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REPRINT

**EFFECTS OF HIGH NEUTRON AND GAMMA FLUXES
ON THE TRANSMISSION CHARACTERISTICS
OF SOME OPTICAL GLASSES**

by

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NOVEMBER 1959

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Presented at: AMERICAN SOCIETY FOR TESTING MATERIALS
Sixty-First Annual Meeting
Boston, June 1958

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Printed in USA. Price \$0.75. Available from the Office of
Technical Services, Department of Commerce,
Washington 25, D. C.

SCR-127
TID-4500 (15th Ed.)
RADIATION EFFECTS
ON MATERIALS

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EFFECTS OF HIGH NEUTRON AND GAMMA FLUXES ON THE TRANSMISSION CHARACTERISTICS OF SOME OPTICAL GLASSES

The design of the Sandia Engineering Reactor Facility (SERF), described earlier in this symposium, presented a unique problem of finding a way to view the virtually unshielded 5-megawatt reactor during operation. Material samples to be irradiated are brought into the 30 x 22 x 9-foot reactor room and positioned by a remotely operated, electrically driven tug while the reactor is operating at full power. A way of directing the placement of these samples from a control room and of observing their performance during irradiation is essential. An extensive study of shielding windows, closed-circuit television, and periscope as possible viewing methods, determined that periscope viewing was most feasible.

An isometric view of the SERF irradiation cell and the position selected for the periscope installation are shown in Figure 1. The radiation levels expected at this position are 3×10^5 R/hr Gamma, and 4×10^9 neutrons having an average energy of 1 mev. In preparing specifications for the design and construction of the periscope, it was decided that the front optical elements which are directly exposed to radiation must have a minimum lifetime of 10,000 hours. This means that they must withstand a total integrated radiation dose of 3×10^9 R of Gammas, and 1.4×10^{17} neutrons/cm², without excessive transmission losses.

Literature surveys and discussions with several people in the fields of remote viewing and radiation-resistant optical materials revealed that optical materials have not been tested extensively at these rates and at such high total integrated dosages. A Sandia program was therefore started to study the effects of radiation at such rates and total doses on the transmission characteristics of available optical glasses. Work on this program is continuing, so the results presented here are only partial. Final results will be prepared as a Sandia Corporation document which should be available later this year.

Samples of several types of optical glass were furnished by the Bausch and Lomb Optical Company, most of which were of the radiation-tolerant or "protected" types developed by Bausch and Lomb under AEC contract for use in radiation experiments. Five "protected" glasses are identified below by the letter "P" following the glass identification number. One unprotected sample was also tested. The six Bausch and Lomb types were these:

517:645P	617:366P
541:599P	649:338P
373:574P	649:338

A sample of Corning's Best Quality Fused Silica was also supplied by arrangement with the Air Force Cambridge Research Center.

Test Procedures and Equipment

All of these samples were exposed to gamma radiation levels of 10^6 , 10^7 , 10^8 , and 10^9 roentgens in the Sandia Kilocurie Cobalt-60 Facility.

Figure 1

Exposures to 10^{10} roentgens were made at the Materials Testing Reactor Gamma Facility by using spent fuel rods with an average photon energy of 0.7 mev. Exposures to mixed reactor radiation (gamma and neutron) were also made at the Materials Testing Reactor. Exposures to integrated fast-neutron (1-mev) fluxes of 10^{12} , 10^{13} , 10^{14} , 10^{15} , and 10^{16} NVT utilized the VG-7 shuttle tube, while exposures of 10^{17} NVT utilized the VH-4 shuttle tube.

The light transmission properties of the glass samples were measured before and immediately after exposure to radiation. The fading, or annealing rate, of the glass discoloration was observed for a period of time after exposure to aid in extrapolating back to the time of removal from the reactor.

The four test procedures followed for exposure to the different types of radiation were as follows:

1. Gamma: Sandia Kilocurie Source Cobalt-60 -- Glass samples were cleaned with dry Kleenex; no solvents were used. The percentage of light transmission of $3500\text{\AA}$ before irradiation was recorded. The samples, wrapped in aluminum foil, were then inserted in the Sandia Kilocurie Cobalt-60 Source for exposure. Light transmission curves were recorded for each test sample after it had been irradiated.

2. Gamma: MTR Gamma Facility -- The glass samples were prepared as above, and the preirradiation measurements were made. The samples, wrapped in aluminum foil, were then lowered into position near the spent fuel elements. Following irradiation, the glass samples were removed, and the percentage of light transmitted was read at two levels of radiation ($8.01 \times 10^9 \text{ R}$ and $1.0 \times 10^{10} \text{ R}$).

3. Neutron Flux: VG-7, MTR -- Glass samples were prepared as in the Cobalt-60 experiment and preirradiation measurements were made. Then the glass was placed in a polyethylene "rabbit" (shuttle container) and inserted in the VG-7 tube. After irradiation the radioactive samples were removed and handled with long tongs behind lead brick shielding. Light transmission curves were next obtained and the rate of annealing noted.

4. Neutron Flux: VH-4, MTR -- The same procedure used in the VG-7 tube was attempted on the glass samples in the VH-4 tube, but the glass melted. The plastic container inside the regular aluminum shuttle tube acted as an oven and did not allow the heat generated by gamma heating within the glass to be conducted away. The experiment was attempted again, with samples simply wrapped in aluminum foil rather than inserted in the polyethylene "rabbit". Results were only slightly better. Although the glass did not melt, it cracked beyond use. Obviously, little information was obtained from this experiment, since melted or broken glass does not give reliable transmission readings. However, the test is being repeated with changes that are expected to eliminate the cracking problem.

