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**A Limited Human Factors
Engineering Assessment of the
242-A Evaporator System: For
Input to the Safety Class II
Systems/Structure Assessment**

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October 1991

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
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EXECUTIVE SUMMARY

A time-limited human factors engineering (HFE) assessment was conducted of the software, hardware, and facilities related to the items in the 242-A Evaporator Safety Class II Systems/Structures. The purpose of this assessment was to determine, prior to the startup of the Evaporator system, the adequacy of the controls and monitors in ensuring safe operations. The results of this assessment are described in this report.

The assessment was conducted by professional human factors engineering staff who are experienced in the evaluation and development of supervisory control and monitoring systems used for process control. Information was collected primarily through interviews with and observations of experienced Evaporator operators. Because implementation of the Monitor and Control System (MCS) is the dominant change in Evaporator operations, the human factors assessment focused primarily on the MCS. Particular attention was directed toward the operator's ability to access information and to correctly and quickly interpret such information. Additionally, the consistency and appropriateness of terminology and symbology used throughout the system were areas of special concentration.

The assessment was performed in the absence of a fully defined operational framework. There were three contributing factors: 1) revisions of the MCS were still in progress, 2) the MCS development and refinement occurred in the absence of a baseline concept of operations, 3) the impact of operator training on the operations of the Evaporator could not be evaluated because operators had not yet received training.

Although the circumstances in which the MCS was assessed did not provide a fully defined operational framework, it was still possible to evaluate the requisite system parameters based on general principles of Evaporator operation and good human factors engineering principles. The accuracy, adequacy, and appropriateness of the following assessment and recommendations can be expected to increase as more system definition is achieved (especially as information from human factors/systems analyses is incorporated into the system definition and refinement process.)

From this assessment, it is apparent that the safe, efficient operation of the 242-A Evaporator system is paramount in the minds of management, operators, and technical support personnel. Evaporator hardware and software design features do reflect this perspective and, as a result, the system has "user friendly" qualities for providing an operator interface for controlling and monitoring the Evaporator system.

Many of the items in this report may stem from Evaporator system development apparently occurring in the absence of a well-defined "Concept of Operations" or the limitations of the Texas Instruments Development Tool used to implement the MCS. Additionally, it appears that on-the-job training is relied on quite heavily to define operator roles as well as to overcome design shortcomings.

Overall, it is recommended that system managers, operators, developers, trainers, and human factors experts jointly develop a Concept of Operations document. This document should provide a systematic means to implement changes, develop training programs, operationally test and evaluate the recommended changes, and define requirements for anticipated system upgrades.

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1.0 BACKGROUND

Prior to the startup of the 242-A Evaporator system, members of the Pacific Northwest Laboratory (PNL) Human Factors Engineering staff conducted an assessment of the controls and monitors related to the issues classified as Safety Class II Systems/Structures. The purpose of this assessment was to determine the adequacy of the controls and monitors in ensuring safe operations of the Evaporator system, and the results were described in a Letter Report dated April 5, 1991. The ensuing comments/recommendations of Westinghouse Hanford Company operations, safety, and management personnel formed the basis of additional human factors activities that resulted in this report.

1.1 SCOPE

A time-limited human factors engineering (HFE) assessment was conducted of the software, hardware, and facilities related to the items in the 242-A Evaporator Safety Class II Systems Structure Table. The areas of concern specified in the Statement of Work for this effort were:

- The adequacy of the monitoring system displays that enable the operator to determine:
  - the current status of each safety class system/structure
  - whether the desired equipment response occurred for a given command
  - actions taken by the system.
- The ability of the operator to initiate response actions based on the information presented via monitoring system displays.
- The adequacy of the alarms with respect to:
  - the presence of alarms for each safety class system/structure
  - enabling the operator to determine system/structure status
  - enabling the operator to determine the appropriate response.
- The suitability of the arrangement of system alarms and monitors in support of timely operator responses to unsafe conditions.

- The accessibility to operators of manual controls for the safety systems.
- The adequacy of direct feedback to the operator at the location of the manual controls indicating that the correct action has occurred.

1.2 LIMITATIONS

The assessment and subsequent recommendations were limited by the following three critical factors:

1. Revisions to the Monitor and Control System (MCS) continued even as the human factors assessment was performed.
2. Development and refinement of the MCS was accomplished without a baseline "Concept of Operations" through which to define the role and number of operators as well as the interaction of such operators with the MCS. (Briefly, such a Concept of Operations defines how all system elements-- hardware, software, personnel, maintenance, procedures, training, etc.-- interact throughout the entire life cycle of the system. It also defines what kinds of information should be presented to the operator and how the operator works with and controls the information presented).
3. The impact of operator training on the Evaporator system safety and effectiveness could not be evaluated because operators had not yet received formal training, but relied upon on-the-job experience.

Although these factors made it difficult to fully define the operational framework, it was still possible to evaluate the requisite system parameters based on general principles of Evaporator operation and good human factors engineering practices. The comprehensiveness of the following assessment and recommendations can be expected to increase as more system definition is achieved--especially as information from human factors/ systems analyses is incorporated into the system definition and refinement process.

1.3 APPROACH

This assessment was conducted by professional human factors engineering staff who are experienced in the evaluation and development of supervisory control and monitoring systems used for process control. Information was collected primarily through interviews with and observations of experienced Evaporator operators.

The Evaporator control system items specified in the 242-A Evaporator Safety Class Systems Structure Table were analyzed using the design principles set forth in standard human factors guideline documents (e.g., NRC 1981, DOD 1989, and Smith and Mosier 1986). Particular attention was directed toward the operator's ability to access information and to correctly and quickly interpret such information. Additionally, the consistency and appropriateness of terminology used throughout the system were of special concentration.

Although the entire Evaporator is being upgraded, approximately 80% of the changes are associated with the control room. Because the implementation of the MCS system is the dominant change in Evaporator operations, and since software changes are often easier to make and have more widespread system impact than do local hardware modifications, the human factors assessment focused primarily on the MCS.

Three system operators were interviewed. None had yet acquired actual operating experience with the system as currently configured, and only one had received formal training on the Texas Instruments software package used to implement the MCS. One operator was interviewed about the operational significance of the items specified in the Safety Table, and two were interviewed about the use of the MCS. In addition, two MCS software engineers were interviewed with regard to the functionality and structure of the MCS.

1.4 RESULTS

Overall, based on the limited review performed, the MCS prototype appears to provide an easy-to-use interface for controlling and monitoring the Evaporator system. In this regard, the following design attributes are particularly noteworthy:

- use of redundant coding (color and shape) to enhance the readability of the system displays
- use of status panels to indicate the overall status of critical aspects of the Evaporator system
- provision of multiple methods for accessing Evaporator system information.

