FOREWORD

This report was initiated by the Vision Section, Protection Branch, Life Support Systems Laboratory of the 6570th Aerospace Medical Research Laboratories. The research was accomplished at the University of Michigan, Ann Arbor, Michigan, under Contract AF 33(616)-6847, Project No. 6301, "Aerospace Systems Personnel Protection," Task No. 630103, "Vision Enhancement and Protection in Aerospace Environment." Donald G. Pitts, Captain, USAF, MSC, of the Vision Section was the contract monitor. The senior author, Professor Edward A. Boettner, of the Institute of Industrial Health and the School of Public Health, the University of Michigan, was the principal investigator. The co-author, Professor J. Reimer Wolter, M.D., of the Department of Ophthalmology, the University of Michigan Medical Center, was the co-principal investigator. This report covers the period from 1 December 1959 to 1 December 1961.

Animal experimentation was performed in accordance with the "Rules Regarding Animal Care" established by the American Medical Association.

ABSTRACT

The spectral transmittance of ultraviolet, visible, and near infrared light through the ocular media of humans has been measured. Using freshly enucleated eyes, the transmittances of each component part (cornea, aqueous humor, lens, vitreous humor) were determined for the wavelength range from 0.22 to 2.8 microns. To date 9 eyes have been measured, ranging in age from 4 weeks to 75 years. Two types of measurements were made: the first to measure the total light transmitted (direct and scattered) at each wavelength and the second to measure the percent transmittance of that light passing directly through the various media without absorption or scattering. The results show that: (a) the transmission of ultraviolet radiation decreases with the age of the eye; (b) the transmission of infrared radiation appears to be independent of the age; and (c) the maximum total transmittance of the whole eye, about 81 percent, is obtained in the region from 600 to 850 millimicrons.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

Wayne H. McCandless

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SECTION I

INTRODUCTION

Information concerning the transmission of electromagnetic radiation through the eye is of importance in two general ways. First, it is information which one must have to assess the possible effect of intense radiation sources on the parts of the eye, e.g., the lens or retina. Second, such data have been used by various investigators to establish or advance certain fundamental concepts in physiological optics. One of the first investigators to concern himself with the transmission was Brucke, who was investigating the reason for the invisibility of ultraviolet rays. Later others investigated the visible and infrared portions of the spectrum. Duke-Elder summarized the work in this field very thoroughly in both volumes 1 and 4 of his textbook (1).

Most of the measurements to date were made using animal eyes (6), especially those of the rabbit (7), and only a few observations were made using human eyes.

Ludvigh and McCarthy in 1938 (2) reported measurements in the visible region on four human eyes of average age 62 years, and all having sarcoma of the choroid. Recently, Geeraets and co-workers (3) measured seven eyes, only two of which could be termed normal. Both of these papers were concerned with the measurement of the whole eye, rather than its components.

Because of the limited amount of data available on human eyes, and especially the lack of measurements on the individual ocular media, a measuring program was started of which this is the first report.

The purpose of this program was to determine the transmittance of the components of as many human eyes as available, so that a good statistical sampling of various ages could be obtained. The measurements were made in the ultraviolet, visible, and near infrared portions of the electromagnetic spectrum, covering the wavelength region from 0.22 to 2.8 microns. The components measured were the cornea, aqueous humor, lens, and vitreous humor.

When electromagnetic radiation passes through a medium, several things can happen to the radiation.

1. It can pass directly through the medium (called direct transmittance in this report).

2. It can be reflected by the medium.

3. It can be scattered by the medium. In this case, all the radiation passing to the medium also emerges, but in random directions.

4. It can be absorbed by the medium, in which case the energy is used either to ionize atoms, to heat the atoms, to cause them to fluoresce, etc.

All four of these phenomena take place when radiation passes into the media of the eye. Some of the energy passes directly through to form an image at or near the retinal surface. Some is scattered by the media, resulting in a general illumination within the eye (4,5). Some is absorbed. A small amount is reflected by surfaces separating media of one index of refraction from media of another index. Most of the reflection takes place at the anterior surface of the cornea, which is the boundary with the greatest change in index of refraction.

In this report, two sets of transmittance measurements of the individual components are described, one set being a measure of direct transmittance and the second set a measure of both the direct and a portion of the scattered. These two sets of data can be better defined by referring to figure 1. The aperture which limits the direct transmittance measurements is so arranged that it accepts only the rays of the direct beam and those within about one degree of the direct. The total transmittance reading is a measure of all the radiation emerging over a cone of about 170° centered about the optical axis. This measurement includes that radiation that is forward scattered. It does not include that portion of the radiation that is back scattered (that portion which is reflected back into the same hemisphere as the original incoming beam).

The eyes used were normal human eyes varying in age from 4 weeks to 75 years. The pathological condition of each eye is described in tables I through IX. The mounting and measuring techniques were first worked out using the eyes of rhesus monkeys. Monkey eyes were also used for preliminary observations of the effect of time after enucleation on the transmittance measurements.