Figure 2 shows some of the equipment used: several glass samples 15 mm x 6 mm x 1.5 mm, the Bausch and Lomb Spectronic 20 Colorimeter for recording the transmission characteristics of the samples, the colorimeter sample holder, and the rabbit capsule which contained the samples during irradiation in the VG-7 tube.

Results

Several curves plotted from the study are presented below to show graphically the results of irradiation on these optical glasses.

Figure 3 shows the effect of increasing integrated doses of just gamma on the transmittance characteristics of two of the Bausch and Lomb protected glasses. Glass D, shown by the upper curve, suffers slight degradation up to a total gamma-only dose of 10^{10} roentgen. This degradation is probably not great enough to impair the use of this glass in a radiation

Figure 2

EFFECT OF TOTAL DOSE (GAMMA) ON TRANSMITTANCE OF GLASSES

MEASUREMENTS AT 5000Å - 10 MINUTES AFTER COMPLETION OF IRRADIATION

Figure 3

environment of this magnitude. Glass E, shown by the lower curve, suffers very little degradation of transmission characteristics up to a total gamma dose of 10^9 R, but degrades rapidly at a total gamma dose of 10^{10} R.

The effect of the transmission characteristics of four glasses, produced by increasing integrated doses of mixed gamma and neutron radiation from reactor exposure, is shown in Figure 4. These measurements were made with a light-source having a wave length of $5500\text{\AA}$. This wave length is of great interest since these glasses will be used in a periscope for human use. Sample Q, Corning's Best Quality Fused Silica, shows no degradation up to a total integrated dose of 10^{16} neutron/sq cm plus the accompanying gamma dose. Glass D, a Bausch and Lomb protected sample, shows only slight degradation up to 10^{16} NVT. On the other hand, Glass E, another Bausch and Lomb protected sample, shows a greater impairment of transmission ability. Finally, Glass E¹, the Bausch and Lomb unprotected sample, shows severe degradation at an integrated dose of 10^{14} NVT and is useless for application at a total dose of 10^{16} NVT.

Figure 5 compares the transmission characteristics of an unirradiated sample of Glass D and a sample irradiated to a total dose of 10^{16} fast neutrons/sq cm plus the accompanying gamma dose from a reactor irradiation. These curves indicate that the difference in transmission is not great at the longer wave lengths of source light. However, at the shorter wave lengths, the irradiated sample shows severe degradation. Figure 6 shows a similar comparison for Glass E, which, as was shown previously, suffers a much greater degradation with irradiation. The results for Glass E¹, an unprotected sample, are shown in Figure 7. As expected, the darkening at all wave lengths is severe.

Figure 8 compares the transmission characteristics of an unirradiated sample Q, Corning's Best Quality Fused Silica, and a sample of the same material irradiated to a total dose of 10^{16} fast neutrons/sq cm plus the accompanying gamma dose from a reactor irradiation. As can be seen, irradiation caused no appreciable darkening of the sample over the entire spectrum of source light used.

Figures 9 and 10 show similar comparisons for exposures to gamma radiation only. Figure 9 compares the effect of a gamma dose of 10^{10} R on a sample of Glass D and an unirradiated sample of the same glass. These results are almost the same as the results shown in Figure 5, of irradiating Glass D to 10^{16} NVT of fast neutrons and accompanying gamma dose from a reactor irradiation. Figure 10 shows irradiated versus unirradiated results for Glass E, with results again similar to those from reactor irradiation.

The last two figures illustrate the recovery of transmission characteristics exhibited by some of the glasses tested at intervals of time after the irradiation was completed. The recovery of Protected Glasses D and E is shown in Figure 11. Following gamma-only irradiation to a total dose of 10^{10} R, the light transmission characteristics at a wave length of $5000\text{\AA}$ of Glass D, which were previously observed to be quite radiation-tolerant, returned to the normal preirradiation values after about 20 hours of healing time. Although the curve shows that Glass E had not returned to the original preirradiated value at the time of test completion, the slope of the curve indicates that it may. However, this glass does not heal fast enough to be practical in the application proposed. Figure 12 illustrates the recovery of the transmission ability of glasses following reactor irradiation to a total dose of 10^{16} NVT of fast neutrons plus the accompanying gamma dose. As seen in preceding curves, Glass D recovers quite well, while Glass E recovers more slowly. Glass E¹, an unprotected sample, recovers much more slowly and would be useless for SERF periscope application.

The results to date of investigation into the transmission ability of optical glasses indicate that it will be possible to use the Bausch and Lomb protected series of glasses for the periscope

application in the SERF. This program of investigation is being continued, and further information will be published as it becomes available.

EFFECT OF TOTAL DOSE (NEUTRONS AND GAMMA) ON TRANSMITTANCE OF GLASSES

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

RECOVERY OF GLASS SAMPLES AFTER GAMMA IRRADIATION

MEASUREMENTS AT 5500Å OF SAMPLES EXPOSED TO 10⁶ RAD γ

Figure 11

RECOVERY OF GLASS SAMPLES AFTER REACTOR IRRADIATION

MEASUREMENTS AT 5500 Å OF SAMPLE EXPOSED TO 10^{16} NVT FAST

Figure 12