INL/EXT-17-44135
Revision 0

Light Water Reactor Sustainability Program

Executive Summary: Prototype Design, Analysis, and Results for a Liquid Radiological Waste Control Room

January 2018

U.S. Department of Energy

Office of Nuclear Energy

INL/EXT-17-44135
Revision 0

Executive Summary: Prototype Design, Analysis, and Results for a Liquid Radiological Waste Control Room

Prepared by
Johanna Oxstrand and Katya Le Blanc

January 2018

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy

ACKNOWLEDGEMENTS

We are grateful for the ongoing support from the radiological waste control room operators and engineering staff at Arizona Public Services. Further, we would like to thank the staff at the Institute of Energy Technology who were an integral part in the experimental design for the operator workshop by providing technical expertise and support with the micro-task data collection activities. This report was made possible through funding by the United States Department of Energy Light Water Reactor Sustainability Program. Lastly, we would like to thank Richard Reister of the Department of Energy and Ken Thomas and Bruce Hallbert of Idaho National Laboratory for championing this effort.

Executive Summary: Prototype Design, Analysis, and Results for a Liquid Radiological Waste Control Room

1. INTRODUCTION

Under the United States Department of Energy Light Water Sustainability Program (LWRS), Idaho National Laboratory (INL) is collaborating with Palo Verde Generating Station (PVGS) to support human factors engineering efforts in the modernization of PVNGS' radiological waste system (LRS) control room.

The studies proposed and conducted by INL are designed to address the inconsistency between different human factors standards, guidance, and conventions. Guidance such as NUREG-0700 leave much of the information open to interpretation. INL goal is to identify whether maintaining a design that is consistent with population stereotypes actually enhances performance, or whether there are alternative designs that yield performance that is better than the designs that maintain those stereotypes.

The overall design concept for the LRS workstation includes system overview displays for the Evaporator system and the Boric Acid Concentrator system. A third display contains overview information for the rest of the LRS. The forth display contains alarm information.

The system overview displays contain embedded controls for valves and pumps, mini-trends, and micro-trends. The mini-trends present data for the controllers and contain alarm setpoint information as well as trending. All other relevant system parameters are shown on micro-trends.

The semi-dull screen approach presents dynamic data, such as trends and live numerical values, in green while active components are white (gray when closed or off). Product streams are differentiated from one another using desaturated pastel colors. Alarm states are presented in saturated red and selected components are indicated by bright blue, see Figure 1.

