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SCHWENCER,A. Licensing Branch 2

SUBJECT: Forwards response to 841219 telcon addressing Sandia recommendations for imporovement in human factor engineering of BWR Owners Group graphic display sys.Discussion of signal validation logic also encl.

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	NRR/DSI/CPB	10	1	1	NRR/DSI/CSB	09	1	1
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January 31, 1985
G02-85-047

Docket No. 50-397

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Schwencer:

Subject: NUCLEAR PLANT NO. 2
GRAPHIC DISPLAY SYSTEM HUMAN FACTORS

As a result of the telephone conversation of December 19, 1984 between Messrs. Raj Auluck and Leo Beltracchi of the NRC staff, and P. L. Powell, H. L. Aeschliman, and D. L. Gano of the Supply System, the Supply System has addressed the recommendations for improvement in human engineering of the BWROG Graphic Display System (GDS) as defined in the Simulator Evaluation of the BWROG GDS Report as prepared by Sandia National Laboratory; Report ALO-1019, printed May, 1983.

Each significant suggestion from this report and our corresponding response is listed in Attachment A. In addition, a discussion of our signal validation logic is provided in Attachment B. We trust this will resolve Mr. Beltracchi's concerns as we understood them to be.

As pointed out in previous responses to the human factors design of the WNP-2 GDS, this is not an inactive effort. Improving the GDS displays at WNP-2 is a continuous effort. The more the displays are used, the more comments we receive from principle users and these improvements are continually being made. With this in mind, it should be noted that statements made in this response regarding the existing design may change in the future and you will not be notified unless

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the changes are significant to the basic design and the FSAR requires updating. Also, Mr. Beltracchi wanted to know how our GDS compared to the General Electric ERIS product line. Since we have no knowledge of this system, we can not provide a comparison.

Should you have any questions, please contact Mr. P. L. Powell, Manager, WNP-2 Licensing.

Very truly yours,

R B Glasscock

for G. C. Sorensen, Manager
Regulatory Programs

DLG/tmh
Attachments

cc: R Auluck - NRC
L Beltracchi - NRC
WS Chin - BPA
JB Martin - NRC RV
AD Toth - NRC Site

ATTACHMENT A

5. HUMAN ENGINEERING CONSIDERATIONS

(Taken From Sandia Report ALO-1019)

This section presents human engineering considerations and guidelines that were developed as a result of evaluating the data collected during this study. It is not intended that they represent a compendium of human engineering specifications for the development and design of all graphic displays. Rather, they are directed at improving the 19 displays used in the GDS evaluated in this study.

As described previously in this report, for purposes of analysis the displays were sorted into four groups, Overview, Bars, Trends, and Limit Regions. From a human factors perspective, however, they can be categorized into three generic classes of displays as follows:

1. The moving bar, which includes the Overview display and the four Bar displays.

2. The time-based, single-variable parameter curve, which consists of all of the Trend displays.

3. The multiple variable parameter, integrated display, which consists of all the Limit Region displays.

Because the GDS is intended to be used under casualty conditions, the comments and suggestions that follow are aimed at increasing the effectiveness of the operators when working under stress.

5.1 Bar Displays

The bar displays presents a series of horizontal bars. Each bar represents a single parameter. The value of a parameter is determined from the length of the bar. In the GDS, all of the bars were oriented in the direction of the x axis.

Of the three types of displays, the bar graph is the most efficient means of presenting large amounts of information in a limited space. This is due to the fact that the variable parameter is presented on one axis only, the horizontal. The vertical dimension of the bar needs only to be wide enough to be easily discriminated by the operator. The width of the present bars could be reduced by one-half and still be adequately visible. This attribute allows a higher density of information to be presented in a given space than either the Trend or Limit displays.

In general, the design and layout of the bar displays meet commonly accepted human engineering standards. However, some problems exist in the following areas:

- Scaling
- Labeling
- Readability
- Alarms

Scaling

The scales should be long enough that the operator can visually discriminate small but significant changes in direction of the bars. In the GDS, the length of the scale is limited by the dimensions of the CRT. In the practical sense, the most effective action option is to make the scale as long as the system will allow. Additional length can be obtained by:

- *reducing the size of the lettering and/or reformating the labels on either side of the x axis of the bars, and*
- *relocating the quantitative readouts above or below the associated bars. This modification might necessitate a reduction in the width of the bars in order to provide sufficient space.*

Labeling

Many of the critical tic marks were not labeled. Some of the operators expressed concern about this omission, particularly with regard to the absence of the alarm setpoint values. Labels should be provided for all critical tic marks.