1.5 REPORT ORGANIZATION

The system was assessed according to the following areas of design: Control Console/Room Configuration, Color Coding, Data Display, Labeling, Feedback, Interactive Control/System Navigation, and General System Attributes. As a result of the assessment, specific human factor items were identified. Each item was categorized with respect to the identified design areas. These items are summarized in two tables in the appendix. Table A.1 in the appendix associates related items with the components specified in the Evaporator Safety Class 2 Systems and Structure Table. Table A.2 in the appendix identifies each item's impact on an operator's ability to control and monitor the Evaporator with respect to the concerns specified in the Statement of Work.

Several items appear to impact the Texas Instruments (TI) hardware and software package used to implement the MCS. These items have been identified in the report and include:

- 4.2 Lack of Alarm List Display Titles
- 4.3 Lack of Alarm List Column Labeling
- 4.4 Ambiguous Scaling on Grids
- 4.5 Ambiguous Markings on Grids
- 5.3 Same Key For Confirming MCS Commands
- 7.2 Unclear Labeling of Alarm List Access Buttons.

It is understood that immediate resolution of these items may be infeasible due to the limitations of the Texas Instruments software and hardware capabilities. Therefore, it is recommended that each of these items be addressed during the next planned software system upgrade.

Finally, because of the constraints of the current assessment, it may be beneficial to re-evaluate all items once the recommendations have been implemented to determine if the modifications have fully accomplished the desired results.

2.0 CONTROL CONSOLE/ROOM CONFIGURATION

2.1 SIMULTANEOUS DISPLAY OF DESIRED INFORMATION

Four MCS work stations are located (without specifically designated positions) in the Evaporator system control work area. All four work stations are not always in use. Operators take advantage of a "free" work station and use two displays simultaneously to more effectively monitor the Evaporator system status. The ability to simultaneously view information could enhance operator/system effectiveness in terms of safety and efficiency.

Example

Typically, when operators are examining a certain component of the system, they display the schematic graphic of the component on one screen and the associated faceplate display on another screen.

Recommendation

Perform an analysis to determine the optimal configuration of existing hardware to provide safe, timely, and effective information presentation and system control. For example, design approaches that might be evaluated include 1) redesigning the MCS console as a suite incorporating two display monitors that can be controlled by the operator via a single keyboard, or 2) providing a monitor and keyboard to support process control with other monitors dedicated to displaying monitoring functions. Either of these design options would permit simultaneous use of different types of display screens as desired by system operators and, if designed and implemented properly, could enhance operator/system effectiveness without adversely affecting system efficiency or safety.

2.2 INCOMPLETE OVERALL EVAPORATOR SYSTEM STATUS REPRESENTATION

Operators expressed concern that the new system, unlike the old control and monitoring system, does not provide a method for quickly and effectively ascertaining the general status of the Evaporator. This could impact the operator's ability to correctly determine plant status.

Example

The old system provided the ability to immediately assess the current status by glancing at the hardware panels. These panels do not exist in the new system, and the operators must call up a series of display screens to gather the information that was previously available at a glance.

Recommendation

Provide the ability to perform quick overall system status checks using appropriate summary displays. This must be accomplished judiciously since display screens can easily become cluttered with too much, or with improperly presented, information. Display clutter could impair an operator's ability to quickly and correctly determine plant status.

2.3 LACK OF DESIGNATED ALARM LIST MONITOR

When more than one monitor is available, operators configure the monitors such that one monitor is devoted to displaying alarm lists while another monitor is used to access specific information. As events occur, the alarm list monitor is constantly consulted. This configuration allows the operators to quickly identify new alarms without disrupting their current work, thereby aiding diagnosis of events in a more timely, systematic manner and reducing the potential for human error.

Example

When responding to an alarm, operators often display the alarm list on one screen and the alarm location on another screen.

Recommendation

Consider MCS console redesign to permit inclusion of a monitor dedicated exclusively to the display of alarm lists. Such a dedicated monitor could help minimize operator information processing and response times to alarms.

2.4 LACK OF A MEANINGFUL ANNUNCIATOR PANEL LAYOUT

The arrangement of the access buttons on the annunciator panel does not reflect a design strategy based on Evaporator operations or physical layout.

Instead, the access buttons appear to be organized in the order that their associated graphics screens were created. As a result, operators often spend time looking for specific access buttons in a random search pattern. By placing the annunciator buttons according to a logical scheme apparent to the operators, time could be saved in both information retrieval and in training since the operators would be able to intuit the location of a button by having knowledge of the type of information it accesses (and vice versa).

Example

See Observation above.

Recommendation

Develop a logical method (based on sequence of use, sequence of signal detection, criticality of operation, similarity of function, etc.) for positioning annunciator buttons so that the location is inherently meaningful to the operators.

2.5 LACK OF EVAPORATOR KILL BUTTON

During specific critical conditions, it may be appropriate for the operator to initiate an emergency shutdown of the system. The work environment does not provide a hardwired Evaporator "kill button" that enables emergency shutdown to be initiated by the operator. Such a control must be designed to allow quick access while precluding accidental activation.

Example

See Observation above.

Recommendation

Consider the installation of an evaporator kill button to permit the operator to initiate shutdown of the system in the event of an emergency.

3.0 COLOR CODING

3.1 INCONSISTENT USE OF COLOR

Color is used throughout the 242-A Evaporator system to convey certain meanings, but it is not used consistently. One color may be used to indicate different meanings on different screens, or a particular system state may be conveyed by different colors. This inconsistency has the potential to cause the operator to misinterpret information and/or fail to detect changes when monitoring the system or responding to alarms. Such misuse of color can contribute to the cluttered appearance of display screens which can, in turn, increase the time needed by an operator to find and respond to important information. The inconsistent use of color can also make system navigation more difficult.

Examples

Indication of Valve State. On the *Evaporator Overview* display, blue text is used to indicate both the open and closed state of a valve. In the *Process Condensate* (Screen 018), the closed position for pump PB-1 is indicated by green or white text, while on the *Overview Evaporator* (Screen 040) white or blue is used.

Indication of Flows. On the Vacuum Condenser (Screen 016) colors are assigned the following meanings: white represents condensate flow, dark blue represents water, and light blue represents steam. Colors are displayed on the *Evaporator Overview* (Screen 040) with the following relationships: white represents venting, dark blue represents water, yellow represents steam, light blue represents process flow, and green represents air.

