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OPTICAL ABSORPTION IN TRANSPARENT MATERIALS FOLLOWING HIGH-TEMPERATURE REACTOR IRRADIATION

by F. C. Douglas, R. Gagosz, and M. A. DeCrescente

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Following High-Temperature Reactor Irradiation

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Optical Absorption in Transparent Materials Following High-Temperature Reactor Irradiation

SUMMARY

An experimental investigation was conducted to determine the optical absorption levels induced in fused silica as a result of exposure to nuclear reactor irradiation over a range of fast neutron fluxes, fast neutron doses, and reactor temperatures. Also included in the investigation were a limited number of specimens made from alumina, hot-pressed beryllia, and single crystal beryllia. Measurements of the ultraviolet transmittance spectrum were made prior to the reactor irradiation, after the reactor irradiation, and after a series of cobalt-60 gamma irradiations. Measurements were also made during and after heat treatments at elevated temperatures. The induced absorption coefficients were determined from these measurements at the centers of absorption bands located at 0.215 and 0.163 microns.

RESULTS

1. Measurements made following reactor irradiation at temperatures of 700 to 1100 C indicated that there was no significant coloration due to long-lived defects in ultraviolet grade Corning 7940 fused silica at wavelengths of 0.215 and 0.163 microns. The actual induced absorption during the reactor irradiation is not known, however, because of two effects which occurred after removal of the capsule from the reactor: bleaching of short-lived defects during the cool-down process, and gamma coloration of defects due to the radioactive capsule.

2. The absorption induced by ambient-temperature cobalt-60 gamma irradiation increased approximately linearly with gamma dose for fused silica specimens which had been annealed for one hour at 1050 C, independent of whether or not the specimens had been reactor irradiated between the annealing and cobalt-60 gamma dose processes. The rate of increase of absorption coefficient with gamma dose was approximately 0.05 cm^{-1}/Mrad for a wavelength of 0.215 micron, and between 0.05 and 0.1 cm^{-1}/Mrad for a wavelength of 0.163 micron.

3. Failure to pre-anneal fused silica specimens before reactor irradiation resulted in a change in the variation of absorption coefficient with gamma dose during post-reactor exposure to a cobalt-60 source. In such tests, the absorption coefficient for a wavelength of 0.215 microns initially increased at a rate of approximately 0.15 cm^{-1}/Mrad before returning to a rate of 0.05 cm^{-1}/Mrad at higher gamma doses.

4. During thermal annealing studies at temperatures of 700 to 900 C, gamma-induced coloration decreased with time at an exponential rate described by a time constant on the order of 50 to 100 sec. These time constants are approximately two orders of magnitude greater than time constants measured during transient tests in a TRIGA reactor.

5. Measurements of the transmittance of aluminum oxide specimens after a 900 C reactor irradiation revealed that a 50 percent loss of transmittance had occurred over the entire ultraviolet region. Neither cobalt-60 gamma dosing nor heat treatment at 900 C significantly affected the post-reactor-irradiation transmittance level. However, a heat treatment at 1200 C for one hour caused substantial recovery in transmittance, the recovery being less at the shorter wavelengths.

6. A hot-pressed polycrystalline beryllium oxide specimen was completely nontransmitting in the ultraviolet region after a 900 C reactor irradiation; a 900 C post-reactor heat treatment produced no recovery.

7. A single crystal beryllium oxide specimen which was irradiated at ambient reactor temperature had an absorption coefficient greater than 12 cm^{-1} over the entire ultraviolet wavelength region, and was nontransmitting for wavelengths shorter than 0.245 micron after the irradiation. This specimen was not heat treated after the reactor irradiation.

INTRODUCTION

The Research Laboratories of United Aircraft Corporation are investigating various technologies associated with gaseous nuclear rocket engines under Contract NASw-847 with the joint AEC-NASA Space Nuclear Propulsion Office. One of the engine concepts to which these technologies can be applied is the nuclear light bulb concept, which is based on the transfer of energy by thermal radiation from gaseous nuclear fuel through an internally-cooled transparent wall to seeded hydrogen propellant. The key problem area which is different in this concept than in other gaseous nuclear rocket concepts is the transparent wall, which must remain transparent in a severe nuclear radiation environment.

It is necessary to employ a material in the nuclear light bulb rocket engine which is transparent to optical radiation over a wide range of wavelengths in a nuclear radiation environment to prevent loss of structural integrity. Two competing processes affect the transmission characteristics of the material in this environment: first, damage is induced by nuclear radiation; and second, damage is annealed by the exposure to elevated temperatures. Therefore, it should be possible to reduce the equilibrium coloration present in a transparent material in a nuclear environment to an acceptable level, or to remove it altogether, by maintaining the material at some elevated temperature.

A number of studies of radiation damage and optical absorption in fused silica and alumina have been published in the scientific literature (Refs. 1-12). These have served largely to identify the absorption bands induced by the radiation and to indicate the nature of the defect responsible for the absorption band. The studies were made by irradiating the specimens at ambient reactor temperature or at cryogenic temperatures and measuring the induced opacity after the irradiation. In some instances, irradiated specimens have been heated and decoloration rates measured by analyzing damaged specimens before and after heat treatment. The interpretation of all these data is complicated because of simultaneous color bleaching and defect annealing, and because a number of defects are produced at low temperature which anneal over a range of energies of activation.

Three investigations have been conducted at the Research Laboratories to investigate radiation damage and thermal bleaching in transparent materials: the investigations described in Refs. 13 and 14 and the investigation described in the present report. In addition, information on the transmission characteristics of unirradiated fused silica has been obtained in the investigations described in Refs. 13 and 14 and in an investigation conducted at the NASA Lewis Research Center (Ref. 15).

Studies of the nuclear characteristics of a specific 4600-megw nuclear light bulb engine (Ref. 16) indicate that the fast neutron flux incident on the transparent wall will be on the order of 5×10^{15} n/cm^2-sec. For a typical engine burning time of 10^3 sec, the total neutron dose on the transparent wall would be approximately 5×10^{18} n/cm^2. A number of different transient reactors can supply a neutron flux equal to that expected in a rocket engine, but the corresponding dose in a single transient pulse is orders-of-magnitude less than in an engine

operating period. Conversely, almost any steady-state reactor can furnish the neutron dose expected in a rocket engine by operating for a time period longer than the expected burning time of the engine, but no available steady-state reactor can furnish a fast neutron flux approaching 5×10^{15} n/cm^2-sec. Because no single type of reactor test can provide simulation of both flux and dose, it was decided to conduct tests in both pulse and steady-state reactors. During the tests in the TRIGA pulse reactor described in Ref. 14, measurements were made before, during, and after the reactor pulses. These tests provide information on short-lived color centers. The tests described in Ref. 13 and in the present report were made before and after (but not during) exposure in a steady-state reactor. These tests were designed to provide information on longer-lived color centers.

Initial investigations at United Aircraft Research Laboratories involved the measurements of the rate of bleaching of color at ultraviolet wavelengths produced by ambient-temperature reactor irradiations of fused silica (see Ref. 13). While such measurements were very difficult to interpret, the information generated indicated that induced color in fused silica could be minimized by maintaining it at an elevated temperature during the irradiation process.

The next step in the program directed toward the eventual determination of the effect of simultaneous nuclear-irradiation-induced coloration and thermal annealing of coloration was to investigate the feasibility of performing reactor-irradiations on specimens at elevated temperatures. The successful result of this investigation generated a program to systematically study the effects of fast neutron flux and dose, as well as specimen temperature, on the induced absorption in the transparent materials by measurements of optical transmittance after the reactor-irradiation. The irradiations and measurements made under this program were carried out using fused silica, alumina, and beryllia, and are described in the following sections.

DESCRIPTION OF EQUIPMENT AND TEST CONDITIONS

Transparent Specimens

The materials selected for study in the present program were fused silica, aluminum oxide, and beryllium oxide. A description of the specimens and materials used is given in Table I. A specimen designation code has been used which is given in Table II and which is the same as that employed in Refs. 13 and 14. The present program has been mainly concerned with the study of fused silica, with the tests on alumina and beryllia being preliminary in nature. The fused silica specimens were polished on the cylindrical surfaces as well as on the faces to facilitate cleaning.

The results reported in Ref. 13 showed that chemically cleaning the specimens in warm (50 C) chromic acid glass cleaning solution prior to nuclear-reactor irradiation and prior to heating during post-reactor-irradiation testing was a necessary part of the preparation procedure for fused silica. In addition, it was felt that a thermal anneal of one hour at 1050 C might tend to minimize the inherent structural variability which exists from specimen-to-specimen. These procedures were followed in the present program, excepting that the specimens irradiated in capsules A through E in the preliminary experimentation were not given the stabilizing pre-reactor-irradiation thermal anneal. The alumina and beryllia specimens were also cleaned in chromic acid, but were not given a thermal anneal prior to reactor irradiation. The processing of the specimens prior to reactor irradiation is is summarized in Table III.

Reactor Test Conditions

Specimens were reactor-irradiated in either core position C-3 or D-1 of the Union Carbide swimming pool reactor. Neutron and gamma flux profiles measured in these positions, plotted in Figs. 1 and 2 for position C-3 and Figs. 3 and 4 for position D-1, show that these positions provide fast neutron fluxes differing by approximately one order of magnitude, and gamma fluxes differing by a factor of approximately 3. The gamma flux in the capsule was found to reach a steady-state after about four hours in the core positions employed. The positions of UARL specimens in capsules F through K (Table IV) relative to the flux profiles are indicated on Figs. 1 to 4.

In order to obtain control over the irradiation conditions, a capsule for the irradiation of specimens at controlled high temperatures was designed and fabricated at the Union Carbide Research Reactor Facility. The capsule consisted of an aluminum container, glass wool insulation, and a cylindrical heater inside of which the specimens were placed. The capsules used for irradiations of capsules A, B, C, and E differed from this in being thin-walled stainless steel containers rather than aluminum. These containers provided somewhat more post-reactor-irradiation gamma dose than was obtained from the new capsules. The specimens were isolated from direct physical contact with the heater by a thin layer of insulation, except in one capsule in the series in which a copper tube was used to contain the specimens. The copper proved unsatisfactory due to the high level of radioactivity (2 curies) from copper-64 which has a gamma emission decay product of 1.34 MeV gamma rays with a 12-hour half life. The copper tube was therefore not used in

subsequent irradiation experiments. The insulation layer was sufficient to bring the specimen temperature up to within approximately one hundred degrees of the desired temperature, and the heater was used to maintain a constant temperature. All capsule heaters were made of graphite with the exception of the capsule used for irradiation at low fast neutron flux, where the heater was made of stainless steel. A new heater was used for each capsule. The capsule was instrumented with a thermocouple to measure the temperature during and after the irradiation. A positive pressure of nitrogen was used to prevent influx of reactor water in case of seal failure. Provisions were also made for flowing nitrogen gas through the capsule after the completion of the irradiation process to hasten the thermal cool-down. The effectiveness of this technique depended on the uniformity of gas flow through the contents of the capsule.

The necessity of using the insulated capsule prevented instantaneous thermal cool-down of the specimens. In addition, induced radioactivity in the capsule provided a source of gamma irradiation even after the capsule was removed from the reactor core. Figure 5 shows the cool-down characteristics during the irradiations performed. The gamma flux and dose due to the radioactive capsule as a function of time after removal from the core are shown in Fig. 6. This data was obtained by instrumenting a capsule with a gamma flux meter in a test equivalent to a controlled irradiation.

The reactor-irradiation conditions used in the present program are summarized in Table IV. Capsules A through E contained no auxiliary heaters but were maintained at elevated temperature through the appropriate selections of insulation thickness and gamma flux. Because of this, a specific predetermined temperature could not always be obtained. These tests were run during a Corporate-sponsored program in order to ascertain the general effects of elevated specimen temperatures on the post-reactor-irradiation values of the induced absorption. Capsules F through J were designed to provide accurately controlled temperature conditions, independent of the level of gamma flux. Capsule K, containing the single crystal beryllia, was reactor-irradiated at ambient reactor temperature, determined to be approximately 160 C.

Cobalt-60 Test Conditions

After reactor-irradiation, some of the specimens were exposed to gamma radiation from an Atomic Energy of Canada, Ltd. 8,000 Curie cobalt-60 source which provides approximately 1.5 Mrads/hr of 2-MeV gamma rays. The total gamma radiation dose was regulated by a timing device which withdrew the specimens from the irradiation chamber on an elevator at the end of a preset period. Charts of the gamma flux profile and a decay chart giving the maximum flux as a function of time to correct for radioactive decay losses were supplied with the unit and were used to obtain precise irradiation doses.

UARL High Temperature Spectrophotometer

The UARL high-temperature spectrophotometer is a dual-beam instrument which measures the spectral transmission characteristics of optical materials while the material is heated to any temperature between 22 and 1100 C and at any wavelength

between 0.15 and 4.5 microns. This spectrophotometer is comprised of three chambers, the largest of which contains the following monachromator sections: ultraviolet, visible, and near-infrared sources; infrared thermocouple detector; and collimating and beam-splitting mirrors. Radiant energy from either of the two sources located in this chamber is selected and focused by the spherical condensing mirror into the entrance slit of the monochromator. The monochromator section is of basic Littrow design utilizing an off-axis parabolic mirror to collimate light from the grating onto the exit slit. Four diffraction gratings are utilized to cover the spectral range of operation and are mounted on a turntable. The monochromatized energy emerging from the exit slit is collimated by another off-axis parabola and then directed by two circular plane mirrors through the chopper system into the second chamber containing the furnace. Two furnace tubes are used to mount and to heat the specimens. Each furnace is comprised of a 12-in.-long, 1-1/4-in.-dia., 0.020-in.-wall tantalum tube supported at each end by water-cooled copper electrodes. These electrodes are carbon-lined to allow the tantalum tubes to slide as they elongate at elevated temperatures. After passing through the sample chamber, the transmitted energy enters the third chamber and is directed by two circular plane mirrors onto the photomultiplier or the lead sulfide detector. The lead sulfide detector is mounted on a turntable and may be positioned directly in front of the photomultiplier. The specimen-to-detector distance with a specimen located at the center of the furnace tube is about 35 inches. The specimen can, if necessary, be mounted at the photodetector, but cannot be heated there. The infrared source system located in this chamber consists of a Nernst glower to provide radiant energy and an arsenic trisulfide lens to collimate this energy. Mounted on the same turntable with the lead sulfide detector are a pair of rectangular plane mirrors which direct the radiant energy from the infrared source system to circular plane mirrors and then into the sample chamber and onto the monochromator section. The total specimen-to-detector distance is 112 inches. These three chambers are connected with high-vacuum ball valves so that the furnace chamber may be opened independent of the rest of the system for the insertion or removal of specimens. The entire system is capable of being evacuated to 20 mm Hg or can be run when filled with an inert gas. It has been the practice to operate the instrument with the chambers filled with argon.

The radiant energy in the ultraviolet, visible, and near infrared regions are monochromatized before entering the sample chamber whereas the infrared spectrum is monochromatized after sampling. There are two reasons for this configuration: monochromatizing of the shorter wavelengths is done initially to eliminate or minimize any optical bleaching of a colored sample which may occur by allowing the full ultraviolet spectrum to be incident upon the sample, while monochromatizing of the longer wavelengths is done terminally to minimize the amount of direct furnace and sample radiation incident upon the thermocouple detector when running the system at elevated temperatures. In addition to the reversed optical beam paths, the optical chopping for each beam direction is accomplished prior to entering the furnace chamber so that any furnace radiation which may be directed onto the operating photodetector will produce a constant signal and thus not be passed by the chopper rectification circuitry to affect the recorded signal. Output is presented on a recording strip chart which displays the ratio of energy transmitted in the sample beam to that transmitted in the reference beam with respect to wavelength. Additional details pertaining to the optical specifications of the spectrophotometer are found in Ref. 13.

This instrument was used in all tests on fused silica requiring measurements of the absorption band at 0.215 microns. In order to be assured of sufficient sensitivity for the study of the band at 0.163 microns, the Seya-Namioka instrument was employed.

Seya-Namioka Far Ultraviolet Monochromator

The Seya monochromator is a single-beam instrument which measures the spectral transmittance characteristics of optical materials over the wavelength range from 0.11 to 0.40 microns at ambient temperature. Radiant energy is directed from the source to a reflectance grating, through the specimen, and then to a photodetector. The specimen under study is mounted in a movable holder approximately two inches from the detector so that it can be withdrawn from the beam path in order to provide a reference signal for the energy being delivered by the source at the wavelength where the transmittance is to be determined. Data are presented in the form of voltage produced by the detector, proportional to the intensity of light falling on the detector, which may be recorded or read using a digital voltmeter. This instrument was used in all tests of the aluminum oxide and beryllium oxide to provide data at wavelengths below 0.15 microns in addition to data at longer wavelengths. The short specimen-to-detector distance is important where diffuse scattered light constitutes a part of the transmitted light to be measured. Measurements of the band reported at 0.163 microns in fused silica using 1/2 mm thick specimens were made on this instrument, since the band was expected to extend to wavelengths near 0.15 microns.

DISCUSSION OF TESTS USING FUSED SILICA SPECIMENS

The transmission characteristics of each fused silica specimen was measured before the specimen was sent to the reactor. After each specimen was reactor irradiated, removed from the capsule and cleaned, the post-reactor room-temperature absorption spectrum was obtained either with the high temperature spectrophotometer in the wavelength range from 0.155 to 0.36 microns or with the Seya monochromator in the wavelength range from 0.110 to 0.36 microns. The specimens were then subjected to heat treatments and cobalt-60 gamma irradiations. The absorption coefficient at a wavelength of 0.215 microns was generally measured during the heat treatments and the absorption spectrum was measured after the heat treatment and the cobalt-60 gamma irradiations. Table V lists the type of examination made for each specimen and the tables where the detailed data may be found (Tables VI through VIII). A summary of the key results is given in the following subsections.

Transmission Characteristics Before Reactor Irradiation

Transmittance measurements made using fused silica specimens show that thin specimens (of the order of 1/2-mm thick) do not transmit as much light at ultraviolet wavelengths near the absorption edge as would be expected on the basis of intrinsic absorption measurements made using thick (up to 30-mm thick) specimens. This result is illustrated by Fig. 7 where the transmittance values at 0.215 microns prior to reactor-irradiation for all specimens used in the present program are plotted as a function of specimen thickness. Absorption levels which would be required to account for the decrease in transmittance below the 0.92 level (which accounts for the reflection loss of 0.08 due to the two surfaces of the specimen), are indicated. If such values were real, the intrinsic absorption of fused silica would depend on thickness at a given wavelength. Since this result cannot be correct, possible explanations have been sought to account for the loss in transmittance. Although the intrinsic properties change slightly for different batches of material, it is more likely that variations in surface finish is the cause. Surface irregularities of the same dimension as the wavelength of the light used for measurement (0.215 microns) are very difficult to eliminate, and the difficulty of maintaining adequate surface quality increases as the thickness of the specimen decreases. It is therefore to be emphasized that meaningful measurements with any specimen can be made of changes in transmittance (equivalent to changes in absorption as induced by processing of the specimen), as has been done in the present program, but that absolute values of absorption can be made only for cases in which the loss in transmission due to absorption is substantially greater than that due to reflection. Results of measurements of the absorption in both unirradiated and irradiated fused silica from Ref. 13 are shown in Fig. 8.

Transmission Characteristics After Reactor Irradiation

In order to ascertain the in-reactor optical absorption level, it is necessary either to measure the transmittance of a specimen during the irradiation process, or to measure the transmittance of a specimen which has been temperature and radiation quenched after the desired radiation dose has been administered. In this

study, transmittance measurements were made after the specimen had received a specified radiation dose. The necessity of using a thermally insulated capsule to perform the irradiations prevented rapid cool-down. Therefore, the results measured represent the conditions immediately at the end of the reactor irradiation only if the processes under consideration have a time constant which is significantly longer than the cooling down time of several minutes (see Fig. 5). In addition, the radioactivity induced in the capsule produced gamma irradiation so that the specimens receive a gamma dose during (and after) cooling (see Fig. 6).

Results of measurements of the absorption characteristics of each of the specimens after reactor irradiation are given in Fig. 9. The absorption coefficients for the specimens from capsules F through J are less than those from capsules A through E. This difference is believed to be due to the pre-irradiation annealing which was employed for the specimens in capsules F through J (see Table III). Another effect attributed to this annealing process is discussed in the following subsection.

The main objective of the reactor irradiation tests was to determine whether damage centers are created during the irradiation process which have a very long half life (i.e., which are very difficult to anneal, even at high temperatures). The low values of absorption coefficient indicated in Fig. 9, particularly for capsules F through J, indicate that the absorption associated with any such long-lived defects is small. Note that the total neutron dose for some of the capsules in the current test program are more than one order-of-magnitude greater than the neutron doses employed in the program described in Ref. 13. As noted in preceding paragraphs, the absorption coefficients shown in Fig. 9 are not equal to the absorption coefficients which are present in the reactor at the end of the reactor irradiation, both because of the possibility of bleaching short-lived defects and the possibility of gamma coloration from the capsule after removal of the specimens from the reactor.

Transmission Characteristics After Cobalt-60 Irradiation

The results of cobalt-60 gamma irradiation of specimen SC 30-2 are listed in Table VI-b and plotted in Fig. 10 in comparison with the results of gamma irradiation of a similar specimen which had not been reactor irradiated. The latter provides a measure of the absorption associated with the gamma damage only, whereas the curve for SC 30-2 shows two coloration processes occurring. The difference curve noted on Fig. 10 is believed to be an indication of recoloration of neutron-induced damage which in this case corresponds to an absorption coefficient of approximately 0.53 cm^{-1}. This has been termed the "saturation" value of the neutron-induced absorption. A similar behavior is shown in Fig. 11 for specimen SC 30-5 (Table VI-f). In this case the "saturation" absorption was obtained by extrapolating the portion of the curve attributable only to gamma coloration to zero cobalt-60 gamma dose. In both cases the specimens were not annealed prior to irradiation.

The technique illustrated in Figs. 10 and 11 appeared to provide a method for determining the long-lived neutron damage created in the reactor process. As a result, this technique was adopted for the specimens in following capsules. Therefore, after reactor irradiation, each specimen was irradiated to a total of

30 Mrads of cobalt-60 gamma rays, with transmittance measurements taken after 12, 18, 24, and 30 Mrad doses to determine the absorption level as a function of gamma dose. After the accumulation of 30 Mrads, the specimen was heated for twenty minutes at the temperature at which it was reactor-irradiated, and the cobalt-60 gamma dose procedure repeated to determine if the thermal treatment which reduced the absorption to zero had annihilated the color centers, or had only bleached them. During the process of heating the specimens, the transmittance was measured as a function of time at 0.215 microns, the center of a major absorption band at ultraviolet wavelengths.

The measurements of the induced absorption level versus gamma dose at 0.215 microns are summarized for the 30- and 5-mm thick specimens in Figs. 12 and 13 for specimens from capsules F through J. A value of approximately 0.05 cm^{-1}/Mrad of cobalt-60 gamma dose was found for the average coloration rate due to cobalt-60 gamma irradiation.

The general shape of the curves in Figs. 12 and 13 for the specimens from capsules F through J are different than for the curves in Figs. 10 and 11. The curves in Figs. 12 and 13 are approximately linear over their entire range; extrapolation of a straight line drawn through the data obtained at high gamma dose levels back to zero dose level indicates a value of "saturation" absorption which is approximately equal to the absorption coefficient indicated at the beginning of the gamma dose process. The reason for the difference in results obtained from Figs. 10 and 11 and Figs. 12 and 13 is not understood. However, it is noted that the specimens employed in producing the data shown in Figs. 12 and 13 were annealed at a temperature of 1050 C before the reactor irradiation, while the specimens employed in generating Figs. 10 and 11 did not receive an annealing treatment. Evidently the annealing process eliminates the cause of the curvature in the data shown in Figs. 10 and 11.

Data on the saturation absorption coefficient obtained from all specimens using the technique described in preceding paragraphs is summarized in Fig. 14. Except for some of the data obtained from specimens from capsules A through E, the data shown in Fig. 14 are a little different from the post-reactor data shown in Fig. 9. As noted in the discussion of Fig. 9, the data in this figure and in Fig. 14 cannot be interpreted as being equal to the absorption coefficient of these specimens immediately at the end of the reactor operating period. In addition to these summary curves, individual data plots for the 30-mm thick specimens are included in Figs. 25-41.

In addition to the studies of the induced absorption coefficients at 0.215 microns conducted with the 30- and 5-mm thick specimens of fused silica, 1/2-mm fused silica specimens were used to measure induced absorption level changes at 0.163 microns, the center of a second reported ultraviolet absorption band. The results of the post-nuclear-reactor-irradiation measurements of induced absorption coefficient, both immediately after the reactor irradiation and after cobalt-60 gamma dosing of the specimens, are summarized in Fig. 15. A great deal of scatter appears; however, a trend is found of increasing induced absorption coefficient with cobalt-60 gamma dose. The average increase in induced absorption coefficient with gamma dose is between 0.05 and 0.10 cm^{-1}/Mrad of cobalt-60 gamma dose. This is in reasonable agreement with the value of approximately 0.05 cm^{-1}/Mrad found for the coloration rate at 0.215 microns. If the coloration at 0.163 microns were

due to the tail of the band at 0.215 microns, the coloration rate would be a fraction of that at 0.215 microns. Thus, although a band at 0.163 microns is not clearly observed, the coloration there is not due to the tail of the 0.215 micron band. A second series of cobalt-60 gamma irradiations after heating the specimen at the reactor irradiation temperature were performed in which similar results were obtained.

Transmission Measurements During Heat Treatment

Moderate-temperature ($\leq$ 300 C) bleaching studies were conducted on specimens from capsules A through E to investigate the character of the bleaching process. The results obtained for three specimens from capsule B are shown in Fig. 16. As the bleaching temperature is increased, at least two processes are evidently occurring as shown by these curves. One of the specimens, SC 30-2, was gamma irradiated after the bleaching process, and then rebleached. The results are illustrated in Fig. 17 from which it can be deduced that two distinct processes are occurring. The calculated time constant, shown on the plot, is defined by the relationship

$$(\alpha_i / \alpha_i \text{ ref}) = \exp(-t/\theta) \tag{1}$$

and represents the time required for the induced absorption coefficient to decrease to (1/e) of its initial value.

Measurements of the increase in transmittance as a function of time at a wavelength of 0.215 microns were also made on the 30-mm thick specimens from capsules F, I, and J during heat treatment at temperatures of 700, 800, and 900 C after gamma irradiation. The induced absorption coefficient value after such heat treatments dropped to zero within the accuracy of the measurements. Therefore, it appears probable that the saturation absorption indicated on Fig. 14 is due primarily to gamma rays from the capsule. Recoloration by cobalt-60 gamma irradiation indicated no remaining defects. These transmittance measurements were used to calculate the induced absorption coefficient level as a function of time at temperature for the specimens at 0.215 microns. The results are plotted in Figs. 18, 19, and 20. The calculated time constants are shown on the plots. These plots indicate that a single, first-order type of process is being observed at these elevated temperatures at a wavelength of 0.215 microns. This is in contrast to the data of induced absorption coefficient versus time at temperature obtained from moderate-temperature bleaching studies conducted using the specimens from the preliminary experiments, capsules A through E, at the same wavelength. These bleaching studies showed two distinct slopes to the bleaching curves, especially in Fig. 17 in which the data for alternate gamma dosing and heat treatment are plotted. Time constants for each slope on Figs. 16 through 20 have been calculated and are plotted in Fig. 21.

Also shown on Fig. 21 is information on bleaching time constants from the TRIGA experiments reported in Ref. 14. The time constants from the TRIGA experiments at temperatures from 300 to 900 C are approximately two orders of magnitude less than those determined in the present investigation. No completely satisfactory explanation has been offered for this difference. The most satisfactory explanation is that

the total coloration in the TRIGA tests is so small that the coloration due to long-lived defects is not noticeable. These long-lived defects, which represent only a portion of the total damage, might be the defects which are associated with the bleaching process in the present experiments. The time constants in Fig. 21 from the present program at high temperatures are on the same order of magnitude as the time for the specimen temperatures to come into equilibrium (Ref. 13). This could cause some effect on the data, but probably not a two-order-of-magnitude effect.

Resolution of the reason for the differences between the time constants at high temperatures determined in the present experiments and those determined in the TRIGA experiments reported in Ref. 14 is extremely important in evaluating the performance characteristics of a nuclear light bulb rocket engine. As noted in Ref. 14 the time constants determined from the TRIGA experiments lead to indication of an absorption coefficient at 0.215 microns during steady-state operation of a full-scale engine of approximately 1.6 cm^{-1}. If the time constant is increased by two orders of magnitude, with the same rate of creation of coloration as for the tests in Ref. 14, the resulting absorption coefficient during steady-state operation would be 160 cm^{-1}. This would result in excessive heating of the transparent wall due to absorption of thermal radiation. However, if the parameter which describes the rate of creation of damage which is associated with this long time constant is less than that indicated in Ref. 14, the corresponding calculated equilibrium absorption coefficient would be reduced. More tests must be conducted to resolve this uncertainty.