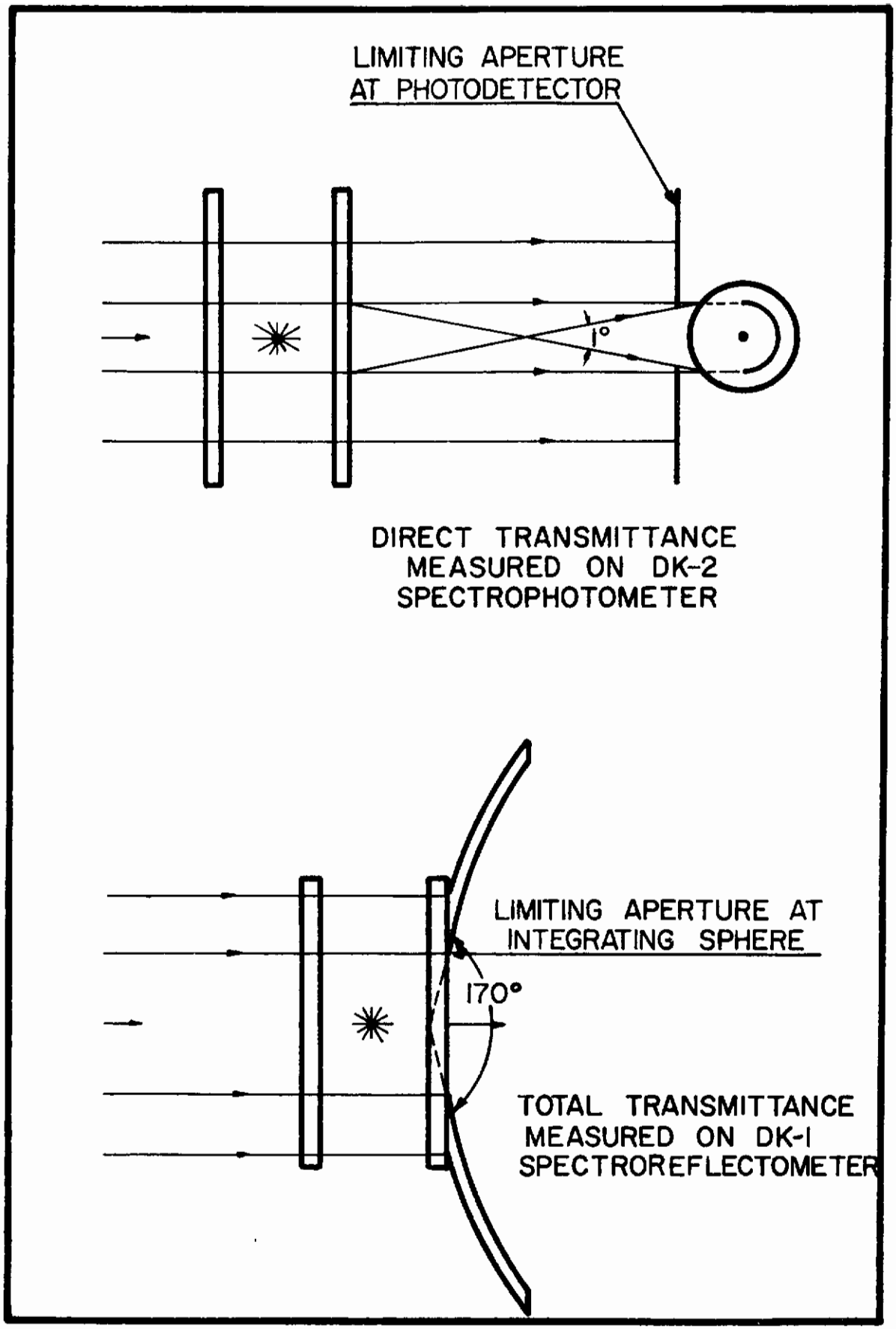

Figure 1. Method of measuring direct and total transmittance

SECTION II

PROCEDURE

The freshly enucleated eye was moved directly from the operating room to the operating room annex, where it was immediately divided into its components.

The aqueous humor was removed by means of a 26 gauge hypodermic needle and syringe. The needle was inserted into the anterior chamber through the corneoscleral limbus and the aqueous withdrawn. It was then transferred immediately to a modified short pathlength Beckman No. 92134 liquid cell. This cell was modified as shown in figure 2A by replacing the conventional 0.5 mm shim by one which is 1.5 mm thick, but has its cross-section reduced to a minimum so that the amount of solution that is required is only 0.12 ml. Except for the smaller infant eye, the volume of aqueous removed was always sufficient to fill the cell. The effect of reflection and absorption by the cell windows was eliminated by using a comparable window in the reference beam of the spectrophotometer. Next, the cornea was removed by cutting around the corneoscleral limbus with Aebli's corneal scissors. The cornea was washed briefly in saline solution and then placed between two cell windows of one millimeter thick fused quartz. This sandwich was then placed in a cell holder as shown in figure 2B, taking care to use only sufficient pressure on the windows to flatten the cornea without compressing it.