Readability

The operators often commented that the tic marks were too small. The length of the tic marks should be increased. This may be accomplished by extending the tics into the body of the bar and/or by decreasing the width of the bars and extending the tics into the resulting space below the bar.

Alarms

Operators commented on absence of color coding of the quantitative readouts. The use of color to indicate status would aid in the rapid comprehension of system status from the readouts.

SUPPLY SYSTEM RESPONSE TO BAR DISPLAY SUGGESTIONS

SCALING

The length of the bars on the WNP-2 displays were increased 23% and additional scaling values were added to improve the ability to discriminate changes in a parameter at a glance.

LABELING

The labeling of tic marks was not incorporated due to the added clutter it creates. It was also assumed that a good operator knows what every alarm setpoint in the Technical Specifications is and, to date, our operators have never questioned what a tic mark represents.

READABILITY

The tic marks were completely redesigned to take the form of a triangle at the top of each bar. This increase in size has resolved this problem.

ALARMS

Color coding the numerical readouts for each parameter is a requirement of the design specification. That is to say, if the parameter exceeds a yellow or red alarm setpoint, the numerical readout of the parameter and the bar are supposed to change colors to yellow or red also. Due to software difficulties, the numerals do not change colors; however, the bars do. This is an outstanding issue at this time; however, as a result of upcoming computer changes, we expect to incorporate this improvement in the future along with a change to increase the size of the numerical readouts to the same height as the bar. We do not consider this a serious deficiency since there have never been any comments from our users regarding this issue.

GENERAL

Many of the specific comments regarding each bar display were also incorporated. In addition, several parameters used mostly for daily operations were added as an incentive to encourage daily use of the displays. An example of a bar display is provided in Figure 1.

5.2 *Trend Displays* *(Taken From Sandia Report ALO-1019)*

The trend displays presented the variable parameter on the y axis and a six-minute time base on the x axis. The resulting trace represented a six-minute history of the parameter being measured.

The unique advantage of the trend display is its pictorial presentation of the six-minute history. The time trace was considered to be important enough to a number of the operators for them to suggest that not only should the time span be increased but that a memory capability be added to the GDS so that they could call up older traces for second looks and detailed examination. (A hard copy printout capability would also serve this purpose.)

A second advantage of the trend display is that it provides a pictorial presentation of the direction of movement of the parameter. (The bar display provides arrows of + and - to indicate the direction of change.) This graphic presentation, coupled with the six-minute history, enhances the operators' ability to make rapid predictions of the subsequent behavior of the system and its future status.

The general design and layout of the trend displays was marginal from a human factors standpoint. Usability problems are present in the following areas:

- *Scaling*
- *Labeling*
- *Readability*
- *Display Reaction Time*
- *Alarms*
- *Alignment of Readout Boxes*

Scaling

The primary usability problems reported by the operators was the difficulty in reading the display due to the limited length of the vertical scales, particularly on displays containing two or more graphs.

The effectiveness of the trend display is extremely sensitive to the number of parameters displayed at one time. The operators' ability to detect small shifts in trends deteriorates rapidly as the number of graphs per display increases. (See Section 5.4 for a discussion of this problem.) Only one graph should be presented in a trend display unless there is a critical interaction between parameters. Then a display with two graphs might be provided if particular attention is given to readability aspects of the design.

If trend displays are limited to a single parameter, the basic guidelines for the design of scales are similar to those for bars. The major difference between them is that, unlike the bar, the trend display requires that both the x and y scales be optimized for readability. Enough concern over compressed scales was expressed by a number of operators that they were willing to delete the mimic and reduce the size of the safety function boxes so that the scales could be lengthened. The scales must provide sufficient range to ensure that the operators can detect the smallest change considered to be of significance.

Labeling

As in the case of the bar displays, the operators were concerned that the critical tic marks were not identified and the alarm setpoint values were not indicated. It was also noted that the units of measure of the readouts were not always identified. The displays should be redesigned to incorporate these features.