One of the specimens tested was observed to have a surface film after being heated to 800 C. This film was identified as a devitrification product: α-quartz. The devitrification of fused silica is not felt to be a problem, but the appearance of such a surface film despite careful handling procedures illustrates the necessity of such procedures to avoid spurious data.

DISCUSSION OF TESTS USING ALUMINA AND BERYLLIA SPECIMENS

Single crystal aluminum oxide specimens were reactor irradiated at 900 C in capsule J. The results of the post-reactor-irradiation transmittance measurements as a function of wavelength are presented in Figs. 22 and 23 for the 2-mm and 1/2-mm thick specimens. Since the heat treatment at 900 C for 20 minutes made no apparent difference in the transmittance, specimen AM 1/2-100 was heated at 1200 C for one hour. As shown in Fig. 23, a substantial amount of transmittance recovery is observed.

Polycrystalline BeO specimens were also reactor irradiated at 900 C in capsule J. After irradiation, they were completely nontransmitting. No improvement was observed after the 900 C heat treatment for 20 minutes, nor did heating at 1200 C for one hour improve the transmittance characteristics.

The single crystal BeO specimens, BL 2-100 from the Lawrence Radiation Laboratory, was reactor irradiated at ambient temperature, which has been measured to be approximately 160 C. The absorption level after irradiation was greater than 12 cm^{-1} throughout the wavelength range 0.150 to 0.290 microns as shown in Fig. 24. No heat treatments were given to this specimen.

REFERENCES

1. Levy, P. W.: Reactor and Gamma-Ray Induced Coloring in Crystalling Quartz and Corning Fused Silica. J. Chem. Phys. 23, 764 (1955).

2. Cohen, A. J.: Impurity-Induced Color Centers in Fused Silica. J. Chem. Phys. 23, 765 (1955).

3. Mitchell, E. W. J. and E. G. S. Paige: The Optical Effects of Radiation Induced Atomic Damage in Quartz. Phil. Mag. Ser. 8, 1, 1085 (1956).

4. Primak, W.: Fast-Neutron-Induced Changes in Quartz and Vitreous Silica. Phys. Rev. 110, 1240 (1958).

5. Levy, P. W.: Reactor and Gamma-Ray Induced Coloring of Corning Fused Silica. J. Phys. Chem. Sol. 13, 287 (1960).

6. Nelson, C. M. and R. A. Weeks: Vacuum-Ultraviolet Absorption Studies of Irradiated Silica and Quartz. J. Appl. Phys. 13, 883 (1961).

7. Compton, W. D.: Radiation Effects in Ionic Crystals. Reprinted from "The Interaction of Radiation with Solids", Proceedings of the International Summer School on Solid State Physics held at Mol, Belgium, August 12-31, 1963. North-Holland Publishing Company, Amsterdam, 1964.

8. Compton, W. D. and G. W. Arnold, Jr.: Radiation Effects in Fused Silica and α-Al_2O_3. Disc. Faraday Soc. 31, 130 (1961).

9. Arnold, G. W. and W. D. Compton: Threshold Energy for Lattice Displacement in α-Al_2O_3. Phys. Rev. Letters 4, 66 (1960).

10. Levy, P. W. and G. J. Dienes: Irradiation Induced Optical Absorption in Al_2O_3. Phys. Rev. 94, 1409 (1954).

11. Levy, P. W.: Color Centers and Radiation Induced Defects in Al_2O_3. Brookhaven National Laboratory Report BNL 5382, April 1961.

12. Levy, P. W.: Annealing of the Defects and Color Centers in Unirradiated and in Reactor Irradiated Al_2O_3. Brookhaven National Laboratory Report BNL 5213, for presentation at the Faraday Society Meeting, Saclay, France, 1961.

13. Douglas, F. C. and R. M. Gagosz: Experimental Investigation of Thermal Annealing of Nuclear-Reactor-Induced Coloration in Fused Silica. UARL Contract report issued as NASA CR-304, September 1965.

14. Gagosz, R., J. Waters, F. C. Douglas, and M. A. DeCrescente: Optical Absorption in Fused Silica During Triga Reactor Pulse Irradiations. United Aircraft Research Laboratories Report F-910485-1, September 1967.

REFERENCES (Cont'd)

15. Edwards, O. J.: Optical Absorption Coefficients of Fused Silica in the Wavelength Range 0.17 to 3.5 Microns from Room Temperature to 980 C. Lewis Research Center, Cleveland, Ohio; NASA Technical Note NASA TN D-3257, February 1966.

16. Latham, T. S.: Nuclear Criticality Studies of Specific Nuclear Light Bulb and Open Cycle Gaseous Nuclear Rocket Engines. United Aircraft Research Laboratories Report F-910375-2, September 1967.

LIST OF SYMBOLS

n	Neutrons
T	Temperature, deg. C or deg. K
t	Time, sec or min
( )ref	( ) Reference value
α	Absorption coefficient, cm^{-1}
α_i	Induced absorption coefficient, cm^{-1}
λ	Wavelength, microns
ϕ	Neutron flux, neutrons/cm^2-sec
θ	Time constant, seconds
$(\ )_i$	Initial value
$(\ )_f$	Final value

TABLE I

SPECIMEN DESCRIPTION

MATERIAL	SPECIMEN CODE	SOURCE	SHAPE	DIMENSIONS
FUSED SILICA	SC	Corning Glass Works "7940"	Right Cylinder	25.4 mm dia. 30, 8, 5, 1/2 mm thick
	ST	Thermal-American, Inc. "Spectrosil"	Right Cylinder	25.4 mm dia. 25 mm thick
ALUMINUM OXIDE	AM	Adolph Meller Co. "ultraviolet Grade" (Single crystal)	Right Cylinder	13 mm dia. 2, 1/2 mm thick
BERYLLIUM OXIDE	BL	Lawrence Radiation Laboratory (Single crystal)	Regular Hexagon	10 mm diagonal 2 mm thick
	BN	National Beryllia Co. (polycrystalline)	Right Cylinder	25 mm dia. 1/2 mm thick

TABLE II

SPECIMEN DESIGNATION CODE

EXAMPLE

S C 30 - 101

- 101 — Specimen Number
- 30 — Specimen thickness in Millimeters
- C — Manufacturer
  - C-CORNING GLASS WORKS
  - T-THERMAL AMERICAN, INC.
  - M-ADOLPH MELLER CO.
  - L-LAWRENCE RADIATION LABORATORY
  - N-NATIONAL BERYLLIA CO.
- S — Type of Material
  - S-FUSED SILICA
  - A-ALUMINUM OXIDE
  - B-BERYLLIUM OXIDE

TABLE III

SPECIMEN TREATMENT PRIOR TO NUCLEAR REACTOR IRRADIATION IN THE UNION CARBIDE RESEARCH REACTOR

CAPSULE	SPECIMEN	TREATMENT	
		CHEM. CLEAN 50 deg C CHROMIC ACID	HEAT TO 1050 deg C, 1 hr
A	SC 30-16	Yes	No
B	SC 30-2 SC 8-2 ST 25-1	Yes Yes Yes	No No
C	SC 30-6	Yes	No
D	SC 30-5	Yes	No
E	SC 30-30	Yes	No
F	SC 30-101 SC 5-101 SC 1/2-101	Yes Yes Yes	Yes Yes Yes
G	SC 30-105 SC 5-104 SC 1/2-107	Yes Yes Yes	Yes Yes Yes
H	SC 30-109 SC 5-110 SC 1/2-111	Yes Yes Yes	Yes Yes Yes
I	SC 30-102 SC 30-112 SC 5-105 SC 1/2-102	Yes Yes Yes Yes	Yes Yes Yes Yes
J	SC 30-107 SC 5-107 AM 2-100 AM 1/2-100 BN 1/2-100 BN 1/2-101	Yes Yes Yes Yes Yes Yes	Yes Yes No No No No
K	BL 2-100	Yes	No
Control	SC 30-113 SC 30-114	Yes Yes	Yes Yes

Note: Capsules A, B, C, D, E, and K irradiated as part of a Corporate-sponsored program

TABLE IV

IRRADIATION CONDITIONS FOR SPECIMENS AT THE UNION CARBIDE RESEARCH REACTOR

CAPSULE	SPECIMEN	IRRADIATION CONDITIONS				GAMMA DOSE FROM CAPSULE AFTER COMPLETION OF NEUTRON IRRAD, MEGARADS
		Temp, deg C	Flux, $(10)^{13}$ n/cm^2-sec	Dose, $(10)^{17}$ n/cm^2	CORE POSITION	
A	SC 30-16	833	1.6	7.8	C-3	4 (Est.)
B	SC 30-2 SC 8-2 ST 25-1	900	1.5	8.1	C-3	4 (Est.)
C	SC 30-6	988	1.6	5.4	C-3	4 (Est.)
D	SC 30-5	1018	1.5	44.8	C-3	5 (Est.)
E	SC 30-30	1170	1.4	5.8	C-3	5 (Est.)
F	SC 30-101 SC 5-101 SC 1/2-101	700	1.90	69.0	C-3	3.6
G	SC 30-105 SC 5-104 SC 1/2-107	800	1.90	5.26	C-3	3.6
H	SC 30-109 SC 5-110 SC 1/2-111	800	0.17	5.89	D-1	3.1
I	SC 30-102 SC 30-112 SC 5-105 SC 1/2-102	800	1.93	70.2	C-3	3.6
J	SC 30-107 SC 5-107 AM 2-100 AM 1/2-100 BN 1/2-100 BN 1/2-101	900	1.91	70.1	C-3	3.6
K	BL 2-100	160	1.5	4.32	--	---
Control	SC 30-113 SC 30-114	---	0	0	None	None

TABLE V

TREATMENT OF SPECIMENS IN POST-REACTOR-IRRADIATION TESTING PROGRAM

CAPSULE	SPECIMEN	POST-REACTOR-IRRADIATION PROCESSING			DETAILS IN TABLE
		Heat Treatment			
		High Temp (≥600C)	Low Temp (≤300C)	Co-60 Gamma Irrad	
A	SC 30-16	X	-	X	VI-a
B	SC 30-2	-	X	X	VI-b
	SC 8-2	-	X	X	VI-c
	ST 25-1	-	X	X	VI-d
C	SC 30-6	-	-	X	VI-e
D	SC 30-5	-	-	X	VI-f
E	SC 30-30	-	-	X	VI-g
F	SC 30-101	X	-	X	VII-a
	SC 5-101	X	-	X	VII-f
	SC 1/2-101	X	-	X	VII-k
G	SC 30-105	X	-	X	VII-b
	SC 5-104	X	-	X	VII-g
	SC 1/2-107	X	-	X	VII-l
H	SC 30-109	X	-	X	VII-c
	SC 5-110	X	-	X	VII-h
	SC 1/2-111	X	-	X	VII-m
I	SC 30-102	X	-	X	VII-d
	SC 30-112	-	X	X	VII-o
	SC 5-105	X	-	X	VII-i
	SC 1/2-102	X	-	X	VII-n
J	SC 30-107	X	-	X	VII-e
	SC 5-107	X	-	X	VII-j
	AM 2-100	X	-	X	VIII-a,c
	AM 1/2-100	X	-	X	VIII-b,d
	BN 1/2-100	X	-	X	-
	BN 1/2-101	X	-	X	-
K	BL 2-100	-	-	-	-
Control	30-113	-	-	X	VII-p
	30-114	-	-	X	VII-q

TABLE VI-a

HISTORY OF FUSED SILICA SPECIMEN SC 30-16
CAPSULE A

	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	-----	---	---	2,700	0.85*	0*	1.0*
2	Reactor irradiation	833	48.8	1.6	7.8	-----	-----	-----	-----
3	Gamma irrad: capsule	---	-----	---	---	4(est)	0.794	0.79	0.935
4	Gamma irrad: fuel elt	---	-----	---	---	1	0.794	0.79	0.935
5	Heat treatment	400	1.8	---	---	-----	0.852	-----	1.02
6	Heat treatment	500	1.2	---	---	-----	0.763	0.036	0.897
7	Heat treatment	600	0.9	---	---	-----	0.797	0.018	0.94
8	Heat treatment	700	0.36	---	---	-----	0.842	0.010	0.99
9	Heat treatment	800	0.36	---	---	-----	0.833	0.006	0.98
10	Gamma irrad: fuel elt	---	-----	---	---	1	0.617	0.106	0.726
11	Gamma irrad: Co-60	40	-----	---	---	6.25	0.458	0.208	0.54

*reference

TABLE VI-b

HISTORY OF FUSED SILICA SPECIMEN SC 30-2
CAPSULE B

STEP		DESCRIPTION OF STEP					Characteristics after step; $\lambda = 0.215$ microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/sec-cm^2	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	----	---	---	-----	0.083*	0*	1.0*
2	Reactor irradiation	900	54	1.5	8.1	5,950	-----	-----	-----
3	Capsule gamma irrad.	---	----	0	0	4	0.188	0.485	0.234
4	Heat treatment	250	12.6	0	0	0	0.477	0.174	0.594
5	Gamma irrad. - Co-60	40	----	0	0	1.17	0.338	0.330	0.421
6	Gamma irrad. - Co-60	40	----	0	0	1.17	0.164	0.530	0.204
7	Gamma irrad. - Co-60	40	----	0	0	1.17	0.137	0.590	0.171
8	Gamma irrad. - Co-60	40	----	0	0	5.85	0.048	0.940	0.059
9	Gamma irrad. - Co-60	40	----	0	0	1.19	0.056	0.890	0.069
10	Heat treatment	250	45.4	0	0	0	0.570	0.112	0.709
11	Gamma irrad. - Co-60	40	----	0	0	9.95	0.079	0.775	0.098
12	Heat treatment	250	9	0	0	0	0.360	0.268	0.448
13	Specimen polished	---	----	0	0	-----	-----	-----	-----
14	Gamma irrad. - Co-60	40	----	0	0	9.95	0.078	0.772	0.097
15	Heat treatment	250	15.8	0	0	0	0.369	0.300	0.459

*reference

TABLE VI-c

HISTORY OF FUSED SILICA SPECIMEN SC 8-2
CAPSULE B

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	----	---	---	------	0.800*	0*	1.0*
2	Reactor irradiation	900	54	1.5	8.1	3,000	-----	-----	-----
3	Gamma irrad: capsule	---	----	---	---	4(est)	0.573	0.412	0.715
4	Heat treatment	300	10.8	---	---	------	0.776	0.040	0.971
5	Gamma irrad: Co-60	40	----	---	---	1.43	0.570	0.404	0.712
6	Gamma irrad: Co-60	40	----	---	---	1.43	0.552	0.469	0.69
7	Gamma irrad: Co-60	40	----	---	---	1.43	0.495	0.600	0.62
8	Gamma irrad: Co-60	40	----	---	---	7.18	0.476	0.645	0.595
9	Gamma irrad: Co-60	40	----	---	---	1.43	0.353	1.03	0.442

*reference

TABLE VI-d

HISTORY OF FUSED SILICA SPECIMEN ST 25-1
CAPSULE B

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/cm^2-sec	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	----	---	---	------	0.853*	0*	1.0*
2	Reactor irradiation	900	54	1.5	8.1	5,450	-----	-----	-----
3	Gamma irrad: capsule	---	----	---	---	4(est)	0.423	0.280	0.496
4	Heat treatment	200	10.8	---	---	------	0.528	0.191	0.618

*reference

TABLE VI-e

HISTORY OF FUSED SILICA SPECIMEN SC 30-6
CAPSULE C

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/cm^2-sec	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	---	---	---	------	0.820*	0*	1.0*
2	Reactor irradiation	988	---	1.6	5.4	------	-----	-----	-----
3	Gamma irrad: capsule	---	---	---	---	4(est)	0.334	0.30	0.407
4	Gamma irrad: fuel elt.	---	---	---	---	1	0.314	0.321	0.383
5	Gamma irrad: Co-60	---	---	---	---	7.25	0.217	0.444	0.265

*reference

TABLE VI-f

HISTORY OF FUSED SILICA SPECIMEN SC 30-5
CAPSULE D

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/cm^2-sec	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	----	---	---	----	------	0.851*	0*	1.0*
2	Reactor irradiation	1018	---	1.5	44.8	------	-----	-----	-----
3	Gamma irrad: capsule	----	---	---	----	5(est)	0.461	0.097	0.542
4	Gamma irrad: Co-60	40	---	---	----	18.2	0.088	0.758	0.891

*reference

TABLE VI-g

HISTORY OF FUSED SILICA SPECIMEN SC 30-30
CAPSULE E

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/cm^2-sec	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	----	---	---	---	------	0.820*	0*	1.0*
2	Reactor irradiation	1170	---	1.4	5.8	------	-----	-----	-----
3	Gamma irrad: capsule	----	---	---	---	4(est)	0.544	0.137	0.663
5	Gamma irrad: fuel elt	----	---	---	---	1	0.498	0.168	0.607
6	Gamma irrad: Co-60	----	----	---	---	1.4	0.337	0.295	0.359

*reference

TABLE VII-a

HISTORY OF FUSED SILICA SPECIMEN SC 30-101
CAPSULE F

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	---	----	------	0.833*	0.0*	1.0*
2	Reactor irradiation	700	360	1.9	69.0	20,000	-----	----	-----
3	Capsule gamma irrad.	----	---	---	----	3.6	0.413	0.23	0.496
4	Co-60 gamma irrad.	40	---	---	----	12	0.116	0.65	0.139
5	Co-60 gamma irrad.	40	---	---	----	6	0.03	1.10	0.036
6	Co-60 gamma irrad.	40	---	---	----	6	0.012	1.40	0.014
7	Co-60 gamma irrad.	40	---	---	----	6	0	——	0
8	Heat treatment	700	1.2	---	----	------	0.859	0.0*	1.031
9	Co-60 gamma irrad.	40	---	---	----	12	0.157	0.567	0.189
10	Co-60 gamma irrad.	40	---	---	----	6	0.064	0.865	0.077
11	Co-60 gamma irrad.	40	---	---	----	6	0.029	1.13	0.034
12	Co-60 gamma irrad.	40	---	---	----	6	0.003	1.88	0.004
13	Heat treatment	700	1.2	---	----	------	0.817	0.0*	0.977
14	Co-60 gamma irrad.	40	---	---	----	12	0.128	0.617	0.154
15	Co-60 gamma irrad.	40	---	---	----	6	0.063	0.855	0.076
16	Co-60 gamma irrad.	40	---	---	----	6	0.039	1.01	0.047
17	Polish specimen	----	---	---	----	------	0.032	1.08	0.038
18	Co-60 gamma irrad.	40	---	---	----	6	0	——	0

*reference

TABLE VII-b

HISTORY OF FUSED SILICA SPECIMEN SC 30-105
CAPSULE G

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	---	----	------	0.842*	0.0*	1.0*
2	Reactor irradiation	800	270	1.9	5.26	15,000	-----	-----	-----
3	Capsule gamma irrad.	----	---	---	----	3.6	0.387	0.2589	0.460
4	Co-60 gamma irrad.	40	---	---	----	12	0.079	0.781	0.094
5	Co-60 gamma irrad.	40	---	---	----	6	0.017	1.288	0.020
6	Co-60 gamma irrad.	40	---	---	----	6	0	———	0.0
7	Co-60 gamma irrad.	40	---	---	----	6	0	———	0.0
8	Heat treatment	800	1.2	---	----	------	0.338	0.30	0.401
9	Co-60 gamma irrad.	40	---	---	----	12	0.077	0.79	0.091
10	Co-60 gamma irrad.	40	---	---	----	6	0.006	1.65	0.007
11	Co-60 gamma irrad.	40	---	---	----	6	0	———	0
12	Co-60 gamma irrad.	40	---	---	----	6	0	———	0
13	Heat treatment	800	1.2	---	----	------	0.106	0.684	0.126
14	Co-60 gamma irrad.	40	---	---	----	12	----	-----	-----
15	Polish specimen	25	---	---	----	------	0.127	0.624	0.151
16	Polish specimen	25	---	---	----	------	0.133	0.609	0.158
17	Co-60 gamma irrad.	40	---	---	----	6	0.047	0.96	0.056
18	Co-60 gamma irrad.	40	---	---	----	6	0.027	1.14	0.032

*reference

TABLE VII-c

HISTORY OF FUSED SILICA SPECIMEN SC 30-109
CAPSULE H

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	1050	3.6	----	----	0	0.85*	0	1.0*
2	Reactor irradiation	800	350	0.17	5.89	6,900	----	-----	----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.84	0.004	0.988
4	Co-60 gamma irrad.	40	---	----	----	12	0.181	0.515	0.213
5	Co-60 gamma irrad.	40	---	----	----	6	0.091	0.736	0.107
6	Co-60 gamma irrad.	40	---	----	----	6	0.033	1.158	0.039
7	Co-60 gamma irrad.	40	---	----	----	6	0.005	-----	0

*reference

TABLE VII-d

HISTORY OF FUSED SILICA SPECIMEN SC 30-102
CAPSULE I

STEP		DESCRIPTION OF STEP					Characterization after step; $\lambda = 0.215$ microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	------	0.864*	0.0*	1.0*
2	Reactor irradiation	800	360	1.93	70.2	20,000	-----	-----	----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.58	0.1315	0.671
4	Co-60 gamma irrad.	40	---	----	----	12	0.137	0.608	0.159
5	Co-60 gamma irrad.	40	---	----	----	6	0.052	0.927	0.060
6	Co-60 gamma irrad.	40	---	----	----	6	0.025	1.17	0.029
7	Co-60 gamma irrad	40	---	----	----	6	0		0
8	Heat treatment	800	1.2	----	----	------	0.825	0.0*	0.955
9	Co-60 gamma dose	40	---	----	----	12	0.158	0.566	0.183
10	Co-60 gamma dose	40	---	----	----	6	0.051	0.998	0.059
11	Co-60 gamma dose	40	---	----	----	6	0.022	1.304	0.025
12	Co-60 gamma dose	40	---	----	----	6	0.005	-----	0.006
13	Polish specimen	25	---	----	----	------	0.004	-----	0.005
14	Polish specimen	25	---	----	----	------	0	-----	0
15	Prior to heat treatment	25	---	----	----	------	0.01	1.535	0.012
16	Heat treatment	800	---	----	----	------	0.774	0.390	0.896
17	Polish specimen	25	---	----	----	------	0.83	0.014	0.961

*reference

TABLE VII-e

HISTORY OF FUSED SILICA SPECIMEN SC 30-107

STEP		DESCRIPTION OF STEP					Characterization after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	0	0.823*	0.0*	1.0*
2	Reactor irradiation	900	370	1.91	70.1	20,000	------	-----	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.743	0.114	-----
4	Co-60 gamma irrad.	40	---	----	----	12	0.149	0.564	0.181
5	Co-60 gamma irrad.	40	---	----	----	6	0.025	1.15	0.030
6	Co-60 gamma irrad.	40	---	----	----	6	0	-----	0
7	Co-60 gamma irrad.	40	---	----	----	6	0	-----	0
8	Heat treatment	900	1.2	----	----	------	0.843	-----	-----

*reference

TABLE VII-f

HISTORY OF FUSED SILICA SPECIMEN SC 5-101
CAPSULE F

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast Neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	---	----	------	0.823*	0.0*	1.0*
2	Reactor irradiation	700	360	1.9	69.0	20,000	------	-----	-----
3	Capsule gamma irrad.	----	420	---	----	3.6	0.753	0.178	0.914
4	Co-60 gamma irrad.	40	---	---	----	12	0.556	0.784	0.676
5	Co-60 gamma irrad.	40	---	---	----	6	0.485	1.06	0.589
6	Co-60 gamma irrad.	40	---	---	----	6	0.452	1.198	0.549
7	Co-60 gamma irrad.	40	---	---	----	6	0.366	1.62	0.445
8	Prior to heat treatment	25	---	---	----	------	0.392	1.43	0.763
9	Heat treatment	700	1.2	---	----	------	0.864	0.0*	1.050
10	Co-60 gamma irrad.	40	---	---	----	12	0.592	0.109	0.7193
11	Co-60 gamma irrad.	40	---	---	----	6	0.513	0.159	0.623
12	Co-60 gamma irrad.	40	---	---	----	6	0.430	0.218	0.522
13	Co-60 gamma irrad.	40	---	---	----	6	0.411	0.238	0.499
14	Heat treatment	700	1.2	---	----	------	------	0.0*	------
15	Co-60 gamma irrad.	40	---	---	----	12	0.569	0.124	0.691
16	Co-60 gamma irrad.	40	---	---	----	6	0.509	0.159	0.618
17	Co-60 gamma irrad.	40	---	---	----	6	0.445	0.205	0.541
18	Polish specimen	25	---	---	----	------	0.444	0.205	0.539
19	Co-60 gamma irrad.	40	---	---	----	6	0.399	0.245	0.485

*reference

TABLE VII-g

HISTORY OF FUSED SILICA SPECIMEN SC 5-104
CAPSULE G

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	---	----	------	0.818*	0*	1.0*
2	Reactor irradiation	800	270	1.9	5.26	15,000	-----	-----	-----
3	Capsule gamma irrad.	----	---	---	----	3.6	0.717	0.28	0.877
4	Co-60 gamma irrad.	40	---	---	----	12	0.553	0.782	0.676
5	Co-60ggamma irrad.	40	---	---	----	6	0.492	1.017	0.601
6	Co-60 gamma irrad.	40	---	---	----	6	0.417	1.35	0.510
7	Co-60 gamma irrad.	40	---	---	----	6	0.382	1.53	0.467
8	Prior to heat treatment	25	---	---	----	------	0.368	1.60	0.450
9	Heat treatment	800	1.2	---	----	------	0.821	0.0*	1.004
10	Co-60 gamma irrad.	40	---	---	----	12	0.571	-----	0.698
11	Co-60 gamma irrad.	40	---	---	----	6	0.472	-----	0.577
12	Co-60 gamma irrad.	40	---	---	----	6	0.431	-----	0.527
13	Co-60 gamma irrad.	40	---	---	----	6	0.387	-----	0.473
14	Prior to heat treatment	25	---	---	----	------	0.364	-----	0.445
15	Heat treatment	800	1.2	---	----	------	0.804	0.0*	0.983
16	Co-60 gamma irrad.	40	---	---	----	12	-----	-----	-----
17	Polish specimen	25	---	---	----	------	0.583	-----	0.713
18	Polish specimen	25	---	---	----	------	0.596	-----	0.729
19	Co-60 gamma irrad.	40	---	---	----	6	0.499	-----	0.610
20	Co-60 gamma irrad.	40	---	---	----	6	0.434	-----	0.531

*reference

TABLE VII-h

HISTORY OF FUSED SILICA SPECIMEN SC 5-110
CAPSULE H

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	1050	3.6	----	----	0	0.825*	0*	1.0*
2	Reactor irradiation	800	350	0.17	5.89	6,900	-----	---	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.836	---	1.013
4	Co-60 gamma irrad.	40	---	----	----	12	0.570	---	0.691
5	Co-60 gamma irrad.	40	---	----	----	6	0.495	---	0.600
6	Co-60 gamma irrad.	40	---	----	----	6	0.434	---	0.526

*reference

TABLE VII-i

HISTORY OF FUSED SILICA SPECIMEN SC 5-105
CAPSULE I

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	------	0.801*	0.0*	1.0*
2	Reactor irradiation	800	360	1.93	70.2	20,000	-----	-----	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.793	0.002	0.990
4	Co-60 gamma irrad.	40	---	----	----	12	0.585	0.628	0.730
5	Co-60 gamma irrad.	40	---	----	----	6	0.502	0.934	0.627
6	Co-60 gamma irrad.	40	---	----	----	6	0.442	1.19	0.552
7	Co-60 gamma irrad.	40	---	----	----	6	0.361	1.59	0.451
8	Prior to heat treatment	25	---	----	----	------	0.392	1.40	0.489
9	Heat treatment	800	1.2	----	----	------	0.652	0.412	0.814
10	Co-60 gamma irrad.	40	---	----	----	12	0.335	1.74	0.418
11	Co-60 gamma irrad.	40	---	----	----	6	0.331	1.77	0.413
12	Co-60 gamma irrad.	40	---	----	----	6	0.274	0.146	0.342
13	Co-60 gamma irrad.	40	---	----	----	6	0.236	0.442	0.295
14	Polish specimen	25	---	----	----	------	0.382	1.48	0.477
15	Polish specimen	25	---	----	----	------	0.369	1.55	0.461
16	Prior to heat treatment	25	---	----	----	------	0.40	1.39	0.499
17	Heat treatment	800	1.2	----	----	------	0.85*	-----	1.061
18	Polish specimen	25	---	----	----	------	0.807	-----	1.007

*reference

TABLE VII-j

HISTORY OF FUSED SILICA SPECIMEN SC 5-107
CAPSULE J

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	------	0.793*	0.0*	1.0*
2	Reactor irradiation	900	370	1.91	70.1	20,000	-----	-----	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.863	0.0*	1.088
4	Polish specimen	25	---	----	----	------	0.858	0.0	1.082
5	Co-60 gamma irrad.	40	---	----	----	12	0.571	0.824	0.720
6	Co-60 gamma irrad.	40	---	----	----	6	0.439	1.35	0.554
7	Co-60 gamma irrad.	40	---	----	----	6	0.389	1.42	0.257