To obtain the lens the zonule was first broken by using the Kirby lens loop with a small amount of pressure on the sclera. Then, the same instrument was used to lift the lens and remove it.

The lens was mounted in a cell containing a supporting shim about 0.2 mm less in thickness than the axial thickness of the lens (see figure 2C). This permitted the lens to be flattened without breaking the lens capsule. The reason for flattening the lens surface was to remove as much of the optical lens effect as possible. However, a complete removal by this technique was not possible because of the varying index of refraction of the inner portions of the lens.

The vitreous was removed from the scleral shell by using a hypodermic syringe with a large opening. This was inserted through the area of the pars plana of the ciliary body. This posterior route for the removal of the vitreous was found to be the best way to avoid contaminating the vitreous with bits of pigment from the posterior iris surface. The spacers used in the vitreous cell (see figure 2D) had a diameter of 13 mm and a thickness of 12 mm so that the vitreous from a single eye was sufficient to fill a cell and still permit a measurement at a thickness approaching that of the same medium in the eye.

The transmittances of the individual components were measured using two spectrophotometers. A Beckman DK-2 Spectrophotometer was used to measure what was

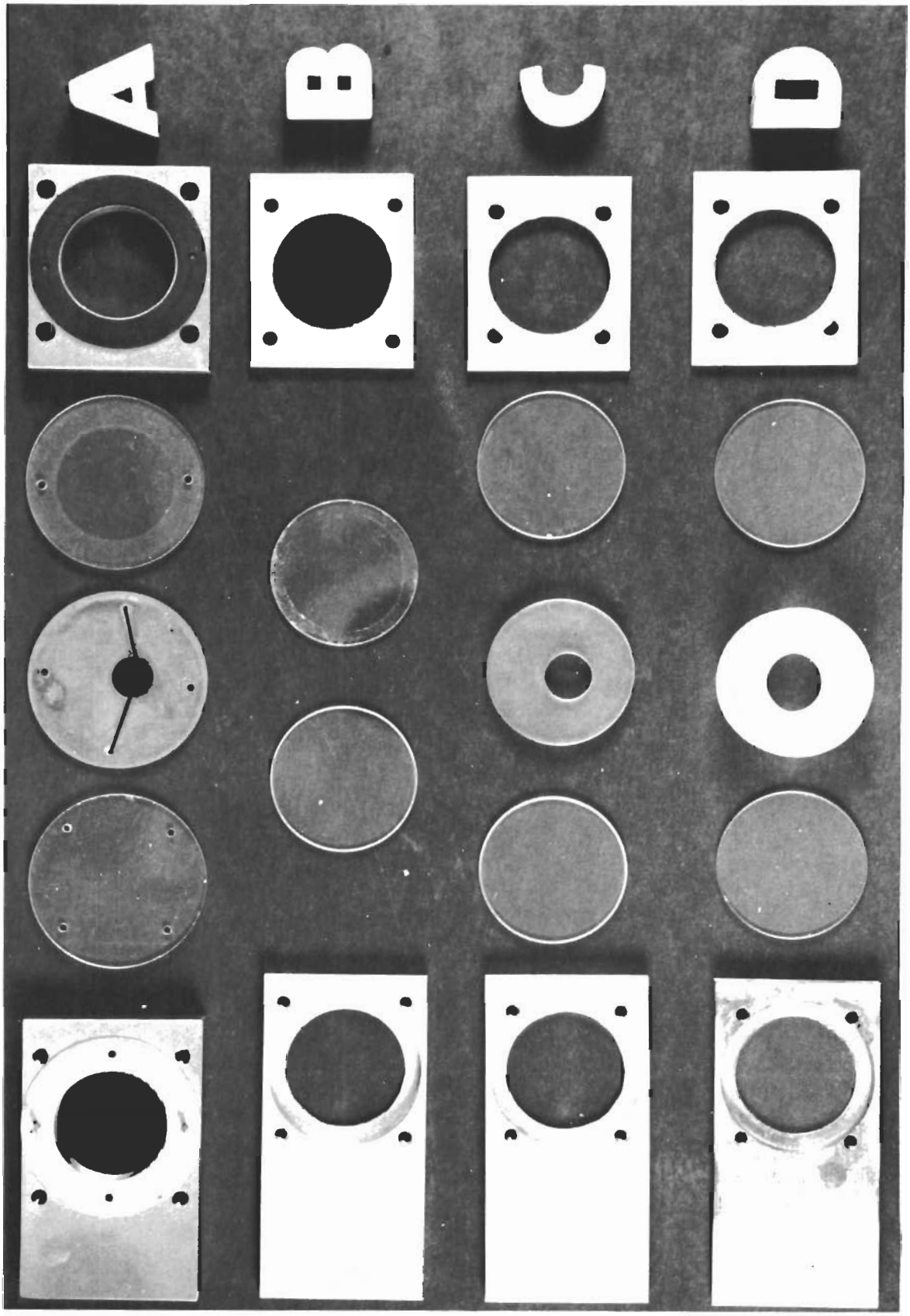

Figure 2. Cells used to contain the ocular media

previously defined as direct transmittance. This instrument is a double beam spectrophotometer, where the detecting phototube compares the intensity of the sample beam with that of the reference beam, with the ratio of the two intensities recorded as percent transmittance. Here, the cells containing the individual components were placed in the sample beam, and a compensating quartz plate was placed in the reference beam. As mentioned previously, this quartz plate cancelled out the effect of reflection and absorption by the quartz windows in the cells. Two diaphragms of equal diameter (6 mm) were placed in the two radiation beams (sample and reference) so that the incident beam of radiation was smaller than the smallest component to be measured.

