NBS CIRCULAR 538

Protective Display Lighting of Historical Documents

UNITED STATES DEPARTMENT OF COMMERCE

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Protective Display Lighting of Historical Documents

A Report by the National Bureau of Standards
to the Library of Congress

National Bureau of Standards Circular 538
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Protective Display Lighting of Historical Documents

1. Introduction

The display and preservation of historical documents is a continuing problem for libraries and museums. The Library of Congress, custodian of the original documents of the Declaration of Independence and Constitution of the United States, requested the National Bureau of Standards to recommend the best means available to modern science for preserving these documents.

Two important qualifications had to be considered in the development of methods for preserving these documents. First, preservation must be effective for an indefinite time into the future. Second, it is desirable that the method of preservation should not detract from the exhibition of the documents.

Two phases of the problem have previously been described in National Bureau of Standards Circular 505, *Preservation of the Declaration of Independence and the Constitution of the United States*.[1] These are the sealing of the documents in an inert atmosphere of pure helium and the use of filters to protect the manuscripts against harmful radiation.

The present report discusses the problem of lighting the Shrine at the Library of Congress, where the documents are displayed, to secure maximum protection while assuring the best conditions for viewing the documents. Many of the considerations entering into the solution of this problem are applicable to the display of documents and art treasures in general.

NOTE: These Documents are on permanent display at the National Archives, Washingtan, D. C.

[1] Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., price, 15¢.

2. Positioning the Lights

The purpose of the lighting is twofold: to provide adequate light for viewing the documents and to emphasize the Shrine and set it apart from its surroundings.

These considerations led to the selection of projection units equipped with adjustable shutters to control the illuminated area. The lamps are mounted above the ceiling, projecting light through ceiling ports. Two units are used to minimize shadows, and each unit is equipped with a variable resistor to control the intensity and equality of illumination.[2]

Projection units should be installed in such a manner as to eliminate or minimize (a) the reflections from cover glasses of cases and from various adjacent surfaces and (b) shadows cast on the documents by observers or parts of the Shrine. Positioning of the lights also depends upon the availability of a location in the ceiling where the lamps are to be mounted and where their ports do not mar the art work. Because of the many marble surfaces that reflect light, the lighting units were mounted on movable towers and experiments were conducted with the units close to their proposed positions.

[2] An indirect lighting system was rejected because the art work on the ceiling would be highly illuminated and imaged in the cover glasses of the cases. The dark areas in the ceiling decorations would absorb much of the light, making the efficiency of the indirect lighting unusually low.

Another suggested means of lighting the Shrine was to construct a canopy over the Shrine and use cove lighting in the canopy. This would have materially altered the appearance of the Shrine and the entire balcony where the Shrine is located. Even a carefully designed canopy would probably detract from the appearance of the Shrine. The canopy would have a high luminance which would be reflected in the cover glasses. The structure would also be a highly undesirable obstacle to viewing the art work on the ceiling. The relief carvings on the Shrine would be subdued under indirect lighting but are enhanced by the beams from projection type equipment.