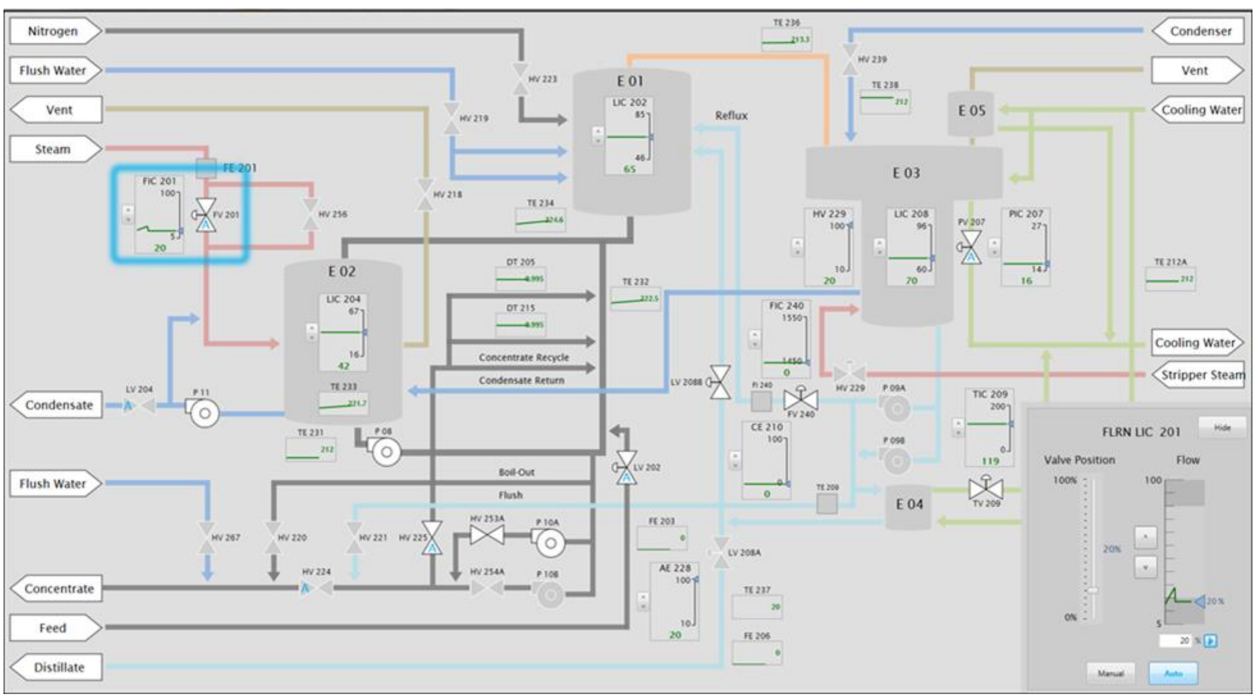


Figure 1. Evaporator system overview with embedded control.

In addition to the micro task study described below, INL researchers collected end-user evaluations of the semi-dull screen approach and conducted an ergonomic evaluation of the suggested upgrades in the local control room. A detailed report of all INL's activities related to the modernization of the LRS conducted between October 2016 and September 2017 are found in these two reports;

- *INL-EXT-17-43226, Prototype Design, Analysis, and Results for a Liquid Radiological Waste Control Room*, and
- *INL-EXT-17-43250, Evaluation of Control Room Interface Designs to Support Modernization in Nuclear Power Plants*.

1.1 Design Workshop at PVNGS

INL conducted a design workshop onsite at PVNGS in August 2017. Twelve auxiliary operators participated in the Evaporator system based workshop. The 12 participants included the entire population of four operators that are fully trained in the LRS system.

Four versions of the display interface were developed; Two versions of background color (a fully dull screen version and a version with colored flow paths) and two representations of component status (white/gray and red/green) as shown in Figure 2 below.

