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C#7905
29 October 1964

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Subject: Proposal for Continuation of Luminescent Rear Projection Screen Development [redacted] Register Number 3-2554 STAT

Gentlemen:

[redacted] has been conducting a feasibility program for the development of a high resolution screen. The program is evidencing a high degree of success and it is the opinion of both [redacted] that continuation of this program will result in a highly desirable projection system. STAT STAT STAT

The basic criteria which was established at the beginning of the program was to increase in the rate of information transfer from the projected image to the observer. We are of the combined opinion that the final result of this program will exceed this goal to the point where today's conventional systems may be obsoleted.

The proposal attached to this letter outlines a one year program utilizing the combined services of [redacted] It is estimated that the total cost of the program will be less than [redacted] We are submitting this proposal to you at this early date with the intent to resolve any of the details as soon as possible, and so that the starting of the new effort can begin with as little time lapse between programs as possible. STAT STAT

Sincerely,

[redacted] STAT

Program Manager

Copy 2 —
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Copy 4 [redacted] STAT
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Copy 1 of 5

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Attachment

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INTRODUCTION

As a result of the current feasibility study several important goals have been achieved in the art of producing better rear projection screens. First, the luminescent screen is non-directional. The true lambertian surface emits equally in all directions. As a result, an evenly illuminated, equally intense image is visible to any number of viewers regardless of their respective positions about the screen. This unique capability cannot be achieved by any other type of screen.

Second, the resolution capability of a transparent luminescent screen can be made equal to any lense-film combination used to form a magnified aerial image. Equivalent resolution capability cannot be found in any conventional screen material. This fact alone removes the screen as the limiting factor in the resolution capability of a rear projection viewing system.

Third, the contrast of the image is independent of ambient lighting. This factor enables the observer to view a comfortably illuminated screen image in a brightly lighted room. The transparent luminescent screen permits the ambient light to penetrate the screen without being scattered and to be absorbed in the cavity behind it. When using conventional screens at high ambient illumination levels one must use exceedingly bright images to maintain contrast between highlights and shadows. The dazzling effect of the bright image reduces the acuity of the observers vision and creates rapid visual fatigue. Conventional light scattering screens add scattered light to the displayed image, while transparent screens, being free of this fault provide adequate visual contrast with comparatively moderate highlight intensity.

In addition, several new approaches towards increasing the efficiency of the overall system have been brought to light by the study. This proposal outlines these approaches and makes recommendations for both continued research by [redacted] to make as efficient a screen material as possible STAT and to construct a prototype viewing system using customer supplied equipment whenever possible.

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ACHIEVEMENTS OF PREVIOUS PROGRAM

Previous work performed in this program has produced screen samples which have demonstrated the feasibility of a transparent rear projection screen system. Ultraviolet light was projected through black and white film to form a visible image on the screen material, the ultraviolet energy being absorbed by the screen material and converted to visible light by photoluminescence.

The projection system designed during this development provided a lens designed to magnify a 70mm image to 30 x 30 inches and was diffraction limited on axis. Aspherization of two of the lens elements provided for high resolution to the edges of the field.

The previous program was only intended to demonstrate feasibility of the system. The duration of the program was not adequate to investigate thoroughly the several interesting possibilities, which became apparent during its course, for improving the efficiency and effectiveness of luminescent screens. In particular the following points are of interest for further investigation.

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DISCUSSION OF PROPOSED INVESTIGATION

1. Anti-reflection coating of the viewing side surface of the screen would reduce the ambient light specular reflections and also reduce internal-reflection trapping of luminescent output. A conventional evaporated coating will be used for this purpose.

Anti-reflection over-coating of some organic phosphor coatings would increase the useful ultraviolet entering the phosphor by as much as 20%. To avoid risk of contamination of the phosphor an organic resin overcoating is an obvious first choice.

2. Intensification of organic phosphor luminescent output by means of an applied electrostatic field is an interesting possibility. This has already been done (U.S. Patent 2,933,602) using powdered ZnS:Mn phosphor in a resin binder. No linear relationship between excitation intensity and light output was claimed. An investigation will be made to find whether field intensification of output can be applied to transparent phosphors and, if so, what the relationship between input and output energy is.

Techniques for energizing the electrostatically enhanced UV image have been characterized to a great extent by what we will call a "shorting type" technique. Conductive films placed on both sides of the luminescent dielectric tend to be unreliable because of the large area, any point of which is subject to voltage breakdown through the dielectric thereby creating failure of the entire screen.

