by the design team. This document will be provided in the upcoming additions to the Reference Design Documentation.

Letter Height: Minimum MMI letter heights were determined using the viewing distances based on control panel size and the visual arc formula found in NUREG-0700. Larger sizes for hierarchical information were based on hierarchical label setups described in report EPRI-NP-3659. The practice was standardized in the HF Standards and Guidelines and the Information Systems documents.

Color: Based on guidance in NUREG-0700, a limited set of basic colors were chosen, to avoid the 'rainbow effect' from overcoding. The color set will be used in the context of control panels, for both control devices and information displays. The bases for this coding may be found in the HF Standards and Guidelines Bases Document. Samples of rationale are provided below.

Black: background color, label text
(rationale: provides high contrast)

Blue: component control status: auto/permissive/on-line
(rationale: Industry standard per EPRI NP-3659)

Green: component status: off/inactive/de-energized/no-flow
(rationale: nuclear power industry convention, meets NUREG-0700 6.5.1.6c.(2))

Red: component status: on/energized/active flow status
(rationale: same as for green)

Yellow: alarm annunciator
(rationale: good warning (attention getting) color per EPRI-3659, available on electro-luminescent displays)

Orange: Component control status: manual; non-alarm annunciator
(rationale: industry convention, supported by orange uses listed in EPRI-3659)

Light Grey (lo intensity white): Static data (e.g. menu options)
(rationale: Per NUREG-0700)

Grey: Dividing lines, piping, non-controllable components, grids, and miscellaneous items; minimally informative and static support items
(rationale: Per table 6.5-7 of NUREG-0700, also for grey & lt. grey, note that items are expected to be of low prominence)

Cyan: Descriptors of dynamic process parameter values
(rationale: draws attention well but not as readable as white, therefore provides visual search landmarks but a non-critical distinction

White: Dynamic data (e.g.-process parameter values & system response to operator touch)
(rationale: high contrast, used per EPRI-3659 for best readability of most informative info)

Purple: wording on labels for post-accident monitoring indicators
(rationale: good contrast with white label background; purple used sparingly per EPRI-3659)

Component and System Status Coding (Refer to Figure 2 for an example):

Use of Fill for inactive/closed/off Components: Standard based on consistency with industry convention for valves in P&ID drawings. Easily discriminable on CRTs and flat panel screens

Use of Hollow for active/open/on: same as for fill; also provides good contrast to fill

Use of Dark (Red/Green/Fill-no fill): Matches conventional control panels which use lights out, leaving dark red/green lenses, to indicate loss of control power. The Nuplex 80+ convention is common to the whole MMI (IPSO, CRTs, control switch backlights, etc.).

Use of Triangles for Active/Inactive System Status: Unique use of triangle shape, no existing or conflicting industry conventions for 'system'. Uses standard Nuplex 80+ red/green and holow/fill

Asterix: Indicates suspect data, used for salience per NASA USE-100, unique use of this code

Underline: Used below descriptors to indicate that there is an operator aid associated with the parameter or component (provides information but low importance). Same rationale as for asterix

Alarm Coding Rationale: (refer to Table 1) Below is the rationale for the alarm coding methods used in Nuplex 80+. Refer to Section 2.6 of the Human Factors Program Plan for System 80+ for a full list of design basis references for the alarm system. In general, a combination of this guidance and the practical limits on display technology, plus flash rates and other clearly specified guidance in NUREG-0700, Sections 6.6.3 & 6.6.4 provided the design basis.

Alarm Priority: Alarms are shape and salience-coded for priority with increasing salience corresponding to higher priority. Salience levels were chosen by empirical evaluation of prototypes. See Figure 1 and Table 1 for details.

Alarm Status: Changes in status of alarms are indicated by flashing and hue, good attention-getting features (per EPRI NP 3659, et. al.). Fast and slow flash rates are used as described in Table 1. Exact flash rates are still to be determined but will fall within the ranges of NUREG-0700. Duty cycles of 50-50 and 25-75 are used as appropriate based on NASA-3000. See Table 1 and Figure 1 for details. Three hues of yellow were selected to allow coding of multiple-status alarm tiles. The 3 hues were acceptable per NASA-3000 and prevented masking, a common problem with multiple input or combined alarms on existing systems.

Audible Annunciation: Momentary audible tones give clear, unambiguous announcement of new, continuing unacknowledged, and cleared alarms. Limiting tone to momentary presence avoids disrupting operators. Tones were selected for sound characteristics per NUREG-0700 and EPRI NP-3448.

The coding techniques conform to general human factors good practice and NRC guidance. Overall coding schemes were chosen to be simple, unambiguous and non-conflicting based on a distillation of the best reference materials available. Similar rationale exists for all coding used in the Nuplex 80+ control complex.