Multiple Meanings Assigned to a Single Color. Yellow is used both to signify that alarms are non-critical and that alarms are inhibited. White text is used both for system component titles (along with light blue) and flow levels. (For an example of this refer to Screen 012 in the system.) Red is used both to indicate that a system (such as a pump, tank, or valve) is active or open as well as to indicate that a system is in an alarm state.

Numbered Boxes for System Navigation. Purple and white boxes around numbers are used to indicate quick access numbers to graphic screens and faceplates.

Open-to-Close Valves. Open-to-Close Valves are represented in blue text on the schematic graphics and in green text on the faceplates.

Recommendation

Develop a consistent color scheme (compliant with appropriate specification documents such as NRC 1981) and apply it to all labeling and graphics screens throughout the MCS.

4.0 DATA DISPLAY

4.1 INCOMPLETE SYSTEM REPRESENTATION OF RADIATION DETECTORS

The operators suggested that the radiation detectors' alarm limits should be shown when the count is approaching a critical level. Currently, operators must remember the limits. Appropriate display of the critical limits could improve their operational performance by minimizing the need to rely on the operator's memory to correctly interpret the displayed information.

Example

The system only indicates radiation levels through the presence or absence of alarms.

Recommendation

Indicate the radiation count in such a manner that it is possible for the operator to determine the current count in relation to critical limits.

4.2 LACK OF ALARM LIST DISPLAY TITLES

There are four alarm categories within the system: P1 (critical Evaporator Alarms, also called "red alarms"), P2 (non-critical Evaporator Alarms also called "yellow alarms"), P3 (MCS system state alarms), and White Alarms (non-critical general system alarms). When an alarm list is displayed for one of these classes, the user does not always receive labeled information indicating the class of alarm. This could cause the operator to misinterpret the information displayed and to respond in a less timely manner to the alarm condition.

Example

The P2 alarm screen title does not state "Non-Critical Alarms."

Recommendation

Provide alarm list titles that indicate the type of alarms being displayed that correspond to the labels used on the alarm access buttons.

4.3 LACK OF ALARM LIST COLUMN LABELING

The columns on the alarm list display screens are not labeled. Appropriate labeling can help minimize the potential for misinterpretation and ambiguity. For example:

<u>Date</u>	<u>Time</u>	<u>Location</u>	<u>Description</u>	<u>Status</u>
03/29/91	01:12:33	PN6	Process Condensate	Stable

Example

The red, yellow, and white alarm lists are not labeled.

Recommendation

Label alarm list columns with respect to the information displayed and its function during the next planned software system upgrade.

4.4 AMBIGUOUS SCALING OF GRIDS

Grid scaling does not always match that of the hardware being represented. Further, scaling levels on some grids make it difficult to discriminate a low level of flow from no flow at all. This could cause the operator to misinterpret the information displayed.

Example

This mismatch can be observed when the flow level is extremely low on faceplates 11-AW-102 and CI-WVR-1.

Recommendation

Ensure that all grids are scaled so that the status of the flow is obvious and that the full range of flows is effectively presented to the operator.

4.5 AMBIGUOUS MARKINGS ON GRIDS

Several of the faceplate flow grids contain red marks to indicate either the maximum possible flow or the level of flow at which a critical alarm is triggered. It is not obvious whether a red mark indicates the maximum flow or

the alarm level. Ambiguous markings can cause misinterpretation of information which in turn could result in the operator taking inappropriate corrective actions.

Example

Screen 41 contains several grids with red lines indicating either maximum flow levels or alarm levels.

Recommendation

During the next planned software system upgrade, eliminate any ambiguity in the markings or symbols on the system displays by appropriate use of color coding and/or labeling.

4.6 LACK OF DIRECT INFORMATION ACCESS

Accessing information often requires a series of two or more button presses rather than a single action. During critical times such as periods of multiple alarms and acknowledgments, such multiple steps could hinder access to information. The potential for such delay is compounded by the lack of navigation and orientation cues (see items 6.1 to 6.4).

Example

In the event of a tank farm alarm, there is no way to immediately identify where the alarm occurred. It is sometimes necessary to access multiple display levels to acquire needed information. This is in contrast to the old system in which each tank farm had its own hardware panel and the operator had only to glance at the panel to find the location of the alarm.

Recommendation

Perform an analysis to determine when certain information should be directly accessible to the operator. This analysis would assist in the determination of appropriate direct access techniques. It is not necessary to make all of the information in the MCS system directly accessible all the time. However, information that is determined to be of a critical nature at certain times should be made directly accessible during those times to ensure a timely response by the operator.

4.7 AMBIGUOUS USE OF GRID GRAPHICS

Grid graphic display formats are used to display two kinds of information: summary system process information and detailed information regarding specific components of the system process. These two types of information are not always clearly differentiated, and the operator could, therefore, mistakenly interpret summary data as detailed information, or vice versa. This potential is heightened if the operator is performing general status checks of the grid flows and, therefore, not reading the associated grid text.

Example

See Observation.

Recommendation

Clearly differentiate grid graphics according to their display function.

4.8 CLUTTERED DISPLAYS

Many of the displays are visually cluttered. Contributing factors include the use of a single color to convey many different kinds of information (see item 3.1), the portrayal of a great deal of information on a single display, and the interference caused by the location of the screen title and screen ID relative to the information displayed on the screen. As a result of such screen clutter, operators often find it difficult to locate the needed information on a screen. This could negatively impact a timely response to the noted system condition.

Example

The *Process Condensate (018)* display contains all three problems cited above.

Recommendation

Implement any of the following recommendations to reduce clutter or judiciously implement all three to minimize the potential for adverse impacts due to screen clutter: 1) reduce the amount of information displayed by placing more of the detailed information in lower level displays; 2) relocate the screen title and screen ID to an area of the screen that is less intrusive

on the information displayed (note: if this approach is taken, the title and ID should be placed in the same location for all of the screens); 3) use color consistently (see item 3.1).

5.0 FEEDBACK

5.1 UNINTENTIONAL DISABLING OF ALARMS

Operators apparently never need to disable alarms and only system engineers use this function. When an operator performs the actions required to inhibit an alarm, the alarm can accidentally be disabled.

Example

The actions for disabling alarms on screen *24 PC-IX Pres, DP* demonstrates this observation.

Recommendation

Eliminate the capability to disable alarms from the operator console.

5.2 LACK OF VALVE-OPENING INFORMATION

Valves have four possible physical states (open, closed, opening, and closing), but only three of these states are indicated on the MCS (open, closed, and closing). This does not allow for a complete representation of the Evaporator's status, which could result in the operator misinterpreting the displayed information.

Example

Valve *HV-SC-1B* on screen *022* demonstrates this observation.