*reference

TABLE VII-k

HISTORY OF FUSED SILICA SPECIMEN SC 1/2-101
CAPSULE F

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.163 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	---	----	------	0.75*	0.0*	1.0*
2	Reactor irradiation	700	360	1.9	69.0	20,000	-----	-----	-----
3	Capsule gamma irrad.	----	420	---	----	3.6	0.785	-----	1.046
4	Co-60 gamma irrad.	40	---	---	----	12	0.695	1.538	0.926
5	Co-60 gamma irrad.	40	---	---	----	6	0.792	-----	1.056
6	Co-60 gamma irrad.	40	---	---	----	6	0.680	1.974	0.906
7	Co-60 gamma irrad.	40	---	---	----	6	0.740	0.282	0.986
8	Heat treatment	----	1.2	---	----	0	0.733	0.465	0.977
9	Co-60 gamma irrad.	40	---	---	----	12	0.712	1.047	0.949
10	Co-60 gamma irrad.	40	---	---	----	6	0.647	2.97	0.862
11	Co-60 gamma irrad.	40	---	---	----	6	0.647	2.97	0.862
12	Co-60 gamma irrad.	40	---	---	----	6	0.635	3.345	0.846

*reference

TABLE VII-1

HISTORY OF FUSED SILICA SPECIMEN SC 1/2-107
CAPSULE G

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.163 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	---	----	------	0.730*	0.0	1.0*
2	Reactor irradiation	800	270	1.9	5.26	15,000	-----	-----	-----
3	Capsule gamma irrad.	----	420	---	----	3.6	0.693	0.107	0.949
4	Co-60 gamma irrad.	40	---	---	----	12	0.80	-----	1.095
5	Co-60 gamma irrad.	40	---	---	----	6	0.66	2.019	0.904
6	Co-60 gamma irrad.	40	---	---	----	6	0.76	-----	1.041
7	Co-60 gamma irrad.	40	---	---	----	6	0.525	6.598	0.719
8	Heat treatment	800	1.2	---	----	0	0.69	1.131	0.945
9	Co-60 gamma irrad.	40	---	---	----	12	0.602	3.872	0.824
10	Co-60 gamma irrad.	40	---	---	----	6	0.630	2.947	0.863
11	Co-60 gamma irrad.	40	---	---	----	6	0.610	3.606	0.835
12	Co-60 gamma irrad.	40	---	---	----	6	0.595	4.091	0.815

*reference

TABLE VII-m

HISTORY OF FUSED SILICA SPECIMEN SC 1/2-111
CAPSULE H

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; $\lambda = 0.215$		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	-----	0.75*	0*	1.0*
2	Reactor irradiation	800	350	0.17	5.89	6,900	-----	-----	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.755	-----	1.006
4	Co-60 gamma irrad.	40	---	----	----	12	0.76	-----	1.013
5	Co-60 gamma irrad.	40	---	----	----	6	0.70	1.387	0.933
6	Co-60 gamma irrad.	40	---	----	----	6	0.627	3.583	0.836
7	Co-60 gamma irrad.	40	---	----	----	6	0.744	0.161	0.992
8	Heat treatment	800	---	----	----	0	0.748	0.060	0.997
9	Co-60 gamma irrad.	40	---	----	----	12	0.667	2.353	0.889
10	Co-60 gamma irrad.	40	---	----	----	6	0.667	2.353	0.889
11	Co-60 gamma irrad.	40	---	----	----	6	0.625	3.654	0.833
12	Co-60 gamma irrad.	40	---	----	----	6	0.657	2.648	0.876

*reference

TABLE VII-n

HISTORY OF FUSED SILICA SPECIMEN SC 1/2-102
CAPSULE I

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.163 microns		
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	------	0.75*	0.0*	1.0*
2	Reactor irradiation	800	360	1.93	70.2	20,000	-----	-----	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.827	-----	1.103
4	Co-60 gamma irrad.	40	---	----	----	12	0.730	0.547	0.973
5	Co-60 gamma irrad.	40	---	----	----	6	0.792	-----	1.056
6	Co-60 gamma irrad.	40	---	----	----	6	0.725	0.671	0.967
7	Co-60 gamma irrad.	40	---	----	----	6	0.698	1.430	0.931
8	Heat treatment	800	1.2	----	----	0	0.754	-----	1.005
9	Co-60 gamma irrad.	40	---	----	----	12	0.730	0.547	0.973
10	Co-60 gamma irrad.	40	---	----	----	6	0.620	3.799	0.827
11	Co-60 gamma irrad.	40	---	----	----	6	0.640	3.180	0.853
12	Co-60 gamma irrad.	40	---	----	----	6	0.585	4.969	0.780

*reference

TABLE VII-o

HISTORY OF FUSED SILICA SPECIMEN SC 30-112
CAPSULE I

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, dec. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor; anneal	1050	3.6	----	----	------	0.757*	0.0*	1.0*
2	Reactor irradiation	800	360	1.93	70.2	20,000	-----	-----	-----
3	Capsule gamma irrad.	----	----	----	----	3.6	-----	-----	-----
4	Heat treatment	250	86.5	----	----	------	0.76	0.0	-----
5	Co-60 gamma irrad.	40	----	----	----	12	0.305	0.30	0.403
6	Co-60 gamma irrad.	40	----	----	----	6	0.118	0.622	0.156
7	Co-60 gamma irrad.	40	----	----	----	6	0.064	0.825	0.085
8	Co-60 gamma irrad.	40	----	----	----	6	0.024	1.15	0.032

*reference

TABLE VII-p

HISTORY OF FUSED SILICA SPECIMEN SC 30-113
CONTROL

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
Number	Type	Temperature, dec. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	--			---	0.888*	-----	1.0*
2	Polish + Chemical Cleaning	---	--			---	0.877	-----	0.988
3	Anneal	800	36				0.877	-----	0.988
4	Polish + Chemical Cleaning	---	--			---	0.883	0*	0.994
5	Co-60 gamma irrad.	40	--			3	0.599	0.128	0.675
6	Co-60 gamma irrad.	40	--			3	0.390	0.270	0.439
7	Co-60 gamma irrad.	40	--			3	0.270	0.391	0.304
8	Co-60 gamma irrad.	40	--			3	0.189	0.509	0.213

*reference

TABLE VII-q

HISTORY OF FUSED SILICA SPECIMEN SC 30-114
CONTROL

Number	STEP	DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns		
	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/(cm^2-sec)	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Absorption coefficient, α, cm^{-1}	Transmissivity
1	Receipt from vendor	---	--	0	0	0	0.744*	-----	1.0*
2	Chemical Cleaning + Polish	---	--	---	---	---	0.747	-----	1.004
3	Anneal	800	36	---	---	---	0.734	-----	0.987
4	Chemical Cleaning + Polish	---	--	---	---	---	0.755	0*	1.015
5	Co-60 gamma irrad.	40	--	---	---	3	0.485	0.146	0.652
6	Co-60 gamma irrad.	40	--	---	---	6	0.225	0.400	0.302
7	Co-60 gamma irrad.	40	--	---	---	3	0.139	0.558	0.187
8	Co-60 gamma irrad.	40	--	---	---	3	0.096	0.681	0.129

*reference

TABLE VIII-a

HISTORY OF ALUMINUM OXIDE SPECIMEN AM 2-100
CAPSULE J

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns	
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/cm^2-sec	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Transmissivity
1	Receipt from vendor	---	370	----	----	------	0.640	1.0*
2	Reactor irradiation	900	367	1.91	70.1	20,000	-----	-----
3	Capsule gamma irrad.	---	---	----	----	3.6	0.396	0.619
4	Co-60 gamma irrad.	40	---	----	----	12	0.380	0.594
5	Co-60 gamma irrad.	40	---	----	----	6	0.332	0.519
6	Co-60 gamma irrad.	40	---	----	----	6	0.342	0.534
7	Heat treatment	900	1.2	----	----	0	0.403	0.630
8	Co-60 gamma irrad.	40	---	----	----	12	0.370	0.578
9	Co-60 gamma irrad.	40	---	----	----	6	0.351	0.548
10	Co-60 gamma irrad.	40	---	----	----	6	0.386	0.603

*reference

TABLE VIII-b

HISTORY OF ALUMINUM OXIDE SPECIMEN AM 1/2-100
CAPSULE J

STEP		DESCRIPTION OF STEP					Characteristics after step; λ = 0.215 microns	
Number	Type	Temperature, deg. C	Time, 10^3 sec	Fast neutron flux, 10^{13} n/cm^2-sec	Fast neutron dose, 10^{17} n/cm^2	Gamma dose, megarads	Transmittance	Transmissivity
1	Receipt from vendor	----	---	----	----	------	0.742	1.0*
2	Reactor irradiation	900	370	1.91	70.1	20,000	-----	-----
3	Capsule gamma irrad.	----	---	----	----	3.6	0.394	0.531
4	Co-60 gamma irrad.	40	---	----	----	12	0.398	0.536
5	Co-60 gamma irrad.	----	---	----	----	6	0.362	0.488
6	Co-60 gamma irrad.	----	---	----	----	6	0.369	0.497
7	Heat treatment	900	1.2	----	----	0	0.375	0.505
8	Co-60 gamma irrad.	----	---	----	----	12	0.336	0.453
9	Co-60 gamma irrad.	----	---	----	----	6	0.383	0.516
10	Co-60 gamma irrad.	----	---	----	----	6	0.343	0.462
11	Heat treatment	1200	3.6	----	----	0	0.573	0.772

*reference

TABLE VIII-c

TRANSMITTANCE CHARACTERISTICS OF ALUMINUM OXIDE SPECIMEN AM 2-100
AFTER NUCLEAR REACTOR IRRADIATION AND SUBSEQUENT
Co-60 GAMMA IRRADIATION
CAPSULE J

Wavelength, microns	Post neutron irradiation	Post 12 magarads Co-60 gamma irrad.	Post 18 megarads Co-60 gamma irrad.	Post 24 megarads Co-60 gamma irrad.	Post anneal, 900 C for 20 minutes	Post 12 megarads Co-60 gamma irrad.	Post 18 megarads Co-60 gamma irrad.	Post 24 megarads Co-60 gamma irrad.
0.165	0	0.238	0	0	0	0	0	1.8
0.170	0.143	0.117	0	0.103	0.112	0.081	0.086	0.102
0.175	0.208	0.187	0.116	0.164	0.172	0.155	0.156	0.167
0.180	0.247	0.228	0.183	0.206	0.215	0.212	0.198	0.218
0.185	0.273	0.272	0.231	0.244	0.260	0.258	0.246	0.271
0.190	0.311	0.306	0.263	0.283	0.301	0.296	0.284	0.315
0.195	0.343	0.344	0.296	0.317	0.342	0.333	0.327	0.352
0.200	0.362	0.359	0.311	0.338	0.363	0.353	0.343	0.372
0.205	0.373	0.369	0.321	0.343	0.362	0.364	0.355	0.380
0.210	0.390	0.379	0.328	0.345	0.369	0.371	0.359	0.384
0.215	0.396	0.380	0.332	0.342	0.403	0.370	0.351	0.386
0.220	0.399	0.375	0.330	0.340	0.407	0.367	0.348	0.390
0.225	0.401	0.373	0.338	0.338	0.397	0.363	0.352	0.389
0.230	0.402	0.372	0.338	0.332	0.394	0.364	0.349	0.387
0.235	0.402	0.373	0.341	0.337	0.388	0.362	0.355	0.388
0.240	0.405	0.378	0.344	0.343	0.385	0.375	0.357	0.400
0.245	0.405	0.381	0.350	0.350	0.391	0.381	0.363	0.405
0.250	0.407	0.389	0.357	0.357	0.388	0.388	0.368	0.411
0.255	0.412	0.396	0.363	0.364	0.407	0.396	0.375	0.417
0.260	0.416	0.402	0.367	0.372	0.403	0.411	0.379	0.425
0.265	0.418	0.407	0.371	0.378	0.400	0.418	0.391	0.431
0.270	0.422	0.411	0.375	0.381	0.399	0.427	0.394	0.438
0.275	0.422	0.413	0.375	0.384	0.401	0.427	0.396	0.440
0.280	0.423	0.412	0.375	0.384	0.400	0.430	0.398	0.452
0.285	0.422	0.414	0.376	0.386	0.408	0.431	0.399	0.451
0.290	0.421	0.412	0.374	0.385	0.404	0.433	0.398	0.446
0.295	0.419	0.411	0.373	0.383	0.399	0.431	0.388	0.443
0.300	0.417	0.408	0.369	0.382	0.395	0.431	0.386	0.447
0.305	0.415	0.407	0.366	0.380	0.389	0.430	0.387	0.443
0.310	0.414	0.404	0.366	0.379	0.386	0.433	0.383	0.444
0.315	0.411	0.402	0.365	0.376	0.399	0.427	0.402	0.440
0.320	0.409	0.400	0.361	0.372	0.396	0.425	0.397	0.430
0.325	0.405	0.397	0.357	0.370	0.386	0.419	0.384	0.426
0.330	0.404	0.395	0.355	0.366	0.381	0.419	0.380	0.438
0.335	0.403	0.393	0.353	0.365	0.384	0.416	0.382	0.436
0.340	0.402	0.390	0.351	0.364	0.386	0.419	0.380	0.433
0.345	0.402	0.394	0.351	0.364	0.387	0.415	0.382	0.431
0.350	0.403	0.391	0.350	0.363	0.385	0.417	0.380	0.431

TABLE VIII-d

TRANSMITTANCE CHARACTERISTICS OF ALUMINUM OXIDE SPECIMEN AM 1/2-100
AFTER NUCLEAR REACTOR IRRADIATION AND SUBSEQUENT
Co-60 GAMMA IRRADIATION
CAPSULE J

Wavelength, microns	Post neutron irradiation	Post 12 megarads Co-60 gamma irrad.	Post 18 megarads Co-60 gamma irrad.	Post 24 megarads Co-60 gamma irrad.	Post anneal, 900 C for twenty minutes	Post 12 megarads Co-60 gamma irrad.	Post 18 megarads Co-60 gamma irrad.	Post 24 megarads Co-60 gamma irrad.
0.165	0.100	0.114	0.217	0.093	0	0	0	0.07
0.170	0.192	0.203	0.134	0.189	0.136	0.104	0.139	0.135
0.175	0.244	0.242	0.198	0.163	0.192	0.163	0.213	0.175
0.180	0.279	0.284	0.221	0.250	0.234	0.203	0.242	0.218
0.185	0.289	0.316	0.256	0.264	0.264	0.236	0.289	0.244
0.190	0.303	0.323	0.292	0.302	0.297	0.267	0.309	0.271
0.195	0.309	0.347	0.317	0.323	0.316	0.290	0.334	0.294
0.200	0.315	0.358	0.332	0.337	0.346	0.304	0.347	0.310
0.205	0.346	0.374	0.343	0.374	0.354	0.314	0.360	0.324
0.210	0.381	0.391	0.359	0.358	0.363	0.322	0.370	0.339
0.215	0.394	0.398	0.362	0.369	0.375	0.336	0.383	0.343
0.220	0.400	0.402	0.373	0.372	0.370	0.341	0.386	0.353
0.225	0.402	0.404	0.374	0.375	0.376	0.344	0.390	0.359
0.230	0.403	0.406	0.380	0.375	0.384	0.346	0.389	0.372
0.235	0.408	0.407	0.385	0.379	0.385	0.351	0.396	0.373
0.240	0.416	0.408	0.388	0.385	0.383	0.356	0.396	0.367
0.245	0.418	0.410	0.391	0.387	0.384	0.362	0.400	0.364
0.250	0.425	0.416	0.392	0.389	0.395	0.366	0.401	0.381
0.255	0.422	0.414	0.396	0.394	0.396	0.369	0.406	0.384
0.260	0.410	0.416	0.400	0.397	0.417	0.375	0.412	0.393
0.265	0.425	0.419	0.403	0.398	0.418	0.377	0.417	0.397
0.270	0.425	0.419	0.404	0.400	0.423	0.381	0.418	0.399
0.275	0.425	0.421	0.405	0.401	0.423	0.392	0.421	0.398
0.280	0.426	0.420	0.406	0.402	0.402	0.393	0.423	0.407
0.285	0.425	0.421	0.407	0.403	0.401	0.396	0.425	0.411
0.290	0.425	0.420	0.407	0.402	0.419	0.394	0.424	0.416
0.295	0.423	0.419	0.406	0.399	0.414	0.393	0.428	0.415
0.300	0.422	0.418	0.404	0.397	0.426	0.391	0.425	0.415
0.305	0.420	0.416	0.402	0.396	0.424	0.397	0.419	0.412
0.310	0.419	0.415	0.401	0.395	0.416	0.395	0.416	0.412
0.315	0.418	0.414	0.399	0.393	0.413	0.390	0.422	0.407
0.320	0.415	0.411	0.396	0.390	0.408	0.387	0.417	0.407
0.325	0.412	0.410	0.393	0.387	0.403	0.382	0.418	0.405
0.330	0.410	0.408	0.392	0.385	0.407	0.380	0.415	0.397
0.335	0.408	0.407	0.389	0.384	0.406	0.382	0.414	0.394
0.340	0.408	0.406	0.389	0.385	0.398	0.380	0.411	0.399
0.345	0.409	0.407	0.389	0.385	0.398	0.386	0.410	0.398
0.350	0.410	0.406	0.389	0.385	0.404	0.385	0.408	0.396

FIG. 1

NEUTRON FLUX PROFILE FOR CORE POSITION C-3 OF UNION CARBIDE RESEARCH REACTOR

FAST NEUTRON FLUX PEAK-$1.5(10)^{13}$ n/(cm^2-sec)

THERMAL NEUTRON FLUX PEAK - $5(10)^{13}$ n/(cm^2-sec)

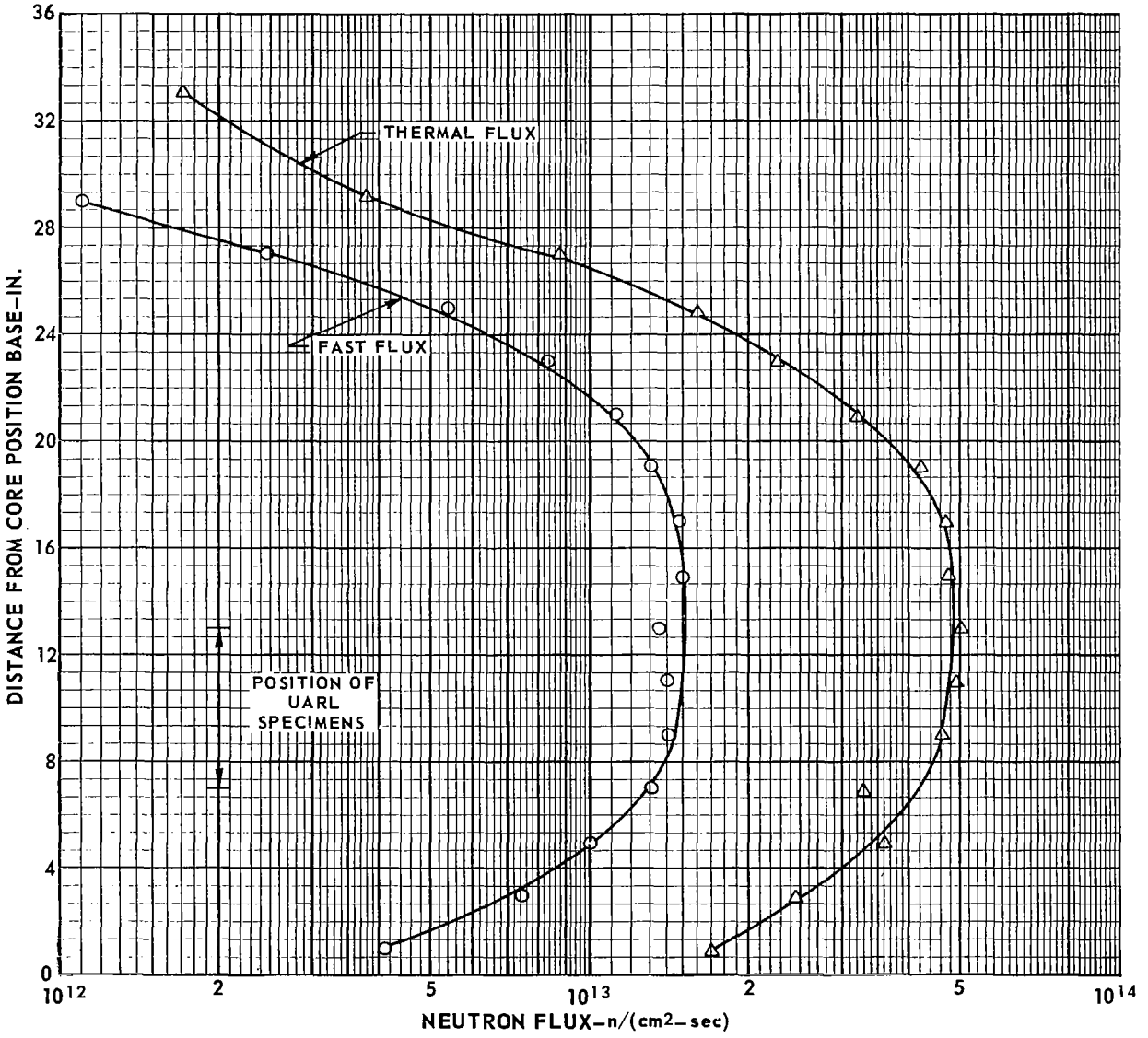


FIG. 2

GAMMA FLUX PROFILE FOR CORE POSITION C-3 OF UNION CARBIDE RESEARCH REACTOR

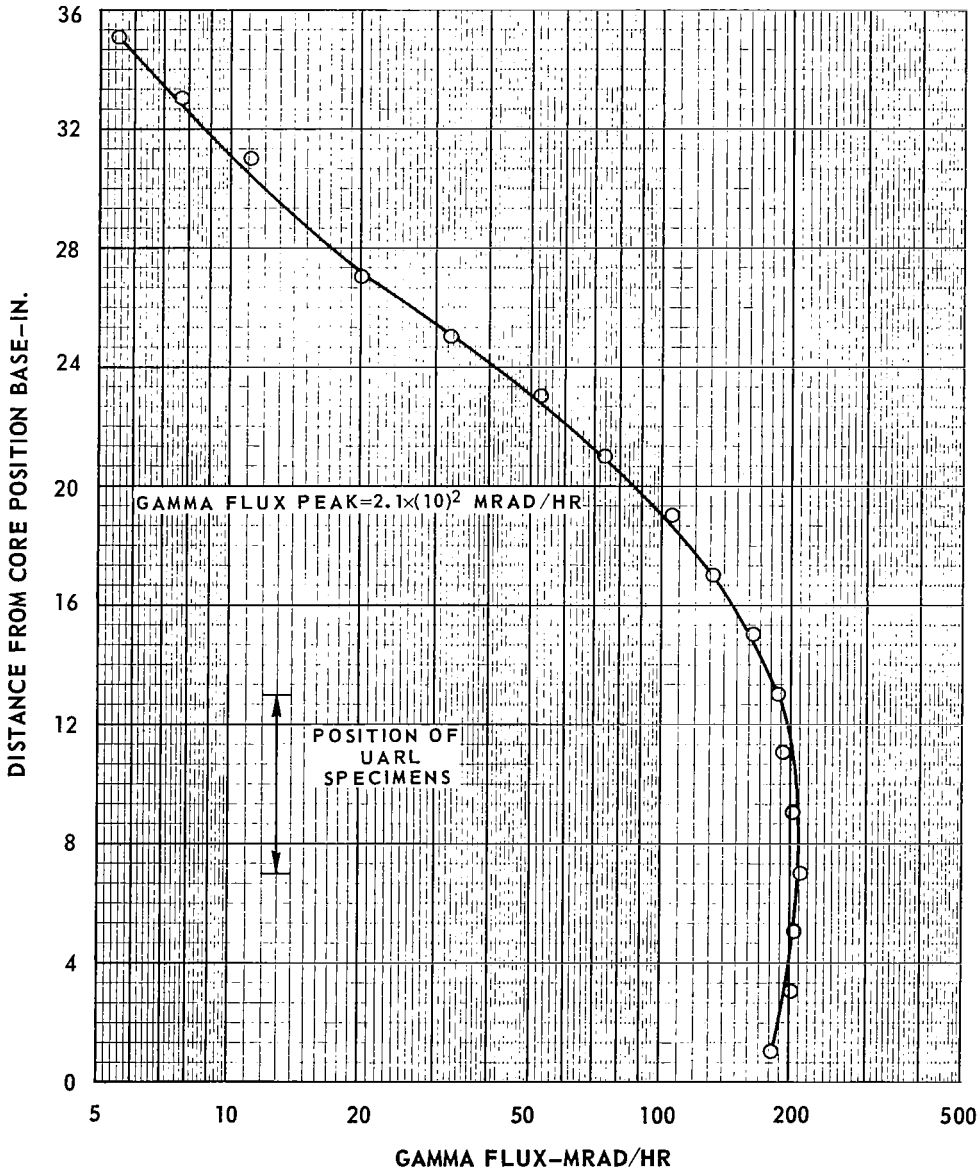


FIG. 3

NEUTRON FLUX PROFILE FOR CORE POSITION D-1 OF UNION CARBIDE RESEARCH REACTOR

FAST NEUTRON FLUX PEAK = 1.62×10^{12} n/(cm^2-sec)

THERMAL NEUTRON FLUX PEAK = 8.0×10^{12} n/(cm^2-sec)