TABLE 1

EXAMPLES OF ALARM CODING

ALARM CONDITIONS

WITHIN THE ALARM SYSTEM, DIFFERENT PRIORITY CONDITIONS ARE REPRESENTED BY THE APPLICATION OF COLOR (shade), DESIGN, AND FLASH RATE. THE TABLE BELOW LISTS THE CONDITIONS AND THEIR DISPLAY ATTRIBUTES:

Unacknowledged Alarms	Display Attribute (same on tile or CRT)
New Priority 1	Fast flash & reverse video
New Priority 2	Solid fast flashing wide border
New Priority 3	Solid fast flashing brackets
New Operator Aid	fast flash orange underline
Acknowledged Alarms	
Cleared Priority 1	slow flash, reverse video
Cleared Priority 2	slow flash, wide border
Cleared Priority 3	slow flash, at brackets
Cleared Operator Aid	not displayed, goes directly to reset
Existing Priority 1	solid background
Existing Priority 2	solid wide border
Existing Priority 3	solid brackets
Existing Operator Aid	solid dark orange
Reset	static non-flashing

Notes:
1-Color: New=Bright Yellow, Existing=Medium Yellow, Cleared=Dull Yellow
2-The highest priority unacknowledged alarm is shown where multiple conditons exist
3-The highest priority acknowledged alarm is shown where multiple conditions exist
4-Unacknowledged and acknowledged alarms are show simultaneously