Recommendation

Add a representation of the valve "opening" state to the MCS displays.

5.3 SAME KEY USED FOR CONFIRMING MCS COMMANDS

The current method for confirming certain commands in the MCS system is to require the operator to issue the same command twice using the same key. An operator might inadvertently activate a command by accidentally pressing the command key twice without intending to or without being aware of having done so.

Example

The process for closing a valve demonstrates the current confirmation method.

Recommendation

During the next planned software system upgrade, establish confirmation commands that differ from initial commands to minimize the potential for accidental issuance of the confirmation command. By making the confirmation input different from the initial input, the operator is forced to become more fully aware of the confirmation action and, therefore, less likely to make an error.

6.0 INTERACTIVE CONTROL/SYSTEM NAVIGATION

6.1 SLOW SYSTEM RESPONSE TIME

Slow system response times are frequently noted. This could adversely affect an operator's ability to remember critical information or to maintain attention on a task. This slow system response can be especially disruptive of an operator's cognitive functioning during periods of high stress or during critical system operations.

Example

To access the location of an alarm and establish the function of the alarm, the operator first accesses a graphic display by pressing the flashing button on the annunciator panel. On the selected graphic, the alarm is highlighted by flashing text. A number located near the flashing text indicates which function key should be pressed to access the relevant alarm list. Should other computations be in progress, or should other operators simultaneously be accessing displays, the display of the requested information may be noticeably slowed.

Recommendation

Use the opportunity of anticipated system upgrade efforts to establish system response times that are compatible with operator task needs in order to ensure that task performance is not degraded due to slowed system responses.

6.2 INADEQUATE INDICATION OF SCREEN HIERARCHY

The current set of graphic and alarm list screens provides little information to the operator regarding the relationships between screens. It is, therefore, often difficult to become orientated to the system (i.e., "know where one is") and to move efficiently (i.e., "navigate") through the system. Operators may become lost within the system structure and not recall which screen was used to arrive at the current display. This can hinder or prevent operators from finding appropriate information and can significantly increase operator response time, training requirements, and probability of error.

Example

See Observation.

Recommendation

Inform operators regarding their location within the system at all times. Techniques that might accomplish this include the development of a graphical representation of the screen hierarchy, appropriate labeling of screens, and/or revising input procedures performed by the operator.

6.3 INADEQUATE INDICATION OF INTER-SCREEN RELATIONSHIPS

Screens that are a part of a sequence of screens give no indication that they are a part of the sequence. Also, screens that have sub-screens, which contain additional information, often give no indication that this information exists and, as a result, users may not realize the information is available. In addition, a false impression of the relationship between screens may arise because the sequential order as indicated by the assigned screen IDs does not represent the operational order. The inaccurate representation of relationships between screens in the system can cause users to become disoriented (i.e., "lose their way") and unable to find appropriate information. A poorly defined inter-screen relationship increases the probability of errors, missed information, longer response times, and greater training requirements.

Example

Faceplates with more than 16 grids extend over several screens but contain no information indicating the number of total screens or which screen in the sequence is displayed.

Recommendation

Devise a method to clearly indicate the relationship among screens in the system. Strategies that might accomplish this include improving the screen IDs (see Item 7.1), and labeling screens so that their relationship to other screens is indicated (e.g., "EH-V faceplate screen 1 of 3").

6.4 INCONSISTENT SCREEN NAVIGATION COMMANDS

The commands used to navigate through the MCS screen hierarchy are not consistent. Table A.3 in the appendix details different commands used to move from one screen to another. Many of these commands work only for certain screens, although there is often no obvious indication on the screens as to which navigation commands are appropriate. In addition, the use of navigation commands is not consistently linked to the type of screen currently displayed. This system can be confusing and frustrating, especially for less experienced users, and can negatively impact the operator's ability to respond to events in a timely manner.

Example

See Table A.3 in the appendix.

Recommendation

Devise a consistent approach to screen navigation and implement it across all categories of displayed information.

7.0 LABELING

7.1 INCONSISTENT DISPLAY NUMBERING

Each graphical display is assigned a unique screen identification number or "screen ID." These screen IDs are used by the operator to directly access the screen by typing in the number. However, the ways in which these numbers appear varies, and the numbers seem to be assigned somewhat arbitrarily. These factors can cause the operator to misunderstand how items of information and screens within the system are related, and can also confuse operators about their location within the system.

Example

On faceplate displays, the screen ID is shown beside the faceplate display titles with no leading zero or parenthesis around the number (e.g., *30 Steam Condensate*), while on schematic displays the screen ID is centered below the screen title enclosed in parenthesis with a leading zero shown as *Steam Condensate (014)*.

Recommendation

Develop a display numbering scheme that promotes formulation of correct relationships between information items and screens, and presents screen IDs in a consistent format. For example, the screen IDs could be assigned so that they indicate both what kind of information a screen contains and where the screen lies within the MCS hierarchy. This scheme should be applied consistently to all screens.

7.2 UNCLEAR LABELING OF ALARM LIST ACCESS BUTTONS

The access buttons P1, P2, and P3 are used to access lists of specific types of alarms (P1-critical alarms/red, P2-non-critical alarms/yellow, and P3-system alarms). Since there is no obvious link between the access button label and the type of alarm it represents, users may have difficulty accessing the correct alarm categories thereby increasing the time to respond to an alarm condition. This problem is compounded when combined with the lack of

alarm list column labeling (see Item 4.2), resulting in the potential for an operator to look at the wrong alarm list in response to an alarm.

Example

This problem is demonstrated by accessing any one of the alarms lists (red, yellow or system) through use of the P1, P2, or P3 keys.

Recommendation

During the next planned software system upgrade, give the alarm access buttons P1, P2, and P3 labels that more meaningfully indicate their alarm type (critical, non-critical, MCS). This practice would be consistent with the scheme used to label the access button for white alarms.

7.3 MULTIPLE NAMES FOR SPECIFIC ITEMS

Some items in the MCS are referred to by several different names. In addition, some of the abbreviations used to label parameters in the old and new system are different even though their meanings are the same. This might cause operators to mistakenly believe that the different names refer to different items or sub-categories of items. This could impact the operator's ability to correctly determine plant status by misinterpreting the displayed information.

Example

"Critical Evaporator Alarms" are also referred to as "P1 alarms" and "red alarms." The old system used *SPG* for specific gravity whereas the MCS uses the abbreviation *DII* for density. These two terms mean the same thing with respect to the parameter value and to the system status.

Recommendation

Make labeling throughout the system in accordance with ISA standards, and give operators specific training on this labeling scheme.