Readability

Operators commented on the absence of a y scale on the right side of the graph. The time history of the trend displays progresses from left to right with the most current value always on the right. No scale markings exist on the right side of the graph. The scale markings should be provided where they can be used by the operators, preferably on both vertical sides of the graph, or, if that is not feasible, on the right side of the graph. The tic marks should be made longer by extending them through the body of the graph as is done in the RPV Level (Fuel Zone)/RPV Pressure display.

Display Reaction Time

The call-up time for the multiple displays ranged up to 14 seconds. A number of operators indicated that this was too slow. The reaction time of the system should be reduced.

Alarms

The trend lines and readout boxes did not change color with a change of status. If both items made the same use of color as the bars in the bar displays, speed of detection of status changes would be aided.

Alignment of Readout Boxes

In multiple graph displays, the operators reported difficulty in relating the readout boxes to the proper graphs. To aid operators in identifying the correct readings, the upper or lower border of the box could be eliminated and the box raised or lowered, as appropriate, to meet the border of the graph with which it is associated. Whatever the design solution, it should be employed consistently throughout all of the trend displays.

SUPPLY SYSTEM RESPONSE TO TREND DISPLAY SUGGESTIONS

SCALING

The problem of small scales was resolved on the WNP-2 GDS by displaying only one parameter trend at a time; plus having the option to display all trends for each safety group at the same time. In this way we have the best of both worlds. In addition, there are three colorgraphic CRT's in the operating zone of the control room. For each trend display, the trend area is maximized on the CRT to provide maximum clarity and detect small changes. Also, it has been found that the time scale for some parameters should be longer than six minutes and were changed accordingly. The reactor vessel mimic was deleted on all displays to make room for larger trends. Also, in an effort to bring the advantages of the bar display to the trend display, a vertical bar was added to each trend.

LABELING

Tic mark labeling was not deemed significant and, in fact, causes problems with clutter. Refer to our response in the Bar Display section.

READABILITY

All our trend displays have scales on both sides of the trend. Tic marks have been improved by using larger color coded triangles.

DISPLAY REACTION TIME

Display call-up times for all singular displays varies from 7 to 14 seconds for the first time it is called up. After a display has been called up once and then is asked for a second time (i.e., after going to another display), it will be displayed in less than 2 seconds. Multiple trend displays take approximately 30 seconds to become active. These times are not much of an improvement over the original BWROG displays, but this is limited by the current technology, not our desire to improve it.

ALARMS

The WNP-2 GDS displays incorporated a vertical bar which changes color according to alarm points. This, along with the color change in the readout boxes, aids in the detection of status change changes.

ALIGNMENT OF READOUT BOXES

This is a non-problem since all our trend displays are singular parameter displays.

GENERAL

In addition to the short term real time trends provided by the standard set of GDS displays, the STA console, TSC consoles, and EOF consoles all have the capability of calling up "GDS Historical" displays which consist of extended time scales of all GDS trends. There are 6 time scale options as follows: 1 hour, 8 hours, 24 hours, 48 hours, One week and Two weeks. A hard copy color printout capability is also being added in early 1985. Figures 1, 2, and 3 are examples of this capability. An example of trend displays is provided in Figure 2.

5.3 *Limit Region Displays* *(Taken From Sandia Report ALO-1019)*

The limit region displays are characterized by the integration of the values of the x and y parameters and the use of an overlay(s) to indicate the limit regions. The operators evaluate the system condition by observing the location of a marker within the limit region. In some of the displays a short time history is provided by providing a tail on the marker.

The design and layout of the limit region display were judged by the operators to be usable. However, two areas for improvement are:

- *Readability*
- *Labeling*

Readability

The position marker (x) presently used interferes with the operators' ability to read a value when it approaches the boundary of the graph or when the trend line moves in the same direction as one of the legs of the x. The x should be replaced with an open-centered x, or a circle, or a triangle so that it does not cover needed information.

Labeling

The labeling of the x axis was typically located along side the upper horizontal boundary of the graph. The placement confused many of the operators because of the stereotyped expectation that this location is used for labeling the y axis.

Labeling (Cont.)