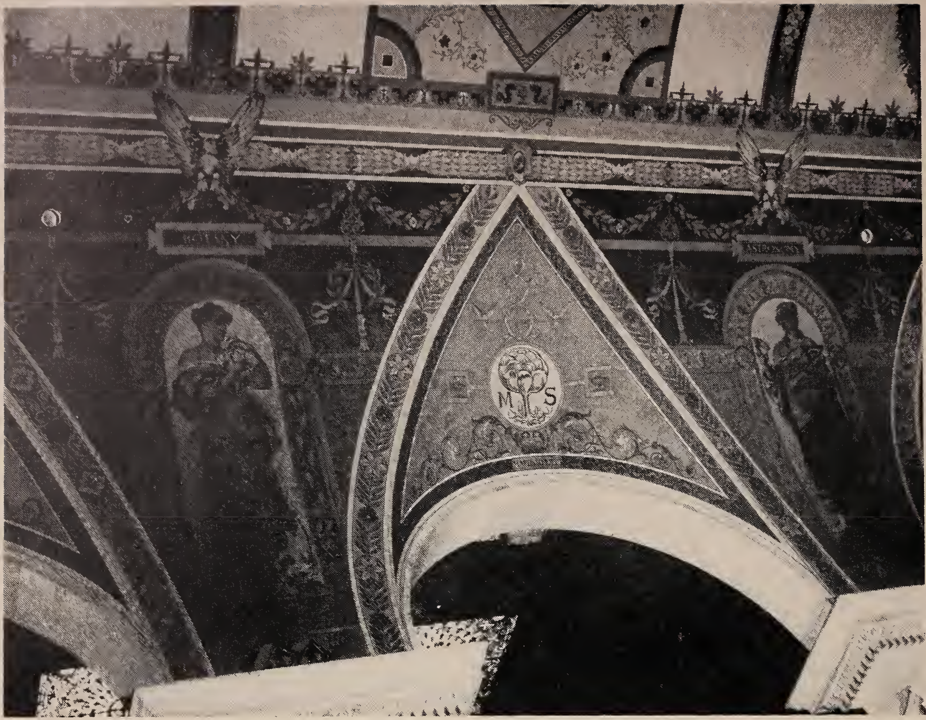


Figure 1. View of the ceiling showing the location of the ports in an inconspicuous portion of the art work. The old units, mounted at the tops of the columns, and the damage to the paintings caused by convection currents are quite obvious. As the new lights are above the ceiling, such damage will not occur in the future. (Library of Congress Photo.)

Careful observation from the positions normally occupied by persons looking at the documents showed the area of the ceiling that could be used without causing reflections. In this satisfactory area there were several portions of the art work where the ports would be quite inconspicuous. The least conspicuous position was at the junction of a number of steel members of the supporting structure of the Library, which made it impossible to mount the lighting units there without altering the steelwork. The second least conspicuous position (fig. 1) in the art work was found to be satisfactory and to have no supporting steel directly behind it.

The units are supported from a trapeze-like framework swung from the **I**-beams of the floor above. With the weight suspended from the 15-inch **I**-beams, there is no weight carried on the ceiling of the corridor where the Shrine is located.

In the hall of the Library of Congress, the Shrine is centered in a panel of black marble flanked on each side by a light-colored marble column. Just beyond these single columns are larger double columns, also of light marble, which protrude further into the open space. The light-colored marble railing that encloses the Shrine joins the wall between these double columns. The inlaid floor of the corridor has been replaced by a dark marble floor within the Shrine. With the projection type lamps selected, it is possible to have the edges of the beams fall in these surrounding dark areas so that they are inconspicuous or almost invisible to anyone outside the Shrine. Aiming discs, consisting of sheet metal plates with 1-inch holes in their center, were placed between the front lens and the shutter of each lamp. Beam centers were aimed at the center hinge of the Constitution case of the Shrine. After the lamps were properly aimed, the discs were removed, the units refocused and the shutters adjusted to bring the edges of the beams within the edge of the Shrine area.

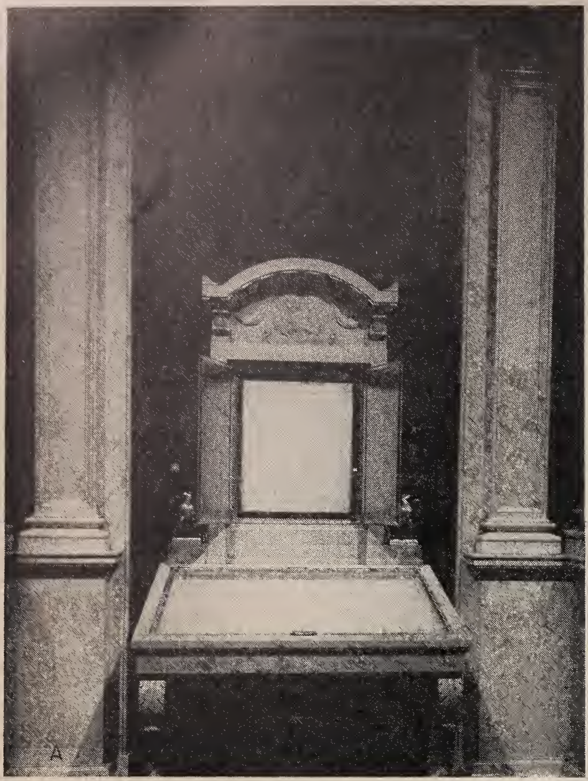
Figure 2. Adjusting the lights for an illumination of 10 footcandles by means of a photoelectric footcandle meter.

