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AT SEA EVALUATION OF LOW LEVEL WHITE
LIGHTING ON SURFACE SHIPS

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SUMMARY

Combat Information Center (CIC) and bridge watchstanders from three surface ships participated in an evaluation of Low Level White (LLW) lighting during at sea operations. At the end of each watch, subjects evaluated the lighting in use and rated the ease of performing various watchstanding tasks. LLW provided many advantages over the standard red or blue lighting, including less eye strain, less fatigue, fewer headaches, and less glare on CRT displays. Overall LLW lighting was preferred by two out of the three ships for use in the CIC area. Recommendations are made for continued study of the operational use of LLW lighting on surface ships.

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For almost a decade U.S. Naval ships have been using two types of chromatic (blue/red) ambient illumination. Throughout the Fleet there is very little standardization leading to various modifications in ambient illumination. Prior to this time, red lighting was the standard nighttime ambient illumination for shipboard use. It was used because it provided enough light to perform various "routine" watchstanding tasks, it produced the smallest effect on the dark adaptation level, or night vision, of watchstanders on the bridge, or in the Combat Information Center (CIC) (Luria and Kobus, 1985).

However, the rapid pace of technology has increased the number and complexity of "routine" tasks performed. These tasks may require the operator to attend to fine detail on visual displays, read color coded information, or be relatively mobile throughout the compartment. This increase in task requirements has led to many complaints regarding the use of red lighting. Operators have complained about headaches, as well as difficulties in reading, log keeping, and an inability to discriminate color coded information. The crew of one ship finally took the matter into their own hands and replaced the red filters with blue filters which were readily available through the GSA catalog. They reported that the blue lighting enhanced performance and recommended that it replace the red. After an evaluation by one additional crew, the Submarine Force adopted blue lighting as a replacement for red (CONSUBLANT, 1982). Yet, one still finds various lighting configurations depending upon the type and class of ship, the compartment, and personnel preference. This condition exists even though the CNO has authorized the use of LLW lighting in operational areas on submarines (CNO, 1986).

At the same time, the continued use of red lighting was being questioned by the Naval Submarine Medical Research Laboratory (NSMRL) and a series of studies was conducted to evaluate the feasibility of replacing the red lighting. The best alternative appeared to be the use of an achromatic lighting system at a level of intensity equal to or lower than that of red illumination. This lighting system, referred to as Low Level White (LLW) lighting, appeared to provide significant improvements in performance without disrupting dark adaptation. For a recent review see (Luria, Kobus, and Neri, 1986).

The initial phase of this research was limited to evaluating the use of LLW lighting for submarines. Theoretically, the results regarding the feasibility of using LLW lighting in operational areas on surface ships should be very similar to the results obtained on submarines. Yet, testing LLW lighting on surface ships requires consideration of several additional variables. The first is that the requirement for dark adaptation on surface ships exists throughout the twilight hours; therefore, the LLW lighting system would be needed for longer durations than on submarines. In fact, most ships continually operate under nighttime illumination conditions in CIC while underway. Thus far, LLW lighting has been used for only short durations as a pre-adapting period. A proper evaluation needs to be performed to determine the feasibility of using LLW lighting for long periods of time. The second consideration is that the compartment and lighting configurations are much different on surface ships than on submarines. The intensity of light in a compartment is obviously directly related to the number and kinds of lights available. In addition, the tasks that the operators perform and the equipment they use may differ significantly between submarines and surface ships.

The goal of the present study was to evaluate the feasibility of LLW as a replacement for the red or blue illumination presently used on surface ships.

Method

Subjects - Watchstanders from the CIC and the bridge areas on three separate ships participated in the at-sea evaluation. Two of the ships were fast frigates (USS Ramsey, FFG-2; USS Sides, FFG-14) and the third was an amphibious assault ship (USS Cayuga, LST 1186).

Filters - Neutral density filter material (film) was used to make sleeves to fit over the light bulbs in the CIC, Bridge, and adjacent passageways. The filters were made to replace the red or blue filters presently used. The intensity of the LLW was not equated to that of the red but was dimmer by 0.4 log units (see Kobus and Luria, 1986).

Procedure - The ships that participated in the evaluation used red or blue lighting as their standard for nighttime ambient illumination. Each ship evaluated the lighting in a different order. Within each ship, the

experimental and standard lighting conditions were presented in a counterbalanced order. Most watchstanders were grouped into three sections; each watch was 4-6 hours long. Questionnaires were given to evaluate how well normal watchstanding duties could be performed under each illumination condition. The watchstanders were asked to rate the illumination on a scale of 1 to 10 for the ease with which the lighting permitted them to perform tasks that were required of their specific watchstation. The final question asked the observer to provide a rating of the "overall" quality of the illumination. The questionnaire was a standard format for all watchstanders. A copy of the questionnaire is shown in Appendix II.