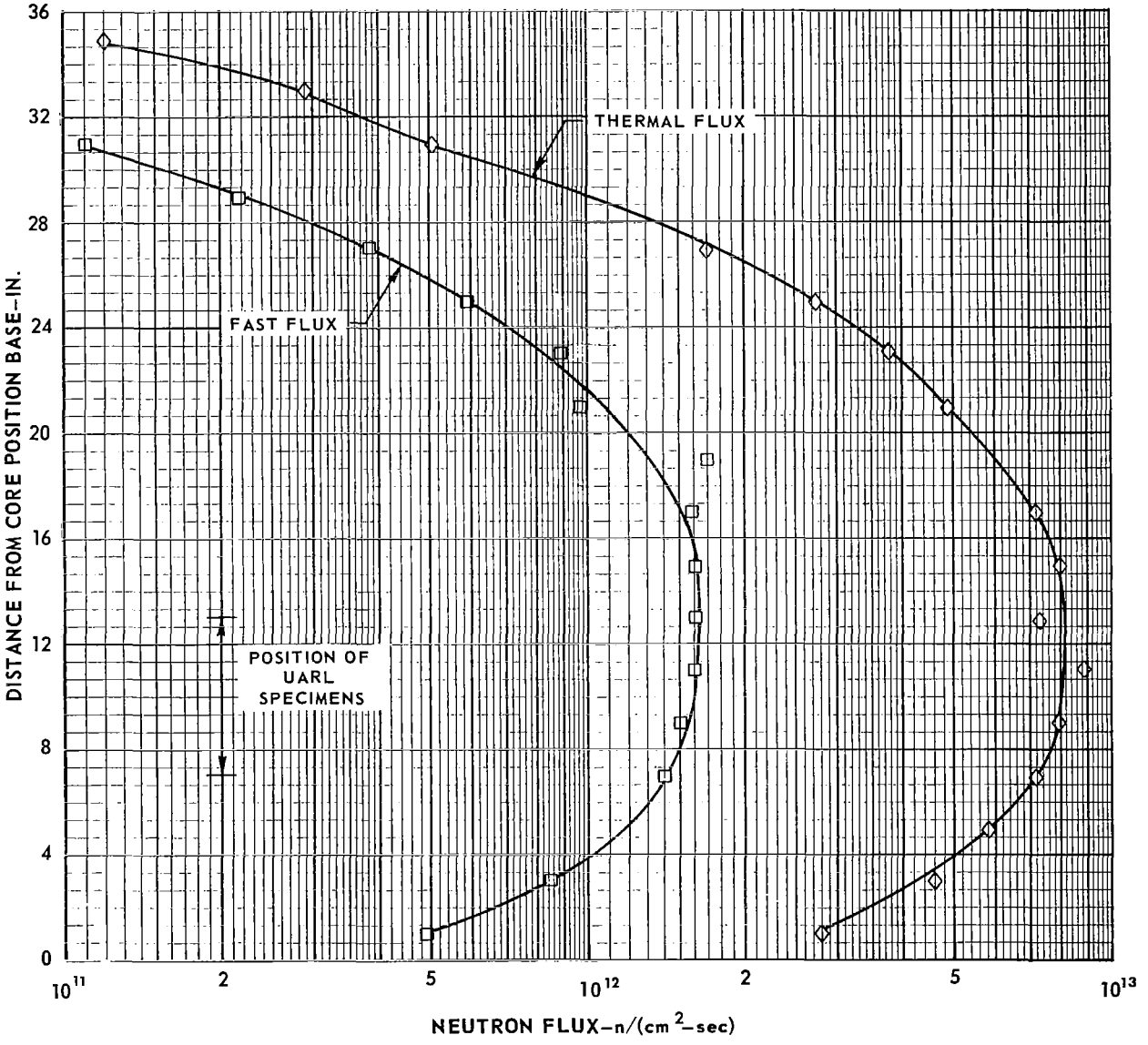


FIG. 4

GAMMA FLUX PROFILE FOR CORE POSITION D-1 OF UNION CARBIDE RESEARCH REACTOR

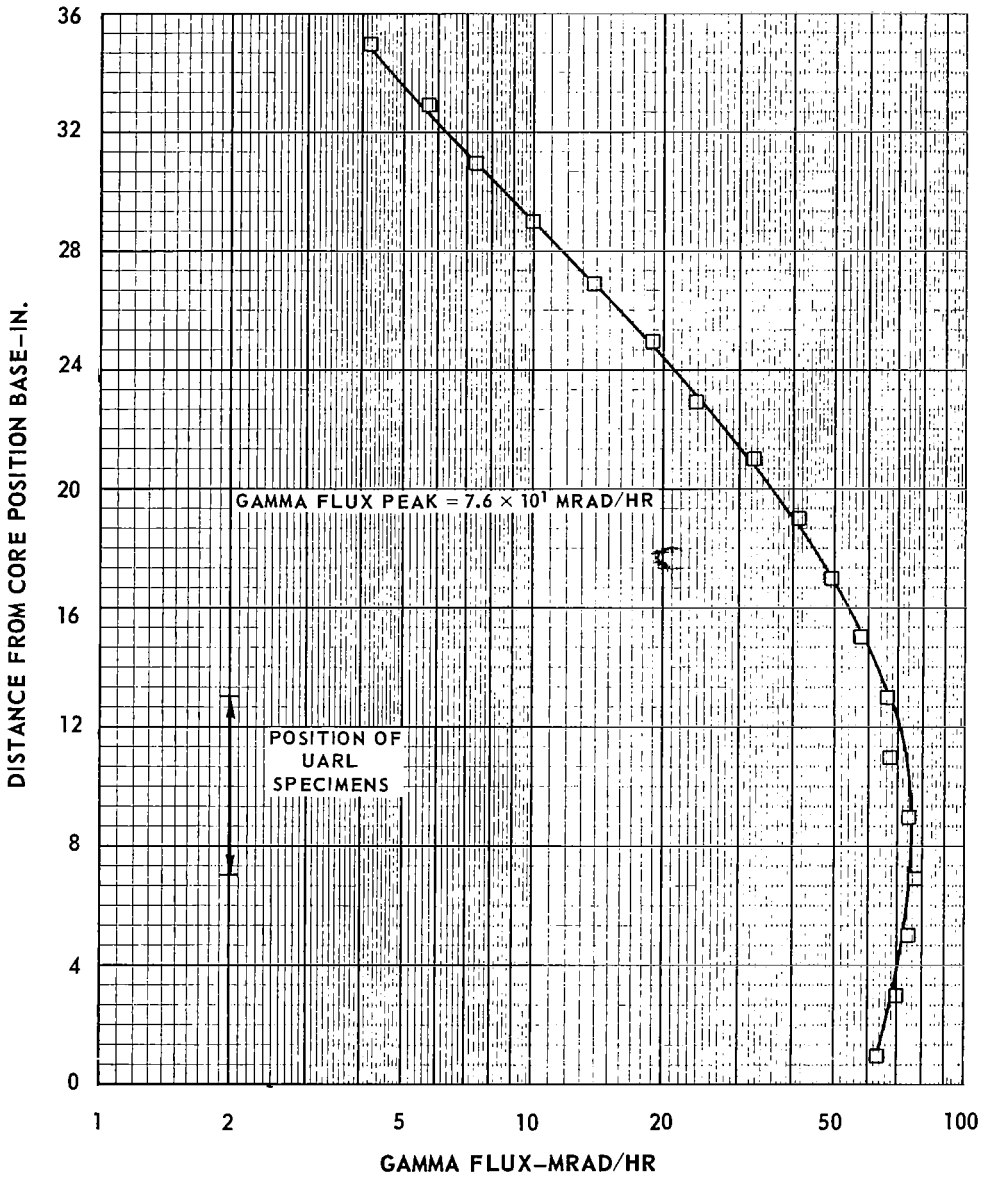
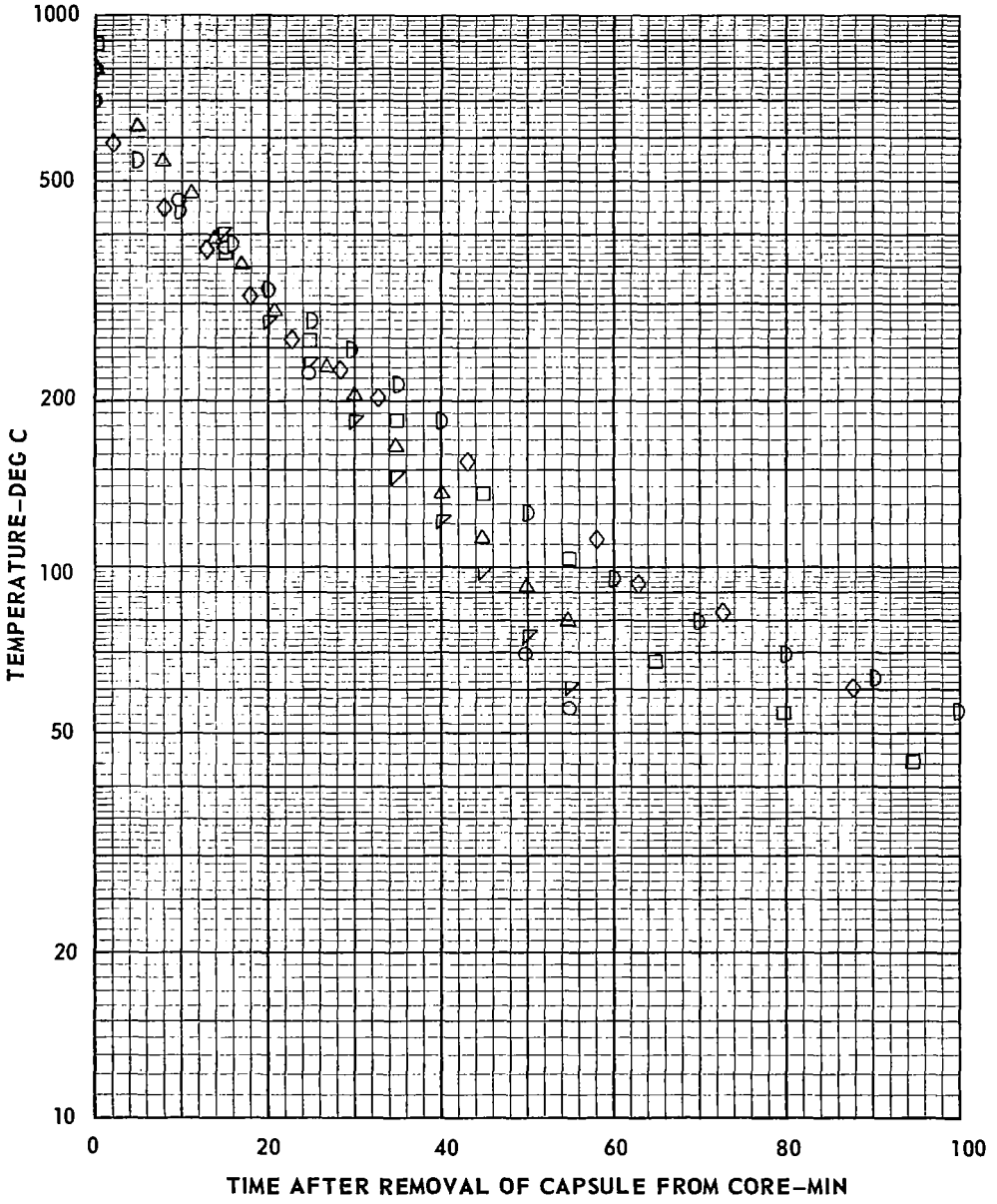


FIG. 5

THERMAL COOLING CURVES FOR FUSED SILICA CAPSULES AFTER REMOVAL FROM UNION CARBIDE RESEARCH REACTOR CORE

SYMBOL	CAPSULE	CORE POSITION	IRRADIATION TEMP DEG C
○	F	C3	700
△	G	C3	800
◇	H	D1	800
◸	I	C3	800
□	J	C3	900
D	CALIBRATION	C3	700



GAMMA FLUX AND DOSE VS TIME AFTER REMOVAL FROM UNION CARBIDE RESEARCH REACTOR CORE

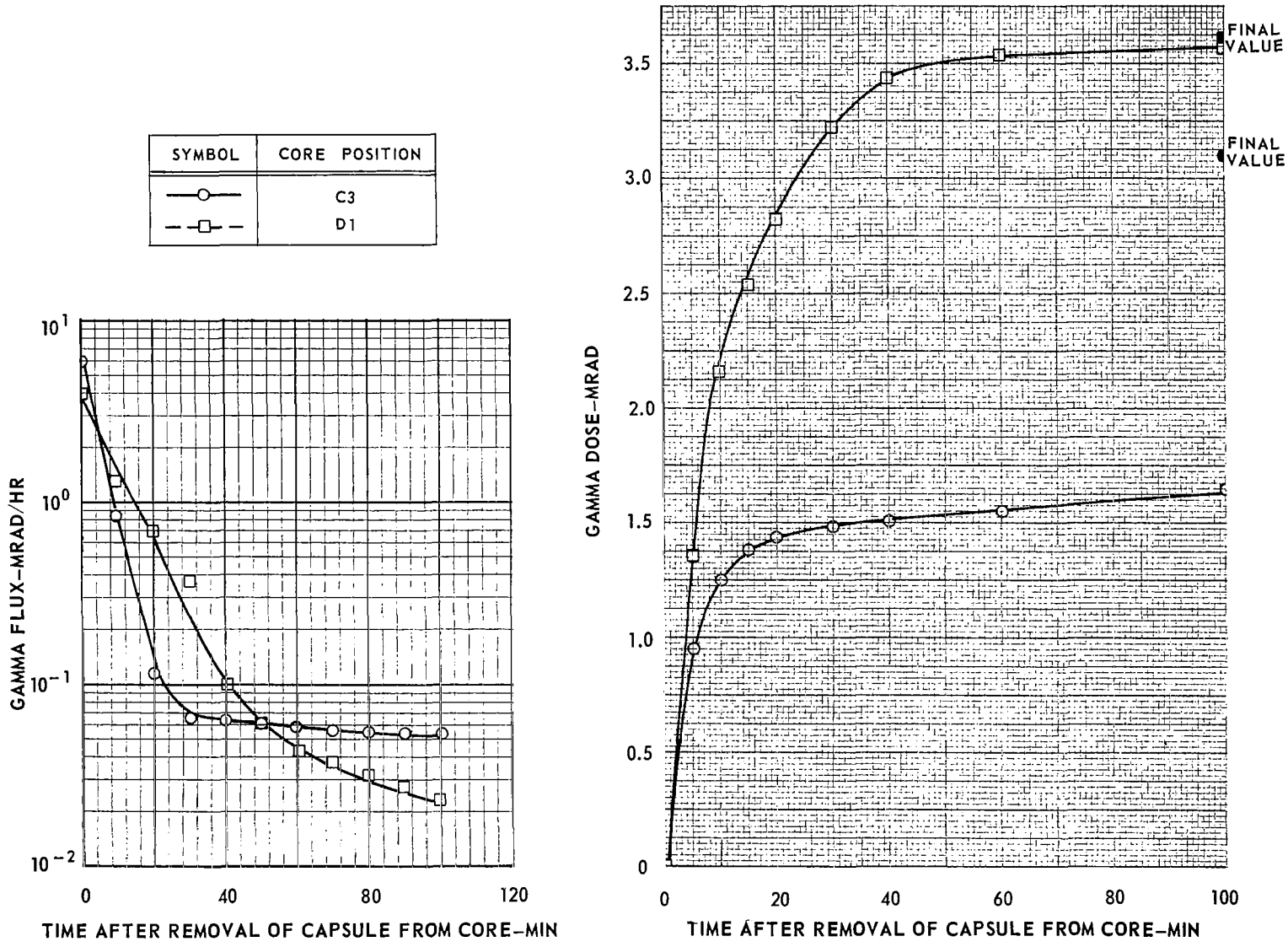


FIG. 6

REFERENCE VALUES OF TRANSMITTANCE FOR CORNING 7940 FUSED SILICA SPECIMENS AT WAVELENGTH OF 0.215 MICRON

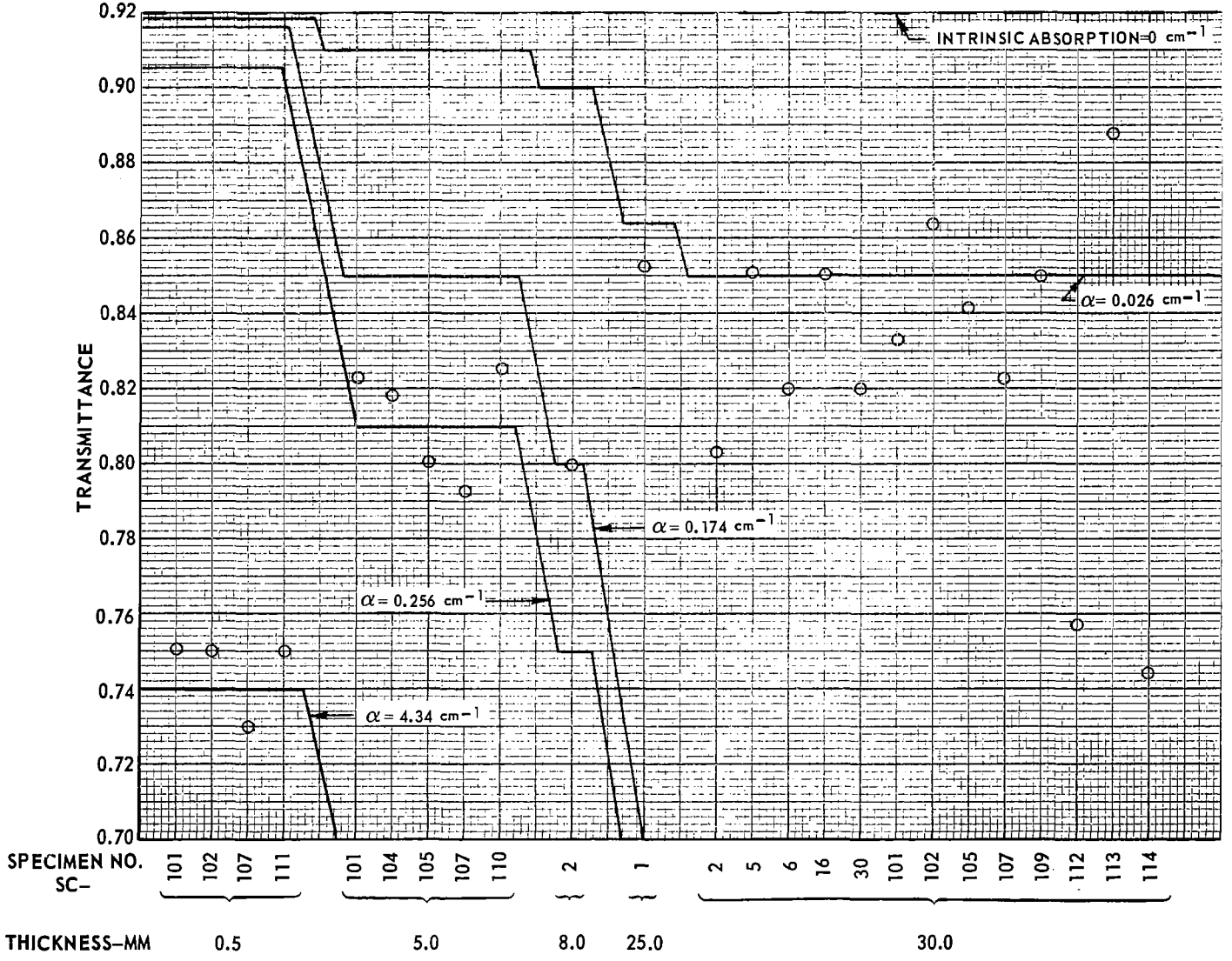


FIG. 7

FIG. 8

TYPICAL ABSORPTION SPECTRA FOR CORNING 7940 FUSED SILICA BEFORE AND AFTER REACTOR IRRADIATION

(MEASURED AT 22 C; SEE REF. 13)

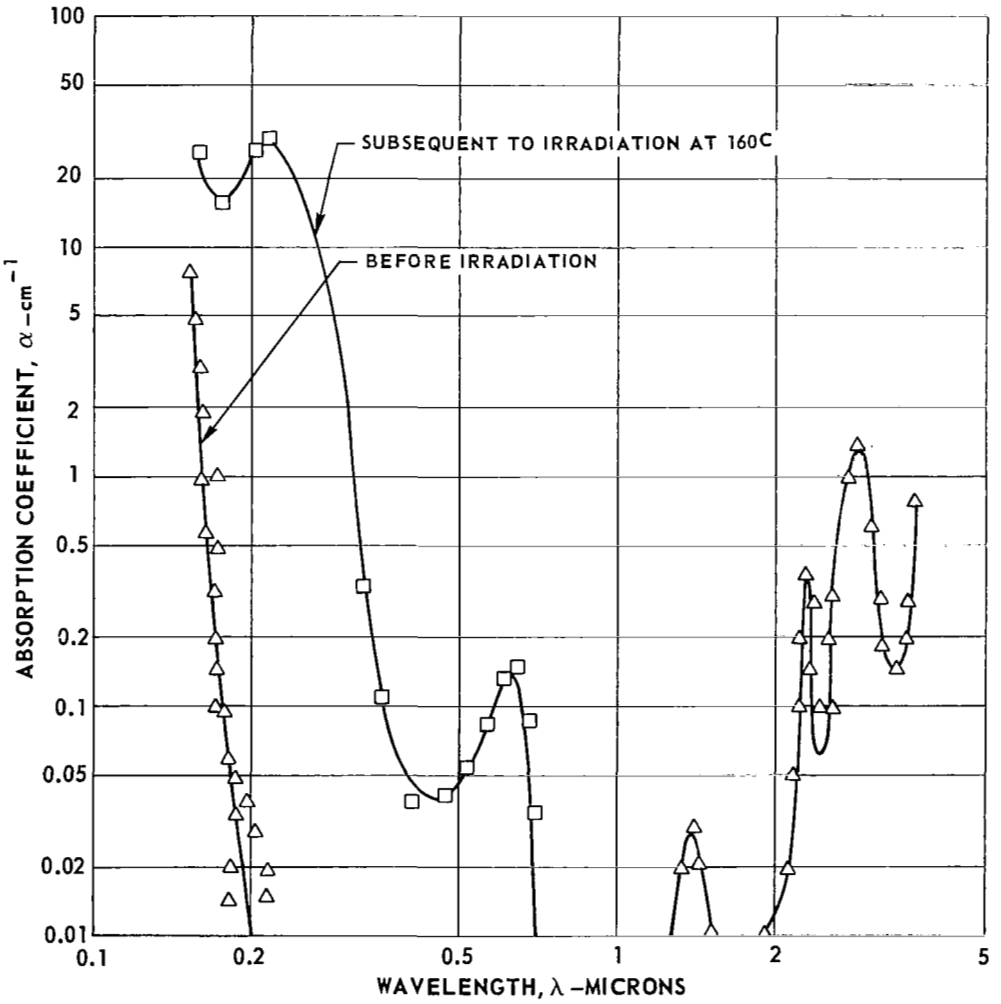


FIG. 9

VARIATION OF POST-REACTOR-IRRADIATION ABSORPTION COEFFICIENT WITH IRRADIATION TEMPERATURE

WAVELENGTH, $\lambda = 0.215$ MICRON

SYMBOL	SPECIMEN	CAPSULE	FLUX 10^{13} nv	DOSE 10^{17} nvt	TEMP. DEG C	ABSORPTION COEFFICIENT– cm^{-1} POST–IRRAD.
◇	SC 30–16	A	1.6	7.8	833	0.79
◇	SC 30–2	B	1.5	8.1	900	0.485
▷	SC 30–6	C	1.6	5.0	988	0.03
▷	SC 30–5	D	1.5	44.8	1018	0.09
▽	SC 30–30	E	1.4	5.8	1170	0.12
○	SC 30–101	F	1.90	69.0	700	0.20
●	SC 5–101	F				0.20
×	$^{\pi}$SC 30–105	G	1.90	5.26	800	0.26
+	$^{\pi}$SC 5–104	G				0.28
◇	SC 30–109	H	0.17	5.89	800	0.0
◆	SC 5–110	H				0.0
▽	SC 30–102	I	1.93	70.2	800	0.14
◥	SC 5–105	I				0.0
□	SC 30–107	J	1.91	70.1	900	0.03
■	SC 5–107	J				0.0

π CAPSULE G RECEIVED EXCESSIVE POST-REACTOR-IRRADIATION GAMMA DOSE DUE TO A COPPER SPECIMEN HOLDER IN THE CAPSULE

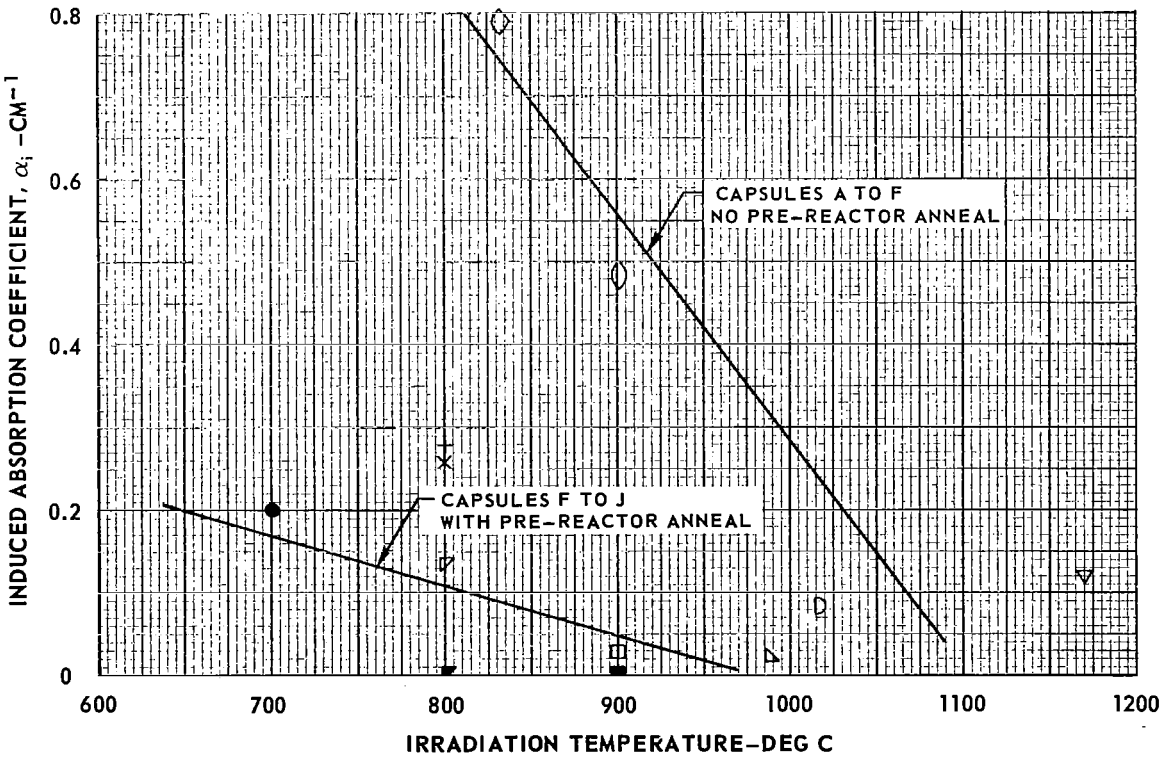


FIG. 10

VARIATION OF ABSORPTION COEFFICIENT FOR FUSED SILICA WITH GAMMA IRRADIATION

CAPSULE B: PRELIMINARY EXPERIMENTATION
WAVELENGTH, λ = 0.215 MICRON

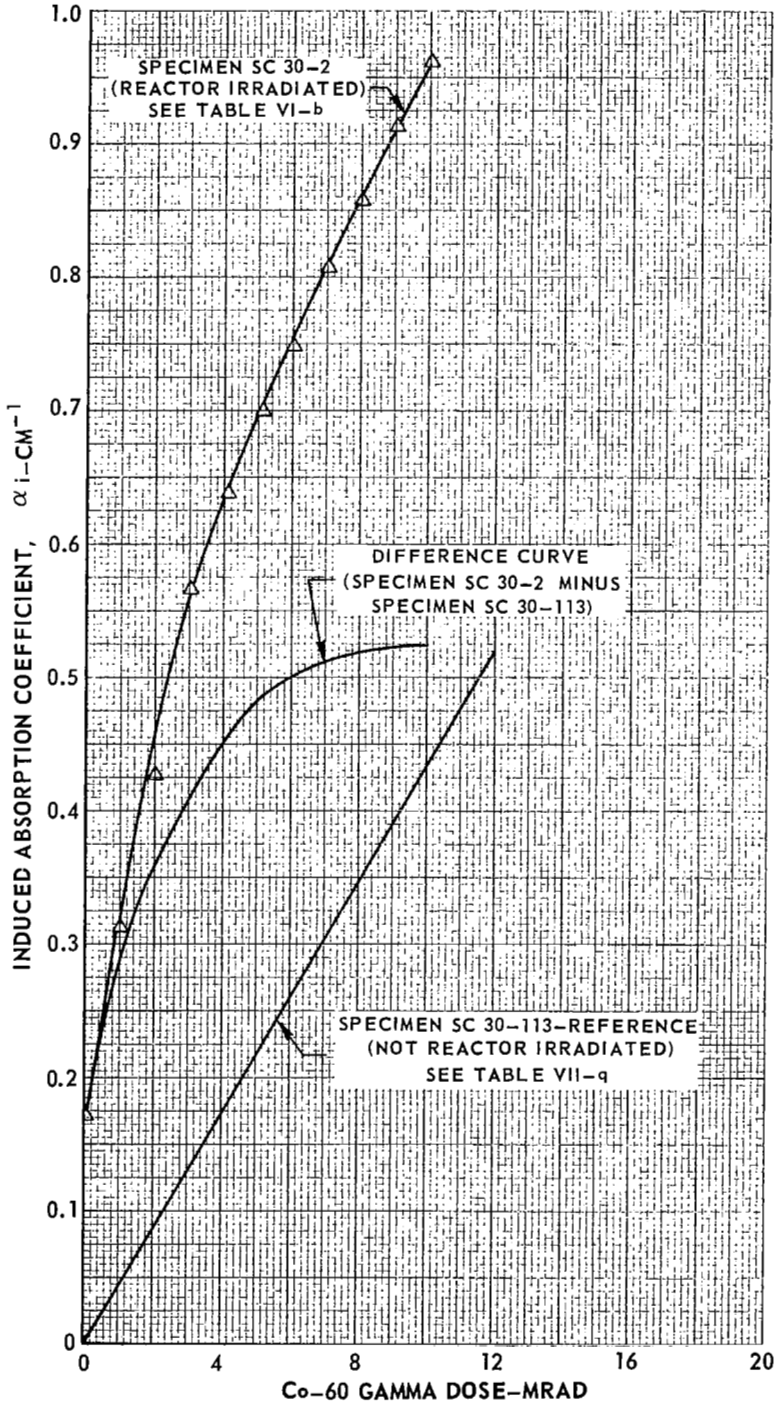
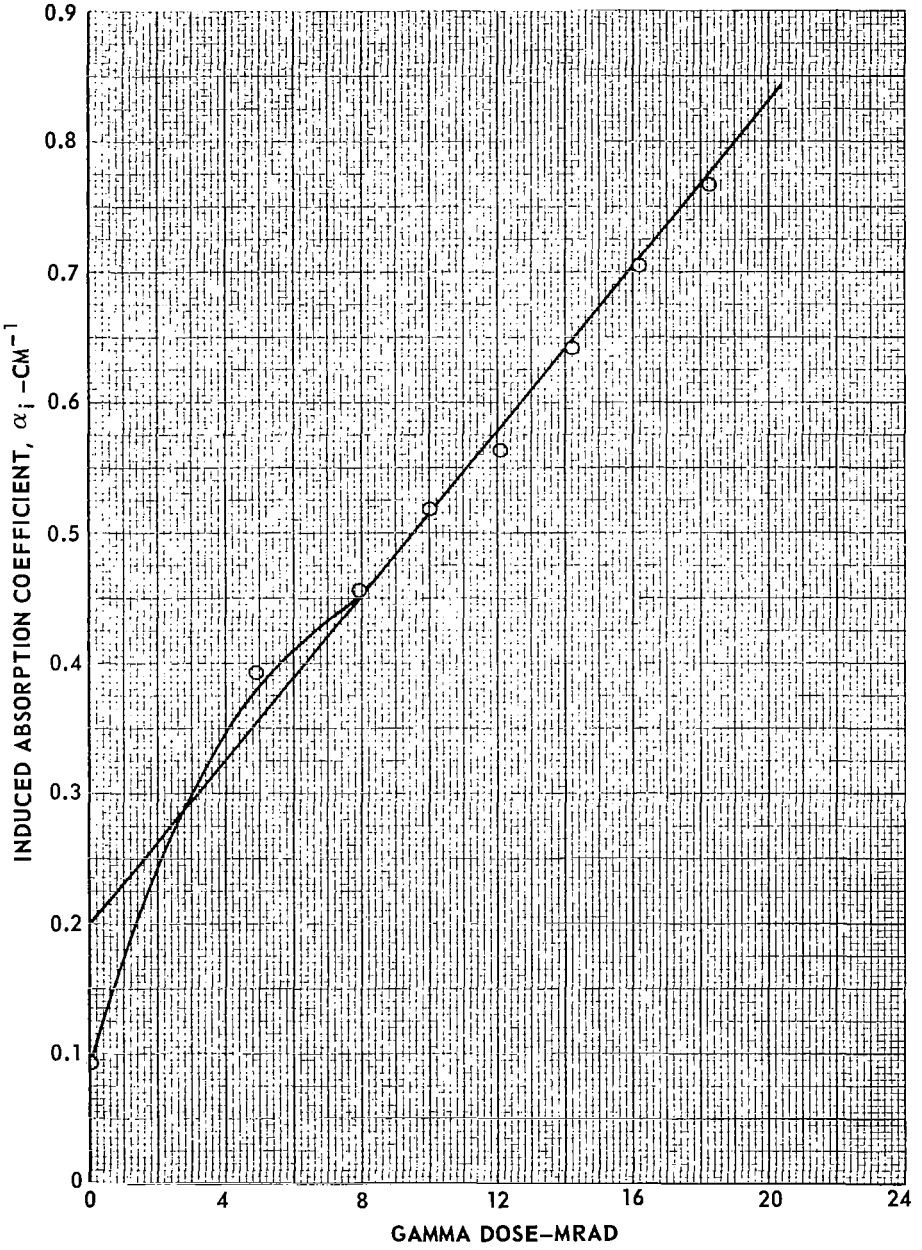