It is also the purpose of this proposed study to examine "non-shorting techniques" such as are now in use in such devices as Xerographic printers or the Memoscope (Tonotron) type of cathode ray tubes. In this technique only one conductive coating is used between the screen substrate and the luminescent coating. The opposite charge is deposited on the screen by electrical corona leakage from a screen of grid wires some distance behind the screen and which may be placed at a point out of focus with respect to the projected image. It is notable that cathode ray tube displays of this type have been produced which consistently display brightnesses of 1000 foot lamberts and which are just now being increased to a brightness of 1700 foot lamberts.

3. Clear cathode ray tube phosphors discussed in the literature reportedly luminesce usefully only when excited by electron bombardment or 2537Å ultraviolet radiation. A possible exception is zinc fluoride phosphor which may be photo-luminescent with 3650Å ultraviolet excitation.

Some transparent phosphor CRTs are used in aircraft cockpit displays. Samples will be obtained for evaluation.

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4. A projection system will be provided which will handle all film sizes from 2-1/4" x 2-1/4" to 9" x 9" and will contain a 30" x 30" transparent screen to accommodate as many observers as possible. This projection system may be folded but for minimum distortion and loss of light a straight throw from film plane to screen is desirable.

5. Our previous investigation of organic luminescent materials was by no means exhaustive. It is possible, but not probable, that the best combination was found. The fact that the greatest luminance output efficiency obtained was about 15% of theoretical maximum, suggests that a continued study may be profitably undertaken. In particular, it is proposed that more emphasis be placed on theoretical investigation of organic systems. Measurements will be made of 20 different materials or combinations thereof although it is not intended that measurements be made of obviously inefficient materials.

6. Luminescent output light of organic coatings must be verified with prolonged exposure, and without exposure to the excitation ultraviolet. Since the organic coatings gave good luminescent output, the problem of brightness maintenance deserves further investigation.

7. There has been some discussion of the best color for screen luminescence. Since the transparent screen is a unique development we suggest consideration for subjective evaluation of the screen color as proposed in the Appendix of this proposal.

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PROPOSED CONTINUATION OF RESEARCH PROGRAM

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The objective of the proposed research program is to investigate theory and methods for development of an improved transparent luminescent screen for use with rear projection ultraviolet excitation. Emphasis will be placed on the theoretical investigation of organic systems and the practical investigation of organic phosphor screen coatings.

The approach would be to utilize the instrumentation and consulting facilities available for the organic study and to use the apparatus previously used, with modifications as required, for organic coatings.

The duration of the program would be one (1) year, the first ten (10) months of which would be devoted to the theoretical and practical investigations. Final and complete reporting will occupy the last part of the program.

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PROPOSED STATEMENT OF WORK FOR THE RESEARCH PROGRAM
([redacted] TO PERFORM) STAT

1. Further examine ultraviolet screen materials, organic only.

2. Conduct literature and theoretical search for a method to produce a brighter screen.

3. Test effect of electrostatic intensification of ultraviolet excited screen output and determine relationship between output brightness and various excitation intensities.

4. Evaluate polished inorganic coatings typical of clear cathode ray tube coatings.

5. Investigate effects on screen brightness and visual contrast of anti-reflection coatings applied to

   a. The substrate

   b. The luminescent organic coating.

6. Make samples, of a few square-inches area, of the most promising screen materials resulting from the above investigation.

7. Provide monthly and final progress reports.

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PROPOSED PROJECTION SYSTEM PROGRAM
([redacted] TO PERFORM) STAT

The objective of the projection system program is to provide a useable prototype viewer with a 30" x 30" screen to handle all film sizes. Different color and/or spare screens will be provided. These screens will be of polished plate glass, anti-reflection coated on one side.

The approach to the production of the screen will be to contact companies now engaged in production typical of this product to determine the least cost approach. Some tooling may be required in any event to produce a uniform, dust free screen.

Two additional lenses for various film formats will be provided. These lenses are to be color corrected for the ultraviolet only.

Part of the projection system program will be directed to the use of maximum energy at the film plane and the removal of heat so generated from the film. At present only an estimate of film temperature can be achieved by assuming that 40% of the total power emitted by the lamp is focused on the condenser system by the internal mirrors. If the 2500 watt lamp is 85% efficient and 10% of the total energy is in the 3654Å line, then:

$$2500 \text{ watts} \times 85\% \times 40\% \times 10\% = 75 \text{ watts}$$

available at the entrance to the condenser system. If we further assume 50% transmission by the condenser then approximately 36 watts of UV energy will be available across an area of 5 square inches resulting in an area power input of 7 watts per square inch of film.