3. Comparison of Old and New Lighting

The former lights used a total of 800 watts and produced about 2 footcandles on the display cases. The new lights require about 300 watts and the illumination is 10 footcandles (fig. 2). This illumination was chosen so that the Shrine would be emphasized but would not be obtrusive. The units are capable of producing several times this illumination, if it becomes desirable at some future time.

To depict the results of the new lighting a series of three photographs was made. These are reproduced in figure 3. In the figure, A is with the new lighting and was taken at *f*32 with an exposure time of 18 seconds, whereas B is of the old lighting at the same exposure and lens opening. This photographic treatment emphasized the shortcomings of the old lighting, and the photographer was accordingly asked to photograph the old lighting as advantageously as possible. This resulted in C which was taken at *f*32 with an exposure time of 3 minutes. The bright spots in the upper portion of C are reflections of the old lighting units. The new lights are so located that their images are not seen in the marble above the Shrine. Just above the eagle on the left in all three prints there is a reflection of the light in front of the elevator across the court. This light has been removed. However, it is interesting to note how the apparent size of the light and the distraction caused by it are reduced by the better lighting provided by the new units. Similarly, note how much less conspicuous are the mirror images cast on the cover glass of the lower case under the new lighting (A), than under the old (B). These images of the vertical case and the gold eagles cannot be entirely eliminated, but the improved light distribution makes them less conspicuous and distracting.

The new equipment is completely above the ceiling of the corridor and will not cause dirt to be deposited on the paintings as did the convection currents around the old lamps.



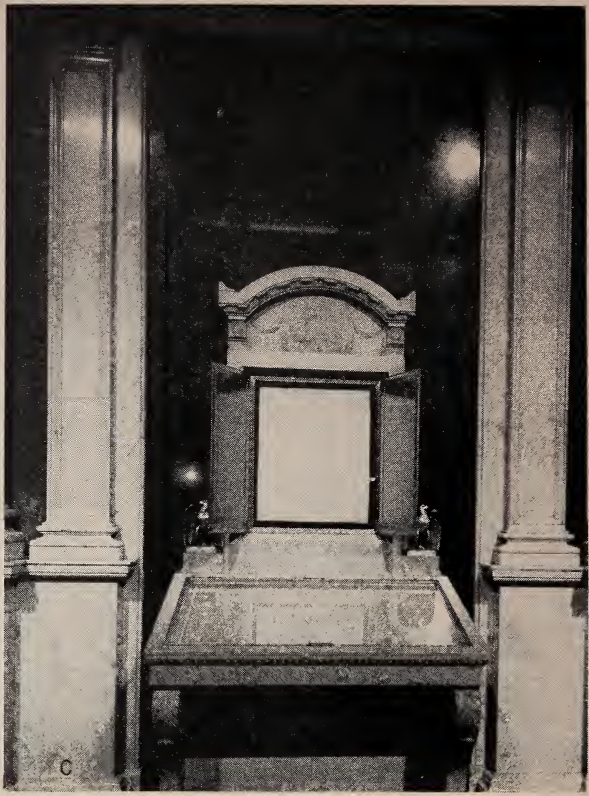


Figure 3A. The Shrine illuminated by the new lights. The exposure was made at $f32$ for 18 seconds. Compare with B and C and notice the absence of reflections of the lighting units in the cases.

Figure 3B. The Shrine illuminated by the old lights. The exposure and film used were identical with those of A. This gives an exaggerated comparison and a photograph with longer exposure was made for C.

Figure 3C. A photograph taken at $f32$ for 3 minutes to present the old lighting as advantageously as possible. The reflections of the units themselves are seen in the upper right and left of the photograph. The greater distraction caused by the reflections of the upper case and eagles is shown by comparison with A.