FIG. 11

VARIATION OF INDUCED ABSORPTION COEFFICIENT WITH Co-60 GAMMA DOSE FOR FUSED SILICA SPECIMEN SC 30-5

CAPSULE D : PRELIMINARY EXPERIMENTATION

WAVELENGTH, λ = 0.215 MICRON



ABSORPTION COEFFICIENT INDUCED IN REACTOR-IRRADIATED 30 MM CORNING 7940 FUSED SILICA SPECIMENS BY Co-60 GAMMA IRRADIATION AT 40 C

WAVELENGTH, λ =0.215 MICRON

SYMBOL	SPECIMEN	CAPSULE	REALTOR IRRADIATION CONDITIONS		
			TEMP° DEG. C	FLUX $(10)^{13}$ n/cm^{2}sec	DOSE $(10)^{17}$n/cm^2
○—	SC 30-101	F	700	1.9	5.5
–△—	SC 30-105	G	800	1.9	5.5
– –◇—	SC 30-109	H	800	0.17	5.89
– – –▽—	SC 30-102	I	800	1.9	5.5
– – – –□—	SC 30-107	J	900	1.9	5.5
– –■– –	SC 30-113	CONTROL	GAMMA DOSE ONLY		

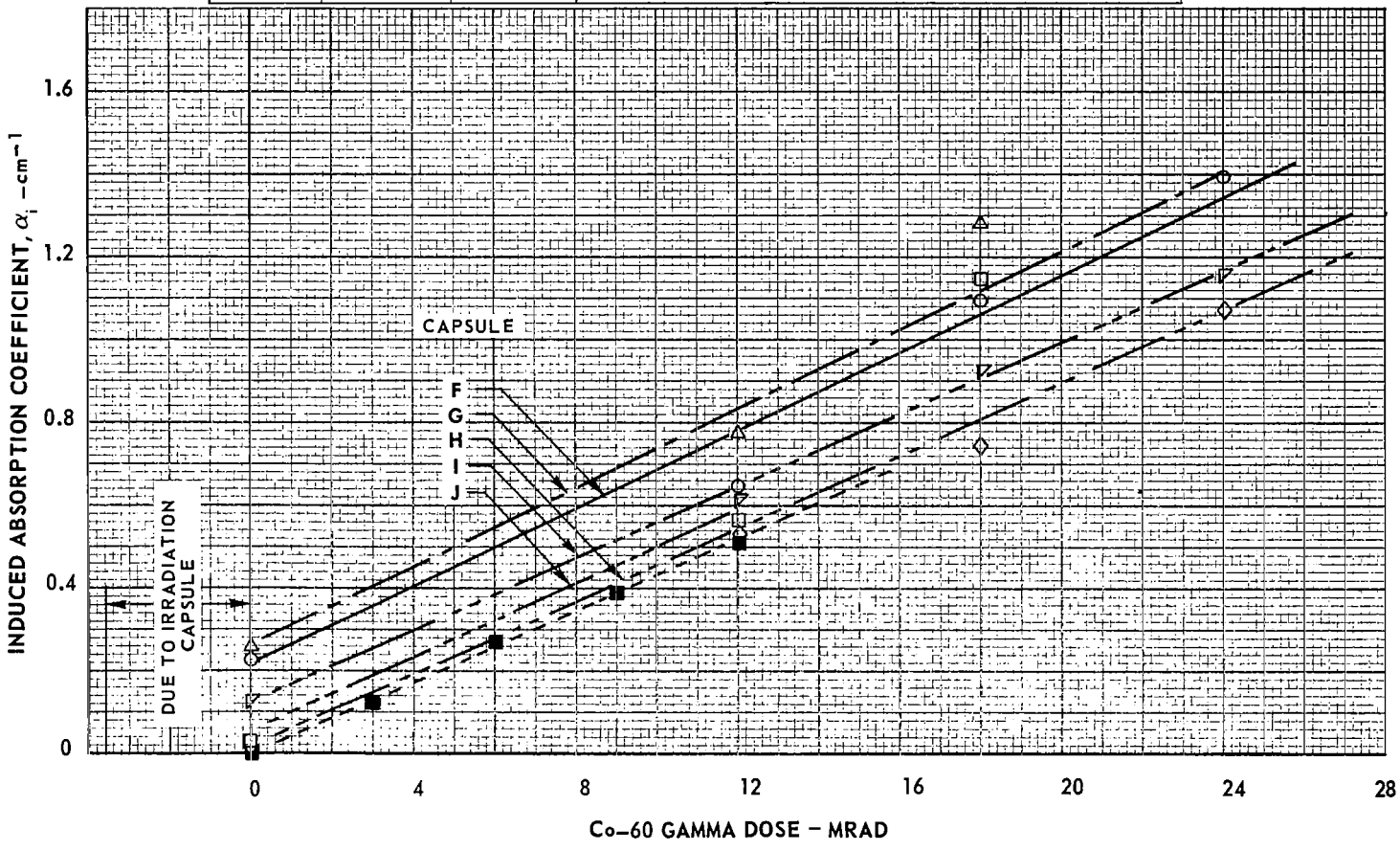


FIG. 12

ABSORPTION COEFFICIENT INDUCED IN REACTOR-IRRADIATED 5 MM FUSED SILICA BY Co-60 GAMMA IRRADIATION AT 40 C

SYMBOL	SPECIMEN	CAPSULE	REACTOR IRRADIATION CONDITIONS		
			TEMP - DEG C	FLUX- 10^{13}n/(cm^2-sec)	DOSE- 10^{17}n/cm^2
○——	SC 5-101	F	700	1.4	69
-△——	SC 5-104	G	800	1.9	5.26
--◇——	SC 5-110	H	800	0.17	5.89
---▽——	SC 5-105	I	800	1.9	70.2
----□——	SC 5-107	J	900	1.9	70.1

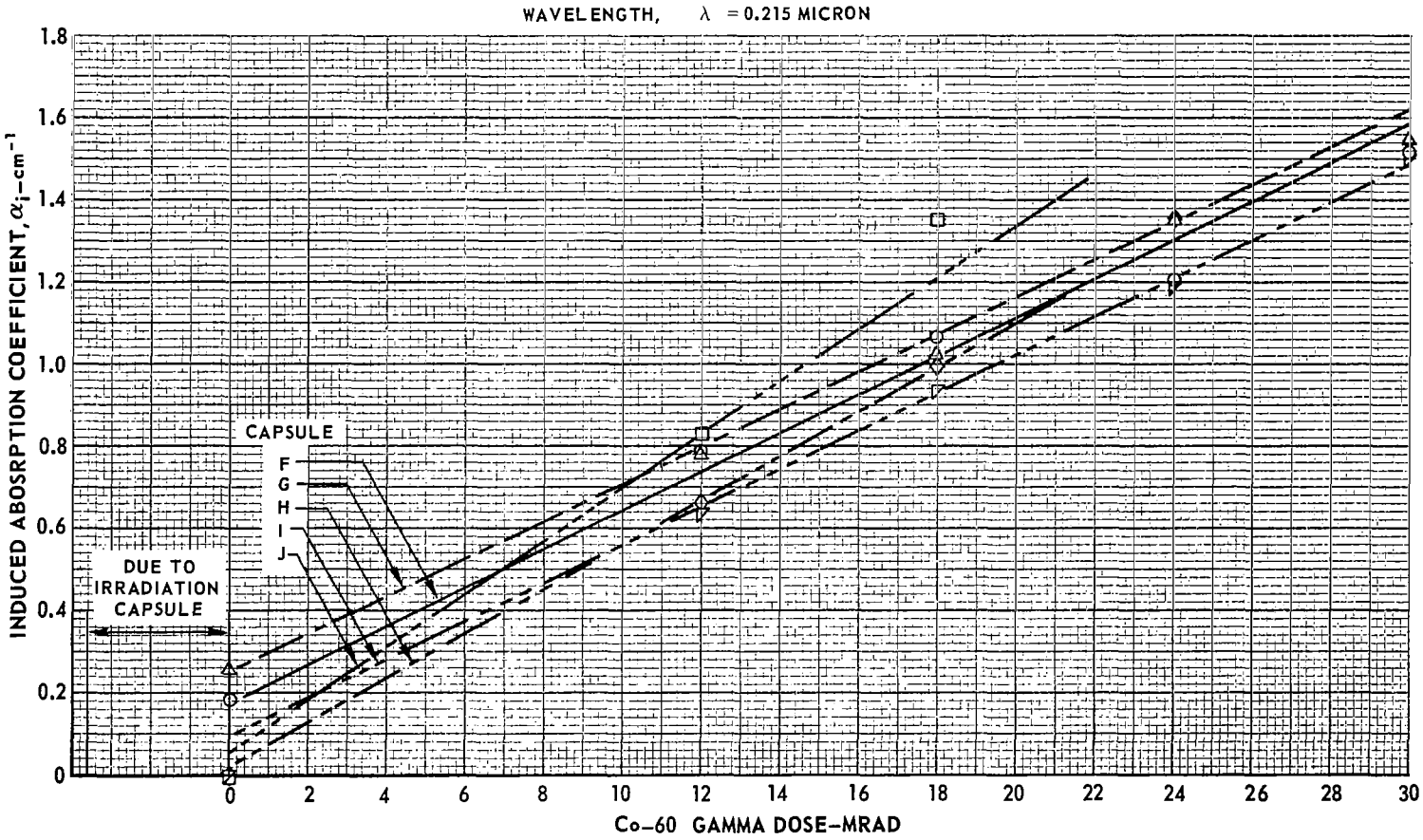


FIG. 13

FIG. 14

VARIATION OF POST-REACTOR-IRRADIATION "SATURATION" ABSORPTION COEFFICIENT WITH IRRADIATION TEMPERATURE

WAVELENGTH, λ = 0.215 MICRON

SYMBOL	SPECIMEN	CAPSULE	FLUX 10^{13} nv	DOSE 10^{17} nvt	TEMP DEG C	ABSORPTION COEFFICIENT-cm^{-1} POST-IRRAD.	ABSORPTION COEFFICIENT-cm^{-1} "SATURATION"
◇	SC 30-16	A	1.6	7.8	833	0.79	0.79
◊	SC 30-2	B	1.5	8.1	900	0.495	0.31
◺	SC 30-6	C	1.6	5.0	988	0.03	0.30
D	SC 30-5	D	1.5	44.8	1018	0.09	0.20
▽	SC 30-30	E	1.4	5.8	1170	0.12	0.12
○	SC 30-101	F	1.90	69.0	700	0.20	0.21
●	SC 5-101	F				0.20	0.18
×	$^{\pi}$SC 30-105	G	1.90	5.26	800	0.26	0.26
+	$^{\pi}$SC 5-104	G				0.28	0.28
◇	SC 30-109	H	0.17	5.89	800	0.0	0.02
◆	SC 5-110	H				0.0	0.03
◸	SC 30-102	I	1.93	70.2	800	0.14	0.13
◸	SC 5-105	I				0.0	0.10
□	SC 30-107	J	1.91	70.1	900	0.03	0.05
■	SC 5-107	J				0.0	0.06

$^{\pi}$ CAPSULE G RECEIVED A LARGE UNDETERMINED GAMMA DOSE AFTER IRRADIATION DUE TO COPPER SPECIMEN-HOLDER IN THE CAPSULE

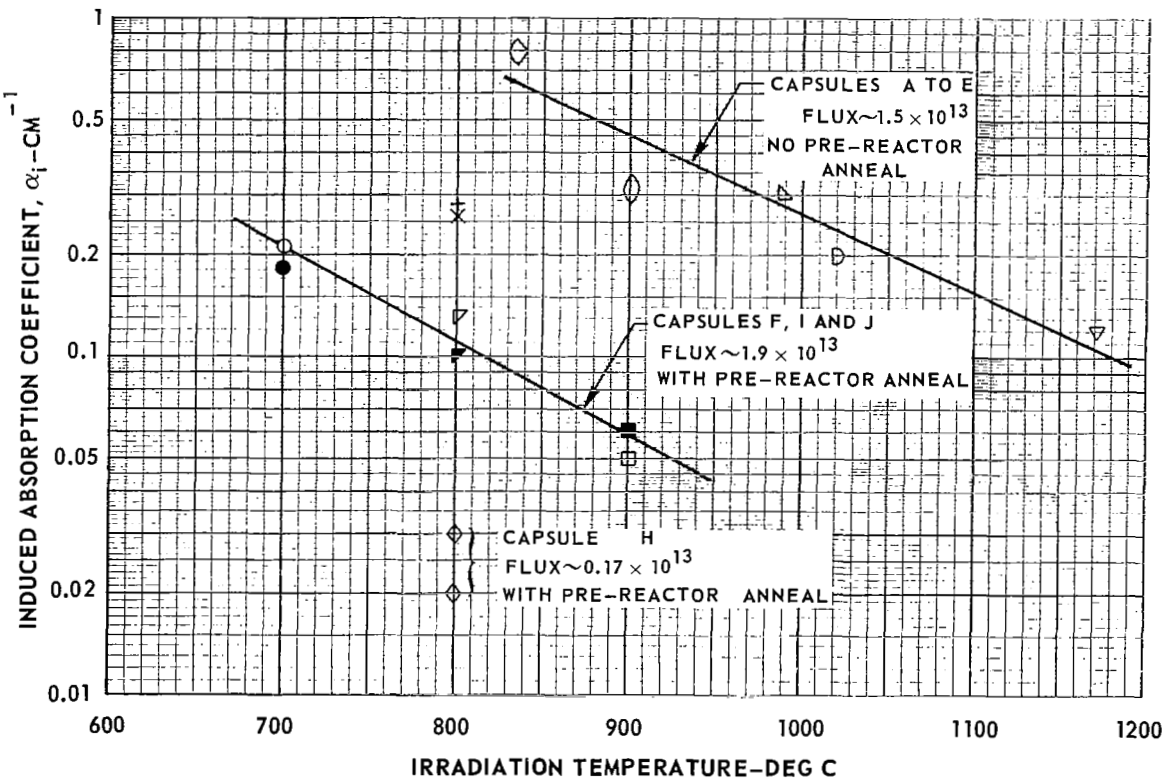


FIG. 15

TRANSMISSIVITY AND ABSORPTION COEFFICIENT INDUCED IN 0.5-MM REACTOR IRRADIATED FUSED SILICA BY Co-60 GAMMA IRRADIATION AT 40 C

WAVELENGTH, λ =0.163 MICRON

SYMBOL	SPECIMEN	CAPSULE	REACTOR IRRAD. CONDITIONS		
			TEMP-DEG C	FLUX-nv(10)^{13}	DOSE-nvt(10)^{17}
○	SC ½-101	F	700	1.9	69
△	SC ½-107	G	800	1.9	5.26
◇	SC ½-111	H	800	0.17	5.89
▽	SC ½-102	I	800	1.9	70.2
□	SC ½-109*	J	900	1.9	70.1

* SAMPLE DESTROYED

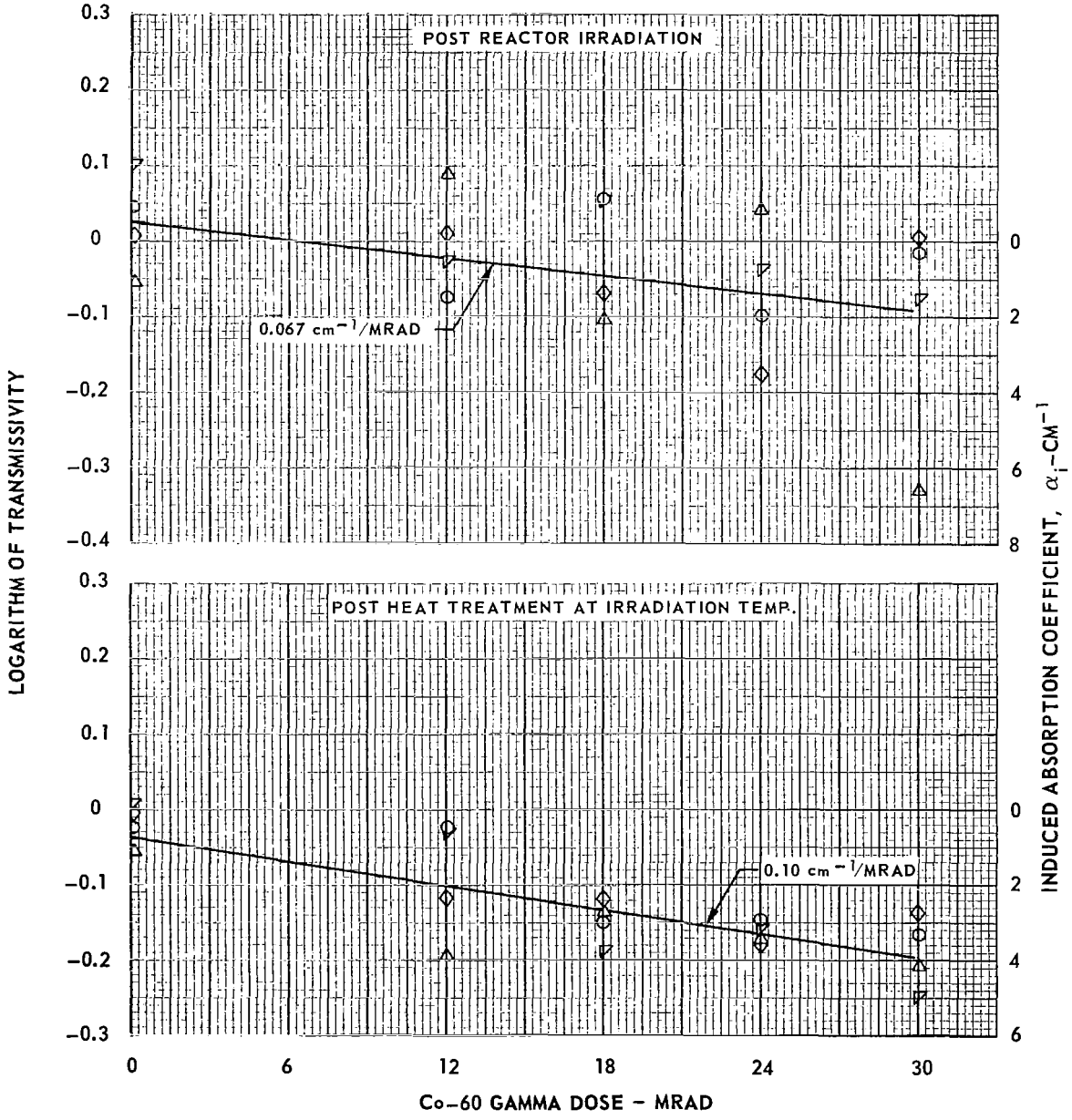


FIG. 16

ABSORPTION COEFFICIENT DURING HEAT TREATMENT OF FUSED SILICA SPECIMENS WHICH HAD BEEN REACTOR IRRADIATED AT 900 C, CAPSULE B

WAVELENGTH, λ=0.215 MICRON

SYMBOL	SPECIMEN	BLEACH TEMP DEG C	INITIAL VALUE OF INDUCED ABSORPTION COEFFICIENT, cm^{-1}
□	ST 25-1	200	0.275
△	SC 30-2	250	0.485
○	SC 8-2	300	0.412

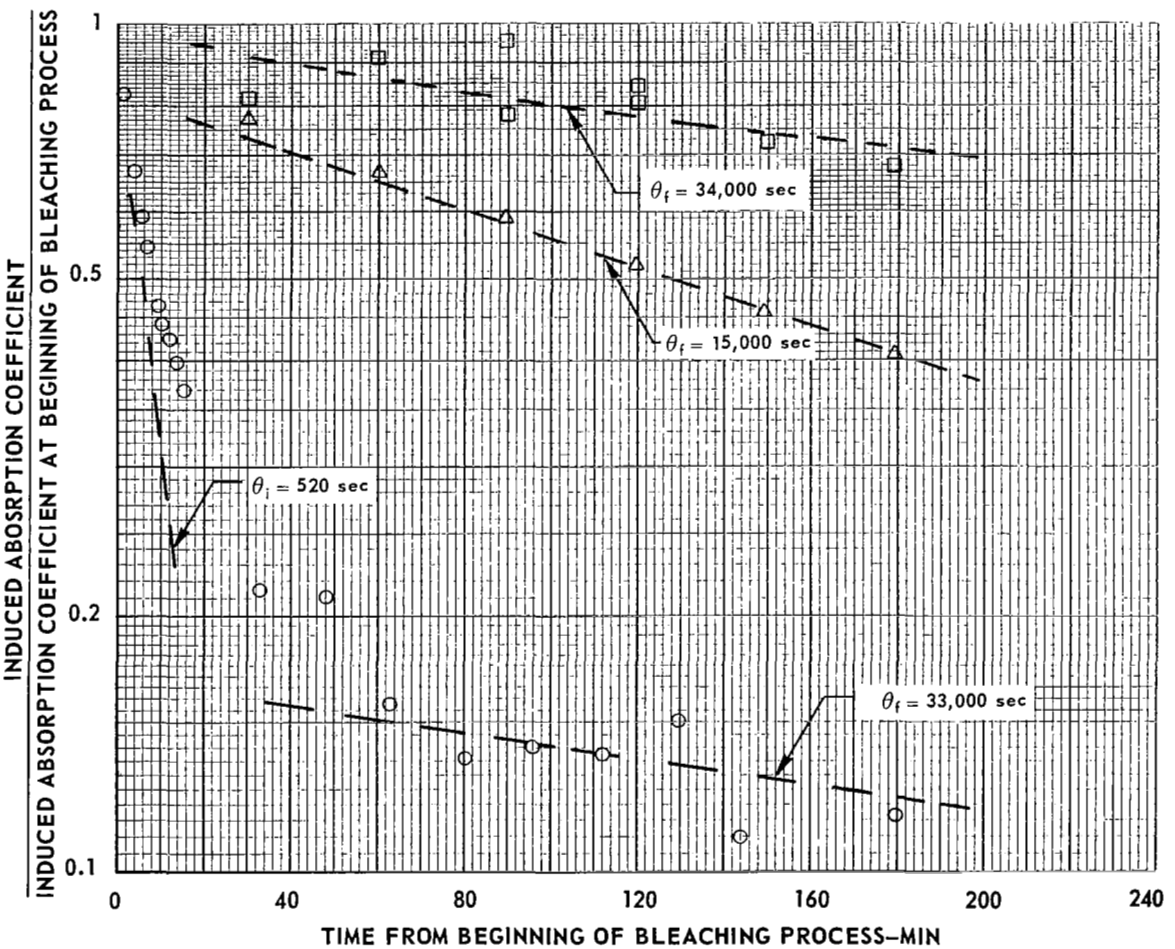


FIG. 17

ABSORPTION COEFFICIENT DURING 250 C HEAT TREATMENTS OF FUSED SILICA SPECIMENS WHICH HAD BEEN REACTOR IRRADIATED AT 900 C CAPSULE B

WAVELENGTH, $\lambda = 0.215$ MICRON

SPECIMEN SC30-2

SYMBOL	STEP[1] (SEE TABLE VI-b)	TREATMENT IMMEDIATELY PRECEDING STEP
○	4	900 C REACTOR AND 4 MRAD GAMMA
□	10	10.6 MRAD GAMMA
◇	12	10 MRAD GAMMA

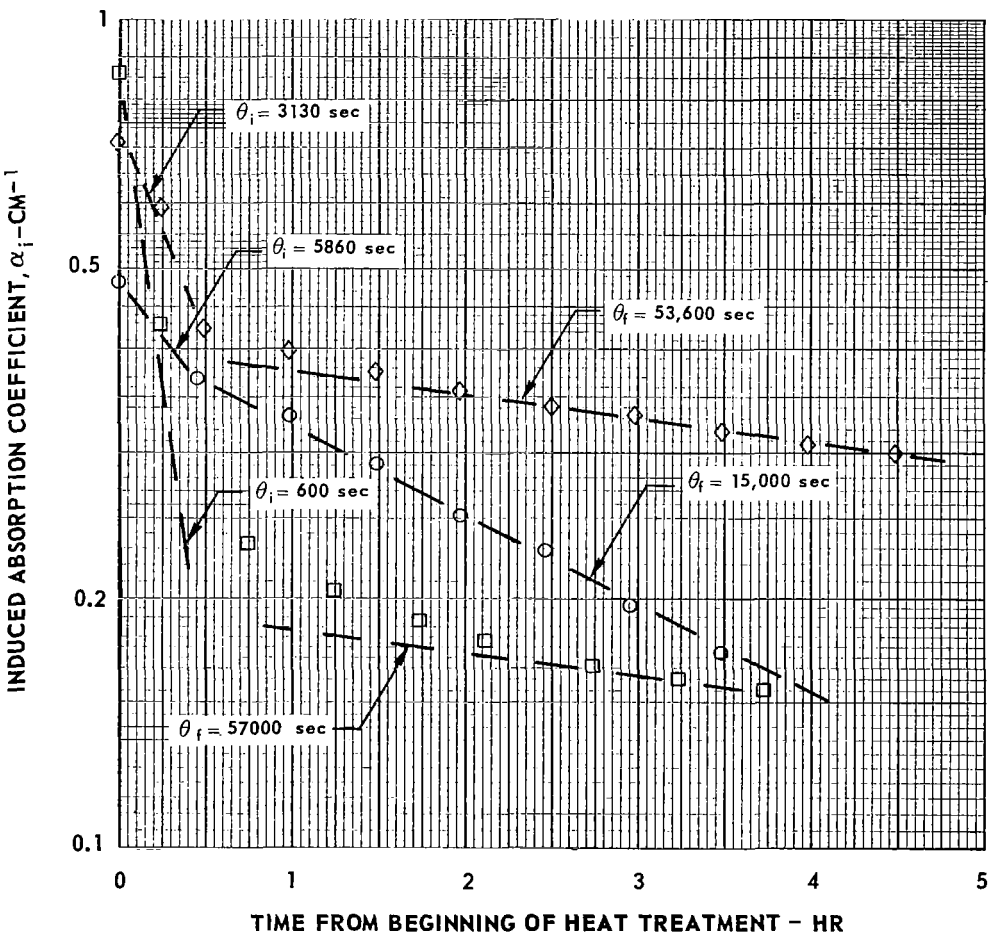


FIG. 18

ABSORPTION COEFFICIENT AT 700 C VS TIME DURING HIGH TEMPERATURE ANNEAL FOR FUSED SILICA SPECIMENS WHICH HAD BEEN REACTOR IRRADIATED AT 700 C CAPSULE F