We can also approach this estimate by considering the screen power requirements and working toward the projector. The power required at the calibration point for the screen for a 5.5 foot lambert emittance is 1.67 milliwatts of energy per square inch at 3654Å. The screen has a total area of 900 square inches.

$$(900)\ (1.66)\ (10^{-3}) = 1.494 \text{ watts}$$

Now if we make a conservative estimate of transmission loss in the projection lens of 60%, we can calculate the power required at the entrance to the lens of

$$\frac{1.494}{0.6} = 2.49 \text{ watts}$$

Next, we will assume that the film may in the extreme case absorb 90% of this energy and we can calculate the total power absorbed by the film as:

$$2.49\ (0.90) = 2.24 \text{ watts}$$

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Since the equipment we are using has a blower capacity of approximately 50 cfm we can now estimate the increase in temperature of the cooling air being passed around the film to cool it.

$$Q = WCp \Delta t_a \ *$$

*From Systems Design Periodical Nov. 1963, Leonhard Katz, "Heat Transfer Design"

Where: Q = heat transfer in BTU/hr

W = air flow in lbs./hr.

Cp = specific heat of air in BTU/lbs./°F

Δt_a = temperature rise of air in °F

$$Q = (2.24)\ (3.41) = 7.64 \text{ BTU/hr.}$$

$$W = (50)\ (.065)\ (60) = 195 \text{ lbs. of air per hr.}$$

$$Cp = 0.241 \text{ specific heat of air at room temperature}$$

Substituting in

$$\Delta t_a = \frac{Q}{WCp} = \frac{7.64}{(195)\ (0.241)} = .162°F$$

These brief calculations can be carried still further to show the maximum temperature rise in the film itself. From the prior calculation of 36 watts power available in the projector itself it is necessary to perform a detailed analysis of film heat dissipation techniques only if full power is required. However, for the purpose of this proposal it is sufficient to say that film heat dissipation is well within control levels especially if compared with standard visible projection systems utilizing filamentary light sources or any other light source utilizing the full visible spectrum.

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PROPOSED STATEMENT OF WORK FOR THE PROJECTION SYSTEM PROGRAM
TO PERFORM)

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1. Construct two 30" x 30" screens from material recommended by the feasibility study and two additional screens from material resulting from the proposed research program.

2. Utilize existing breadboard projector, lens and filters for construction elements of a prototype viewer where possible.

3. Provide two additional lenses for larger film formats.

4. Install GSE film handler into projection system.

5. Provide necessary operating manuals.

6. Provide subject color evaluation tests manuals and final evaluation acceptance test at the customer's facility.

7. Check plasma lamp source feasibility.

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APPENDIX

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APPENDIX

A PROPOSAL FOR SUBJECT COLOR EVALUATION TO OBTAIN THE MOST EFFICIENT LUMINESCENT SCREEN COLOR

TECHNICAL DESCRIPTION

At the present stage of development the High Resolution Screen presents a choice of monochromatic color fluorescence. The optimum choice of color should be based on the primary purpose of efficiency in the transfer of detailed image information from the screen to the observer.

To provide the best solution to this problem some subjective evaluation under controlled conditions are recommended by this proposal as a controlled experiment.

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METHOD FOR PROJECTION SCREEN COLOR EVALUATION

The following description outlines a proposed method for evaluating the relative visual resolving efficiency of rear projection screens having different spectral emission characteristics.

GENERAL:

A light enclosure will be constructed for control of the visual environment. Screens to be evaluated will cover a circular opening at one end of the light enclosure. Acuity test objects will be projected at controlled intervals on a screen from outside the enclosure. Screen brightness will be varied over a number of levels for viewing. Each of a number of subjects will observe and report on details of the test objects from an opening in the opposite end of the light enclosure. Subjects selected will have normal vision and be comparable in other major respects to persons expected to view the screens under work conditions. The investigation of factors that may have an influence on the results obtained is covered in an appendix.

DETAILED SPECIFICATIONS:

A. Light Enclosure

The light enclosure consists of a semi-circular box with back illumination provided by small incandescent bulbs. Provision is made for covering each of the lights with two 2" x 2" color filters. Figure 1 is a plan view of the enclosure, showing the general layout with major dimensions and suggested materials. Figure 2 is an interior elevation view of the enclosure with subject seated in viewing position.