4. Appendices

4.1. Photochemical Reactions of Document Materials

One of the principal causes of deterioration of materials in documents, textiles, and paintings is radiant energy. Radiant energy is a form of wave motion by which energy from a radiant source is transmitted through space in much the same way that radio waves are transmitted. When radiant energy strikes an object, some of this energy is usually absorbed, and often the absorbed energy is sufficient to decompose certain molecules, particularly of organic compounds. Thus, when some substances are exposed to radiant energy, they are changed chemically. The production of an image on photographic film is a familiar instance of this phenomenon.

a. Paper

The yellowing and eventual embrittlement of newsprint or similar papers is a familiar phenomena. It has long been assumed that yellowing occurs whenever paper is exposed to radiant energy over sustained periods of time. However, NBS research [3] indicates that some types of paper bleach when irradiated in air if the temperature is not allowed to exceed about 30° C during irradiation, but that all papers yellow during irradiation if the temperature is not controlled.

A typical example of the two opposing effects is found in an experiment on a soda-sulfite paper specimen. Two sheets were irradiated at a distance of 25 centimeters from the flame of a Pyrex-enclosed carbon arc. Sheet A was maintained at a temperature near 30° C; sheet B had no temperature control. The extent of yellowing or bleaching was determined by measuring the reflectance of a particular area of each sheet for violet-blue energy. After 10 hours' exposure the reflectance of sheet A increased from 60 percent to more than 67 percent, but the reflectance of sheet B decreased from 60 percent to less than 53 percent. The two competing processes, bleaching and yellowing, occur simultaneously; the net observable effect indicates whether changes from radiant energy or from temperature rise predominated. Thus, if a white paper turns yellow when irradiated, photochemical reactions probably have not played the dominant role.

The bleaching effect of radiant energy was also simulated on papers yellowed by relatively long-time aging by scorching them at high temperature.

[3] Photochemical Stability of Papers, by Herbert F. Launer and William K. Wilson, J. Research NBS **30**, 55 (1943) RP1517.

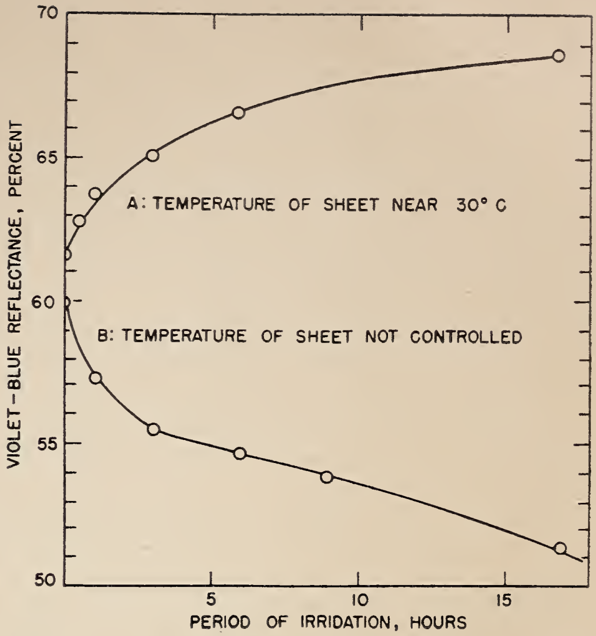


Figure 4. Color changes in paper irradiated with and without temperature control, using the carbon arc.

One paper, manufactured before the year 1700, was blotched brown; another, made before 1791, was an even deep-yellow color. A third paper was an experimental hand sheet made from a refined sulfite pulp, containing a thermocouple to measure the sheet temperature on exposure to a carbon arc; this paper had attained a temperature of 280° C and had been scorched brown within a few minutes in a previous test. The three papers, when exposed to radiant energy at 30° C, bleached extensively (table 1). The scorched paper nearly regained its original whiteness, while the second paper became as white as a bleached new-rag paper.

This effect may have practical significance for documents discolored by age or heat; bleaching may greatly heighten the contrast and permit more legible photographs to be made. This method of bleaching, of course, has the drawback that the radiant energy concurrently causes some deterioration of the cellulose.