The total transmittance measurements were made using a Beckman DK-1 Spectroreflectometer. This differs from the DK-2 instrument only in that the radiation from the monochrometer terminates in an integrating sphere, where it illuminates the sphere wall. The sphere is illuminated alternately by the reference beam and the sample beam. The detecting photocell measures the wall illumination of the sphere, rather than the direct beams. By placing the eye specimen holder immediately before the sample beam part of the sphere, all of the radiation transmitted by the sample, both direct and forward scattered, enters the sphere and contributes to the wall illumination, and therefore to the phototube signal. Once again, the phototube measures the ratio of the wall illumination resulting from the two beams, and converts this information into percent transmittance.

The preliminary work on this project, to test both the cells and the measuring techniques, was done using the eyes of rhesus monkeys immediately after death. These eyes, although only 20 mm in diameter as compared with 25 mm for the human eye, appear anatomically similar to the human eye. One of the first experiments performed with these eyes was to determine the effect on transmission of the length of time between enucleation and the measurements. Some measurements were started as soon as 15 minutes after the eye was removed. Repeat measurements extended the test to as much as four hours. The results showed only minor changes in transmission. They are discussed in the next section with a similar test on human eyes.

SECTION III

RESULTS

Nine human eyes, ranging in age from 4 weeks to 75 years have been measured. Figures 3,4,5, and 6 show the transmittances of the four components (aqueous, vitreous, lens, and cornea), giving the curve of a particular eye whose data are representative of those measured. The corresponding data for all the eyes are given in tabular form in tables I through IX. Each of the tables consists of two pages. The first page gives the pathological condition, experimental conditions, and the accuracy of measurement. The second page is a tabulation of the transmittance data.

a. Cornea

This component transmits radiation from 300 mμ in the ultraviolet to 2500 mμ in the infrared (see figures 3A and 3B). The transmittance increases rapidly from 300 mμ and reaches about 70% at 380 mμ. From 500 mμ to 1300 mμ, the transmittance is greater than 90%. Beyond 1300 mμ, the absorption bands of water appear (1430 and 1950 mμ) but the transmittance between the bands remains high. It should be noted that the greatest difference between the direct and total transmittance, which represents the amount scattered, is shown in the cornea measurements. Another point of interest in the transmittance curve of the cornea is the absorption band at 415 mμ. This compares with the position of the oxyhemoglobin band in the blood and may be due to presence of blood or another material either externally or internally. However, care was taken to wash the cornea briefly in saline before mounting it in the measuring cell. This band was not found in any of the corneas removed from monkey eyes. A further discussion of this absorption band appears in the section "Evaluation of Data."

b. Aqueous Humor

This component begins transmitting at 210 mμ in the ultraviolet and continues to 2400 mμ in the infrared (see figures 4A and 4B). In the ultraviolet, it has a strong absorption band at 265 mμ which some investigators have attributed to protein. Through the visible region, the aqueous has a high transmittance, slightly less than that of an equal thickness of water. Its transmittance in the infrared contains water absorption bands at 980, 1200, 1430 and 1950 mμ. Furthermore, its complete absorption beyond 2400 mμ is due to water in the aqueous. Only the direct transmittance is reported since no difference could be found between the direct and total transmittance measurements. Visual observation of the aqueous after removal from the anterior chamber also shows no evidence of light scattering. However, a

small amount of scattering (less than 2%) could be present and still escape detection by either method.

c. Lens

Transmittance through the lens extends from the ultraviolet to an upper limit at 1900 mμ in the infrared (see figures 5A and 5B). The ultraviolet and short wave length visible light transmittance varies considerably with the age of the eye. The lens of the young child begins transmitting at 300 mμ; however, an absorption band centered at 360 mμ reduces the transmittance to a very low value below 390 mμ. Because of this absorption band, the lens of a child has a transmitting band centered at 320 mμ of about 8% under 5 years and less than 0.1% by the age of 22 years. This same transmittance band was found in the lenses obtained from monkey eyes. The transmittance of the young eye begins increasing rapidly about 390 mμ, and reaches 90% at 450 mμ. The rate of increase is considerably slower for the older lens, e.g., a 63 year lens begins transmitting at 400 mμ but does not reach 90% transmittance until 540 mμ. In addition, the light scattering by the older lens is much higher. The direct transmittance of the young lens at 700 mμ is about 88%, while the 75 year lens measured only 41%. The lens continues to have a high transmittance to 1400 mμ in the infrared and demonstrates the usual water bands at 980, 1200, and 1430 mμ.