SPECIMENS SC 30–101 , SC 5–101
WAVELENGTH, λ=0.215 MICRON
SEE TABLES VII –a, VII–f

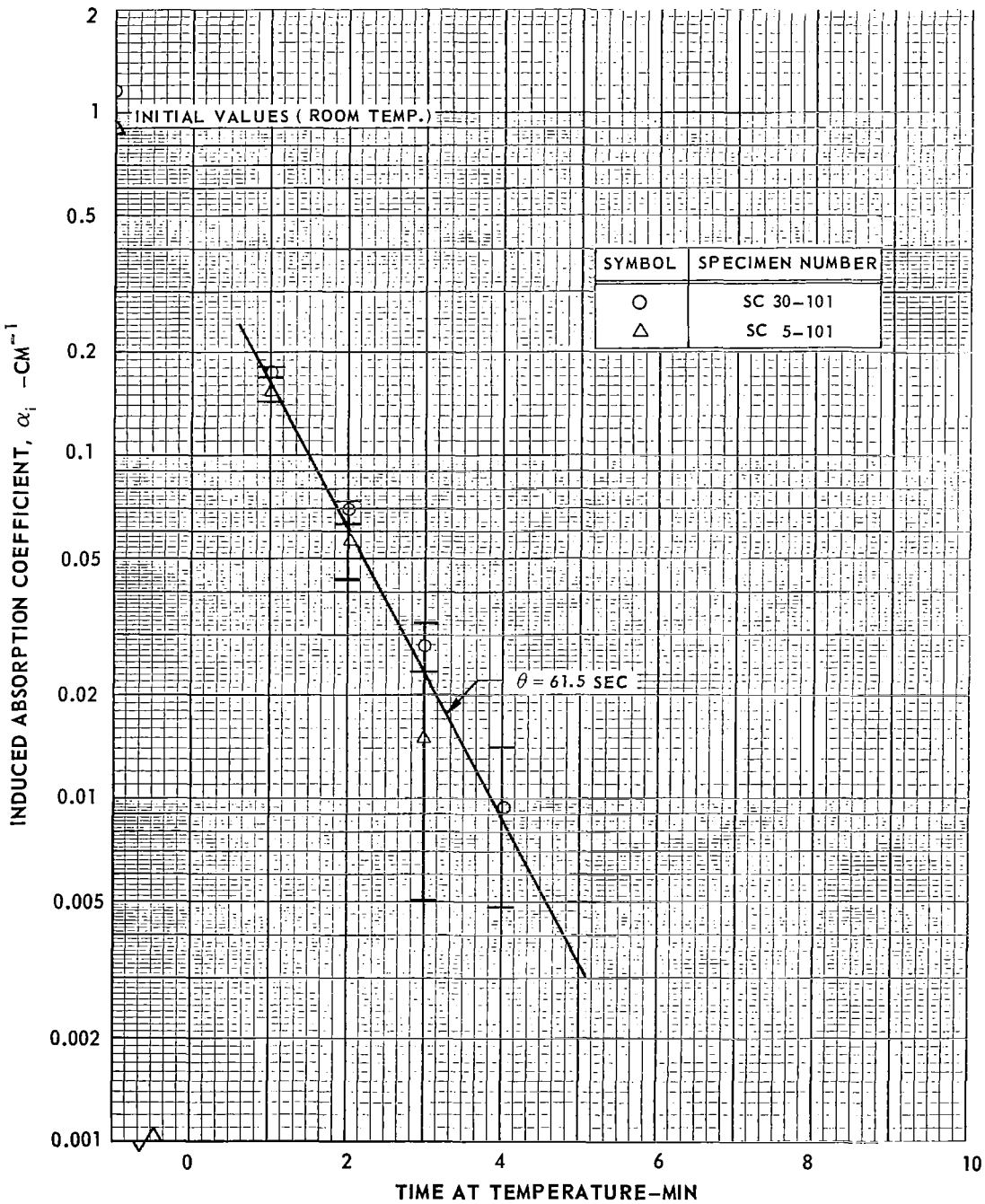


FIG. 19

ABSORPTION COEFFICIENT AT 800 C VS TIME DURING HIGH-TEMPERATURE ANNEAL FOR FUSED SILICA SPECIMENS WHICH HAD BEEN REACTOR IRRADIATED AT 800 C CAPSULE H

SPECIMEN SC 30-109
WAVELENGTH, $\lambda = 0.215$ MICRON
SEE TABLE VII-C

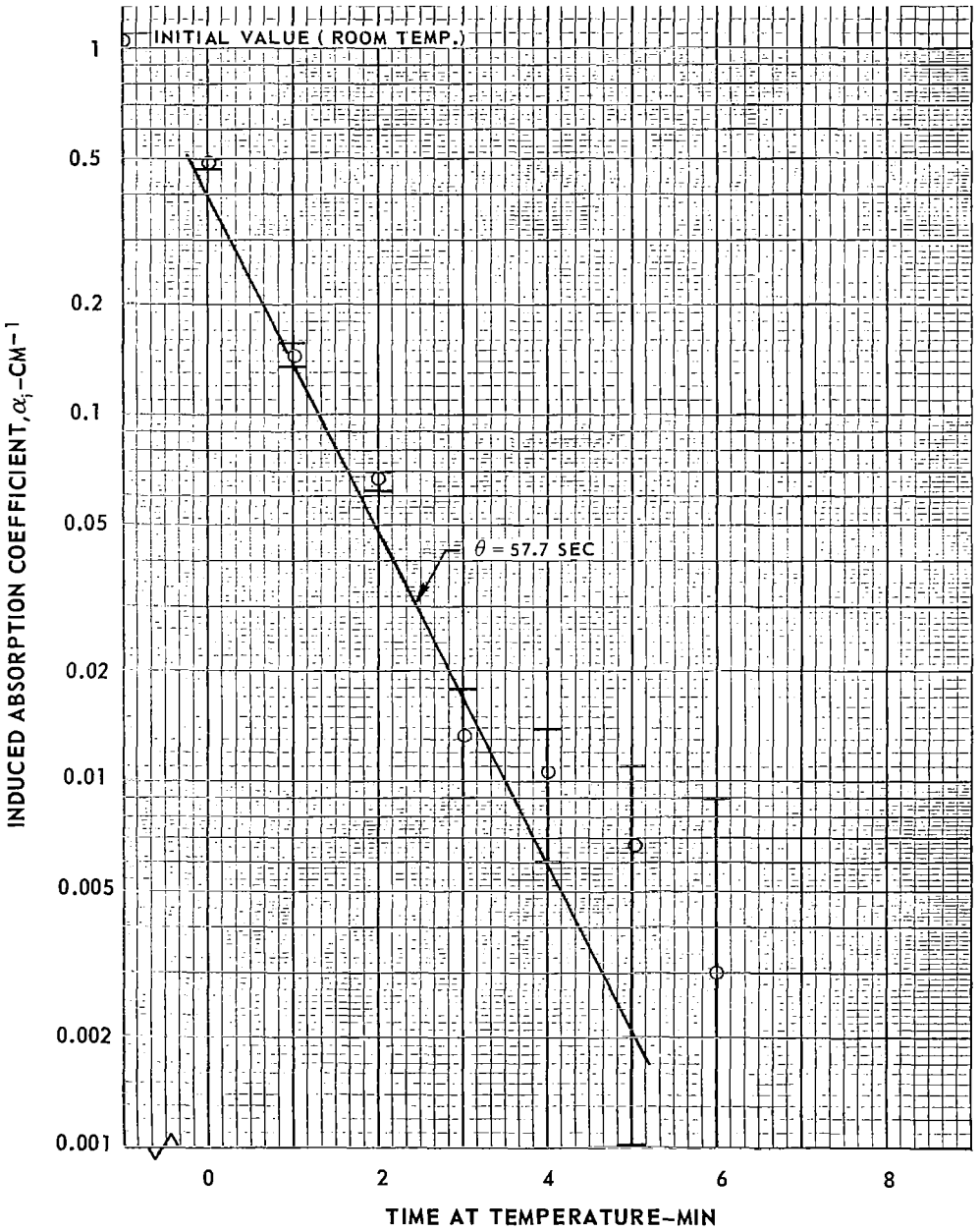


FIG. 20

ABSORPTION COEFFICIENT AT 900 C VS TIME DURING HIGH TEMPERATURE ANNEAL FOR FUSED SILICA SPECIMENS REACTOR IRRADIATED AT 900 C, CAPSULE J

SPECIMEN SC 30-107
WAVELENGTH, $\lambda_i = 0.215$ MICRON
SEE TABLE VII-e

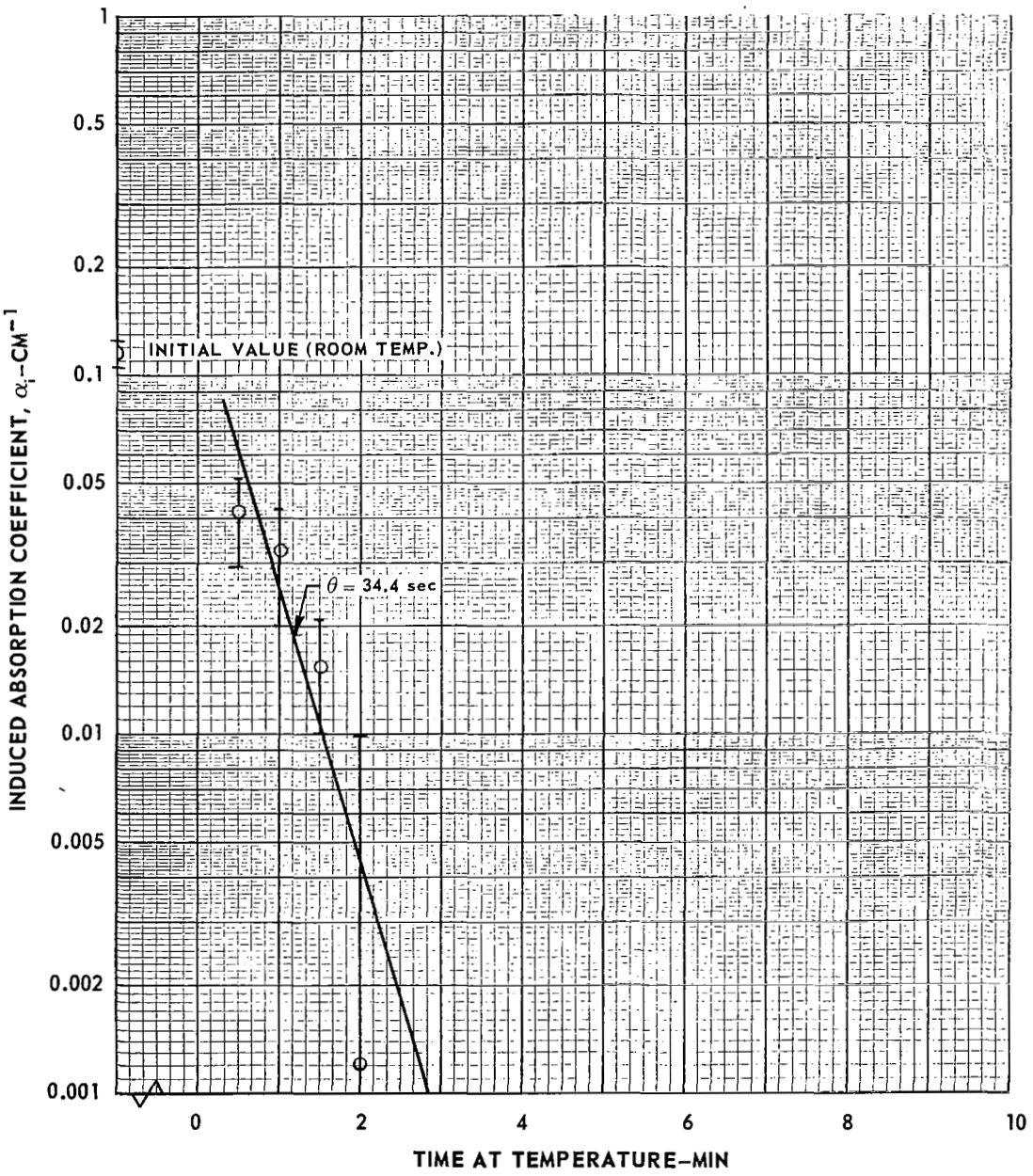


FIG. 21

TIME CONSTANT FOR REMOVAL OF RADIATION INDUCED COLOR FROM REACTOR-IRRADIATED FUSED SILICA VS TEMPERATURE

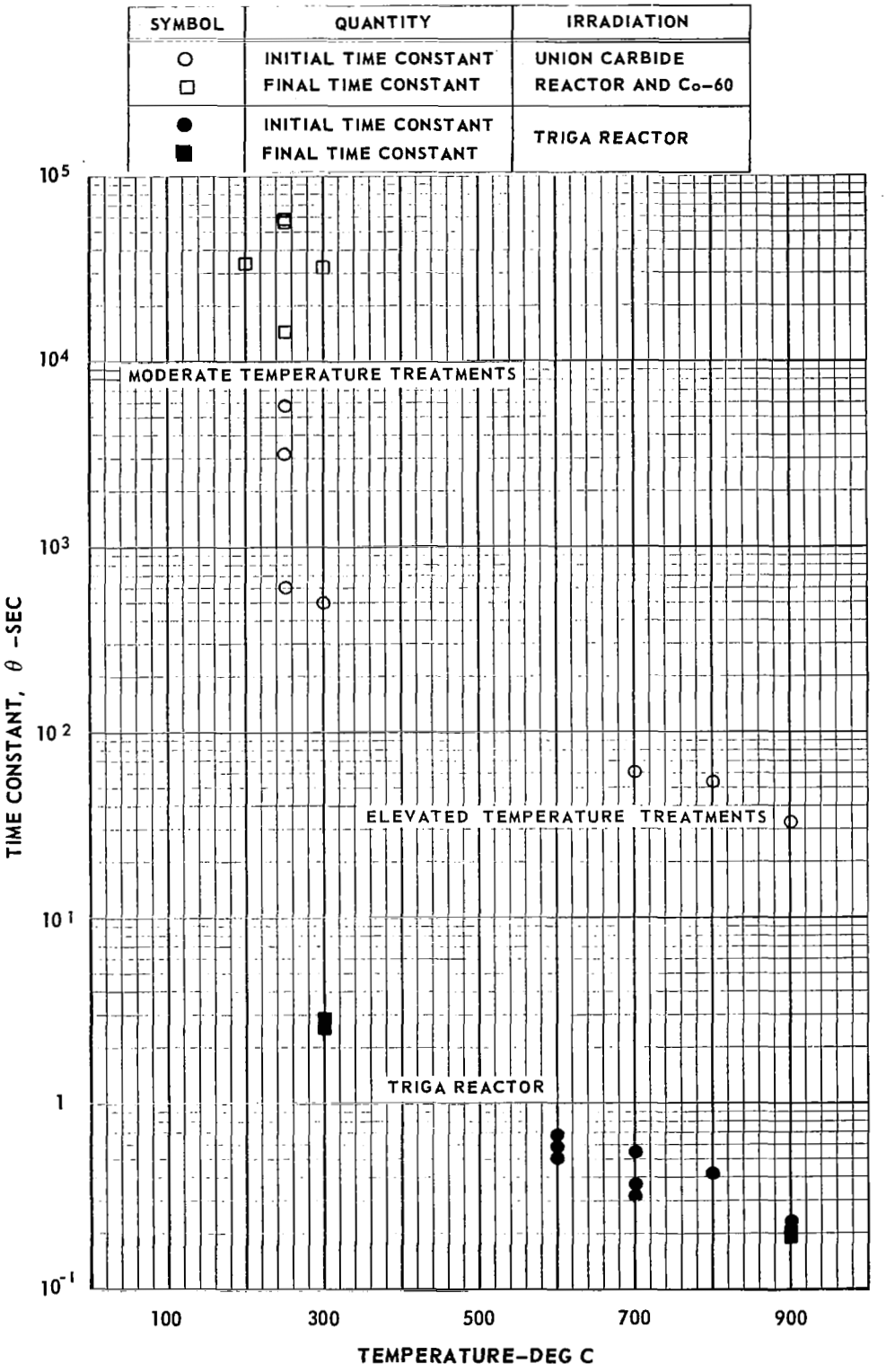


FIG. 22

TRANSMITTANCE CHARACTERISTICS OF ALUMINUM OXIDE SINGLE CRYSTAL SPECIMEN AM 2-100 AFTER REACTOR IRRADIATION AT 900°C AND SEQUENTIAL Co-60 GAMMA IRRADIATIONS AND HEAT TREATMENTS

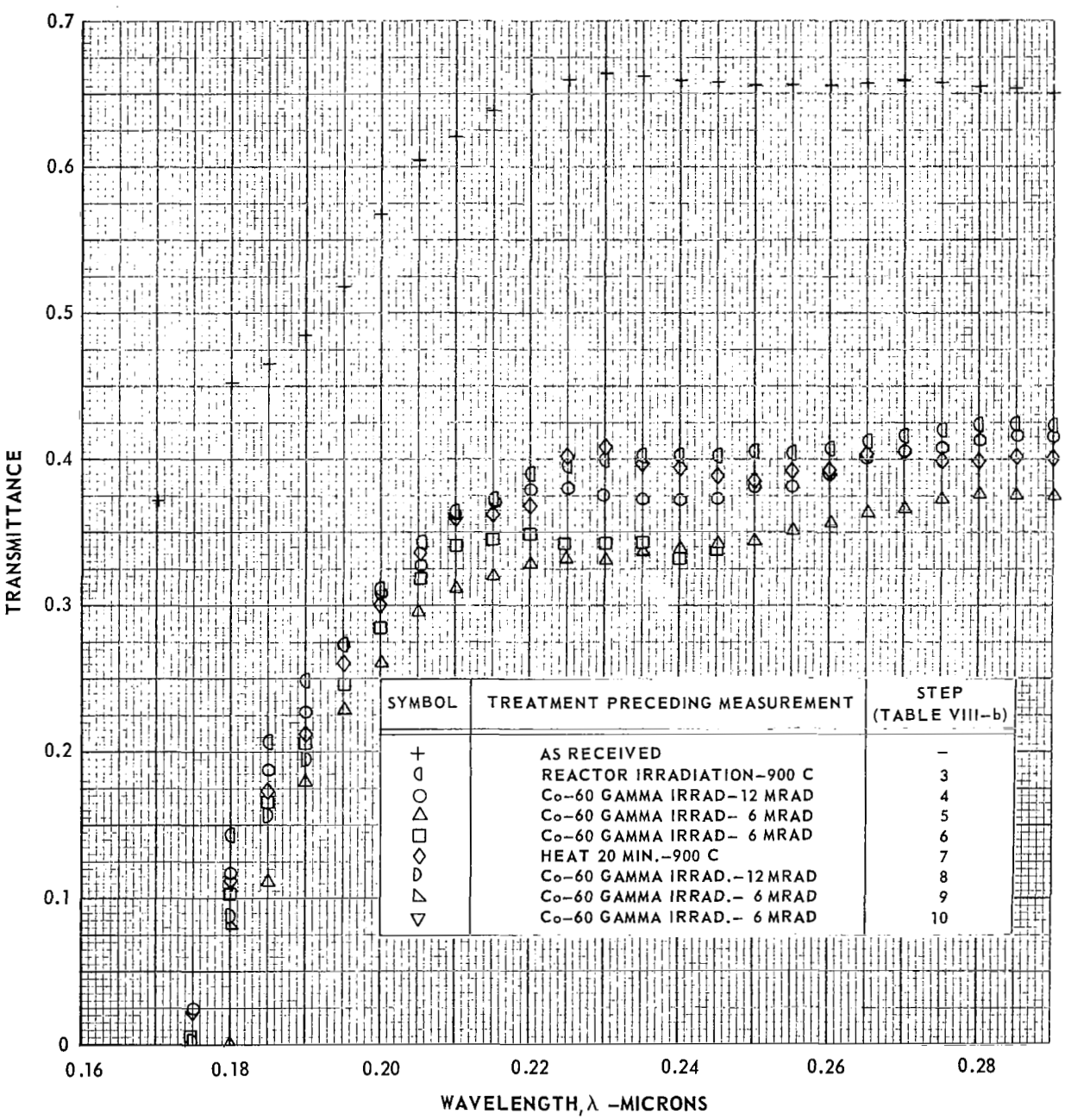


FIG. 23

TRANSMITTANCE CHARACTERISTICS OF ALUMINUM OXIDE SINGLE CRYSTAL SPECIMEN AM½ -100 AFTER REACTOR IRRADIATION AT 900 C AND SEQUENTIAL Co-60 GAMMA IRRADIATIONS SPECIMEN THICKNESS: ½ mm

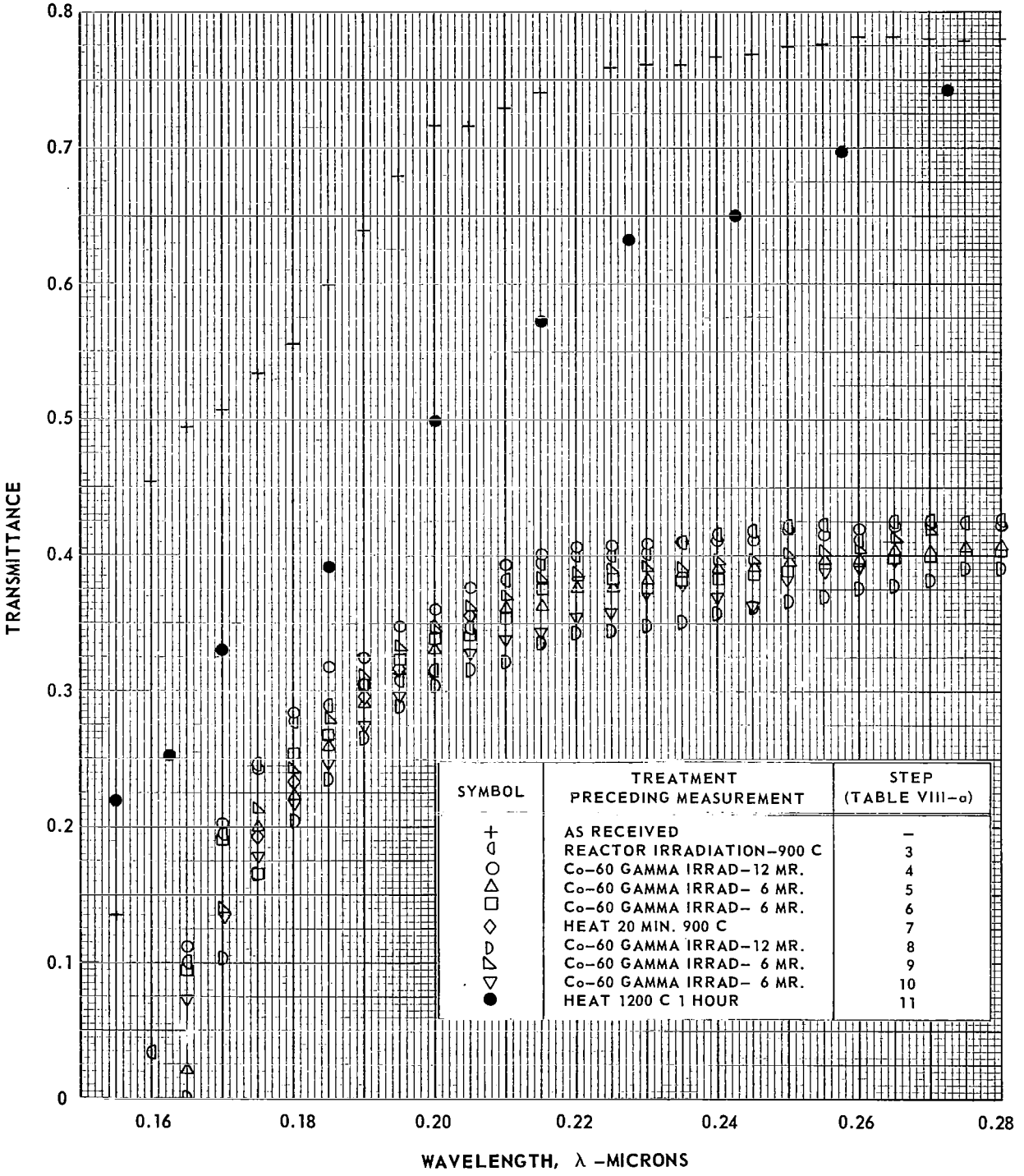


FIG. 24

TRANSMITTANCE OF SINGLE CRYSTAL BeO SPECIMEN BL 2-100 BEFORE AND AFTER 900 C REACTOR IRRADIATION

SYMBOL	TREATMENT PRECEDING MEASUREMENT
○	PRE-IRRADIATION
□	POST IRRADIATION

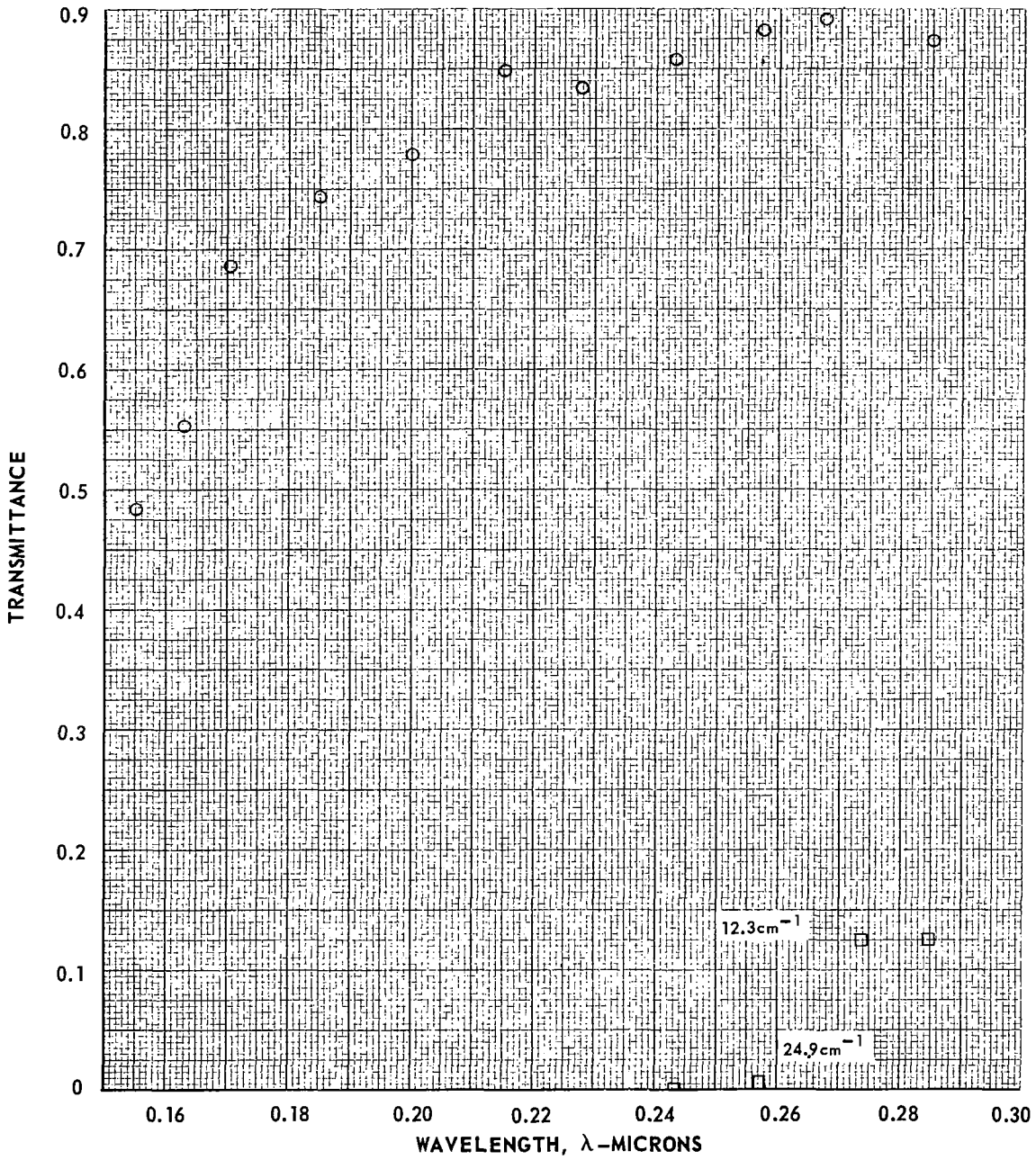


FIG. 25

TRANSMITTANCE SPECTRUM OF 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30-101 REACTOR IRRADIATED AT 700 C, CAPSULE F, AND SUBSEQUENTLY Co-60 GAMMA DOSED

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII-a)
○	AS RECEIVED	1
□	REACTOR IRRAD., AT 700C	3
△	12 MRAD GAMMA DOSE	4
◇	6 MRAD GAMMA DOSE	5
▽	6 MRAD GAMMA DOSE	6
◁	6 MRAD GAMMA DOSE	7
D	HEAT TREATMENT 700C	8