Table 1. *Effect of radiant energy upon the violet-blue reflectance of papers*

Kind of paper	Reflectance	
	Before irradiation	Irradiated 40 hours
Rag, very old (1790)	32. 0	53. 4
Rag, very old (1791)	46. 8	65. 7
Sulfite, scorched at 280° C	36. 0	53. 7

b. Inks

Most seventeenth- and eighteenth-century black writing inks were iron-gall inks. They flowed easily from a quill pen, penetrating the fibers to form a black insoluble compound. These inks are quite difficult to bleach or remove from paper without leaving some evidence of alteration. The basic ingredients of iron-gall inks were ferrous sulfate, tannic acid, gum arabic, and a solvent, such as water, wine vinegar, ale, or beer.

Examination of documents of this period reveals that the iron-gall inks have either remained black, turned rusty brown, or faded out completely. Tests indicate that sunlight decomposes the tannic acid in the ink, causing the writing to turn brown or to fade completely.[4]

The exact effect of radiant energy on the ink of a particular document can be determined only by actual tests on the documents themselves. A close approach could be made by testing documents in which the same type of ink is used on the same type of parchment, both being of the same age as the document to be preserved.

4.2. Protection from Deterioration Caused by Radiant Energy

The specific effects of radiant energy on materials significant in the current project were discussed in appendix 5 of Circular 505, *Preservation of the Declaration of Independence and Constitution of the United States*. This information is included here for the convenience of those whose primary interest is the lighting problem.

a. Effect of Radiant Energy

Studies of the deterioration of irradiated cellulose products show that, although the greatest damage is caused by ultraviolet energy of wavelengths shorter than 360 millimicrons, damage is still appreciable for wavelengths up to 500 millimicrons. This includes all of the violet and blue part of the visible spectrum. An investigation of the deterioration of low-grade paper when irradiated at certain wavelengths gave the results shown in table 2. The figures indicating damage are on an arbitrary scale and show relative values. Correction was made for variations in incident flux density and time so that the results refer to the same irradiance for each unit wavelength interval throughout the spectrum.

The deterioration of animal parchment is not as rapid as that of the low-grade paper for which the damage factors were determined. The energy in the short-wavelength end of the visible spectrum and in the ultraviolet are, however, known to be the most damaging.

TABLE 2. *Relative damage of radiant energy*

Wavelength in millimicrons	Relative damage, arbitrary scale
546	1
436	22
405	60
389	90
365	135

b. Incident Radiant Energy

Radiant energy from incandescent-filament lamps and from diffused daylight is incident on the cases at the present location of the Shrine. The incandescent-filament light is predominant. Direct sunlight can not reach the documents. The spectral distribution of the radiant energy from these sources is taken to be 2,800° K and 6,500° K for the incandescent-filament lamps and the diffused daylight, respectively.

The effectiveness of the incident energy in causing damage and in usefulness for viewing are compared in table 3. The values for the damage factors were derived from table 2, and the luminosity factors are those adopted by the International Commission on Illumination.

A study of the data of the preceding table indicates that energy of wavelengths shorter than

TABLE 3. *Comparison of damage and usefulness factors of radiant energy*

Wavelength in millimicrons	Relative damage factors	Relative luminosity factors (usefulness)
360	145	0. 0000
380	107	. 0000
400	66	. 0004
420	37	. 0040
440	20	. 023
460	12	. 060
480	6. 5	. 139
500	3. 7	. 323
520	2. 1	. 710
540	1. 2	. 954
560	. 7	. 995
580	. 4	. 870
600	. 2	. 631
620	. 1	. 381
640	. 05	. 175
660	. 0	. 061
680	. 0	. 017
700	. 0	. 004
720	. 0	. 001

[4] Black Writing Ink of the Colonial Period, by William K. Barrow, The American Archivist [4] **XI**, 291 (1948).

about 500 millimicrons contributes very materially to the deleterious effect, while its usefulness in seeing (as represented by the luminosity factors) is not as great as that of longer wavelengths in the range from 500 to 620. The wavelengths greater than 620 contribute useful light (although in diminishing amount with increasing wavelength) and cause comparatively little deterioration.