d. Vitreous Humor

The vitreous transmits from 300 mμ in the ultraviolet to 1400 mμ in the infrared (see figures 6A and 6B). Its ultraviolet transmittance increases rapidly to 80% at 350 mμ. It, like the cornea, has an absorption band at 415 mμ which could be due to contamination. The transmittance in the visible region is greater than 90%, but begins dropping rapidly in the infrared. The water bands at 980 and 1200 mμ are very strong, and no transmittance is noted beyond 1400 mμ. The direct transmittance is noted beyond 1400 mμ. The direct transmittance is about 10% less than the total transmittance through the entire transmitting region.

e. Transmittance of the Entire Eye

From the transmittance data of the representative components (figures 3-6), the successive transmittances as radiation passes through the eye were computed and are tabulated in table X.

In making this computation, the loss due to reflection of normally incident radiation at the interface between air and the cornea was included. Reflection losses between the other surfaces (e.g., aqueous-lens) was neglected as they total less than 0.3%. This is only a small fraction of the mean deviation.

The maximum transmittance is 81.4% at 650 mμ. In the closing months of the research covered by this report, a technique was developed in which a window was cut into the posterior of the eye to permit the measurement of the transmittance through the entire ocular media. No human eye was available for such measurements during the period of the contract. However, the technique was tested on the eyes of rhesus monkeys. The maximum transmittance obtained with one eye, corrected to the thickness of human eyes, was 86% at 650 mμ. This is about 5% higher than the calculations using our representative data (table X), but would be obtained using the highest values in our data.

SECTION IV

EVALUATION OF DATA

Several factors may affect the validity of the results, including the condition of the eyes, the length of time between enucleation and the measurements, and the accuracy of the instrumental methods and measuring techniques. As stated previously, only normal eyes were used in this study. The pathological condition of each eye is given in tables I through IX. The effect of time after enucleation was carefully studied on several monkey eyes and two human specimens. Contrary to the results of Boynton, et al., and DeMott, et al.,[4,5] only a little time effect was found. However, they attribute the change to a drying out of the specimen. In the work described here, the components were placed in sealed cells so that evaporation was negligible.

The only measurable change with time was noted in the transmittance of the aqueous humor in the vicinity of 230 millimicrons in the ultraviolet. There is an isolated transmission band at this wavelength (see figure 4A) separated from the longer transmitting wavelengths by an absorption band at 265 millimicrons. The amount of absorption at this latter wavelength decreases with time, resulting in an increase in the height and a slight shifting to longer wavelengths of the transmission band at 230 millimicrons.

For example, the aqueous of one monkey eye measured 1.9 percent at 232 millimicrons 30 minutes after enucleation. A subsequent measurement at 3 hours showed a transmittance of 4.2 percent at the peak, which shifted to 236 millimicrons. Likewise, the human eye described in table VI measured 1.1 percent at 235 millimicrons 40 minutes after enucleation and 1.9 percent at 240 millimicrons at 4 hours.

Through the remainder of the transmission spectrum any change with time was less than the reproducibility of our measuring technique. It should be noted that any transmission change in the first few minutes after enucleation would not have been detected in these experiments as the first readings were made at 15 minutes or more after enucleation.

The accuracy of the spectrophotometer readings depend on the instruments, the amount the radiation beams must be masked to match the size of the specimens, the cleanliness of the cell windows, and the ability to match the window in the reference beam with those in the cells. The instrumental deviations were determined by making repeat runs on glass samples using diaphragms of the sizes necessary to measure the eye components. From these measurements it was determined that the mean deviation for the direct transmittance of the cornea, aqueous, and vitreous was 1.2% before thickness corrections. That for the lens was 1.5%. The mean deviation

of the total transmittance data was 1.5% except for the lens. The mean deviation of the lens was 2% before thickness correction.

Some of the measurements were made at thicknesses less than found in the eye to have sufficient medium to fill the cell. This was true principally of the aqueous and vitreous humors. The lens was compressed slightly to diminish its optical power. The measured transmittances were converted to the transmittance for the average thickness of the component in the eye of a normal adult[1] by using Bouguer's Absorption Law. Both the measured and final thicknesses are given in tables I through IX. In converting the transmittances, the mean deviations are increased by a corresponding amount as indicated in the tables I through IX. It should be noted that some of the early measurements were made using thinner cells and, as a result, the mean deviation after correction is as high as 5%. This error was reduced by making new cells which permitted measurements to be made at a greater thickness. Another possible source of error is the accidental contamination of the components with blood not normally present. For example, the 415 mμ band of oxyhemoglobin can easily be detected in blood diluted to one part in 20,000 with a smaller effect in the 550 mμ region.

Much trouble was encountered in obtaining vitreous completely free of pigment from the iris posterior and in some of the eyes the large difference between the direct and total measurements can be attributed to the presence of a small amount of the pigment. In those cases where the contamination was apparent, it is noted in the data table.

SECTION V

CONCLUSIONS

In measuring the spectral transmittance of the ocular media of nine human eyes, much useful data were obtained. However, the number of specimens measured was not sufficient to obtain as good a statistical accuracy as one would like, especially to evaluate more accurately the effect of age on the light transmission of the eye.