Further evidence of operator confusion was found when they filled out the questionnaire. In completing Part 2 of the questionnaire, the operators were asked to enter the title of the display being evaluated in the appropriate space. In the case of the limit region displays, as many different titles were entered as there were major headings in the graphs. The titles should be relocated to eliminate confusion. Otherwise, the displays could contribute to communication problems among operators in casualty situations.

SUPPLY SYSTEM RESPONSE TO LIMIT REGION DISPLAY SUGGESTIONS

READABILITY

The WNP-2 GDS uses an equal-armed rectilinear cross (+) with a red dot in the middle. When the cross moves, the red dot stays and leaves a trail of where it's been and provides insite into which direction it's trending. As it approaches the limit boundary and subsequently crosses it, there is no interference with the operators' ability to know the relationship between the center of the cross and the boundary line. This is primarily due to the red center of the blue cross.

LABELING

The labeling of these displays is in the same location and similar format as all other displays and, thus, the confusion experienced on the BWROG displays was eliminated. In addition, all units are defined on the same axis as the scale, and all titles are in the upper left hand corner opposite the time.

GENERAL

To aid in the interface with the Emergency Operating Procedures, these displays provide a reference to the specific section of the Chapter 5 Emergency Operating Procedures (EOP) to which each display is used. Some displays have more than one reference.

SUPPLY SYSTEM ADDITIONAL COMMENTS AND CONCLUSIONS

In addition to the generic human factors improvements noted above, many display-specific suggestions were also incorporated. In addition to our own operators' participation in the BWROG study, they were also asked to provide on an informal basis, comments on the preliminary WNP-2 display set, and many of their comments were incorporated. The WNP-2 GDS design engineer was also intimately involved in the BWROG activities and provided several major improvements to the original WNP-2 display set. Among these are the following features:

1. Addition of a digital clock which if not updating, indicates the display is also not current.

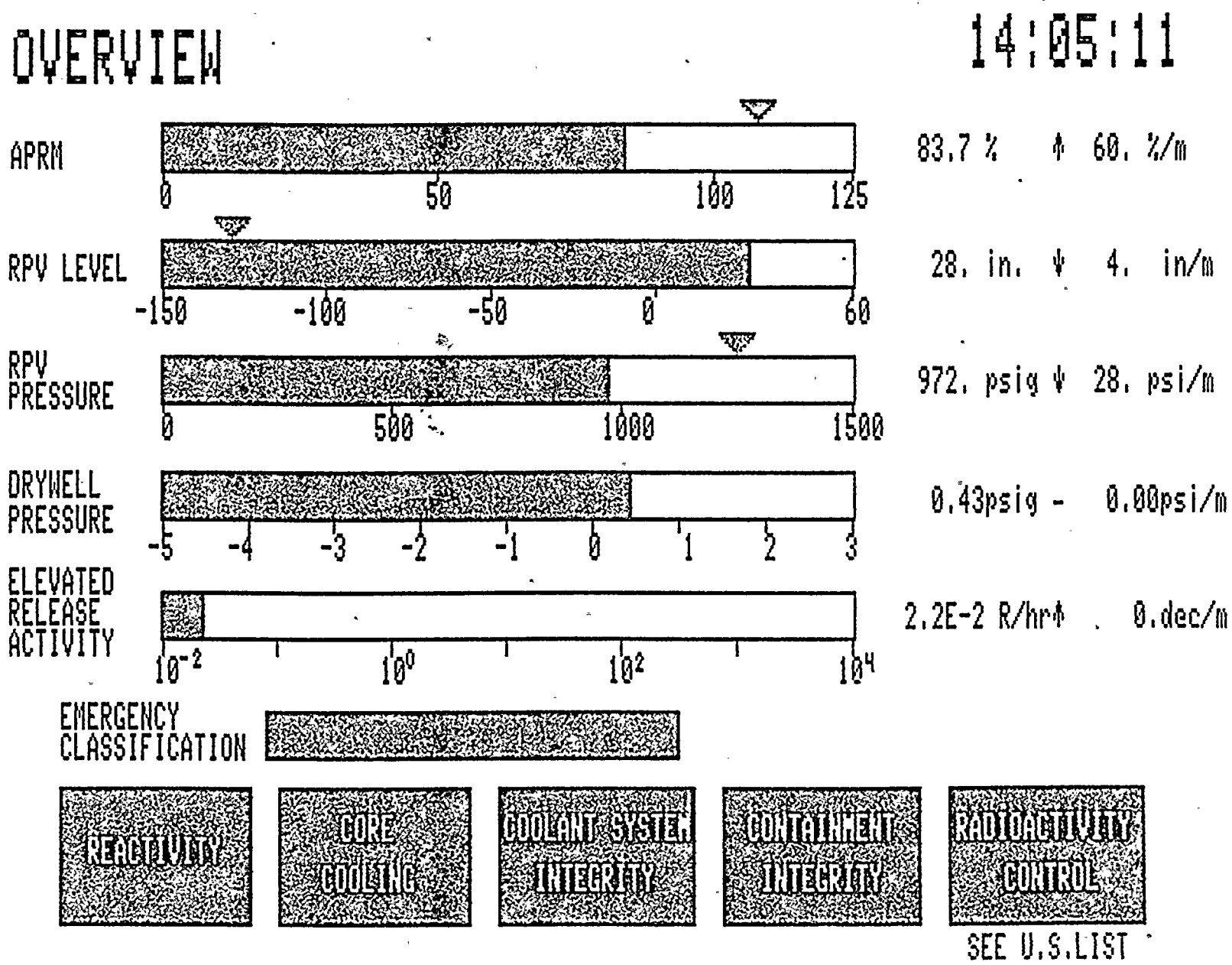
2. Expansion of display logic from one page to over 150 pages to improve the "intelligence" of the displays.