Most watchstanders were grouped into three sections; each watch was from 4-6 hours in duration. Each ship evaluated the lighting in a different order. Two ships evaluated the LLW first, and the third evaluated the red lighting first. Within each ship the lighting conditions were presented in a counterbalanced (ABBA) order. Questionnaire were given to evaluate how well normal watchstanding duties could be performed under each illumination condition. The watchstanders were asked to rate the illumination on a scale of 1 to 10 for the ease with which the lighting permitted them to perform tasks that were required of their specific watchstation. The final question asked the observer to provide a rating of the "overall" quality of the illumination. Questionnaires were a standard format used for all watchstanders.

Results

The responses to each of eleven questions comparing red and LLW lighting for operational use were subjected to a one-way analysis of variance. The analyses were completed separately for each ship and the number of subjects in each analysis varied from 13 to 79 depending upon whether or not the question pertained to a specific watchstation. Separate analyses were conducted for each area on the ship.

Bridge Analyses -

The LLW on the bridge provided statistically significant improvements. Such operational tasks such as log keeping and reading color coded material were improved, and the crews reported fewer headaches. There was, however, one significant degradation, glare off the bridge windshield reduced visibility on overcast evenings. This reduction in visibility superseded

any of the positive results found using this lighting. It is possible that increasing the neutral density of the filters for the lights on the bridge would solve the problem, but until this has been demonstrated, LLW must be considered inappropriate for the bridge. No further analyses of the bridge data will therefore be discussed.

Table 1. Statistically significant improvements using LLW lighting on the Bridge.¹

<u>QUESTION</u>	<u>SHIP</u>	<u>PREFERENCE</u>
Ease in reading colored plots	USS Cayuga	LLW
Ease in reading colored pubs	USS Ramsey	LLW
	USS Cayuga	LLW
Ease in making log entries	USS Ramsey	LLW
Ease in dark adapting	USS Ramsey	LLW
	USS Cayuga	LLW
Lighting best to reduce eye fatigue	USS Ramsey	LLW
Reduction in headaches	USS Cayuga	LLW
OVERALL DESIRABILITY	USS Ramsey	LLW
	USS Cayuga	LLW

¹ NOTE: The above results were found using LLW lighting on moon-lit evenings. However, the glare on the Bridge windows on over-cast evenings caused by the LLW lighting was very high. Therefore, the use of LLW lighting on the Bridge was eliminated.

CIC Analyses -

The same questionnaire was also used for the CIC data collection. Table 2 lists the significant results of each type of lighting used in the CIC area for each ship. Fourteen differences were statistically significant. Of these, eleven favored the LLW and only three the blue light. All three were from the USS Sides. There were no significant differences from the USS Cayuga. Again, some operational duties were improved and other improvements were reductions in fatigue and the number of headaches. The crew of the USS Sides reported an improvement in the ease of reading colored publications and a reduction in fatigue under blue, leading them to conclude that the blue was more desirable.

DISCUSSION

The overall acceptance of LLW lighting in the CIC was mixed. For one ship the LLW lighting was rated better than the standard red or blue lighting in every case. A second ship found very little difference between the two lighting systems. The third ship reported that the blue lighting was better for certain tasks. It should be pointed out that the number of questionnaires completed was significantly higher for the first ship discussed.

Although, the statistical results were mixed, two of the ships sent messages to Naval Health Research Center (NHRC) supporting the use of LLW lighting in the CIC area (see appendix 1). In fact, one ship, the USS Ramsey FFG-2, requested to keep the filters on board for further evaluation. A second evaluation reported by the USS Ramsey provides further support for the use of LLW lighting in the CIC area (see Appendix 1, item 5).

Throughout all of the evaluations of both submarines and surface ships, this was the first study in which any crew reported an overall preference for blue lighting rather than LLW. It is true that in the first study of this kind carried out in the Sonar Operational Trainer, at the Submarine Base, Groton, CT, (Kinney, Luria, and Ryan, 1982), two crews preferred blue to dim white light. However, black cloth was used to dim the white light. This method is very inferior to the use of neutral density sleeves and produced an unpleasant effect which most likely accounts for those results.

The reason for the preference for blue on the USS Sides in this study appear to be related to the type of diffuser (light cover) on the lights and to the number of lights in the compartment. This ship has fewer lights in

TABLE 2. Statistically significant differences for each question between lighting conditions in the CIC area.