To complete the program, the following steps appear necessary, and will be carried out by these investigators as human eyes are available:

1. Measure the separate media of more eyes, especially in the 10 to 40 year ages.

2. Measure the total transmittance of several whole eyes to see how the results compare with the calculated results of this report.

3. Measure the light scattered by the whole eye, over the posterior half using photocell techniques for the measurement.

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TABLE I

DATA ON HUMAN EYE, 4 WEEKS, FEMALE

March 31, 1961

Age: 4 weeks Sex: Female Case Number: 977417

Pathological Condition:

A normal eye removed because of an undifferentiated sarcoma growing in the orbit. The normal anterior chamber fluid, cornea, lens, and vitreous were removed immediately after enucleation.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Lens:	Measured at 2.3 mm thick Data converted to 3.0 mm thick
Aqueous Humor Vitreous Humor	There were not sufficient aqueous and vitreous humors for measurement

Elapsed time between enucleation and measurements.

Direct Transmittance:	45 to 90 minutes
Total Transmittance:	100 to 150 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Lens:	Direct Transmittance:	± 2.0% transmittance
	Total Transmittance:	± 2.8% transmittance

TABLE I (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220							
240							
260							
280	< 0.1						
300	2.5			0.0			
320	17.			3.5			
340	22.5	71.5		1.0			
360	28.	76.		0.0			
380	32.	79.5		0.0	0.0		
400	35.5	79.5		2.6	4.1		
420	35.5	77.		39.	45.5		
440	41.5	84.		62.	82.		
460	46.	91.		68.	90.		
480	48.5	92.		70.	92.		
500	51.	93.5		71.	94.		
550	54.5	93.5		74.	94.		
600	59.5	95.		77.5	94.		
650	61.5	95.5		79.5	95.5		
700	62.5	95.5		81.5	94.		
750	63.5			82.			
800	65.			82.			
850	66.5			82.			
900	68.			81.5			
950	67.			79.			
980	66.			76.			
1000	67.			77.			
1100	70.			80.5			
1200	66.5			63.			
1300	68.5			67.5			
1400	31.			1.5			
1445	9.0			0.0			
1550	18.			0.5			
1600	45.5			13.5			
1700	51.			16.			
1800	41.			9.			
1900	0.0			0.0			
1950	0.0						
2000	0.5						
2100	9.						
2200	16.5						
2300	10.						
2400	1.0						
2500	0.0						

TABLE II

DATA ON HUMAN EYE, 2 YEARS, MALE

November 23, 1960

Age: 2 years Sex: Male Case Number: 968923

Pathological Condition:

Undifferentiated sarcoma of unknown duration growing in the orbit. The eye was entirely normal. The anterior chamber fluid, cornea, lens, and vitreous were removed immediately after enucleation of the eye.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Aqueous Humor:	Measured at 1.5 mm thick Data converted to 3.0 mm thick
Lens:	Measured at 2.9 mm thick Corrected to 3.2 mm thick
Vitreous Humor:	Measured at 11.7 mm thick Corrected to 15. mm thick

Elapsed time between enucleation and measurements.

Direct Transmittance:	25 to 90 minutes
Total Transmittance:	100 to 150 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Aqueous:	Direct Transmittance:	± 2.2% transmittance
Lens:	Direct Transmittance:	± 1.8% transmittance
	Total Transmittance:	± 2.5% transmittance
Vitreous:	Direct Transmittance:	± 1.6% transmittance
	Total Transmittance:	± 1.8% transmittance

TABLE II (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220			0.3				
240			0.8				
260			0.0				
280	< 0.1	< 0.1	< 0.1			0.0	0.0
300	1.0	10.5	43.	0.0	0.0	1.0	1.4
320	13.	64.5	81.	4.	5.5	56.	71.
340	18.	73.	81.	0.0	0.0	58.5	72.
360	21.5	78.5	81.	0.0	0.0	61.	74.
380	25.5	81.	81.	0.0	0.0	61.	70.
400	28.5	83.0	78.	3.0	5.	51.	52.
420	30.5	84.	79.	45.	48.	45.5	52.5
440	34.5	88.	89.	80.	88.	65.	81.
460	37.	90.	89.	84.	93.	70.	87.
480	39.5	91.5	91.	85.	95.	71.5	89.
500	41.5	92.5	91.	86.5	95.5	72.5	91.
550	45.5	93.	92.	87.5	96.5	73.	88.5
600	49.5	94.	94.	88.	97.	73.5	95.5
650	53.	94.5	94.	88.5	97.	75.5	96.
700	56.	95.	95.	89.5	97.	76.5	95.5
750	58.5	95.5	96.	89.5	97.	76.5	93.5
800	60.5	96.	95.5	90.	97.5	76.5	93.5
850	62.5	96.	93.	90.	97.	75.5	91.
900	64.	96.	92.	90.5	96.	73.5	88.
950	65.	95.	86.	88.	90.	56.	66.
980	63.	93.	82.	86.	88.	40.5	49.5
1000	64.	94.5	83.	87.	89.5	43.5	56.
1100	67.5	96.	92.	90.	93.	65.	73.
1200	63.5	90.	68.	65.	70.	12.5	20.
1300	65.5	90.	67.5	64.	70.	13.	15.5
1400	36.	37.	< 0.1	3.	3.5	1.0	1.5
1445	10.	14.	0.0	0.0	0.0	0.0	0.0
1500	17.5	28.	< 0.1	0.0	0.0	0.0	0.0
1600	43.5		10.	8.5	10.		
1700	48.5		16.5	11.	14.		
1800	40.		5.5	5.5	6.5		
1900	0.5		0.0	0.0	0.0		
1950	0.0						
2000	0.5		0.0				
2100	9.		0.8				
2200	16.5		2.7				
2300	10.		1.0				
2400	1.5		< 0.1				
2500	0.0		0.0				