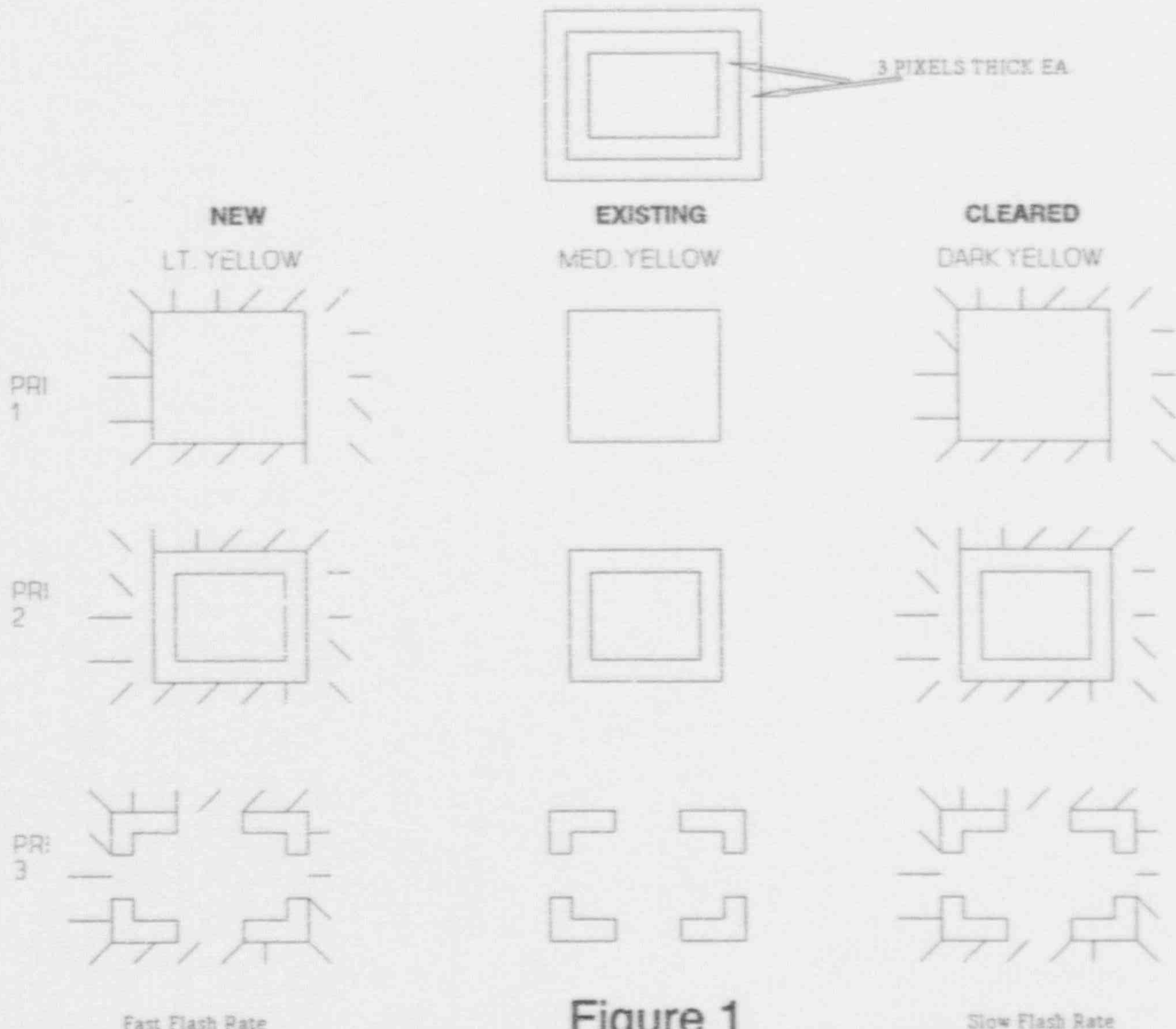

Figure 1
Examples of Alarm Coding

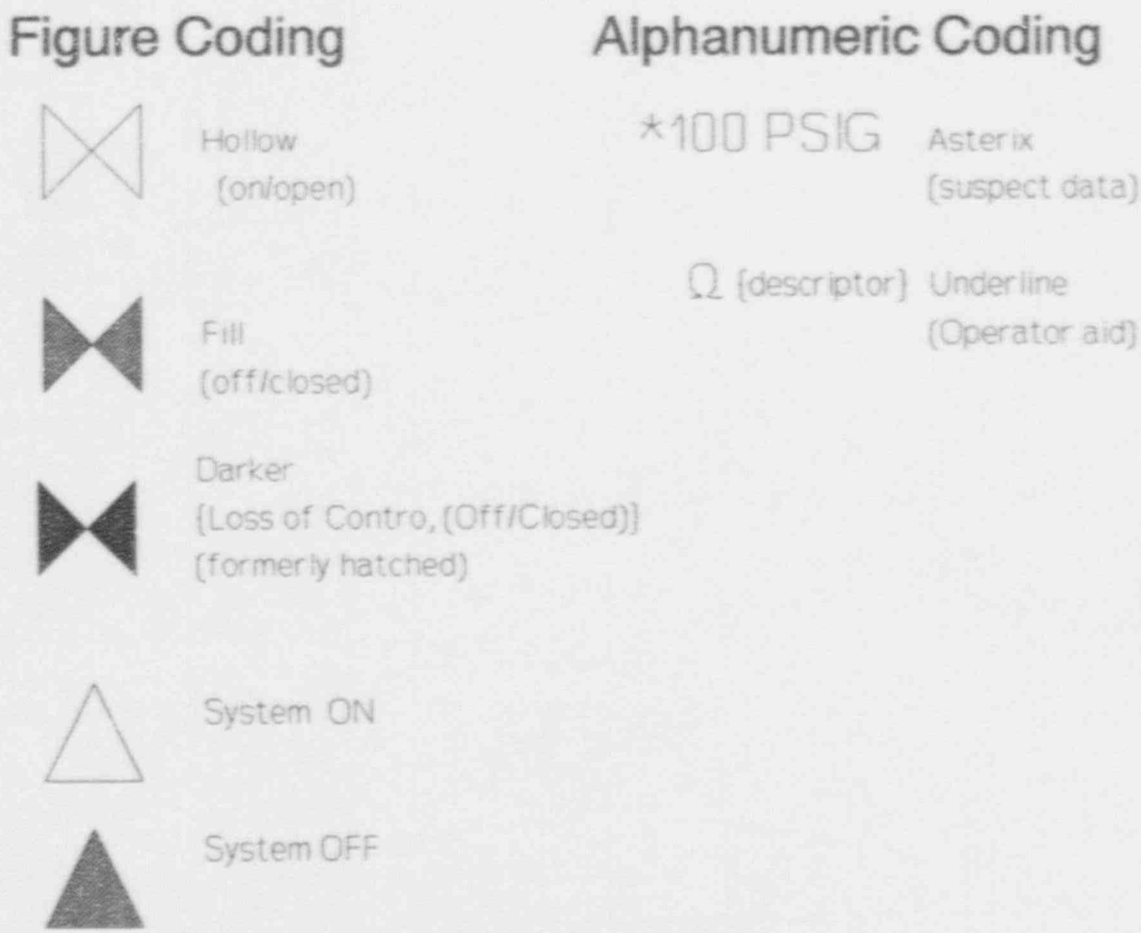

Figure 2

Examples of Nuplex 80+ Coding Techniques

(USE IN CONJUNCTION WITH 620.5-1 CODING MATRIX)

Question 620.13:

How does C-E plan to demonstrate that "improved plant comprehension" has been achieved over the reference design for:

a. improved alarm presentation and handling

b. continued plant operation with loss of 1 or 2 diverse information display systems

c. integration of normal and accident monitoring displays

d. improved usability of the information presentation methods used to reduce required operator information processing requirements.