This means that an appreciable decrease in harmful radiant energy can be realized by excluding energy of wavelengths shorter than about 500 millimicrons. The filter required to accomplish this, although highly selective, does not produce in the observer an impression of a strongly chromatic illuminant, and is of sufficiently high luminous transmittance to permit adequate lighting of the documents without the use of excessively large lamps.

c. The Protective Filter

A laminated glass, made with a plastic interlayer in which the necessary light-absorbing material has been incorporated, has been installed in the cover door of each case of the Shrine. The Eastman Kodak Company cooperated in supplying the necessary large yellow cellulose acetate sheet required for this project. The yellow acetate sheet is similar in optical properties to a Wratten 4 filter and absorbs completely in the range from 310 to 430 millimicrons. Both sides of the filter were coated with polyvinyl butyral to facilitate lamination with glass. The large size glass laminates were prepared by the American Window Glass Company.

The spectral transmittance of a 2-inch square cut from an 8 by 10 inch sample lamination is presented in table 4.

Table 4. *Spectral transmittance of protective filter*

Wavelength in millimicrons	Transmittance of sample	Wavelength in millimicrons	Transmittance of sample
300	0. 000	530	0. 83
320	. 000	540	. 84
340	. 000	560	. 84
360	. 000	580	. 84
380	. 000	600	. 84
400	. 000	620	. 83
420	. 000	640	. 83
440	. 000	660	. 82
460	. 000	680	. 80
470	. 01	700	. 79
480	. 17	720	. 78
490	. 50	740	. 76
500	. 70		
510	. 78		
520	. 82		

d. Effectiveness of the Protective Filter

In table 5, the spectral energy values for 6,500° K have been adjusted to give equal luminosity with those for 2,800° K (see sums of columns 5 and 6), that is, for equal illumination from the two types of source, without any protective filter in use. When the protective filter is used, the radiant energy passes through the filter twice, once to

Table 5. *Relative usefulness, in viewing documents, of sources at 2,800° and 6,500° K*

Wavelength millimicrons	Relative luminosity factors	Relative energy		Relative usefulness in viewing		T^2, protective filter	Relative usefulness with protective filter	
		2,800° K	6,500° K	2,800° K	6,500° K		2,800° K	6,500° K
360	0. 0000	0. 06	1. 04	0. 00	0. 00	0. 00	0. 00	0. 00
380	. 0000	. 09	1. 08	. 00	. 00	. 00	. 00	. 00
400	. 0004	. 14	1. 11	. 00	. 00	. 00	. 00	. 00
420	. 0040	. 20	1. 14	. 00	. 00	. 00	. 00	. 00
440	. 023	. 28	1. 15	. 01	. 03	. 00	. 00	. 00
460	. 060	. 37	1. 14	. 02	. 07	. 00	. 00	. 00
480	. 139	. 47	1. 13	. 06	. 16	. 03	. 00	. 00
500	. 323	. 59	1. 11	. 19	. 36	. 49	. 09	. 18
520	. 710	. 72	1. 08	. 51	. 77	. 67	. 34	. 52
540	. 954	. 85	1. 05	. 81	1. 00	. 71	. 57	. 71
560	. 995	1. 00	1. 02	. 99	1. 02	. 71	. 71	. 72
580	. 870	1. 15	. 98	1. 00	. 85	. 71	. 71	. 60
600	. 631	1. 30	. 94	. 82	. 59	. 71	. 58	. 42
620	. 381	1. 46	. 90	. 56	. 34	. 69	. 39	. 23
640	. 175	1. 61	. 87	. 28	. 15	. 67	. 19	. 10
660	. 061	1. 76	. 83	. 11	. 05	. 67	. 07	. 03
680	. 017	1. 90	. 79	. 03	. 01	. 66	. 02	. 01
700	. 004	2. 04	. 75	. 01	. 00	. 62	. 01	. 00
720	. 001	2. 18	. 72	. 00	. 00	. 61	. 00	. 00
				5. 40	5. 40		3. 68	3. 52