TABLE III

DATA ON HUMAN EYE, 4-1/2 YEARS, FEMALE

May 11, 1960

Age: 4-1/2 years Sex: Female Case Number: 837052

Pathological Condition:

Eye with primary optic nerve atrophy following removal of an optic nerve glioma. The cornea, aqueous, lens and vitreous were entirely normal and were removed immediately after the enucleation of the eye.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Lens:	Measured at 2.3 mm thick Data converted to 3.2 mm thick
Vitreous Humor:	Measured at 3.2 mm thick Data converted to 15 mm thick

Elapsed time between enucleation and measurements.

Direct Transmittance:	15 to 170 minutes
Total Transmittance:	70 to 140 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Aqueous:	Direct Transmittance:	± 4.5% transmittance
Lens:	Direct Transmittance:	± 2.1% transmittance
	Total Transmittance:	± 2.9% transmittance
Vitreous:	Direct Transmittance:	± 4.3% transmittance
	Total Transmittance:	± 5.0% transmittance

TABLE III (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220			0.0				
240			0.5				
260			0.1				0.0
280	< 0.1	< 0.1	0.4			0.0	< 0.1
300	2.0	8.5	22.	0.0	0.0	< 0.1	0.2
320	27.	57.	78.	6.5	9.0	11.5	51.
340	35.	65.	86.	1.7	2.	15.	57.
360	40.	68.	86.	0.4	0.6	17.5	63.
380	43.5	69.5	86.	1.0	1.5	20.5	60.
400	46.	65.	81.	12.5	14.	19.5	54.
420	46.	63.	81.	56.	64.	19.5	57.
440	53.5	77.	93.	71.	90.	24.5	65.
460	57.5	85.5	94.	74.	93.	26.5	67.5
480	60.5	88.	94.	76.	93.5	28.	71.
500	62.5	89.5	94.	78.	94.	30.	72.5
550	66.	92.	95.	72.	95.	33.5	74.
600	71.	93.	95.	85.5	95.	35.5	76.
650	73.	94.	96.	87.	95.5	39.5	78.
700	75.5	93.	96.	88.	96.	43.0	80.
750	77.5	93.5	96.5	88.5	96.	45.	80.5
800	79.	94.	96.5	89.	96.	46.5	80.
850	80.5	95.		89.5	96.	47.5	78.5
900	81.5	95.		90.	95.5	48.5	76.
950	81.	95.		85.	90.	42.	49.
980	80.5	93.5		79.	82.	30.	44.
1000	81.5	94.		81.	84.	33.	49.
1100	85.	94.5		86.	88.	49.	63.
1200	80.	91.5		64.	67.	11.	16.
1300	82.	90.		67.	70.	14.5	23.5
1400	40.	59.		1.7	4.	< 0.1	< 0.1
1445	19.0	24.5		0.0	0.0	0.0	0.0
1500	27.5	33.		0.2	0.5	0.0	0.0
1600	58.0	68.		9.4	14.5		
1700	63.5	71.		11.5	15.5		
1800	55.5	61.5		5.5	6.3		
1900	3.	5.		0.0	0.0		
1950	0.0	0.5		0.0			
2000	1.	3.		0.0	0.0		
2100	17.	22.					
2200	26.5	31.					
2300	18.	21.					
2400	5.5	8.					
2500	0.0	0.5					

TABLE IV

DATA ON HUMAN EYE, 23 YEARS, FEMALE

September 23, 1960

Age: 23 years Sex: Female Case Number: 899014

Pathological Condition:

A normal eye with an undifferentiated sarcoma growing around and behind it. The eye had to be removed with the tumor. During surgery the eye was perforated and most of the vitreous was lost.

Cornea, aqueous, and lens of this normal eye were removed immediately following the enucleation.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Aqueous Humor:	Measured at 1.5 mm thick Data converted to 3.0 mm thick
Lens:	Measured at 2.3 mm thick Data converted to 3.2 mm thick
Vitreous Humor:	Not measured.

Elapsed time between enucleation and measurements.