<u>QUESTION</u>	<u>SHIP</u>	<u>PREFERENCE</u>
Ease in reading colored plots	USS Ramsey	LLW
Ease in reading colored publications	USS Ramsey USS Sides	LLW BLUE*
Ease in making log entries	USS Ramsey	LLW
Ease in reading panel lettering	USS Ramsey	LLW
Ease in reading Illuminated display panel	USS Ramsey	LLW
Ease in viewing CRT scope	USS Ramsey	LLW
Ease in dark adapting	USS Ramsey	LLW
Reduction in fatigue	USS Ramsey USS Sides	LLW BLUE*
Reduction in the number of headaches	USS Ramsey	LLW
Likelihood of continuing to work after watch	USS Ramsey	LLW
OVERALL DESIRABILITY	USS Ramsey USS Sides	LLW BLUE*

* The analysis on the USS Sides was based on the smallest sample size (n=13).

the CIC compartment than the USS Ramsey. In addition, the lights on this ship all had the "egg-crate" type diffusers. This type of diffuser tends to channel the illumination in a vertical column, thus reducing the amount of light being "spread" throughout the compartment. This reduces the overall level of ambient illumination compared to the standard configuration. The preference for blue on this ship, therefore, is probably due to the fact that blue lighting appears brighter than LLW both for peripheral vision and during mesopic (twilight) lighting conditions. This results from what is called the "purkinje shift": blue light becomes relatively brighter as the light level gets dimmer and the light receptors around the periphery of the retina become dominant. The relative brightness of the blue light was no doubt preferable to dimmer light. However, it should be pointed out that of all the low level or chromatic ambient illumination conditions, blue is by far the worst for dark adaptation.

The use of LLW lighting on the Bridge proved to be effective only on bright moonlit nights. The glare produced on the bridge windows while using LLW lighting reduced visibility significantly. The use of LLW lighting on the bridge was therefore terminated. The use of LLW lighting on the bridge is not recommended.

We recommend that the evaluation of LLW lighting on surface ships continue. Our results indicate that the use of LLW lighting provides many significant advantages over the red/blue lighting presently used. Further research is needed to support these results as well as to investigate a possible replacement for the night-time lighting presently used on the bridge. In addition, research is required to determine if LLW lighting is feasible for all classes of U.S. surface ships.

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APPENDIX I



DEPARTMENT OF THE NAVY

USS CAYUGA (LST 1186)
FPO SAN FRANCISCO 96682 1R07

3960
Ser 00/377
21 August 1987

From: Commanding Officer, USS CAYUGA (LST 1186)
To: Commanding Officer, Naval Health Research Center, San Diego, CA

Subj: LOW LEVEL WHITE LIGHT EVALUATION

1. During the period 10-14 August 1987 USS CAYUGA (LST 1186) participated in an evaluation of low level white lighting while underway in the SOCAL opareas conducting independent steaming exercises.
2. Low level white lighting was tested on the bridge, in CIC and the Commanding Officer's cabin (which on an LST also serves as the sea cabin).
3. The use of the low level white light as compared to the traditional red lighting is considered to be an improvement in CIC but not so for the bridge or the Commanding Officer's cabin. The white light intensity on the bridge was too great, creating an unacceptable glare on the bridge windows. The low level white light in the Commanding Officer's cabin was considered to be too dim for continuous use and did not allow for rapid night adaptation.
4. The professionalism of LT Charles V. Chesson, MSC, USN is to be commended. His management of the evaluation was conducted smoothly and without impact on concurrent taskings. In addition, his collateral assistance in officer and CPO training in the Navy's PrT program was particularly appreciated.

M. A. OUBLE

ROUTINE

R 142129Z SEP 87 PSN 540445522

FM USS RAMSEY

TO COMNAVSURFPAC SAN DIEGO CA

INFO COMUSCOPSGRU THREE
COMUSCOP TWO THREE
NAVHLTHRSCHCN SAN DIEGO CA

COMUSCOP SEVEN
COMUSCOP FIVE

UNCLAS //N23900//

SUBJ: LOW LEVEL WHITE (LLW) LIGHTING SYSTEM EVALUATION

A. COMNAVSURFPAC SAN DIEGO CA 221523Z JUL 87

1. IAW REF A LLW LIGHTING SYSTEM WAS EVALUATED UNDERWAY 13-18 AUG

87. WATCH STANDERS IN CIC, SONAR, EW MODULE AND THE BRIDGE FILLED OUT QUESTIONNAIRES ON A WATCH TO WATCH BASIS. EXISTING SHIPS (BLUE) LIGHTING WAS EVALUATED ON 13 AND 17 AUG. LLW LIGHT WAS EVALUATED 14-18 AUG. LLW LIGHTING WAS ACHIEVED BY USING PHOTOGRAPH FILTER MATERIAL IN PLACE OF RED/BLUE FILTER TUBES.