3. Addition of computer-driven, symptom-based Emergency Classification aid to all displays.

4. Addition of Containment Isolation information to provide the operator with a single display that will identify acceptable containment isolation or not.

5. A touchpad interface for use by the operator which has a touchpoint for each display, and if any parameter on that display is in an alarm condition, the touchpoint will blink; slow for a yellow condition and fast for a red alarm condition. This maximizes the human inter-relationship by minimizing the understanding required of the user.

In conclusion, we believe the WNP-2 GDS to be one of the best in the industry and again invite you to come and see it.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APRM
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50
100
125
83.7 %
60. %/m
RPV LEVEL
-150
-100
-50
0
60
28. in.
4. in/m
RPV PRESSURE
0
500
1000
1500
972. psig
28. psi/m
DRYWELL PRESSURE
-5
-4
-3
-2
-1
0
1
2
3
0.43psig -
0.00psi/m
ELEVATED RELEASE ACTIVITY
10-2
100
102
104
2.2E-2 R/hr
0.dec/m
EMERGENCY CLASSIFICATION
REACTIVITY
CORE COOLING
COOLANT SYSTEM INTEGRITY
CONTAINMENT INTEGRITY
RADIOACTIVITY CONTROL
SEE U.S.LIST

Figure 1

ATTACHMENT A

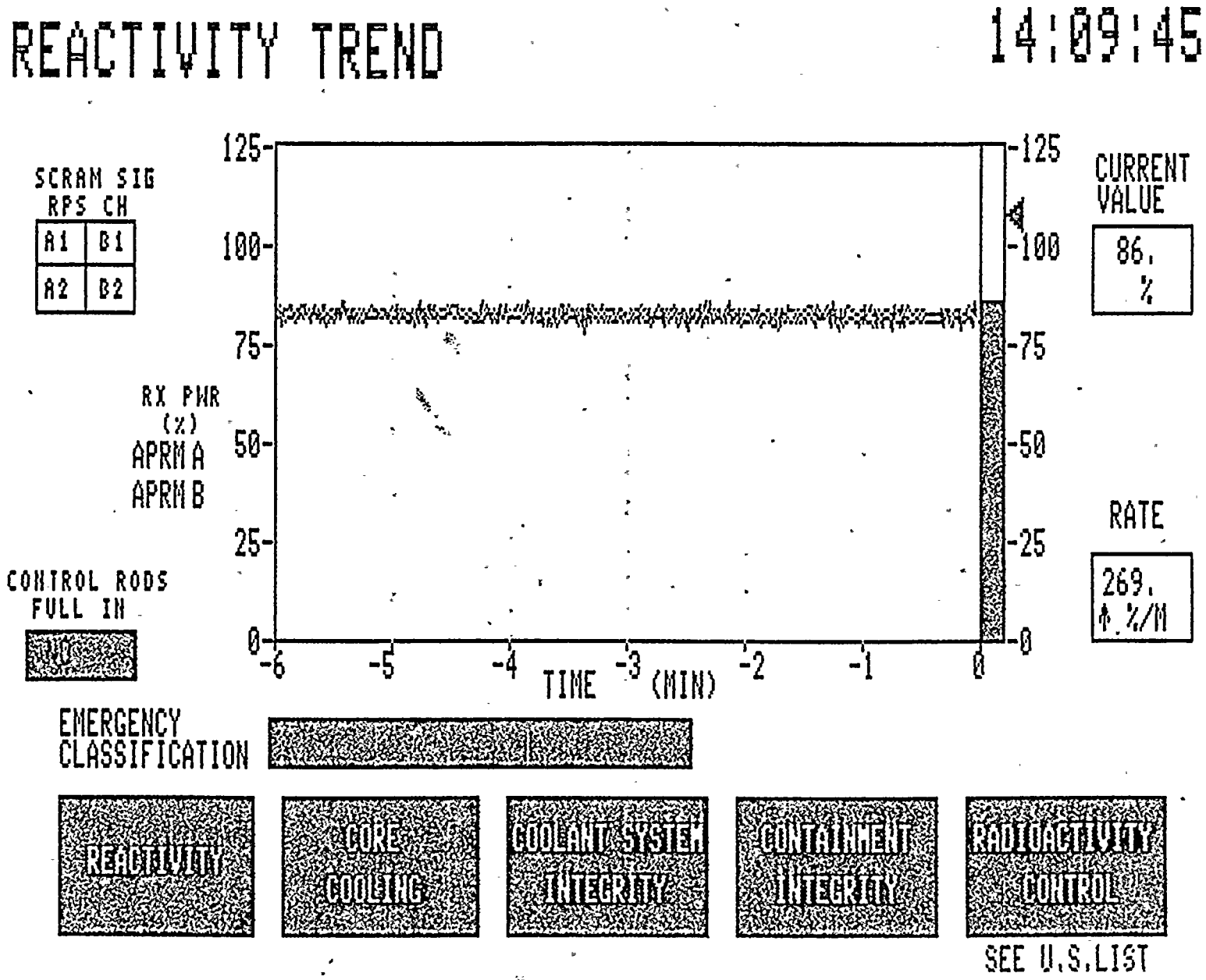
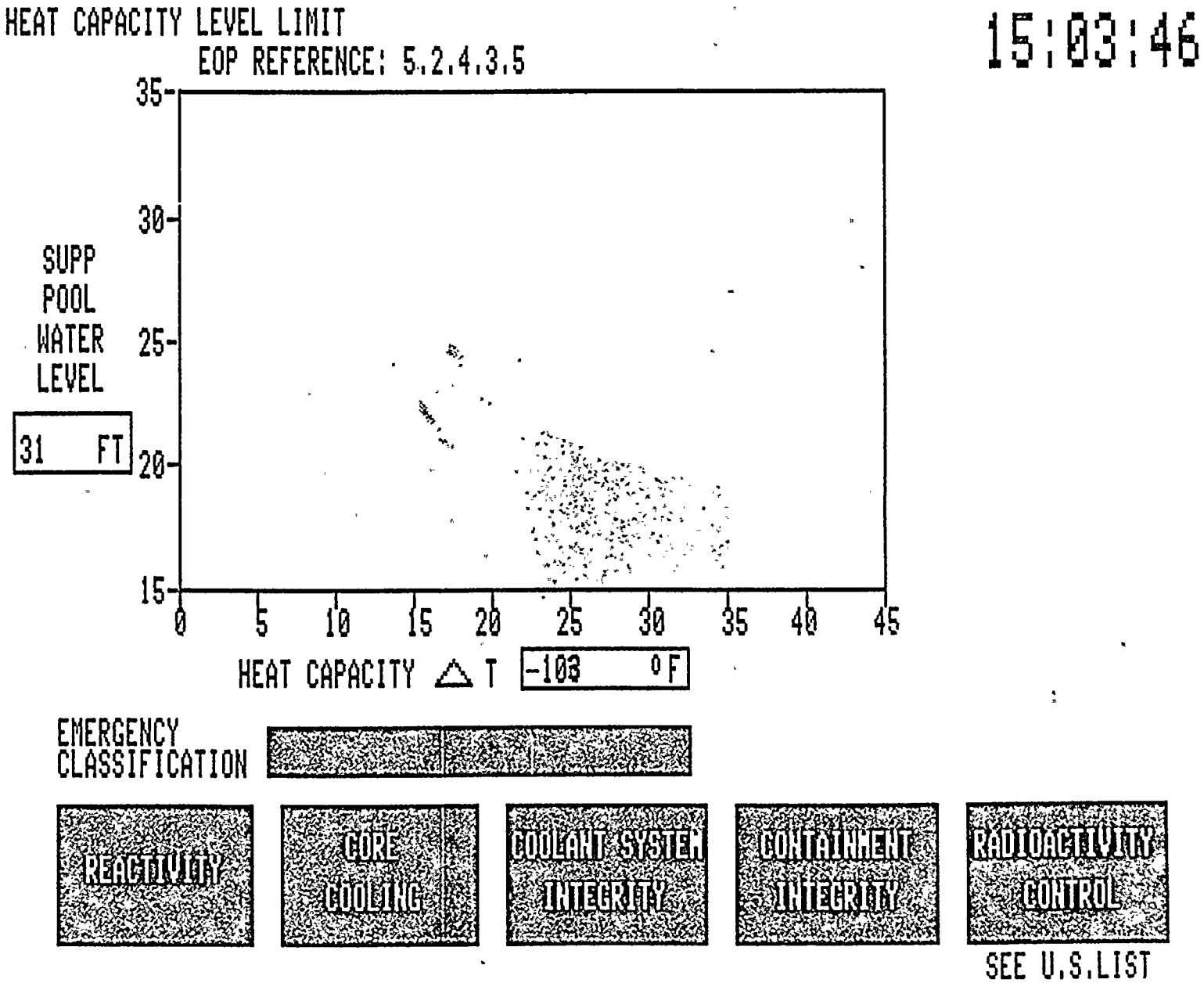