Response to 620.13, Item a. (Revision 1):

C-E has addressed the issue of the alarm hardware and how it was chosen, based on analyses and evolution, in Sections 3.3 and 3.4 of the Human Factors Program Plan which is being submitted as an additional response to RAI 620.1. However, it should be noted that alarm hardware specifics for Nuplex 80+ are not final at this time. This additional information is in response to the alarm technical areas discussed during 11/17/91 and 12/4/91 meetings between the NRC Human Factors Branch and C-E, GSI HF 5.2, GSI I.D.5(1) and to satisfy NRC requests for additional detail in 620.13 (a).

The phraseology from CESSAR/DC such as "improved plant comprehension" of the alarm system requires clarification. Features such as improved comprehension and reduced cognitive workload are desirable and, indeed, are design goals of the man-machine interface design for Nuplex 80+. However, it would be extremely difficult or impossible to measure the dependent variable or conduct studies to objectively determine if these goals were reached. In addition, there is no available baseline data for such comparisons. The Nuplex 80+ alarm scheme will result in some such improvements as shown by reduction of actual numbers of alarm tiles and other hardware features. However, the design basis is to demonstrate that adequate operator performance is achieved, not optimal or improved performance. See supplemental response to RAI 620.12 for a further explanation, if necessary.

Adequate operator performance will be demonstrated through the analyses and reviews described in the Human Factors Program Plan. Operator performance during transients will provide the basis of this demonstration. Reviews of alarm inputs and systems designs from existing, licensed System 80 plants will supplement this determination. Design reviews of the DIAS system (which incorporates the alarm tiles) and the CRTs continue to provide a venue for human factors input to the system, as well as for input from experienced operators on the permanent staff of the design team. Prototyping provides a further opportunity for review and

design input, as described in the plan.

Systematic analyses of operations are planned for the entire Nuplex 80+ design, as outlined in the program plan. These include validation, as described in the plan and following the methodology used in the Nuplex 80+ Function and Task Analysis Report and the Nuplex 80+ Verification Analysis Report, both of which have been submitted as reference documentation for the design certification process. Additional analyses will include suitability reviews and validation. Alarm system analysis was not performed prior to Nuplex 80+ design because of the plethora of industry and regulatory material available. Instead, an evaluation of this material was conducted, as described in Section 2 of the program plan.

The following background studies and references contributed to the Nuplex 80+ alarm scheme:

-The Halden Reactor Studies

-Control Room Reviews

-EPRI ALWR Requirements, Chapter 10

-NUREG-0700, Chapter 6

-NUREG/CR-3217, 3898

-EPRI NP-3448

These studies and references influenced the design in the following ways:

-Halden Studies: Provided basis for using critical functions and success path monitoring as bases for alarms.

-Control Room Reviews: DCRDRs highlighted human factors problems with the existing System 80 annunciation methods, allowing designers to avoid these pitfalls. This combined with other lists of 'classic' alarm system problems (e.g., in NUREG-0700), to develop the list presented below:

NUPLEX 80+ ALARM DEVELOPMENT

TYPICAL ALARM SYSTEM HF PROBLEMS	THE NUPLEX 80+ SOLUTION
1. Alarm Overload/Cascading	Alarm reduction based on:
a) multiple alarms for same condition (e.g.-channel a, b,c,d,x,y)	-signal validation prior to alarm checking, eliminates multiple channels
b) spurious alarm due to instrument failure	-signal validation eliminates spurious alarms
c) inappropriate alarms for plant/equip. status	-mode/equipment/EOG dependency ensures alarms are relevant & not due to normal line-up
d) poor organization/priority	-spatial dedication for alarms relating to significant operator actions only; provides greater salience to most important alarms
2. Nuisance Alarms -alarms not valid or appropriate *spurious alarms *contact bounce *phantom alarms	Nuisance alarms eliminated: -software smoothing (eliminates contact bounce) -mode/equipment dependency
3. Audible Signal Problems	-No silencing required -separate tones/freq. for new & cleared alarms -momentary reminder tones (for unack. new & cleared)
4. Alarm Format Problems -wording and lettering -grouping and location -poor organization -unclear coding	Addressed via systematic application of human factors and industry guidance for: -wording, letter height -alarm categorization -panel & screen location -coding and meaning
5. Conventional Hardware Problems -inconsistent lighting levels -bulb burnout -inadequate change capability	Eliminated via DIAS/CRT: -no bulbs or LEDs -software disable/alarm downgrade