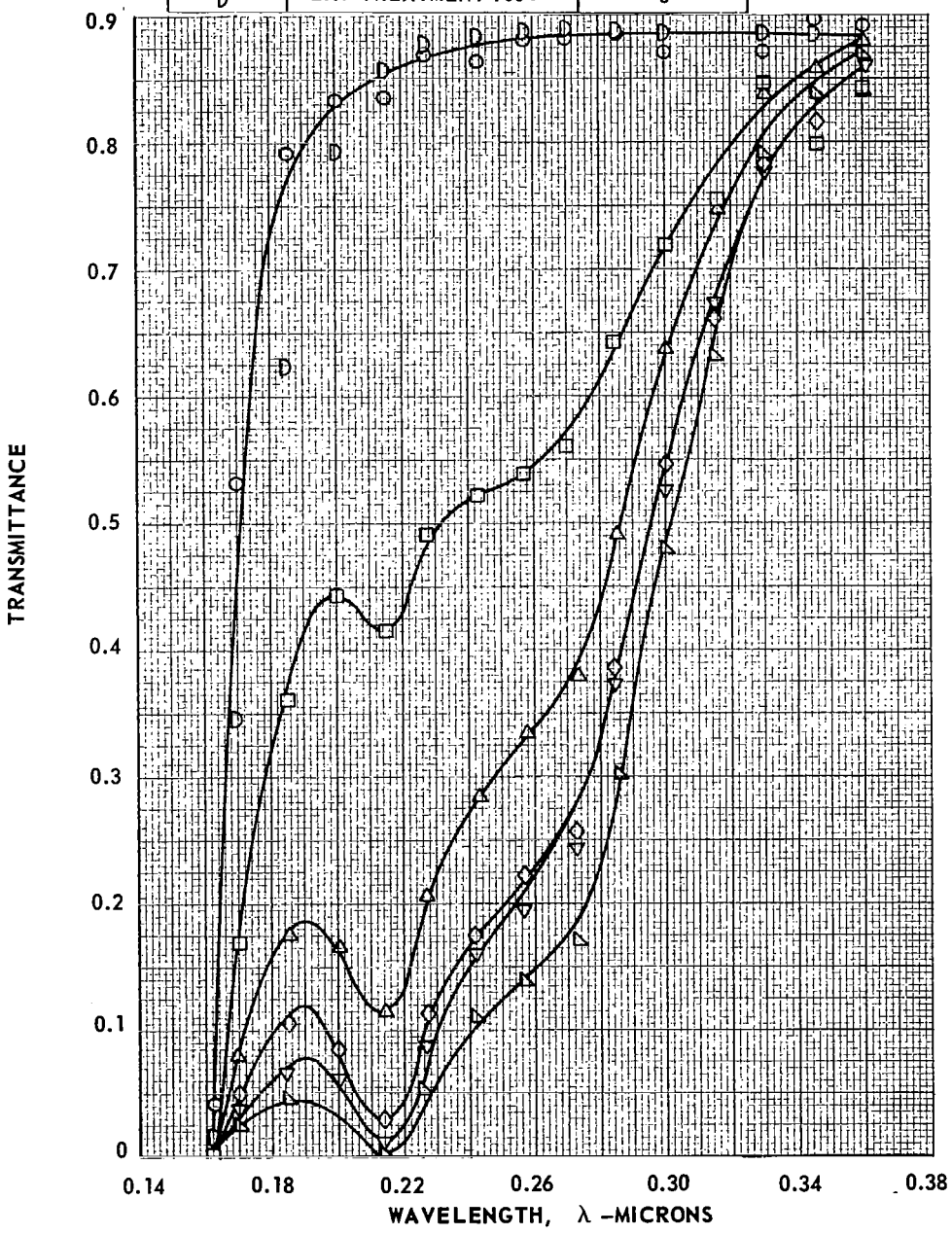


FIG. 26

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30-101 REACTOR IRRADIATED AT 700C, CAPSULE F, AND SUBSEQUENTLY Co-60 GAMMA DOSED

WAVELENGTH, $\lambda = 0.215$ MICRON

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII-a)
○	RECEIPT FROM VENDOR	1
□	REACTOR IRRAD; 700C	3
△◇▽◺	Co-60 GAMMA IRRAD.	4-7
◗	HEAT TREATMENT 700C	8
▲◆▼◣	Co-60 GAMMA IRRAD.	9-12
◗	HEAT TREATMENT 700C	13
▲◆▼	Co-60 GAMMA IRRAD.	14-16

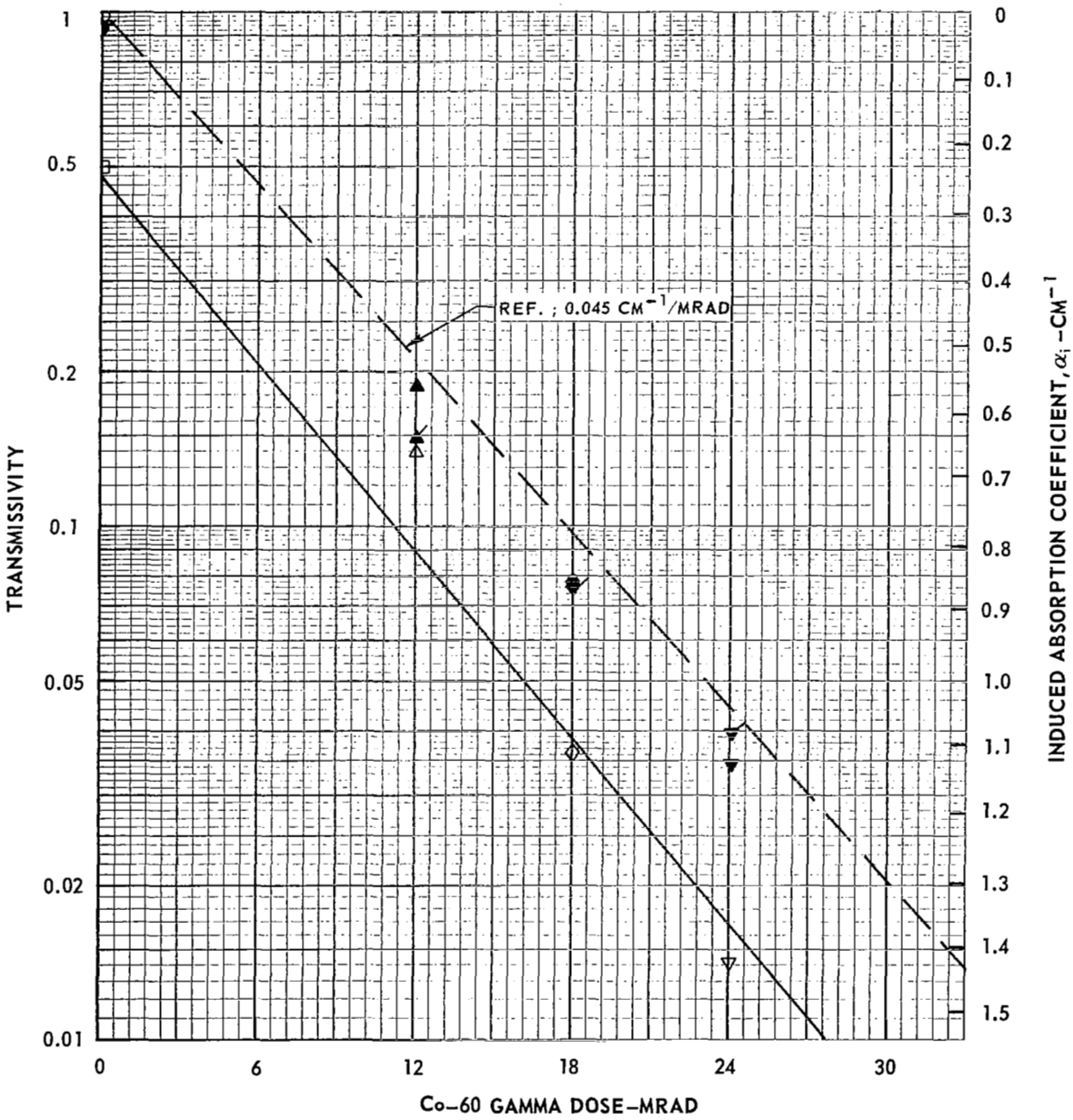


FIG. 27

TRANSMITTANCE SPECTRUM OF 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–105 REACTOR IRRADIATED AT 800 C, CAPSULE G, AND SUBSEQUENTLY Co–60 GAMMA DOSED

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–b)
○	AS RECEIVED	1
□	REACTOR IRRAD., AT 800 C	3
△	12 MRAD GAMMA DOSE	4
◇	6 MRAD GAMMA DOSE	5

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–b)
▽	6 MRAG GAMMA DOSE	6
◺	6 MRAD GAMMA DOSE	7
D	HEAT TREATMENT 800 C	8

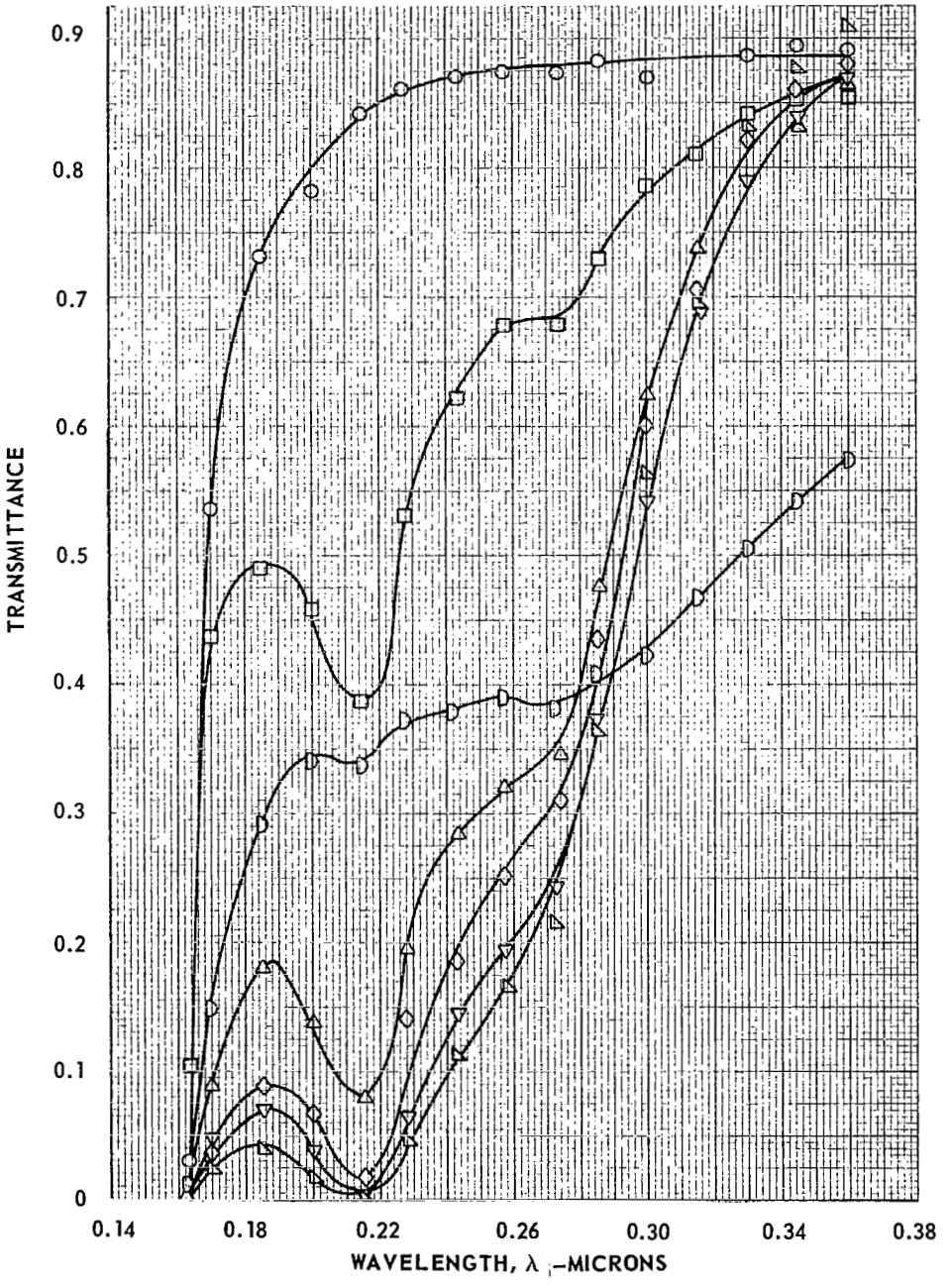


FIG. 28

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30-105 REACTOR IRRADIATED AT 800 C, CAPSULE G, AND SUBSEQUENTLY Co-60 GAMMA DOSED

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII-b)
○	RECEIPT FROM VENDOR	1
—□—	REACTOR IRRAD: 800C	3
-△◇▽◺-	Co-60 GAMMA IRRAD.	4-7
◗	HEAT TREATMENT 800C	8
▲◆▼◣	Co-60 GAMMA IRRAD.	9-12
◗	HEAT TREATMENT 800C	13
▲	POLISH SPECIMEN	16
◆▼	Co-60 GAMMA IRRAD.	17-18

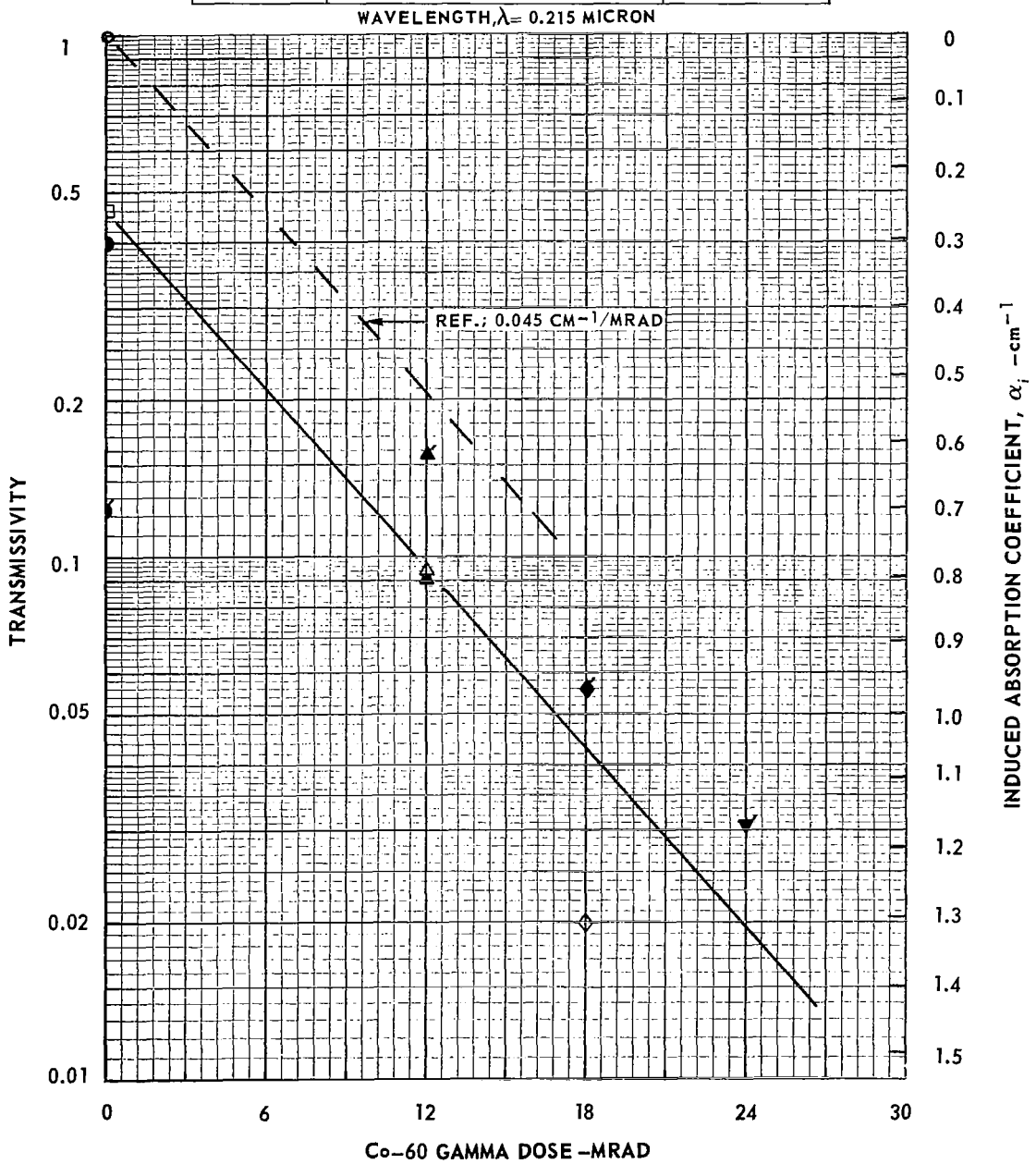


FIG. 29

TRANSMITTANCE SPECTRUM OF 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–109 REACTOR IRRADIATED AT 800 C, CAPSULE H, AND SUBSEQUENTLY Co–60 GAMMA DOSED

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–C)	SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII-C)
○	AS RECEIVED	1	▽	6 MRAD GAMMA DOSE	6
□	REACTOR IRRAD., AT 800 C	3	◺	6 MRAD GAMMA DOSE	7
△	12 MRAD GAMMA DOSE	4	D	HEAT TREATMENT–800 C	8
◇	6 MRAD GAMMA DOSE	5			

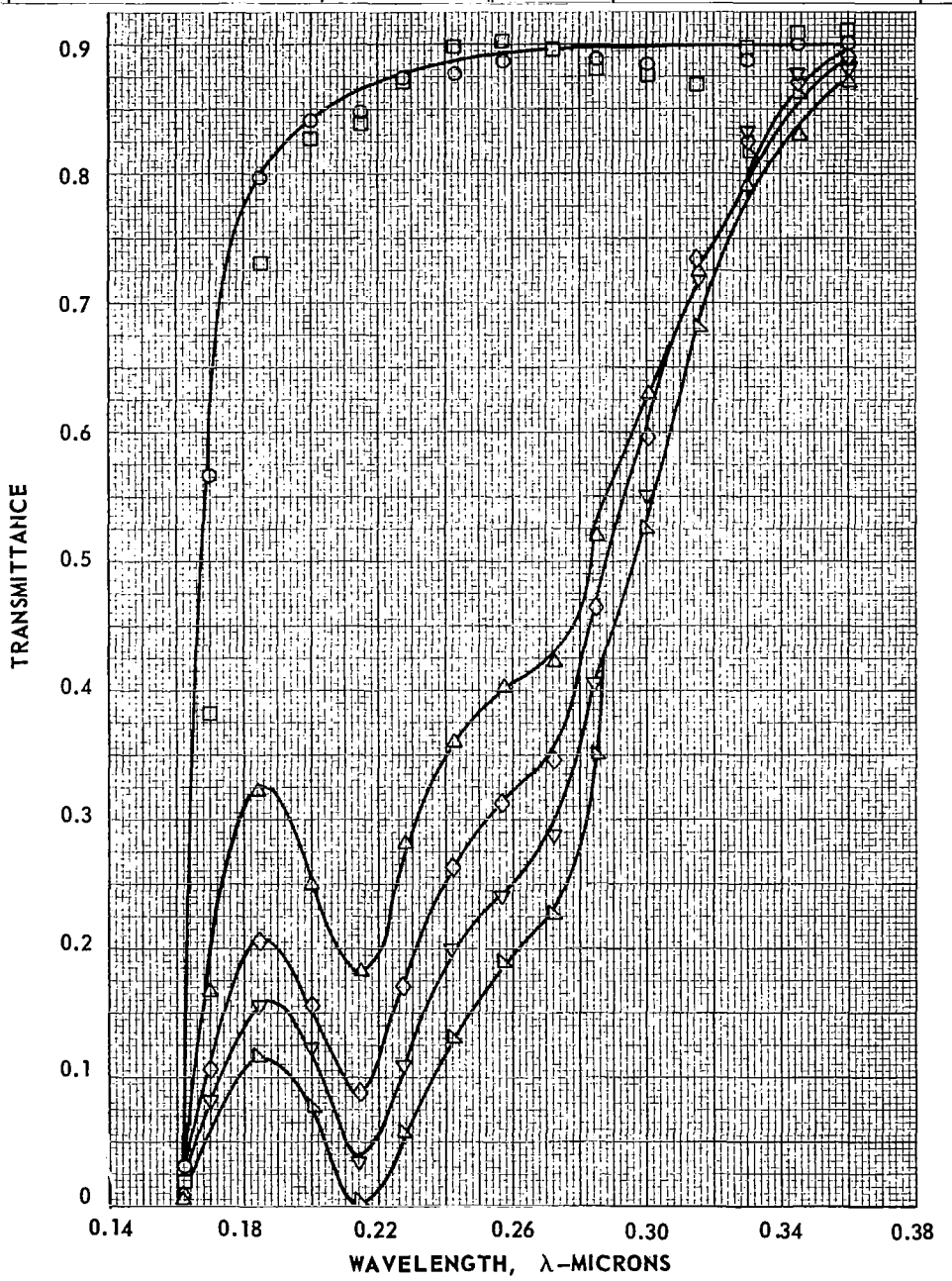


FIG. 30

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30-109 REACTOR IRRADIATED AT 800 C, CAPSULE H, AND SUBSEQUENTLY Co-60 GAMMA DOSED

WAVELENGTH, $\lambda = 0.215$ MICRON

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII-c)
○	RECEIPT FROM VENDOR	1
—□—	REACTOR IRRAD: 800C	3
△ ◇ ▽ ◺	Co-60 GAMMA IRRAD.	4-7

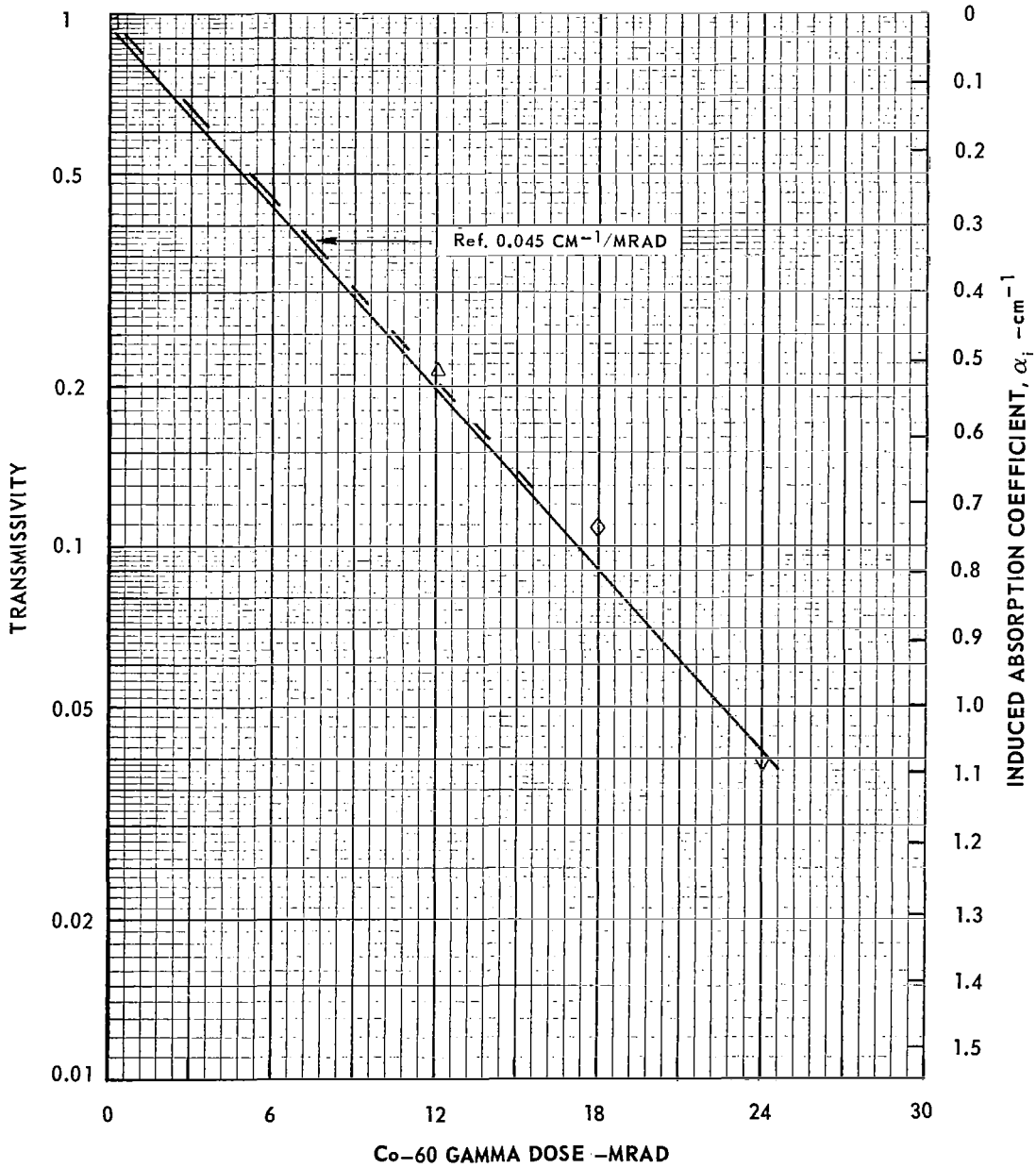


FIG. 31

TRANSMITTANCE SPECTRUM OF 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–102 REACTOR IRRADIATED AT 800 C, CAPSULE I, AND SUBSEQUENTLY Co–60 GAMMA DOSED

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–d)	SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–d)
○	AS RECEIVED	1	▽	6 MRAD GAMMA DOSE	6
□	REACTOR IRRAD., AT 800 C	3	◺	6 MRAD GAMMA DOSE	7
△	12 MRAD GAMMA DOSE	4	D	HEAT TREATMENT 800 C	8
◇	6 MRAD GAMMA DOSE	5			

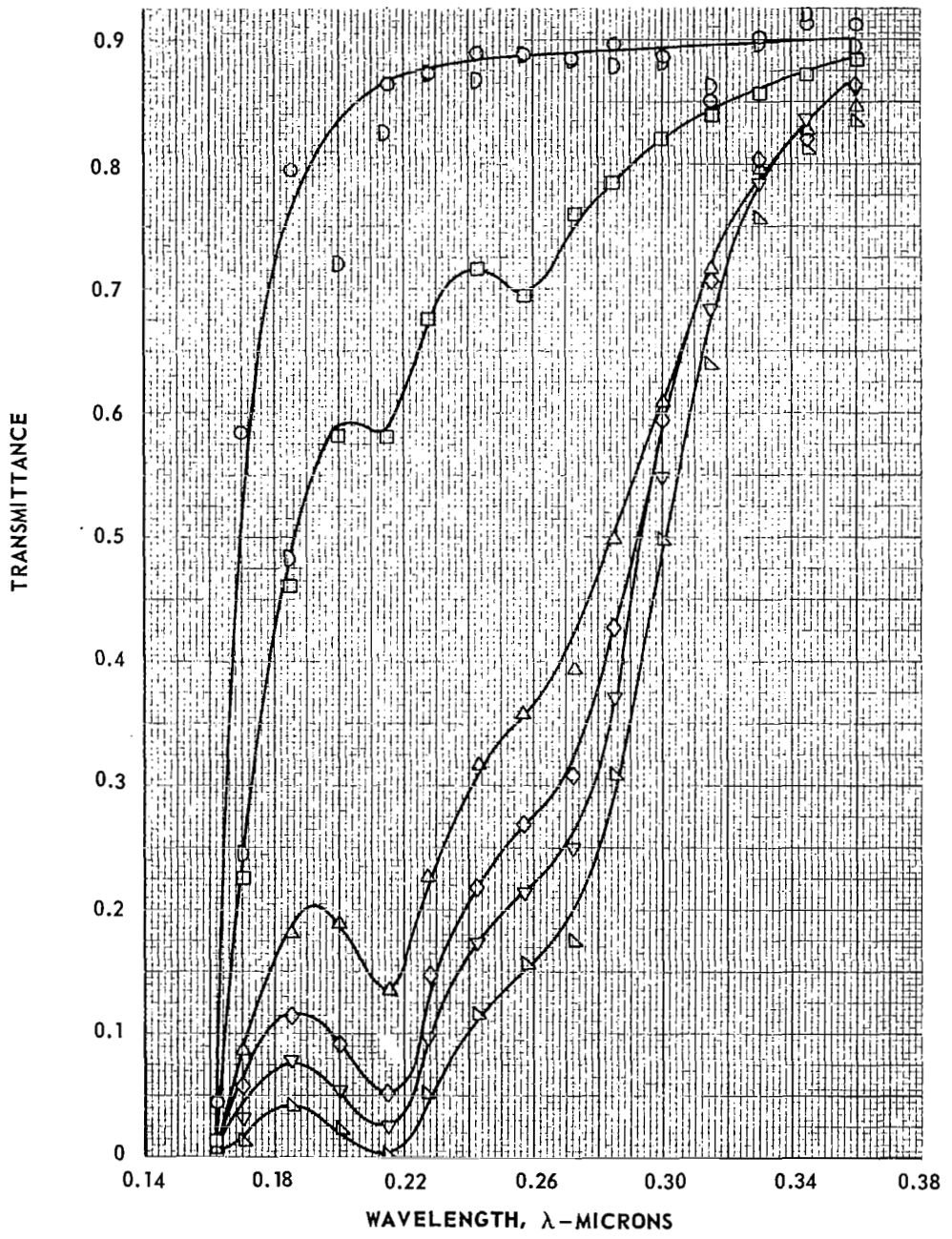


FIG. 32

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–102 REACTOR IRRADIATED AT 800 C, CAPSULE I, AND SUBSEQUENTLY Co–60 GAMMA DOSED