Figure 2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EOP REFERENCE: 5.2.4.3.5
15:03:46
SUPP POOL WATER LEVEL
31 FT
35
30
25
20
15
0
5
10
15
20
25
30
35
40
45
HEAT CAPACITY △T -103 °F
EMERGENCY CLASSIFICATION
REACTIVITY
CORE COOLING
COOLANT SYSTEM INTEGRITY
CONTAINMENT INTEGRITY
RADIOACTIVITY CONTROL
SEE U.S.LIST

Figure 3

ATTACHMENT B

WNP-2 SIGNAL VALIDATION FOR THE GRAPHIC DISPLAY SYSTEM

Where possible, GDS signals are validated prior to processing on a real time basis by comparing the displayed signal with a companion signal. If a companion signal is not available, one is generated using a combination of other signals; if possible.

If the signal validation is not achieved, the operator will be informed by the words "INVALID SIGNAL" displayed either in the bar for bar graph displays or in the trend graph for trend displays.

For those signals which do not provide an input to a bar or trend display but are used for display derivation (e.g., SRMs), the invalid signal point ID will be displayed at the bottom left of the screen in red text.

In addition to the signal validation logic, there are two other sets of logic that provide the user with information regarding an abnormal signal condition. In most cases, each displayed parameter has at least 2 redundant signals. Each display logic is unique as to whether it will display the largest or the smallest signal. However, if the dominant signal goes off scale, the bar will be emptied of color and the text "OFF SCALE HIGH" or "OFF SCALE LOW" will be displayed in the bar and on the trend display. Secondly, under security passwords is the capability to delete any signal from inputting to GDS. If one signal is bad and it's the dominant signal, it can provide erroneous information (usually detected by the validation logic). The capability to delete this input signal until it is repaired allows the continued use of this parameter via the other signal. If for some reason both signals are bad and they are subsequently deleted, the text "SIGNAL UNAVAILABLE" will be displayed in the bar and on the trend displays. Also, if any signal is in "surveillance" (i.e., deleted from scan), each and every display will have a note at the lower right corner which states "SEE U.S. LIST"; meaning to go to the Under Surveillance Listing to determine which signals are bad.

The priority for these three error messages are as follows:

1. Signal Unavailable
2. Invalid Signal
3. Off Scale High or Low