-too many combined alarms	-many more inputs possible
a) hard to know cause of flash	a) exact alarm messages
b) combined reflash masks priorities	b) sorts priority-shows higest
c) combined reflash masks existing	c) alarms can be shown together (via coding)
d) combined reflash hides cleared or masks uncleared to show cleared	d) shows all conditions; cleared and existing
6. Hard to test	-alarm testing from same input in conjunction w. control/protection system -active display heartbeat
7. Alarm Significance Unclear	Significance Visual Mapping used to relate alarm to procedure being used
8. Classic Alarm Acknowledge Problems (Global/Local)	Alarm Acknowledge Criteria -single point, single page to ensure alarms are recognized before flashing & audibles are eliminated -stop flash/resume eliminates visual noise during conditions where the operator is unable to individually recognize/ack. each new condition
9. Alarm Access Difficulty in CRT navigation	-alarm mapping to sectors, directories allows 2-touch access to all alarms, lists allow 1-touch access; for single alarm conditions, it is automatically identified in display window
10. Multiple Alarm Conditions difficult to diagnose	-alarm lists sorted by time or plant area

-EPRI ALWR Requirements: These requirements, as they pertain to alarm system design, were factored in to the Nuplex 80+ alarms scheme to develop features and definitions noted in the 'Key Factors in Generic Alarm System Development' provided below:

KEY FACTORS IN GENERIC ALARM SYSTEM DEVELOPMENT
NUPLEX 80+

-Alarm Reduction Method
*Process Representation Value

-Mode Considerations
*Mode Criteria
*Mode Switching Methods

-Alarm Prioritization
*Prioritization Display Coding
*Prioritization Criteria
*Prioritized Display Behavior

-Alarm Acknowledge Features
*Acknowledgement Criteria
(single point, single page, viewable only)
*User Query/Acknowledgement Response Behavior

-Ops. Alarm Message/List Format Behavior

-DIAS Design
*DIAS tile screen design and Behavior
*DIAS/DPS Alarm Interaction/Allocation

-Audible Design

-Stop Flash/Resume Design

-Alarm Presentation Mapping Design:
*Tiles/Parameter
*Component/parameter Descriptors
*System/Train/Flowpath Descriptors
*Page and Directory Options

-Alarm Significance Mapping Design Criteria
*EPG Selection Dependency; 1 to 1 mapping for Success

Paths
    *CF, PH, ED

-Compliance to non-alarm Regulatory Guidance:
    *Reg Guide 1.97
    *NUREG-0696

-NUREG-0700, Chapter 6: All functional requirements for the alarm system man-machine interface listed in this document were used as design goals and were met.

-NUREG CR/3217: This reference, along with many industry reports such as EPRI NP-3659 and 3448 helped form the basis for 'Nuplex 80+ Alarm Acceptance Criteria', provided (for illustration, these are not formal DAC) below:

NUPLEX 80+
Alarm Acceptance Criteria

1. Verify Mode-Dependency Of Alarms
   (NO ALARMS INAPPROPRIATE TO PLANT MODE)

   -Normal Operations
   - *plant dark at power
   - *no 'status' alarms (no action required) present

   -Normal Transients
   - *no extraneous alarms during SU, SD, HS
   - *no external alarms during normal Rx trip

2. Alarms Specific to Event

   -Abnormal Transients
   - *alarms correct for event:
     LOCA, SGTR, ESDE, LOOP, LOAF, BLACKOUT
     N+1 EVENT (appropriate to functional recovery)

   -Normal Reactor Trip
   - *alarms indicate only unusual items not normal 'wake of trip' status information

   -Dynamic simulation verifies:
   - * no cascading alarms (alarm avalanche)
   - * no alarms based on inappropriate equipment status
   - * no phantom alarms (cause must be discernable)

3. Verify Alarm Priorities

   -All Alarms Must Meet Priority Definition when Simulated

4. Reduced Number of Alarms

   -The number of alarm tiles actuated during events is less in Nuplex 80+ than in conventional plants)
   - *examine transients noted above (high workload)
   - *number of nuplex alarms< number of alarms for reference

plant (e.g.-System 80 of same size)

-(Pending Availability of a System 80 simulator)

5. Event Identification

-Through a combination of alarms, operators shall be able to identify abnormal transients during simulation

6. Verify All Display Alarm Criteria Have Been Met

*Alarms are categorized by panel and function
*Alarms can be acknowledged individually or in small groups
*Alarm status and representation (cleared, acknowledged, etc.), are as described
*process display page, display fields, and navigation are as described
*alarm suppression features work as described

8. Verify Useability

-Working Prototype; verify with users that:
*Acknowledge, Test, and Reset functions and actions are understood
*prioritization scheme and navigation are understood
*various software-based coding schemes are understood

Criterion: When a novice user, after <30 minutes of instruction, can understand the above and demonstrate accurate use.