WAVELENGTH, λ = 0.215 MICRON

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–d)
○	RECEIPT FROM VENDOR	1
—□—	REACTOR IRRAD: 800C	3
△ ◇ ▽	Co–60 GAMMA IRRAD.	4–6
◗	HEAT TREATMENT 800C	8
▲ ◆ ▼	Co–60 GAMMA DOSE	9–11

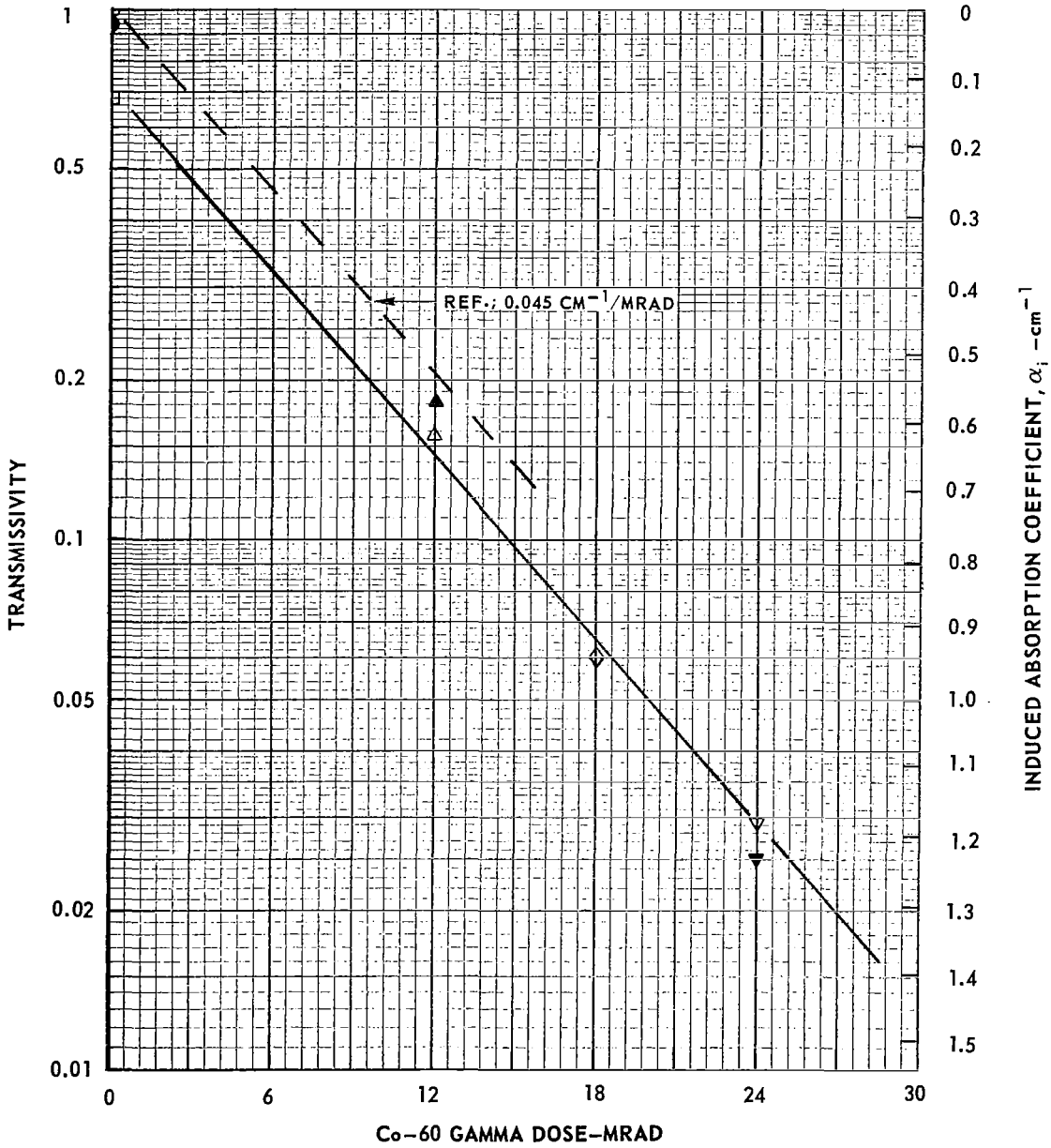


FIG. 33

TRANSMITTANCE SPECTRUM OF 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–107 REACTOR IRRADIATED AT 900 C, CAPSULE J, AND SUBSEQUENTLY Co–60 GAMMA DOSED

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–e)	SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–e)
○	AS RECEIVED	1	▽	6 MRAD GAMMA DOSE	6
□	REACTOR IRRAD., AT 900 C	3	◺	6 MRAD GAMMA DOSE	7
△	12 MRAD GAMMA DOSE	4	D	HEAT TREATMENT–900 C	8
◇	6 MRAD GAMMA DOSE	5			

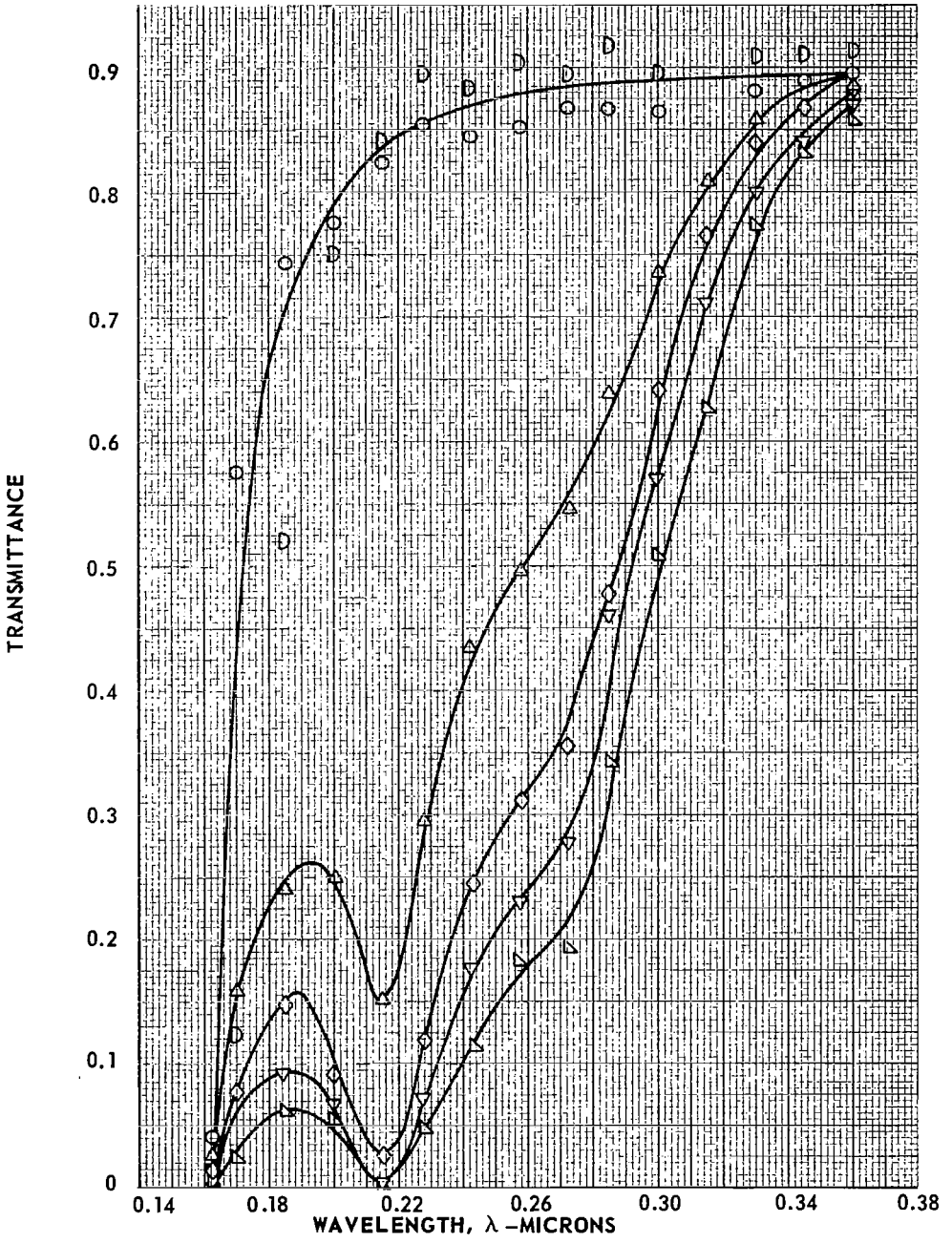


FIG. 34

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30-107 REACTOR IRRADIATED AT 900 C, CAPSULE J, AND SUBSEQUENTLY Co-60 GAMMA DOSED

WAVELENGTH, λ = 0.215 MICRON

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII-e)
○	RECEIPT FROM VENDOR	1
—□—	REACTOR IRRAD. 900 C	3
-△ ◇ ▽ ◺-	Co-60 GAMMA IRRAD.	3,4,5,6,7

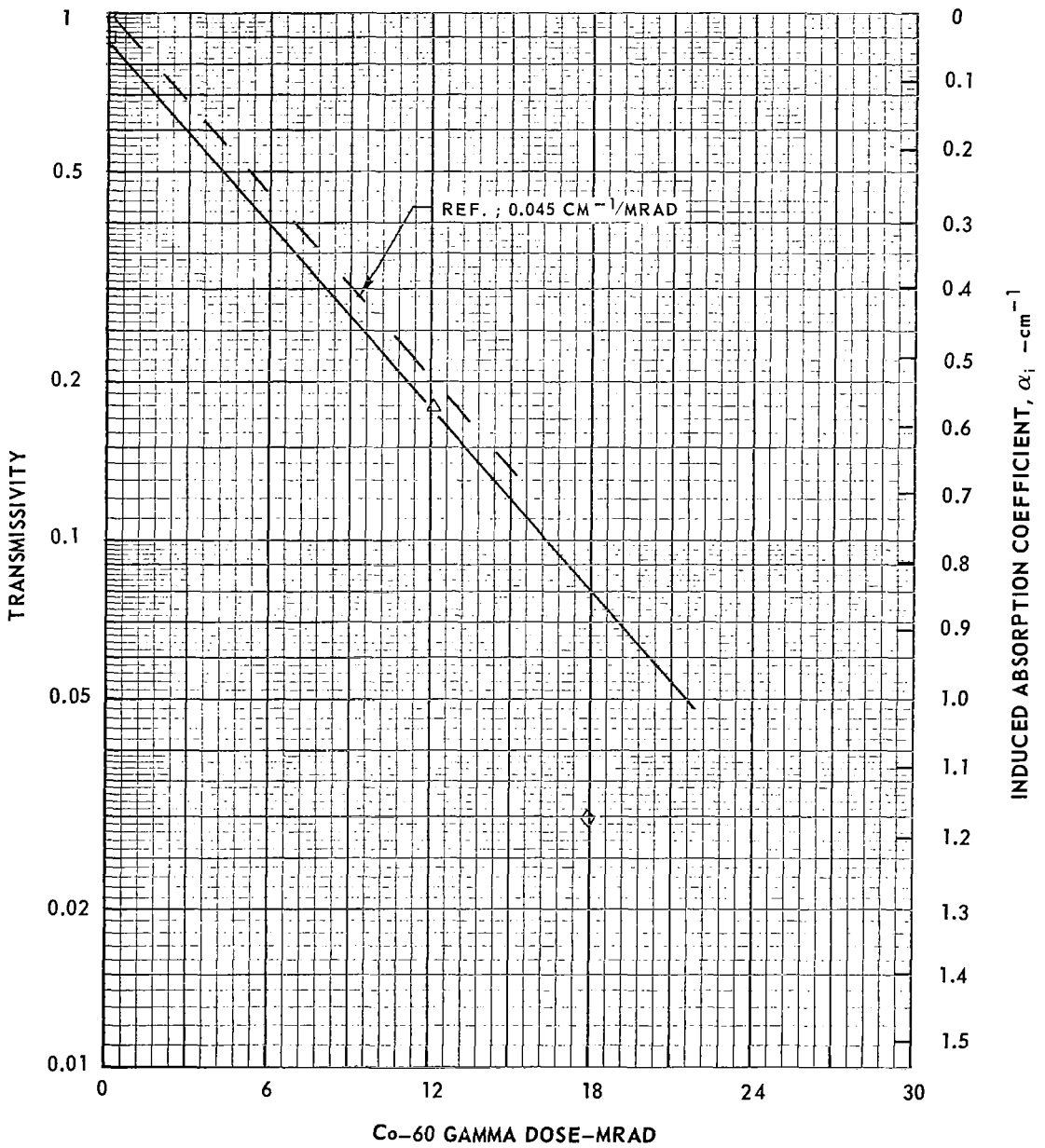


FIG. 35

TRANSMITTANCE SPECTRUM OF 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–112 REACTOR IRRADIATED AT 800 C, CAPSULE I, BLEACHED AT 250 C, AND SUBSEQUENTLY Co–60 GAMMA DOSED

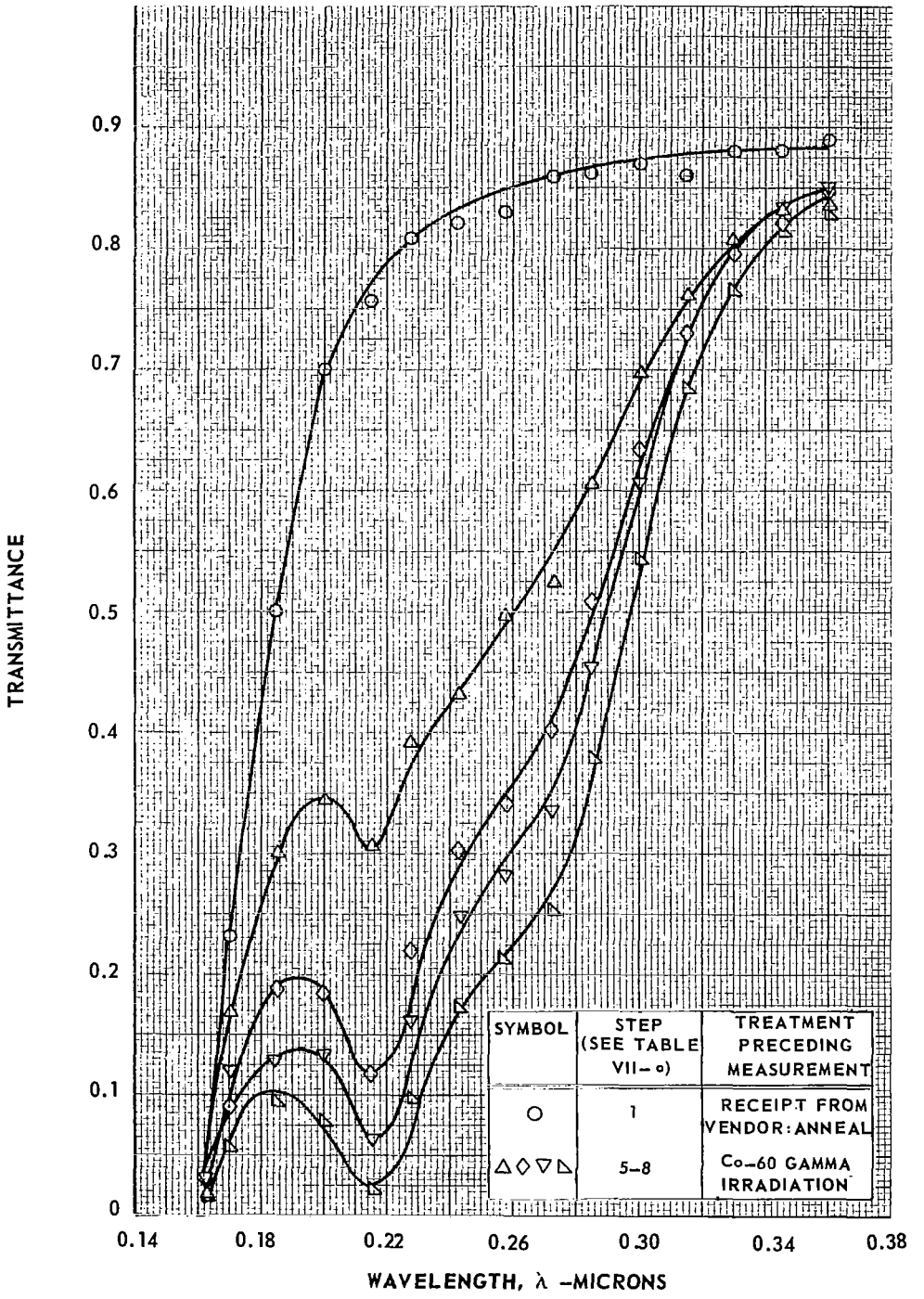


FIG. 36

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–112 REACTOR IRRADIATED AT 800 C, CAPSULE 1, BLEACHED AT 200 C, AND SUBSEQUENTLY Co–60 GAMMA DOSED

WAVELENGTH, λ = 0.215 MICRON

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–p)
○	RECEIPT FROM VENDOR	1
△◇▽◺	Co–60 GAMMA IRRAD.	5–8
D	HEAT TREATMENT	9

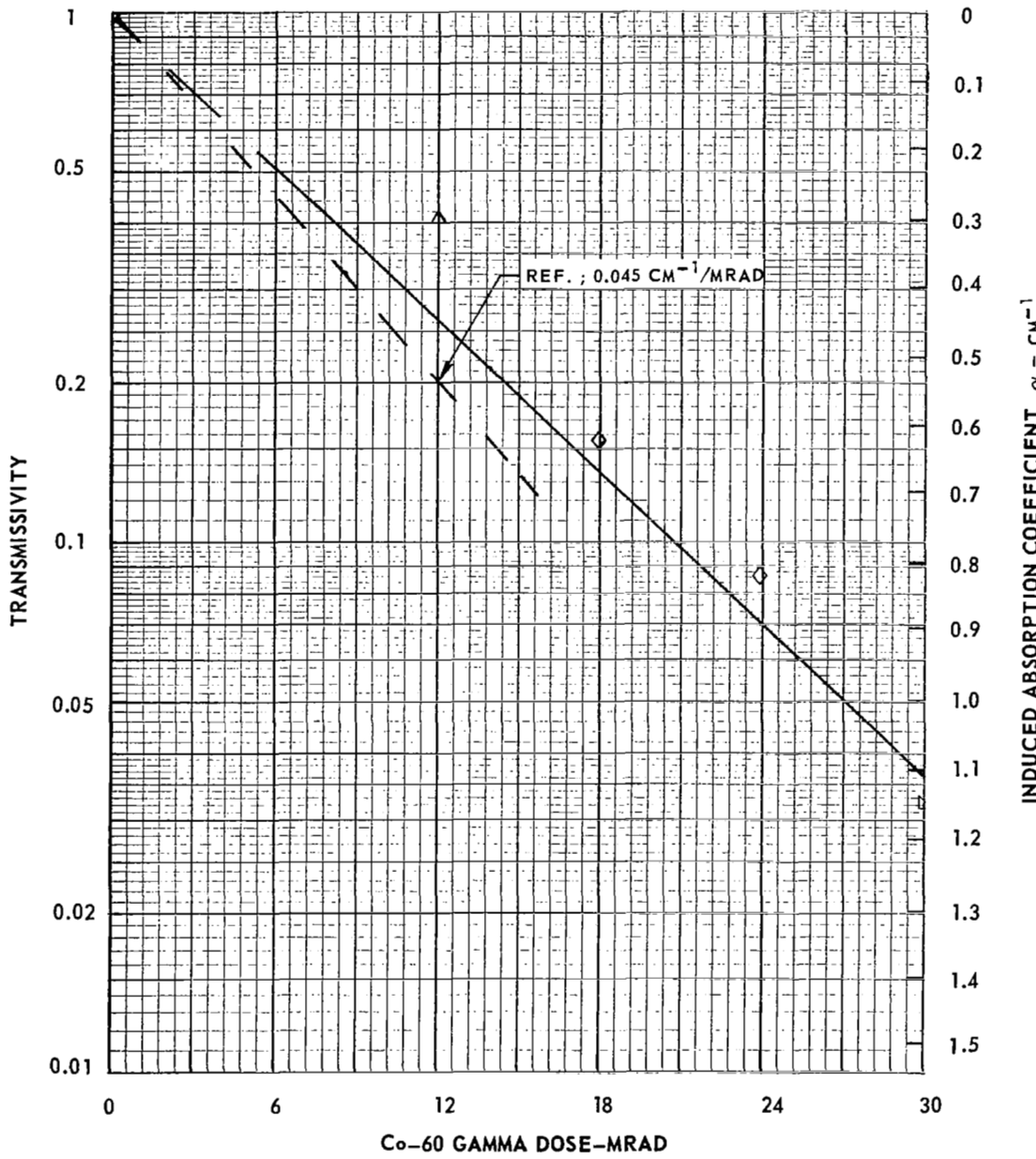


FIG. 37

TRANSMITTANCE SPECTRA OF 30 mm CORNING FUSED SILICA SPECIMEN SC 30-113, CONTROL, RECEIVED FROM VENDOR, HEATED AT 1050 C, AND SUBSEQUENTLY Co-60 GAMMA DOSED

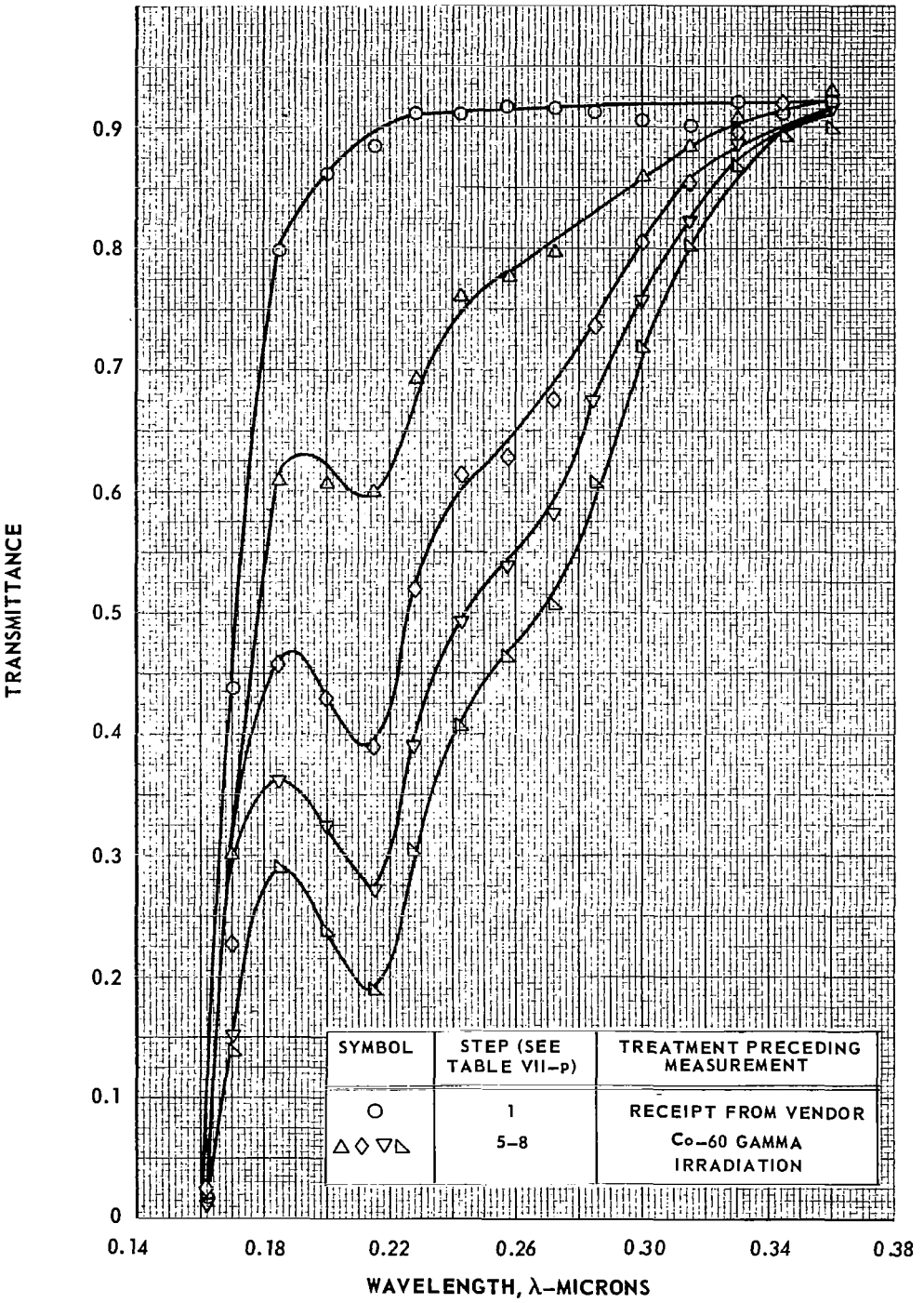
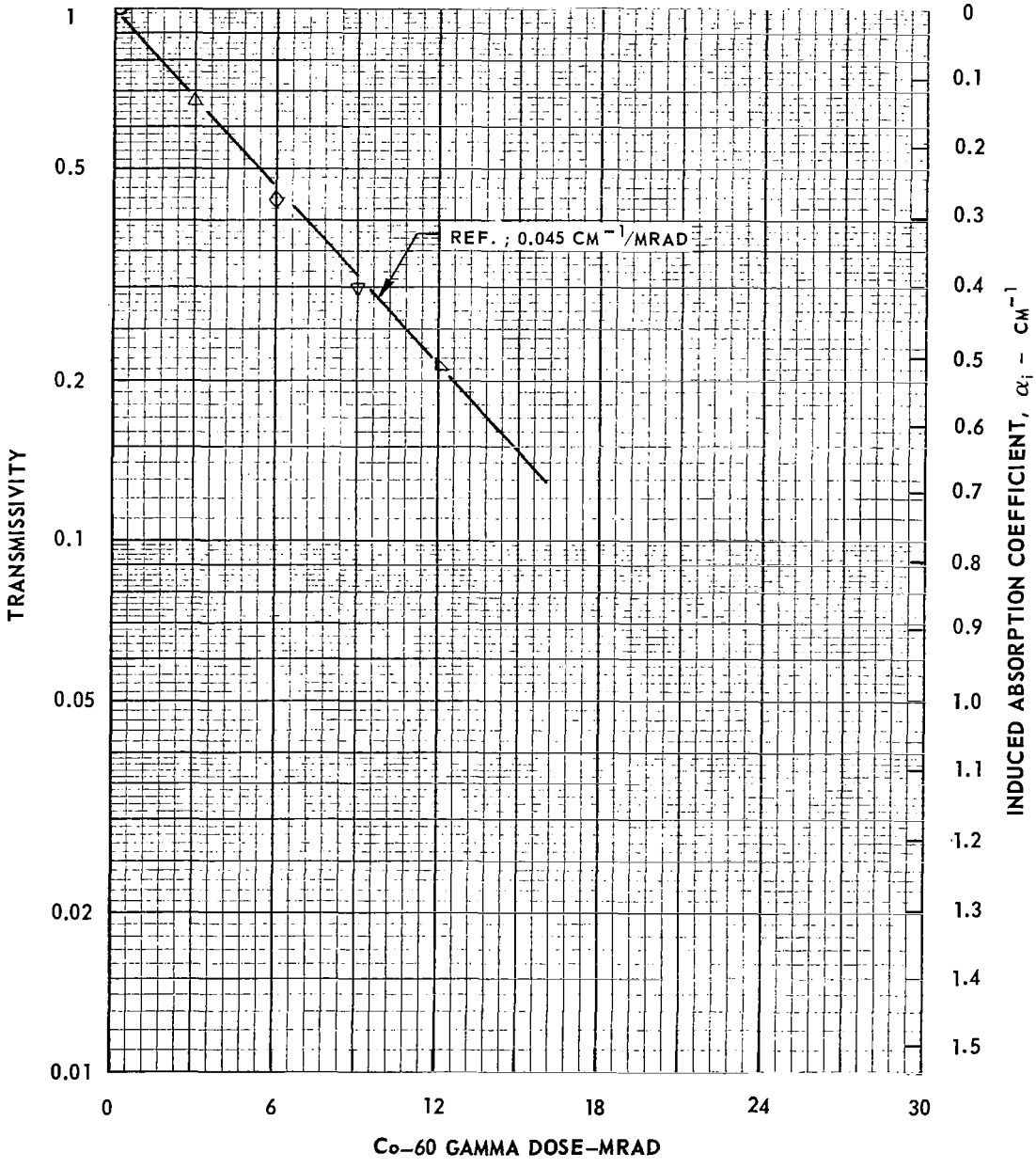


FIG. 38

TRANSMISSIVITY AND ABSORPTION COEFFICIENT FOR 30 mm CORNING 7940 FUSED SILICA SPECIMEN SC 30–113, CONTROL, RECEIVED FROM VENDOR, HEATED AT 1050 C, AND SUBSEQUENTLY Co–60 GAMMA DOSED

WAVELENGTH, λ = 0.215 MICRON

SYMBOL	TREATMENT PRECEDING MEASUREMENT	STEP (SEE TABLE VII–p)
○	RECEIPT FROM VENDOR	1
△◇▽◺	Co–60 GAMMA IRRADIATION	5-8



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