B. Projection System

The projection system consists of two projectors, a controlled position mirror for selecting one of the two for illumination of the viewing screen, and a slide change mechanism for one of the projectors. Figure 3 is a plan view of the system. The mirror position is controlled by a Brush (or similar) pen motor. The slide change mechanism is either a Bausch & Lomb 2¼x2¼ (or similar) projector or is a simple hand controlled disk, whichever proves feasible on the basis of other considerations.

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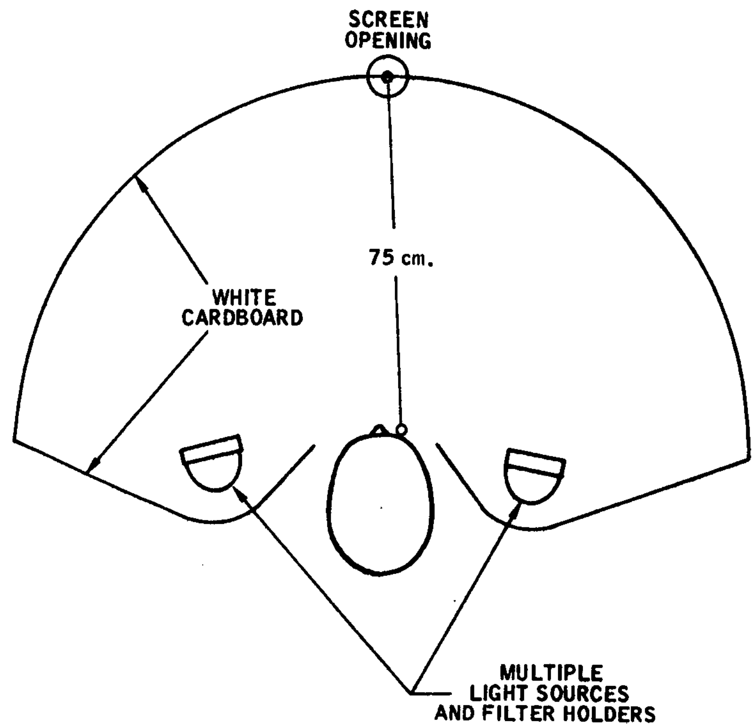

FIGURE 1

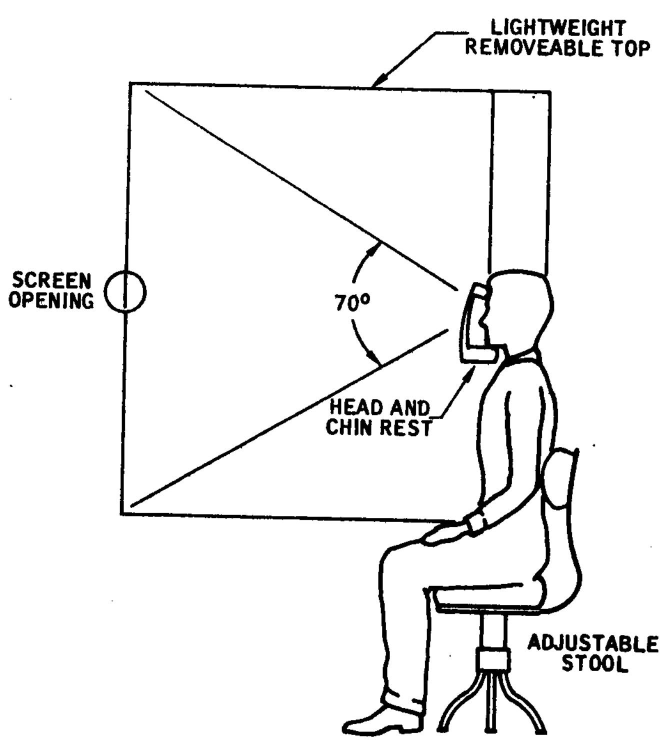

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FIGURE 2

C. Acuity Test Slides

The test slides each contain one or more Landolt ring, acuity test objects. The Landolt ring is illustrated in Figure 4. The dimensions shown are nominal. Exact dimensions, the test object configuration on the slides and the number of slides needed will be specified separately.

D. Subjects

The sample of subjects employed for the evaluation depends somewhat on the precision with which a difference in screens is to be specified, and the extent of interest in the possibility that the results obtained will depend on the particular sample of subjects investigated. In general terms, it is expected that a difference between screens under normal viewing conditions will depend on their relative luminous efficiency and the relative visual accommodation for light in the portions of the spectrum involved. If this is the case, there should not be a wide range of variation of the results over individuals.