Table 6. *Relative damage from sources at 2,800° and 6,500° K*

Wavelength in millimicrons	Relative damage factors	Relative energy (adjusted to equal luminosity)		Relative damage for equal luminosity		*T*, protective filter	Relative damage with protective filter	
		2,800° K	6,500° K	2,800° K	6,500° K		2,800° K	6,500° K
360	145	0. 06	1. 04	8. 7	151	0. 00	0. 00	0. 00
380	107	. 09	1. 08	9. 6	116	. 00	. 00	. 00
400	66	. 14	1. 11	9. 2	73	. 00	. 00	. 00
420	37	. 20	1. 14	7. 4	42	. 00	. 00	. 00
440	20	. 28	1. 15	5. 6	23	. 00	. 00	. 00
460	12	. 37	1. 14	4. 4	14	. 00	. 00	. 00
380	6. 5	. 47	1. 13	3. 1	7. 3	. 17	. 53	1. 24
500	3. 7	. 59	1. 11	2. 2	4. 1	. 70	1. 54	2. 87
520	2. 1	. 72	1. 08	1. 5	2. 3	. 82	1. 23	1. 89
540	1. 2	. 85	1. 05	1. 0	1. 3	. 84	. 84	1. 09
560	. 7	1. 00	1. 02	. 7	. 7	. 84	. 59	. 59
580	. 4	1. 15	. 98	. 5	. 4	. 84	. 42	. 34
600	. 2	1. 30	. 94	. 3	. 2	. 84	. 25	. 17
620	. 1	1. 46	. 90	. 15	. 09	. 83	. 12	. 07
640	. 05	1. 61	. 87	. 08	. 04	. 82	. 07	. 03
660	------	1. 76	. 83	----	------	. 82	----	----
680	------	1. 90	. 79	----	------	. 81	----	----
700	------	2. 04	. 75	----	------	. 79	----	----
720	------	2. 18	. 72	----	------	. 78	----	----
				54. 43	435. 43		5. 59	8. 29

reach the documents and the second time to reach the observer's eye. The values given in the seventh column are, accordingly, the squares of the transmittances for the filter. The relative usefulness with the filter in place is given in the last two columns of table 5 and a comparison of the sums of the corresponding columns shows that the filter reduces the usefulness by nearly the same amount, 32 percent for the 2,800° K source and 35 percent for the 6,500° K source.

In table 6, using the same energy values as in table 5, the sums of the fifth and sixth columns show that, for equal illuminations (without the protective filter), diffused daylight is materially (about 8 times) more damaging than incandescent-filament light. When the protective filter is used, the relative damage is as given in the last two columns. When these sums are compared with those of the corresponding damage from unfiltered sources, it is seen that the damage is reduced by 90 to 98 percent for 2,800° K and 6,500° K, respectively. As just shown in the previous paragraph this is accompanied by reductions of only 32 and 35 percent in the usefulness of the light.

A filter identical to that installed in the covers of the cases of the Shrine was placed over the lighting units. This causes a further decrease of about 26 percent in the deleterious effect, with a corresponding decrease of only about 16 percent in the usefulness of the light. An additional advantage of the use of the same filtering medium is that it tends to "wash out" or reduce the appearance of color in the radiation filter. Furthermore, the reduction in spectral range of the light reaching the observer will reduce the chromatic aberration of his eye and tend to make the characters on the documents appear more distinct.

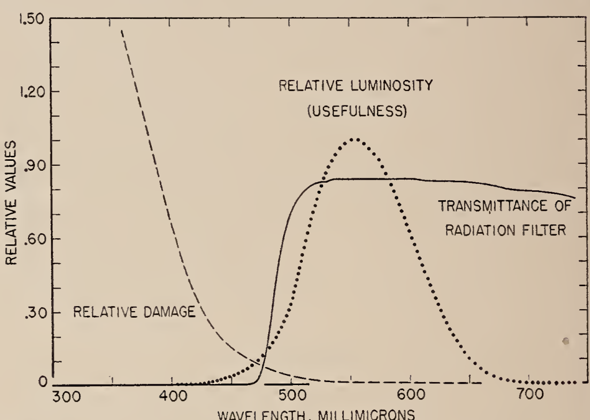


Figure 5. The relative damage caused by radiant energy, the relative luminosity factors (usefulness), and the transmittance of the protective filter are shown. It is apparent that the protective filter absorbs most of the energy believed to be potentially damaging, while transmitting freely most of the energy useful to the human eye for seeing. Complete details of the data on which these curves are based are given in NBS Circular 505, Preservation of the Declaration of Independence and the Constitution of the United States.

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DEPARTMENT OF COMMERCE

UNITED STATES OF AMERICA