7.4 INCONSISTENT USE OF LABELS

The closed state of a valve is labeled several different ways, which could cause confusion for operators and impact their ability to take appropriate corrective actions.

Example

The *Evaporator Overview* (screen 040) uses the letter "C" to indicate closed and the letter "O" to indicate open. For *Process Condensate* (screen 301), the positions are labeled as either Open or Closed.

Recommendation

Develop a consistent labeling scheme and apply it to all labeling throughout MCS.

7.5 INCONSISTENT LOCATION OF SCREEN TITLES

Screen titles, when present, are positioned at different locations on the screen. Additionally, in some cases the title serves both as a display title and as a label for a particular aspect of the graphic. The latter practice is confusing because two different methods are used to title a screen. The differing location makes information hard to find, causes the operator to search the display for information, and adds to the impression that the display is cluttered. This could cause the operator to misinterpret the displayed information and increase the time required to locate information.

Example

The schematic graphic displays place the screen title in the lower right-hand corner of the display, while the trend displays place the screen title along the Y axis of the trend graph. Additionally, "O" could mistakenly be read as a numeric zero ("0").

Recommendation

Develop a consistent display titling scheme.

8.0 GENERAL ATTRIBUTES

8.1 DISTRIBUTION OF SYSTEM INFORMATION

The current method of using both the Computer Automated Surveillance System (CASS) and MCS system could increase operator workload and training requirements. Also, there is the potential for delays in problem identification and timely responses to any given problem due to the lack of immediately available and appropriately integrated information.

Example

It is necessary to refer to a hard copy printed out by the CASS system in order to monitor Tank Farm liquid levels and line leak detection alarms.

Recommendation

Incorporate the information from the CASS system into the MCS system.

8.2 INADEQUATE OPERATOR KNOWLEDGE OF SYSTEMS INTERLOCKS

Many new interlocks have been installed into the Evaporator system and are presently being incorporated into the MCS. Operators must use past experience and knowledge of the system to gather an overview of interlock operations. This overview does not, of course, include the new interlocks of which the operators are not yet aware. Because the inclusion of new interlocks has only just started and no formal interlock training has yet been received by the operators, it is premature to assess their operational impact with respect to safety.

Example

See Observation.

Recommendation

Revisit the impact of interlocks on the safe operation of the Evaporator system as part of the development of an Evaporator system Concept of Operations. A detailed study of the relationship between system interlocks and the displayed information should be performed.

8.3 TRAINING APPROACH AND ADEQUACY

Operators obtain knowledge of the system through use of the MCS in their daily operations, which do not include operating the Evaporator, participation in MCS software application training courses, and exposure to the MCS system during its development. Formal training program plans or implementation were not available for human factors assessment.

Example

No operators have received formal training for monitoring the Evaporator via the MCS.

Recommendation

As far as can be determined, operator training (primarily on-the-job-training) is an important remediation strategy for dealing with Evaporator/job design deficiencies. Early development of a comprehensive training program is, therefore, recommended. Note, however, that operator training, in addition to being an expensive process, is considered the least "desirable" of the four approaches to minimizing system hazards (the others, in order of preference, being elimination, protection, and warning--see DOD 1984).

8.4 LACK OF DIAGNOSTIC AIDS

The current system is primarily set up to promote the detection of anomalous conditions (e.g., alarm states) and indicate their location. The system assists the operator in performing rudimentary diagnoses to identify the probable cause of an anomalous condition. However, any diagnostic activity is heavily dependent on the operator's knowledge of the system and the system history that the operator has gained through experience and training.

Example

See Observation.

Recommendation

Enhance the system by incorporating features that directly assist the operator in diagnosing the causes of events. This would, in turn, facilitate the performance of appropriate responses to anomalous conditions and would

improve the operator's ability to identify such conditions earlier, thereby reducing the amount of training and experience required to safely operate the system.

8.5 SIMULTANEOUS TASK REQUIREMENTS

When many alarms occur in quick succession, a single operator may be overloaded in terms of his/her ability to respond to the event(s) in a timely and effective manner. The operator may be placed in a situation where it is necessary to simultaneously monitor overall system status, respond to new alarms, monitor the status of previous alarms and, depending upon the previous alarms status, take appropriate action. This set of operational circumstances could cause the operator to respond inappropriately or perhaps fail to respond to an alarm condition. The inability to simultaneously view summary status display and alarm lists has the potential to exacerbate inappropriate responses by the operator under this set of operational circumstances.

Example

When an initial alarm occurs, the operator locates the alarm by either accessing the alarm display directly by stepping through the graphic displays or by using an alarm "hot key" (P1,P2,P3, White Alarm) to display a list of current alarm descriptions and locations. The operator then monitors the status of the alarm through either a graphic or faceplate screen. Conflict may arise when new alarms occur before previous alarm(s) are resolved, and the operator must also view summary displays to better determine the cause and appropriate corrective action to take with respect to the alarm condition(s). In such instances, the operator is placed in a situation that requires integration of discrete sets of information from sources that must be independently accessed.

Recommendation

Conduct a careful analysis of operations to specifically address those areas, such as workload and integration of discrete sets of information, that directly impact an operator's performance. This analysis would provide a framework upon which to develop and test operating procedures (based, for

example, on one versus two versus three operators). Further, operational needs would be clearly defined within a known operational environment. This information could be used as a point of reference to systematically evaluate different staffing levels and the appropriate roles for each operator using such criteria as safety and cost, and could thus contribute to the development of suitable system hardware/software.

8.6 ABSENCE OF REMOTE DETECTORS ON EXHAUST FILTERS

Currently, exhaust filter radiation counts must be monitored locally. This may increase the operators' potential exposure to radiation, and the time constraints inherent in this process decrease the operators real-time knowledge of the system radiation levels (which is an important diagnostic tool for detection of such items as spray leaks).

Example

The radiation counts on exhaust filters are not indicated on the MCS system.

Recommendation

Place remote radiation sensors on the exhaust filters and link them to the MCS system.

8.7 LACK OF TOXIC LEAK DETECTION MONITORS

Currently, no monitors in the Evaporator detect the presence of toxic material. Since a great deal of the process material is toxic, the presence of toxic fumes might, in some cases, be a better indicator of contamination (spray leaks, etc.) than radiation. Additionally, of course, operator safety concerns are associated with the undetected presence of toxic materials.

Example

No information about the presence of toxic material is presented on the MCS system.

Recommendation

Install toxic material detection equipment in the Evaporator and link it to the alarm structure on the MCS.