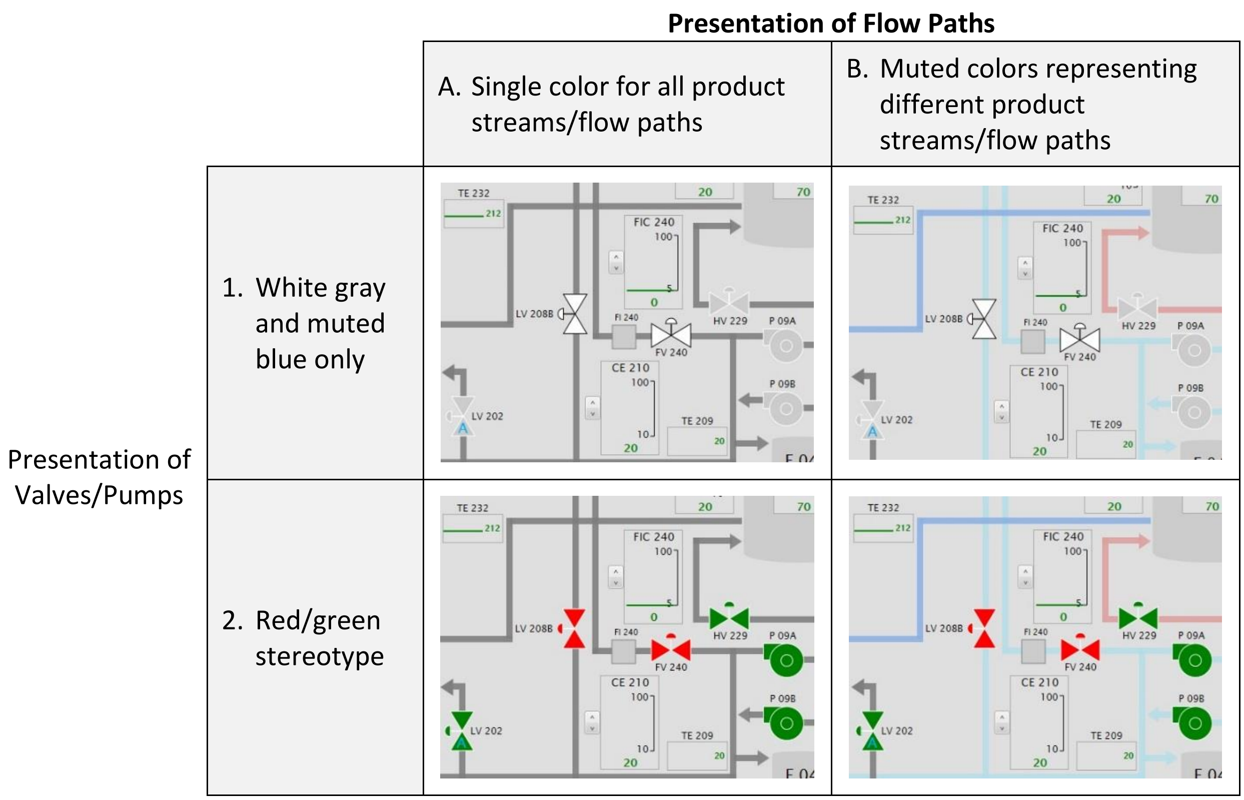


Figure 2. Versions of interfaces developed to test color scheme.

The INL team used a micro task study where participants answered many questions regarding current and future system status based on a static image of the current system state. Comparing how operators answered questions within each interface is well suited for design decisions such as the effect of color choice on performance. The micro task study helped address research questions such as;

1. Do red/green component status indications help operators determine component state faster or more accurately than white/grey component status?

2. Do red/green valve and pump indications help operators more quickly determine how a system is aligned?
3. Do color coded product streams improve the operator's ability to identify consequences of system configuration more accurately or more quickly?
4. What are the interactions between the different color use strategies (i.e., do color coded product streams reduce the effect of red/green valves or the salience of alarms)?
5. Does the dull screen help the operator detect alarm states more quickly or accurately?

1.2 Results

Table 1 on page 4 illustrates the main findings from the micro task study. In short, the results suggest there is little basis for maintaining the red/green stereotypes, but using the alternate design might improve operator performance.

INL recommends using color sparingly, choosing muted colors for static display elements such as background, and reserving saturated color for highlighting abnormal states and other important dynamic information.

2. PATH FORWARD

INL's human factors activities related to the LRS will be completed by the end of the fiscal year of 2018. The 2018 activities include an onsite evaluation of the Boric Acid Concentrator system display, an evaluation of navigation between systems and displays, and multiple smaller studies aiming to gather technical bases for the proposed overall design philosophy.

In addition, the INL team will develop a prototype of the envisioned end-state for the main control room. The prototype, initially developed in the INL Human Systems Simulation Laboratory, will be a mix of dynamic (functional) and static boards.

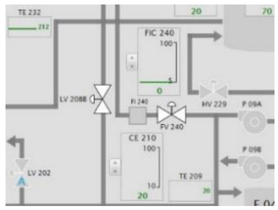
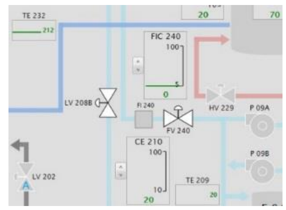
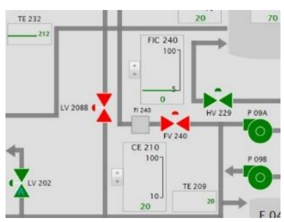
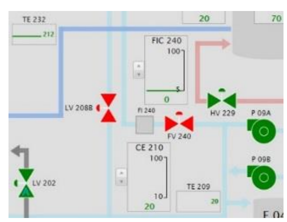
		Flow Path color		
		Single color for all product streams/flow paths	Muted colors representing different product streams/flow paths	Component color Results
Component color	White gray and muted blue only	 ✓ Best Alarm detection performance	 ✓ Fastest response time for identifying system alignment and consequences ✓ Most efficient visual search time for identifying system alignment and consequences	✓ Most efficient “comprehension time”
	Red/green stereotype			✓ Fastest Response times and better search efficiency for identifying component state × Lowest Accuracy when identifying component state

Table 1. Summary of micro task results.