9. Functional Layout

-Alarms shall be functionally laid out with alarms on the same panel as associated controls and indicators

-NUREG 3898: Provided details on alarm processing

EPRI NP-3448: Showed the usefulness of retaining spatial dedication

Throughout the design process, relationships between the human factors of the alarm system and other plant information and control methods are standardized and designed to conform to good human factors practice. This is accomplished by providing two documents to designers, the Nuplex 80+ Information System Description Document and the Human Factors Standards and Guidelines Document. These documents, which are based on the aforementioned references and others as described and referenced within, assure standardization of the MMI features such as flash rate, prioritization, letter size, color coding, location, etc.

The development of Design Acceptance Criteria for the alarm system will further assure that the design does not deviate from operational needs and the principles of good human factors engineering. The Design Acceptance Criteria for the alarm system add assurance that the design is acceptable in terms of its functionality and useability.

Question 620.16:

How was the task analysis used by those responsible for the individual panel designs? On what basis was the allocation of tasks made to specific places of equipment?

Response to 620.16 (Revision 1):

C-E has addressed the issue of System 80+ task analysis in numerous documents as well as one of the technical discussion areas during meetings with the NRC Human Factors Branch on 11/17/91 and 12/4/91). Additional information in response to this RAI is limited to the areas specifically requested by the NRC, namely the relationship between task analysis, task allocation, and panel layout.

The following description of how task analysis is factored into control panel layout uses the RCS panel as an example. The same methodology shall be followed in all Nuplex 80+ control panel layouts for System 80+. This method is standardized by means of the Control Panel Layout Guidelines document, found in the Nuplex 80+ reference documentation volumes and CESSAR-DC, Section 18.3. Details on the specific RCS panel layout method may be found in the System 80+ Reactor Coolant System Control Panel arrangement document, in Volume 5 of the reference documentation volumes. Further details on the use of task analysis in the panel design process can be found in the Human Factors Program Plan which is being submitted to supplement the response to RAI 620.1.

TASK ANALYSIS AND PANEL LAYOUT
NUPLEX 80+

I. FTA IS THE FIRST STEP IN NUPLEX PANEL LAYOUT
(*RCS Panel is the Example)

1.-Assignment of Functions

A. Review of FTA/Computer sort of FTA data to identify functions

B. Evaluate Functions; determine applicability to RCS

C. Engineering/ Operations review of Reactor Coolant System functions

D. Compile function list

2.-Functions Organized Into Groups

A. Reactor Coolant Pumps

B. Reactor Coolant Seal/Bleed

C. Reactor Coolant System

3.-Functions Organized On Panel

* The most frequently used functions (based on operating procedures and experience, as well as FTA data) are on the central portion of the panel, others on the periphery, based on their functional relationships (hardware interface/energy flow) with the adjoining panel sections.

4.-High Level Function Analysis

A. Review list of functions and subfunctions to determine adequacy of groups, based on operations

B. Focus on operating mode

II. DETERMINATION AND ASSIGNMENT OF ALARMS, INDICATIONS, AND CONTROLS

1.-Develop List of Needed Alarms, Indications, & Controls

A. Review Function and Task Analysis

B. Computer Sort:
*Identify Parameters and Characteristics for the RCS

C. Evaluate Parameters and Characteristics:
* Assign to functional groups (based on procedures, systems and operating experience)

D. Independent Evaluation for Other Parameters and Characteristics; for example:
* I&C design requirements
* System 80+ RCS P&ID
* Support system P&IDs
* System 80 operating procedures

E. Engineering and Operator Evaluation
*of parameters and characteristics

F. Compile Information Requirements List

G. Review FTA Results and Other Documents:
* to identify controls for RCS panel function

H. Engineering and Operations Evaluation:
*evaluate list
*modify list

2. Further Engineering Performed

-In addition to the FTA
-Hardware selection for the MMI
-verification and validation

Alarms and indications are examined separately from controls. Monitoring tasks were evaluated extensively via the Function and Task Analysis. Control tasks were evaluated to confirm that control allocations for previous System 80 plants remained applicable for System 80+. This was because the control requirements and MMI format for Nuplex 80+ were essentially the same as for existing System 80 plants. Even in cases where flat panel displays were used for process control, the function and appearance for the controllers was very similar to conventional Manual/Auto stations. Not so the indicators; although the type and nature of the information being indicated remained the same for Nuplex 80+ as in existing plants, the man-machine interface used to present it has a different format and does not operate in the same way. Therefore, a new FTA was needed primarily for monitoring tasks and to a lesser degree for control tasks.