At least six subjects should be run covering ages from about 20 to 60 years and including both sexes. This will permit some determination of the extent of the problems involved. The results can then be reviewed for an evaluation of the need for further investigation with a larger subject sample.

A suggested distribution of age and sex is: 20 yrs. - female, 30 yrs. - male, 35 yrs. - female, 40 yrs. - male, 50 yrs. - female, and 60 yrs. - male.

Some attention will need to be given to assuring a satisfactorily high level of motivation so that it is reasonable to expect that reliable data will be obtained.

All subjects will be tested for normal near and far acuity (Bausch-Lomb Orthorater) and color vision (Dvorine or American Optical color deficiency test).

E. Illumination Environment

The light enclosure illumination level is to be set to give a surround brightness one-half log unit below the maximum screen brightness for the screen with the lowest luminous efficiency (Spectra Brightness Meter measurement).

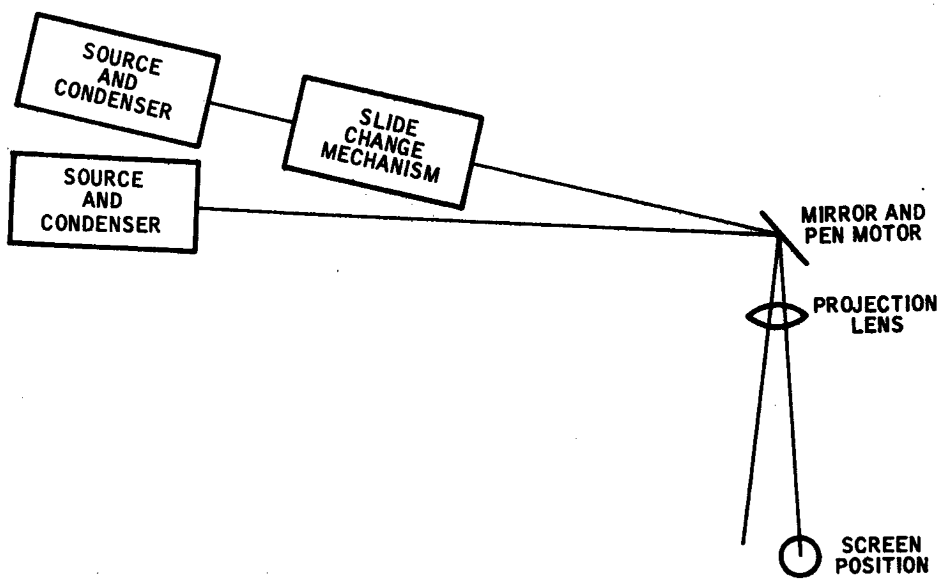
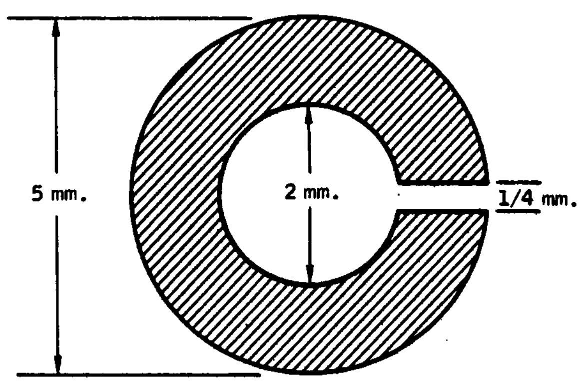


FIGURE 3



LANDOLT RING

FIGURE 4

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F. Data Collection

Subjects will be given a brief period of practice and familiarization with the procedure. Provision will be made for setting the test object size during the practice period to yield a subject report error in approximately one of eight presentations.

Data will then be collected for thirty-two test objects at each of four levels of screen brightness covering the range from maximum brightness to a level predetermined to result in a subject report error in about six of eight presentations.

Test objects will be presented on subject demand, using a three second time limit for report and a two second inter-trial interval. Three series will be taken at each screen brightness level, beginning at maximum screen brightness and proceeding to the least screen brightness and then alternating least to maximum and maximum to least. Two minutes adaptation period will be introduced following each change in screen brightness level.

Subjects will be requested to report a number (1-8) indicating their best estimate of the position of the opening in the Landolt ring, followed immediately by a number (0-3) indicating their degree of confidence in the estimate.

Each of two screens will be tested in a one hour experimental session. The order of screen presentation will be alternated over subjects.

Detection thresholds will be obtained by a modified serial exploration technique at the end of each series, for each screen.