8.8 COMPLEX PROCESSES REQUIRED TO FIND SOME SPRAY LEAKS

Some spray leaks require removal of large plates over the Evaporator in order to locate the leaks with the remote cameras. This removal requires the presence of a crane operator, which could seriously delay location and correction of a leak, and may serve to decrease the operator's knowledge of the exact system status. Given the frequent nature of spray leaks, the ability to locate them should be uncomplicated.

Example

See Observation.

Recommendation

Make probable locations for spray leaks as visually accessible as possible, perhaps by remote camera placement.

9.0 CONCLUSION

From this assessment, it is apparent that the safe, efficient operation of the 242-A Evaporator system is paramount in the minds of management, operators, and technical support personnel. Evaporator hardware and software design features do reflect this perspective and, as a result, the system has "user friendly" qualities for providing an operator interface for controlling and monitoring the Evaporator system.

In general terms, many of the items reported herein may stem from Evaporator system development apparently occurring in the absence of a well-defined "Concept of Operations." This Concept of Operation would provide baseline definitions of such system elements as Evaporator hardware and software, the number and role of operators, and the interaction between the operators and the systems. Such a Concept would not only serve as a guide to the development process but, perhaps more importantly, also as a relatively stable foundation from which to consider the numerous changes that have occurred during system development. Simply stated, Evaporator system development has been a very dynamic process (e.g., with respect to degree of automation to be provided) and this has, in effect, created a "moving target" to be hit by system developers, most notably, those responsible for MCS software.

Among other issues, this problem may influence the approach taken for operator training. "On-the-job training" appears to be relied on quite heavily to define operator roles as well as to overcome design shortcomings. As an alternative, it is recommended that system managers, operators, developers, trainers, and human factors experts jointly develop a Concept of Operations document through which to:

- systematically enhance the evaporator system's control and monitoring hardware and software system
- plan and direct development of an effective training program
- implement the changes recommended herein
- ensure the ease of incorporating desired and required future changes

- assess the limitations imposed by the Texas Instruments hardware and software.

The MCS system is currently undergoing Operational Test Procedures (OTP) that are identifying many problems with the design of the system, and many of these items are being passed to the software developers for correction.

The OTP could be used as a tool for reporting, evaluating, and correcting human factors engineering design flaws. Additionally, an approach to problem remediation could be developed that reflects the collaborative efforts of experts (i.e., operators), software engineers, and human factors experts.

Additionally, the limitations said to be imposed by the Texas Instruments hardware and software package should be assessed further, and the results of this assessment could be used to define requirements for the anticipated upgrades to this system.

10.0 REFERENCES

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APPENDIX

TABLES

TABLE A.1. 242-A Evaporator Safety Class 2 Systems and Structures*

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
EVAPORATOR AND PUMP ROOMS (Floor, roof, walls, roof, coverblocks and interior floor drains)	2	Liq Conf Rad Exp Air Conf (for air conf see also K1 Vent System)	Room access control (roof access control needs to be addressed) Maintain coverblocks in place during operating mode	Need analysis of unmitigated spray release to determine offsite soil contam levels. This could drive SC-1 or reasonable Admin Control Action. Note: Sump is single barrier, always challenged by liquid. Need integrity assessment.		X	7.8

*The Criterion and Target - Descriptions columns were omitted to allow space for the Human Factors Items Column in this table

**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
CANYON, PUMP STORAGE ROOM, TRUCK LOADOUT ROOM (Floor, roof walls, roof and interior floor drains)	2	Liq Conf Rad Exp Air Conf (for air conf see also K1 vent system)	Room access control (roof access control needs to be addressed)	Need analysis of unmitigated spray release to determine offsite soil contamination levels. This could drive SC-1 or reasonable Admin Control action.	X		1.1 2.1 3.3 5.1 6.1 3.2 6.4 5.4
SAMPLER CABINET (Incl drains, shielding on sampler piping)	2	Liq Conf Rad Exp	Admin control	Determine drainage capacity of sampler cabinet - need to confine catastrophic failure of sampler piping.	X		1.1 2.1 3.3 5.1 6.1 3.2 6.4 5.3 5.4

**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
SAMPLER CABINET LEAK DETECTION SYSTEM	2	Liq Conf	Leak detection alarm response action needed at a minimum.	Same as sampler cabinet issue above. Interlock and/or barrier may be required, depending on time to mitigate catastrophic failure. "Safe shutdown" may apply to this interlock.	X		1.1 2.1 3.3 5.1 6.1 3.2 6.3 6.4 5.3 5.4
EVAPORATOR LIQUID LEVEL MONITORING INTERLOCK, AND ALARM SYSTEM	2	Rad Exp Liq Conf	Admin control required for alarm response action	Confirm and document in FSAR that overflow from vessel remains confined from evap vessel to 102-AW. Recommend interlock to initiate dump on high liquid level in evap vessel. "Safe shutdown" may apply to this interlock.	X		1.1 2.1 3.3 5.1 6.1 3.2 6.3 6.4 5.3 5.4

**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
K1 VENT SYSTEM AND STACK MONITOR SYSTEM AND NECESSARY BUILDING ATTRIBUTES	2	Air Conf	Admin control to shutdown process on loss of K1 vent system and/or stack monitor safety function Admin control to monitor rad level on filters to limit duration of a spray release event and to protect facility workers from excessive exposure.	Need analysis of unmitigated spray release to determine offsite soil contamination levels. This could drive SC-1 or reasonable Admin Control action. Need analysis to determine consequence from normally present cell contamination if vent system shutdown. Need analysis of exposure rate from filter housing to determine if additional preventive/mitigative measure needed to mitigate excessive, acute exposure to unsuspecting worker. Need analysis cross ventilation.	X		1.1 2.1 3.3 5.1 4.2 6.1 3.2 5.3 5.4 --
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**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
VESSEL VENT STACK MONITOR AND ALARM SYSTEM	2	Air Conf		Analysis to date limited to 8 hour duration. Need unmitigated analysis to determine if 2-1 and 2-2 criteria are exceeded and to identify any preventive/mitigate measures needed.	N/A	N/A	N/A
RC-3 PROCESS CONDENSATE MONITORING AND DIVERSION SYSTEM	2	Liq Conf			X		1.1 2.1 3.3 5.1 6.1 3.2 6.4 5.3 5.4
EXTERIOR SLURRY AND SUPERNATE PIPING AND LEAK DETECTION SYSTEM	2	Liq Conf	Admin control of excavation, process fluid properties, etc.	Need to consider cathodic protection implication. Need to reconcile with revised/new Ch.9 accident scenarios #1 and #4	X		1.1 2.1 3.3 5.1 6.1 3.2 6.4 5.3 5.4