Allocation of tasks to specific pieces of equipment was made based on a number of factors such as hardware properties of the equipment, regulatory constraints on the reliability and use of equipment, software functions possible on the equipment, operating experience, and, the human factors 'suitability' of the equipment to the task. In other words, based on reference documentation such as Salvendy's Handbook of Human Factors, MIL-STD-1472D, and Van Cott & Kincade's Human Engineering Guide to Equipment Design, it is known what types of hardware are appropriate to generic task types such as monitoring, discrete component control, etc. Using this basis, different tasks were allocated to the basic equipment types: Big Screen, CRT, Electro-Luminescent Displays (ELDs), and Discrete Pushbutton Switches. The rationale for choosing these hardware types is discussed at length in the Human Factors Program Plan. The nature of the identified tasks may be found in the Nuplex 80+ Function and Task Analysis Report.

Some examples of allocation of tasks to specific pieces of equipment are illustrated below, to show design methods used. Electro-Luminescent Displays are used as the sample hardware for the tasks described. Note that required information and control charicteristics were selected and this selection drove the hardware decision, as described in Section 3 of the Human Factors Program Plan.

Because of the qualification and high reliability of these devices, ELDs are appropriate for tasks which must be performed during events for which CRTs and Big Screen are unqualified, i.e.- assumed unavailable, such as a seismic event. The DIAS hardware is programmable to display information and permit control in a wide variety of formats. The ability of this hardware to display digital and analog trend data for a parameter simultaneously makes it particularly suited to tasks requiring discrete and long-term monitoring simultaneously. Thus were variables such as pressurizer pressure, RCS temperatures, and steam generator levels placed on ELDs for monitoring tasks. The ability to provide spatial dedication of information (not possible on a CRT where a variety of displays might be called up) also made them more appropriate for frequent or key monitoring tasks.

The suitability of this hardware to discrete and analog data presentation, as well as to format of a control interface with feedback and larger 'button' sizes made the ELDs ideal candidates to replace traditional hardwired Manual/Automatic Stations for process control. Hardware and software properties of the displays allow the user to change and see setpoints while also viewing actual parameter data. As a result, process control tasks such as pressurizer temperature regulation were allocated to the ELDs.

ABB-CE uses the same allocation practice for the other main pieces of hardware. The IPSO display (big screen) is suited only to overview monitoring for a variety of reasons. Pushbutton switches are suited only to discrete control tasks as so only key success path control functions were assigned to them. A description of the human factors rationale for the selection of all control room equipment types can be found in the Human Factors Program Plan.

Question 620.24:

Describe the workload analysis for one and three person operation of the controlling workspace. Describe how the task loading and work loads change.

Response to 620.24 (Revision 1):

The issue of analysis of crew sizes and how the Nuplex 80+ design supports them has been addressed in discussions of the seven technical areas of human factors concern at meetings with the NRC HF Branch on 11/17/91 and 12/4/91.

To clarify phraseology from CESSAR/DC and previous draft responses to this RAI, the discussion on the range of potential task loadings (e.g.-infinite) are not germane to the issue of workload analysis of proposed crew sizes. Per discussions with the Human Factors Branch of the NRC, the goal of one-person operation applies not to the entire control room, but only to the controlling workspace. It is accommodated by the design of the Master Control Console (MCC). The basis for designing a controlling workspace for a one-person crew was provided by Requirement 4.2.4, Chapter 10 of EPRI-ALWR-URD. This staffing level was analyzed as part of a commitment to meet the one-person staff for operational scenarios described below:

The Nuplex 80+ Function and Task analysis found that, for anticipated conditions, the one-person crew was able to handle the normal workload demands of operation. Those conditions analyzed for the one-person crew size included only normal steady-state operations and escalation from hot standby to full power operations, as well as immediate post-trip actions. Nuplex 80+ is not designed such that cold shutdown to hot standby, recovery from trip, and normal shutdown could be managed by the one-person crew.

The immediate post-trip actions were considered to be the limiting condition of operations based on C-E's experience with similar plants. Walkthroughs were performed with the emergency procedure guidelines for System 80 and it was concluded that workload demands on a single operator were highest immediately post trip. A description of the analysis can be found in Section 18.5.1.8 of CESSAR-DC with full details in the aforementioned FTA report (NPX80-IC-DP-790-02).

Staffing levels form the design basis for the Nuplex 80+ configuration and floor plan. The one, three and six-person crews, were based on EPRI guidelines (ALWR URD) and task sequences required (e.g.-during post-trip for the three-person crew). The one and three person crew sizes represent minimum staffing for the limiting evolutions, hot standby to power, and post-trip,

respectively. Other pant operating modes are expected to be bounded by these staffing needs (i.e.-require crews of one to three). These sizes will be validated at the integration test facility using design acceptance criteria. Refer to Sections 2 and 6 of the Human Factors Program Plan for supplemental information.