2. THE FOLLOWING ADVANTAGES OF LLW LIGHTING OVER EXISTING BLUE LIGHTING WERE OBSERVED.

- A. LLW LIGHT SIGNIFICANTLY REDUCED GLARE ON RADAR REPEATERS
- B. PLOTTING AND READING COLOR-CODED NAVIGATION CHARTS WAS EASIER.
- C. WATCH STANDERS FELT LESS FATIGUED AFTER STANDING WATCHES IN LLW LIGHTING THAN IN RED/BLUE LTG.
- D. PUBLICATIONS WERE EASIER TO READ USING LLW LIGHT
- E. AT NIGHT, IT TOOK LESS TIME FOR DARK-ADAPTATION AS WATCH STANDERS MOVED BETWEEN CIC AND THE BRIDGE. LLW LIGHT REDUCES THE LIGHTING INTENSITY MORE THAN THE BLUE FILTERS.

3. DISADVANTAGES IN THE USE OF LLW LIGHTING

- A. IN SOME CASES, A DOUBLES THICKNESS OF LLW FILTER MATL WAS REQUIRED TO REDUCE LTG INTENSITY TO DESIRED LEVEL.
- B. INCANDESCENT GLOBE FIXTURES ARE NOT AVAIL TO REPLACE EXISTING RED GLOBES WITH LOW LVL LTG GLOBES.

4. RECOMMENDATIONS

- A. DEVELOP STANDARD STOCK LLW FILTERS TO REPLACE EXISTING RED FILTERS USED FOR ALL PASSAGEWAYS AND BERTHING COMPARTMENTS FLUORESCENT LTG.
- B. USE LOW WATTAGE (15 WATT) BULBS AS AN INTERIM FIX TO REDUCE NIGHT LIGHTING INTENSITY IN PASSAGEWAYS.
- C. REPLACE EXISTING BLUE FILTERS WITH LLW LIGHTING FILTERS

5. ALL LTG FIXTURES WERE RESTORED TO STANDARD CONFIGURATION FOR LOW LVL LTG TEST. ADDITL OPS (18-11 SEP) AGAIN PROVED THAT STD RED/BLUE LTG WAS INFERIOR TO PROPOSED LLW LTG, ESPECIALLY IN CIC/BRIDGE. DURING TESTING NAVHLTHRSCHCN REP STATED WILLINGNESS TO RETURN TO RAMSEY TO INSTALL LLW LTG FOR CONTINUED EVALUATION. RAMSEY STRONGLY DESIRES INSTALL LLW LIGHT FILTERS IN CIC, SONAR, EW MODULE AND PILOT HOUSE. REQUEST RAMSEY BE AUTHORIZED TO INSTALL LLW FIXTURES FOR INDEFINATE PERIOD FOR CONTINUED EVALUATION.

BT

APPENDIX II

SAMPLE QUESTIONNAIRE

LLW QUESTIONNAIRE

Watch Station: _____
Color of Light: _____

Time of Watch: _____

Indicate difficulty level by circling a number (1= difficult, 10= easy).

1. Rate the difficulty of reading colored plots.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

2. Rate the difficulty of reading publications.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

3. Rate the difficulty of making log entries.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

4. Rate the difficulty of reading panel lettering.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

5. Rate the difficulty of reading illuminated display panels.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

6. Rate the difficulty of viewing CRT scopes.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

7. If you had to go through other compartments (passageways, bridge), rate the difficulty or discomfort of the changes in brightness and the time to readapt.

HARD **EASY**
1---2---3---4---5---6---7---8---9---10

Comments?

8. Rate how tired your eyes got during the watch.
(1= tired; 10= not tired at all)

1---2---3---4---5---6---7---8---9---10

Comments?

9. Did you get a headache? Yes or No

Comments?

10. Rate how likely you are to stay up and do other things after this watch.

HARD

EASY

1---2---3---4---5---6---7---8---9---10

Comments?

11. Rate the quality, desirability, effectiveness, etc., of this light.
(1= bad; 10= good)

BAD

GOOD

1---2---3---4---5---6---7---8---9---10

Comments?

12. Were any of the lights distracting or annoying? (How so?)

13. Additional comments.

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