**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
EXTERIOR EVAPORATOR DRAIN PIPING AND LEAK DETECTION SYSTEM (334, 335, 338)	2	Liq Conf	Admin control of excavation, process fluid properties, etc.	Need to consider cathodic protection implication.		Cass System	3.6
				Need to reconcile with revised/new Ch 9 accident scenarios #1 and #4	--	--	--
CLEAN-OUT BOX LEAK DETECTION AND SHUT-DOWN INTER-LOCK AND THOSE ATTRIBUTES OF THE COBS WHICH SUPPORT THE LEAK DETECTION FUNCTION Also COB posts and chains and soil to reduce rad exposure	2	Liq Conf Air Conf Rad Exp	Admin control in the form of posts, chains, and signs	Need analysis of unmitigated spray release to determine offsite soil contamination levels. This could drive SC-1 or reasonable Admin Control action.		Cass System	3.6
				Need rad exposure analysis at COBs. Interface issue with COB drains to supernate lines outside facility boundary (SN-219).	--	--	--
						Cass System	3.6

**Only items with direct impact on the systems and structures are listed

TABLE A.1.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
PIT WALLS, BLOCKS, AND SURROUNDING SOIL FOR SHIELDING PIT LEAK DETECTION AND SHUTDOWN SYSTEM AND ATTRIBUTES OF PITS NECESSARY TO SUPPORT LEAK DETECTION SYSTEM TO PROVIDE LIQ AND AIR CONF FUNCTIONS	2	Liq Conf Air Conf Rad Exp	Admin control to keep pit blocks in place during operation and to prevent excavation of soil surrounding pits during operation.	Need analysis of unmitigated spray release to determine offsite soil contamination levels. This could drive SC-1 or reasonable Admin Control action.	X	N/A	1.1 2.1 3.3 5.1 4.2 6.1 3.2 5.3 5.4
SOIL AND CONCRETE ABOVE EXTERIOR SN, SL, AND DR PIPELINES	2	Rad Exp	Admin control to assure sufficient shielding	Note: SAR takes credit for soil preventing spray release and minimizing surface pool size	N/A	N/A	N/A

**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
EVAPORATOR DRAIN LINE 343	TBD			Need analysis of toxicological consequences from a pool of process solution, process condensate, and decon chemicals resulting from a failed drain line. Required to determine if SC-2 protection needed for unsuspecting facility workers and onsite workers. Note: single pipe	X	X	7.8
COOLING WATER/USED RAW WATER LINES AND WATER SERVICES DRAIN AND SANITARY SYSTEMS	TBD			Need analysis of liquid backflow/siphon potential throughout facility.	X	X	1.1 2.1 3.3 5.1 6.1 3.2 6.4 5.3 5.4

**Only items with direct impact on the systems and structures are listed

TABLE A.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
EVAPORATOR DUMP SYSTEM AND FEED PUMP SHUTDOWN SYSTEM	2	Safe Shutdown		Note: Safet shutdown to be defined in OSRs and may be applied to previously identified interlocks. Safe shutdown presently assumed to be an empty evaporator vessel with feed and slurry pumps de-energized. Recommend installation of a hard-wired interlock system to accomplish "safe shutdown."	X	X	1.5
TBD		Prev Crit		Determine if evaporator hardware is needed to prevent criticality in evaporator or tank farm.	N/A	N/A	N/A
TBD		OSR		Dependent on completion of OSRs.	N/A	N/A	N/A
TBD		SAR Credit		Dependent on completion of Chapter 9.	N/A	N/A	N/A

**Only items with direct impact on the systems and structures are listed

TABLE A.I.1. (contd)

Systems and Structures	Safety Class	Safety Function	Admin Control Credit Items	Issues	Human Factors Items**		
					MCS Related	Other	Item
TBD		Prevent SSC Failure		Dependent on outcome of detailed analysis of safety class systems (FMEA, fault tree analysis, etc.)	N/A	N/A	N/A

**Only items with direct impact on the systems and structures are listed

TABLE A.2 Human Factors Items that Impact Control and Monitoring of the MCS

Control and Monitoring Needs Attribute Item	Non-Alarm Specific							Alarm Specific			
	Current Status	Correct System Response	Feedback System Actions	Initiate Response	Manual Controls Access	Manual Controls Feedback	Current Status	Initiate Response	Indicate Class II	Monitors	Arrangement Controls
1.0 Control Console/Room Configuration											
1.1 Simultaneous Display of Information	X	X	X	X	-	-	X	-	-	X	-
1.2 Incomplete Overall Evaporator Status System Representation	X	X	X	X	-	-	X	X	X	X	
1.3 Lack of Designated Alarm List Monitor	X	-	X	-	-	-	X	X	X	X	-
1.4 Lack of Meaningful Annunciator Panel Layout	X	X	X	X	X	X	X	X	-	-	X
2.0 Use of Color Coding in the MCS											
2.1 Inconsistent Use of Color	X	X	X	-	-	-	X	-	X	-	-
3.0 Data Display											
3.1 Incomplete system Representation of Radiation Detectors	X	X	X	X	-	-	-	-	-	-	-
3.2 Lack of Alarm List Display Titles	X	X	-	X	-	-	X	X	-	-	-
3.3 Lack of Alarm List Column Labeling	X	X	-	X	-	-	X	X	-	-	-
3.4 Ambiguous Scaling of Grids	X	X	X	X	-	-	X	-	X	-	-
3.5 Ambiguous Marking on Grids	X	X	X	X	-	-	X	X	X	-	-
3.6 Lack of Direct Information Access	-	-	-	X	X	-	-	X	-	-	-
3.7 Ambiguous Use of Grid Graphics	X	X	X	-	-	-	-	-	-	-	-
3.8 Cluttered Displays	X	X	X	X	-	-	X	X	X	X	-

TABLE A.2. (contd)

Control and Monitoring Needs Design Attribute Item	Non-Alarm Specific						Alarm Specific				
	Current Status	Correct System Response	Feedback System Actions	Initiate Response	Manual Controls		Current Status	Initiate Response	Indicate Class II	Arrangement	
					Access	Feedback				Monitors	Controls
4.0 Feedback											
4.1 Unintentional Disabling of Alarms	-	-	-	X	X	X	-	X	-	-	-
4.2 Lack of Valve-opening Information	X	-	X	-	-	-	X	-	-	-	-
4.3 Same key used to continue comments	-	-	-	X	X	X	-	X	-	-	-
5.0 Interactive Control/ System Navigation											
5.1 Slow System Response Time	X	X	X	X	-	-	X	X	X	-	-
5.2 Inadequate Indication of Screen Hierarchy	X	-	-	X	-	-	X	X	-	-	-
5.3 Adequate Indication of Inter-Screen Relationships	X	-	-	X	-	-	X	X	-	-	-
5.4 Screen Navigation Commands	-	-	-	X	X	X	-	X	-	-	-
6.0 Labeling											
6.1 Inconsistent Display Numbering	-	-	-	X	X	-	-	X	-	-	-
6.2 Unclear Labeling of Alarm List Access Buttons	X	-	-	X	-	-	X	X	-	-	-
6.3 Multiple Names for Specific Items	X	X	-	X	X	-	X	X	-	-	-
6.4 Inconsistent Use of Labels	X	X	-	X	X	-	X	X	-	-	-
6.5 Inconsistent Location of screen titles	X	-	-	-	-	-	X	-	-	-	-