G. Data Processing

Mean, and confidence weighted mean, frequency of seeing curves will be plotted against screen brightness level for each of the three illumination series for each screen for each subject. These curves will be examined for differences between screens over subjects. The obtained variation between sex and age will be noted. Statistical significance of the differences obtained will be calculated if the data indicate that such an evaluation is necessary.

H. Remarks

The evaluation is designed to produce results that are reasonably comparable to ordinary viewing conditions. The data are collected for this reason under binocular vision and for the natural pupil.

A parallel line grating test object is an alternate choice. The Landolt ring has been introduced, however, to provide a minimal search condition roughly comparable to the work conditions.

The particular subjects initial color preferences are not considered an important factor. Preference for one screen or another is expected to move in the direction of greatest screen resolution. However, preference ratings will be obtained from each subject on completion of the test to determine whether there is a consistent trend in this respect.

It is understood that work viewing conditions will vary and differ from those under which the evaluation is made. However, it is not expected that such variation from the test condition will materially affect the direction of an obtained difference between screens if it is consistent over illumination levels and subjects.

APPENDIX

The investigation is readily extended to cover additional factors. Some improvement may occur on axis by using visible emission from the source to form a direct image at the screen. An additional experimental run can be made to determine how much improvement is possible with a combined direct and fluorescent image for both on axis and off axis conditions.

It is possible that an obtained difference between two screens can be manipulated somewhat by varying the spectral characteristics of the viewing environment. This could be due either to a change in relative visual contrast of the test object under different color adaptation conditions, or to a difference in the accommodation to illumination in different spectral regions. The contribution of these factors can be examined by inserting appropriate color filters in the light enclosure sources for additional experimental runs.

It is also possible that the results obtained for a test object covering the foveal region would not apply to the peripheral vision involved in a task requiring visual search to an important degree. The influence of this factor can be determined by a redesign of the test object to require the location and report of a singular figure imbedded at random within a complex configuration.

The projection of an image on an efficient rear projection screen results in a screen image brightness and contrast that is essentially independent of the general illumination environment. This situation differs from an ordinary viewing situation in which a viewed object reflects the general illumination and thereby retains a fixed relation to the visual surround indepndent of the illumination level. The situation also differs from that for front projection in which the image contrast is a function of the general illumination level. It is to be expected that the visual resolution of a rear projection image will depend on the general illumination environment in the case of an efficient projection screen that does not reflect front illumination and that this will differ somewhat from optimal viewing conditions for other viewing situations. It may be worthwhile, for this reason, to obtain results for a range of general illumination levels as a means for locating an optimum level.

The detailed design of experiments to obtain data on the above points should be based on results from the main experiment and an examination of the relevant literature.

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DETAILED TEST PROGRAM

TEST EVALUATION

Prepare all materials for color evaluation on both high and low contrast targets (Landolt Rings).

a. Prepare 8 each 35 mm slides for projection of high contrast (1000:1) target consisting of a Landolt Ring.

b. Prepare 8 each 35 mm slides for projection of low contrast (2:1 or optional) consisting of a Landolt Ring.

c. Obtain 2 light sources and one Bausch & Lomb 2¼ X 2¼ projector with automatic slide changer.

d. Obtain 4 color filters, two objective lenses with irises and polacoat screen.

e. Obtain color filters for test box environmental lighting.

f. Construct mirror control consisting of brush pen motor with mounted mirror.

g. Assemble test enclosure and components. Wire and test for remote operator control. A cardboard enclosure supported by wood framing is anticipated.

SUBJECT PREPARATION

a. Select 12 subjects as follows, two of each as follows

20 year old females
30 year old males
35 year old females
40 year old males
50 year old females
60 year old males

Consultant to aid in selection.

b. Check all subjects for visual acuity near and far (13 inches and 27 inches) and for color vision. Use of optometrist services is recommended to minimize cost of test equipment. American Optical Projecto Chart or Bausch & Lomb Orthorator and Dvorine or American Optical Color deficiency test.

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c. Consultant to assist in selection of 6 of the 12 subjects to continue in test, others to remain in obeyance if acceptable.

d. Prepare written test instruction for subjects to be certain that all subjects receive the same information and have consultant brief all concerned.

e. Run Test with Consultant present. Run 64 test objects past each subject, 32 high contrast and 32 low contrast targets, at each of 4 levels of screen brightness as outlined by consultant.

f. Consultant to reduce data and make recommendations.

PREPARATION OF TEST REPORT

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