As pointed out in Sections 1-4 of the FTA report, the nature of tasks which must be performed for the System 80+ plant, and the information needs in Nuplex 80+ do not vary significantly from previously-licensed System 80 plants such as Palo Verde 1,2,& 3. The Nuplex 80+ control complex is evolutionary and not revolutionary. The control room is designed to upgrade the MMI by capitalizing on newer technologies and lessons learned in the nuclear and other process industries. However, much of the documentation and experience gained from the current generation of C-E power plants remains relevant to the operator of System 80+.

The following high level tasks were considered for different operating modes:

Hot Standby to Normal Operations:

*Complete Plant Monitoring and Operations

Normal Start-up/Shutdown:

*Reactor Plant Monitoring and Control

*Turbine Plant Monitoring and Control

Post Trip:

*Primary System Success Paths and Control Functions

*Secondary System Success Paths and Control Functions

*Emergency Success Paths (at ESF panel)

A further discussion of the operating crew options for Nuplex 80+, potential roles of additional operators (allocation of tasks), and workload analysis for Nuplex 80+ may be found in the response to RAI 620.25.

Question 620.25:

Describe the basis for the design goal of one person control of operations between hot standby and full power. Were separate task analyses performed for one and three person operations? How does the allocation of tasks among the staff change in the control room for one person, three person and a full six person shift?

Response to 620.25 (Revision 1):

The issues of allocation and crew sizes and how the Nuplex 80+ design supports them have been addressed in discussions of the seven technical areas of human factors concern at meetings with the NRC HF Branch on 11/17/91 and 12/4/91.

To clarify phraseology from CESSAR/DC and previous draft responses to this RAI, discussion on the range of potential task loadings (e.g.-infinite) are not germane to a description of chosen crew sizes.

The basis for designing a controlling workspace for a one-person crew was provided by Requirement 4.2.4, Chapter 10 of EPRI-ALWR-URD. The three and six-person crew sizes do not reflect specific EPRI or NRC goals but, rather, represent a range of potential crew sizes based on typical utility staffing levels.

Separate analyses were not performed for the one, three, and six person crew sizes. Although the assignment of tasks and the number of crew members may change, depending on a given utility's preference, the number and nature of the tasks do not. Nor is there a difference in the functions the plant systems must perform or the control room information needs based on task size.

The allocation of tasks between multiple crew members is a key design consideration. This has been addressed in the design of the Nuplex 80+ control complex, through the floor plan design and allocation of systems to panels. With the crew size of three (for post-trip recovery), there is still only one operator envisioned to be at the Master Control Console (MCC) area to control normal success paths, hence the task analysis would not change at all for the bulk of normal operations, since these are all controlled from the MCC. The remaining two operators in the 3-person crew size would include one operator assigned to the safety and auxiliary consoles to control emergency success paths and one senior reactor operator at the CRS console, monitoring overall critical functions and directing success path strategies. For other plant operating modes, other staff allocations are possible but the one and three person crews are considered the minimum crew sizes for the limiting cases of operation.

The crew size of 6 is envisioned to include two operators at the MCC. However, these individuals will not interfere with one

another since every section of the MCC has its own spatially dedicated displays and any CRT display can be called up on any of the CRT screens. Further, since the panel layouts mimic plant energy flow, the task sequence moves logically around this 'horseshoe', allowing for an even break-off of tasks without interference.

The other four crew members are envisioned to be one each at the Safety and Auxiliary consoles, and two at the Control Room supervisor's console. The crew at Safety and Auxiliary consoles will have no job overlap since the functions assigned to these two sets of panels are quite different. During emergencies, this will consist of monitoring and restoration of success paths. The two crew members at the supervisor's console are envisioned to be supervisory and STA/advisor personnel. They will have the ability to call up any CRT display on their own two CRTs and to monitor the plant via the IPSO display, however, they will not perform any control tasks. The 6-person crew is not a routine staffing level but might represent extra consulting and/or backup personnel brought in by a given utility should an abnormal transient occur.

Although separate analyses for the larger crew sizes were not performed, it should be noted that further human factors analyses are planned for the Nuplex 80+ control room. These will include walk-through/talk-through type analysis and further review of the control room design using System 80 (or System 80+, if available) Emergency Procedure Guidelines as the task basis. For this analysis, a simulated full operating crew will be used. Per the aforementioned meetings with the NRC HF Branch, issue of crew sizes will be included in the design acceptance criteria as they are developed over the next year.

A summary of logic for operating crew sizes is provided below:

Crew Size:	Minimum	Maximum
Mode		
Start-up	bounded by normal & post-trip operating minimums	6
Normal Ops.	One Person	6
Post-Trip	Three Person	6

Crew sizes will be validated at the integration test facility. A further discussion of the operating crew options for Nuplex 80+, potential roles of additional operators (allocation of tasks), and workload analysis for Nuplex 80+ may be found in the response to RAI 620.24.