TABLE A.2. (contd)

Control and Monitoring Needs Design Attribute Item	Non-Alarm Specific						Alarm Specific				
	Current Status	Correct System Response	Feedback System Actions	Initiate Response	Manual Controls		Current Status	Initiate Response	Indicate Class II	Arrangement	
					Access	Feedback				Monitors	Controls
7.0 General Attributes											
7.1 Distribution of System Information	X	X	-	X	-	-	X	X	-	-	-
7.2 Inadequate Operator Knowledge of System Interlocks											
7.3 Training Approach and Adequacy	▲						Not Assessed				▲
7.4 Lack of Diagnostic Aids	▲						Not Assessed				▲
7.5 Simultaneous Task Requirements	X	X	X	X	X	X	X	X	X	X	X
7.6 Absence of Remote Detectors on Exhaust Filters	▲						Future Enhancement to System				▲
7.7 Lack of Leak Detection Monitors	▲						Future Enhancement to System				▲
7.8 Complex Processes Required to Find Some Spray Leaks	▲						Future Enhancement to System				▲
7.9 Use of Data Derived From Operational Test Procedures	▲						Future Enhancement to System				▲

TABLE A.2. (contd)

Control and Monitoring Needs Design Attribute Item	Non-Alarm Specific						Alarm Specific				
	Current Status	Correct System Response	Feedback System Actions	Initiate Response	Manual Controls		Current Status	Initiate Response	Indicate Class II	Arrangement	
					Access	Feedback				Monitors	Controls
1.0 Control Console/Room Configuration											
1.1 Simultaneously Display of Information	X	X	X	X	-	-	X	-	-	X	-
1.2 Overall Evaporator Status System Represented	X	X	X	X	-	-	X	X	X	X	
1.3 Designated Alarm List Monitor	X	-	X	-	-	-	X	X	X	X	-
1.4 Announcables	X	X	X	X	X	X	X	X	-	-	X
2.0 Color											
2.1 Inconsistent the of Color	X	X	X	-	-	-	X	-	X	-	-
3.0 Data Display											
3.1 Representation of Radiation Detectors	X	X	X	X	-	-	-	-	-	-	-
3.2 Alarm List Display Titles	X	X	-	X	-	-	X	X	-	-	-
3.3 Alarm List Column Labeling	X	X	-	X	-	-	X	X	-	-	-
3.4 Scaling of Grids	X	X	X	X	-	-	X	-	X	-	-
3.5 Marking on Grids	X	X	X	X	-	-	X	X	X	-	-
3.6 Direct Information Access	-	-	-	X	X	-	-	X	-	-	-
3.7 Use of Grid Graphics	X	X	X	-	-	-	-	-	-	-	-
3.8 Cluttered Displays	X	X	X	X	-	-	X	X	X	X	-

TABLE A.2. (contd)

Control and Monitoring Needs Design Attribute Item	Non-Alarm Specific						Alarm Specific				
	Current Status	Correct System Response	Feedback System Actions	Initiate Response	Manual Controls		Current Status	Initiate Response	Indicate Class II	Arrangement	
					Access	Feedback				Monitors	Controls
4.0 Feedback											
4.1 Inhibit/Disable Inputs	-	-	-	X	X	X	-	X	-	-	-
4.2 Opening Slate for Values	X	-	X	-	-	-	X	-	-	-	-
4.3 Same key used to continue comments	-	-	-	X	X	X	-	X	-	-	-
5.0 Interactive Control/ System Navigation											
5.1 System Response Time	X	X	X	X	-	-	X	X	X	-	-
5.2 Indication of System Sources Heirarchy	X	-	-	X	-	-	X	X	-	-	-
5.3 Indication of Inter-Screen Relationships	X	-	-	X	-	-	X	X	-	-	-
5.4 Screen Navigation Commands	-	-	-	X	X	X	-	X	-	-	-
6.0 Labeling											
6.1 Display Numbering	-	-	-	X	X	-	-	X	-	-	-
6.2 Labeling of Alarm List Access Buttons	X	-	-	X	-	-	X	X	-	-	-
6.3 Names for Specific Items	X	X	-	X	X	-	X	X	-	-	-
6.4 Use of Labels	X	X	-	X	X	-	X	X	-	-	-
6.5 Location of Screen Titles	X	-	-	-	-	-	X	-	-	-	-

TABLE A.2. (contd)

Control and Monitoring Needs Design Attribute Item	Non-Alarm Specific						Alarm Specific				
	Current Status	Correct System Response	Feedback System Actions	Initiate Response	Manual Controls Access	Feedback	Current Status	Initiate Response	Indicate Class II	Monitors	Arrangement Controls
7.0 General Attributes											
7.1 Distribution of System Information Between MCS and CASS System	X	X	-	X	-	-	X	X	-	-	-
7.2 Interlocks											
7.3 Training Materials	↓						Not Assessed				▲
7.4 Diagnostic Assistance System Evolves	↓						Not Assessed				▲
7.5 Further Human Factors Engineering Evolution	↓						Future Recommendation				▲
7.6 Performance of Tasks Simultaneously	X	X	X	X	X	X	X	X	X	X	X
7.7 Remote Detection on Exhaust Fillers	↓						Future Enhancement to System				▲
7.8 Toxic Leak Detection Monitors	↓						Future Enhancement to System				▲

TABLE A.3. Some Methods for Navigating Through the Monitor and Control System

METHOD USED	Keyboard Key	Arrows	Arrows	Page	Prev	Arrows	Quick Access
MCS SYSTEM	Screen Icon						
				Page	Prev		
Screens							
Display associated graphic		X	X	X	X	X	X
Display associated text				X	X		X
Displays next page in sequence		X	X	X	X	X	
Displays previous page		X	X	X	X	X	
Display continued on right and/or left		X	X	X	X		
Keyboard							
Quick access keys		X	X			X	X
Keypad			X				X
Quick access key/keypad			X				X

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