Direct Transmittance: 35 to 150 minutes
Total Transmittance: 160 to 180 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Aqueous:	Direct Transmittance:	± 2.2% transmittance
Lens:	Direct Transmittance:	± 2.1% transmittance
	Total Transmittance:	± Not measured

TABLE IV (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220							
240							
260							
280	< 0.1	< 0.1					
300	1.0	6.5					
320	16.	41.					
340	23.	50.	17.				
360	31.	58.	17.5				
380	37.	66.	20.	0.0			
400	40.	69.	18.5	5.5			
420	41.	68.	20.5	33.			
440	45.	74.	30.	58.5			
460	51.5	81.	32.5	68.			
480	54.	83.	35.	72.5			
500	55.5	84.	37.	75.			
550	59.	85.	41.	79.5			
600	62.	86.5	45.	82.5			
650	64.	87.5	49.	84.5			
700	66.5	87.1	53.5	86.			
750	68.5	87.	55.	87.			
800	70.5	87.	58.	88.5			
850	71.5	87.	59.5	89.			
900	73.	87.	61.	89.			
950	73.	87.	59.	87.			
980	71.	86.	50.5	83.			
1000	72.	87.	52.	84.			
1100	74.5	86.5	55.	89.			
1200	70.	82.5	39.	71.			
1300	71.5	82.5	41.	73.5			
1400	35.	36.5	0.4	5.5			
1445	11.	18.	0.0	0.0			
1500	20.5	30.5	< 0.1	1.0			
1600	49.	61.	5.	18.5			
1700	53.	62.	9.	22.			
1800	43.5	53.	3.	13.			
1900	0.5	4.1	0.	0.0			
1950	0.0	0.0					
2000	0.5	2.0	0.				
2100	11.	16.	< 0.1				
2200	18.5	24.5	0.3				
2300	11.	17.	< 0.1				
2400	1.5	4.5	0.0				
2500	0.0	0.0					

TABLE V

DATA ON HUMAN EYE, 42 YEARS, MALE

November 30, 1960

Age: 42 years Sex: Male Case Number: 968450

Pathological Condition:

A normal eye which had to be removed because of carcinoma extending from the ethmoidal sinus area into the orbit.

Anterior chamber fluid, cornea, lens, and vitreous of this normal eye were removed immediately after enucleation.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Aqueous Humor:	Measured at 1.6 mm thick Data converted to 3.0 mm thick
Lens:	Measured and reported at 3.2 mm thick
Vitreous Humor:	Measured at 11.7 mm thick Data converted to 15 mm thick

Elapsed time between enucleation and measurements

Direct Transmittance:	130 to 210 minutes
Total Transmittance:	60 to 120 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Aqueous:	Direct Transmittance:	± 2.2% transmittance
Lens:	Direct Transmittance:	± 1.5% transmittance
	Total Transmittance:	± 2.0% transmittance
Vitreous:	Direct Transmittance:	± 1.6% transmittance
	Total Transmittance:	± 1.8% transmittance

TABLE V (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220			0.0				
240			0.3				
260			0.0				
280	< 0.1		0.1				0.0
300	1.0	8.2	17.			0.0	1.0
320	10.	48.5	73.5			60.	74.
340	14.	61.5	78.			64.	80.
360	18.5	69.	81.5			66.5	81.
380	22.	75.	84.5	0.0	0.0	67.	82.
400	25.	78.	86.	2.5	5.5	62.	79.
420	26.	78.	88.	32.	42.	56.	80.
440	29.5	86.	89.5	50.	70.5	72.	93.
460	33.5	90.	91.	56.5	78.	75.5	95.
480	37.	91.	92.5	62.	85.	76.5	96.
500	40.	91.5	94.	66.5	90.	77.5	96.
550	42.5	92.5	96.	72.5	93.	77.5	96.
600	48.5	94.	96.	77.	95.	80.	97.
650	52.	95.	95.5	79.5	95.5	80.5	97.
700	54.5	95.5	95.	81.	96.	81.	97.
750	56.5		95.	83.		81.5	
800	58.5		94.5	84.5		81.	
850	60.		94.5	85.		78.5	
900	62.		94.	85.5		75.5	
950	61.		87.	78.		60.	
980	59.		77.5	75.		41.	
1000	60.		80.	76.		44.5	
1100	63.		85.5	81.		65.	
1200	60.		60.5	57.5		12.5	
1300	62.		62.5	61.		12.5	
1400	27.		0.6	1.5		0.0	
1445	9.		0.0	0.0			
1500	17.		< 0.1	0.0			
1600	41.		8.7	8.0			
1700	46.		15.	10.			
1800	37.		50.	4.5			
1900	0.5		0.0	0.0			
1950	0.0						
2000	0.0		0.0				
2100	9.		< 0.1				
2200	15.5		0.1				
2300	9.		< 0.1				
2400	1.5		0.0				
2500	0.0						

TABLE VI

DATA ON HUMAN EYE, 51 YEARS, FEMALE

September 30, 1960

Age: 51 years Sex: Female Case Number: 474809

Pathological Condition:

7 months history of malignant melanoma of the choroid—round cell type. Very little retinal detachment is seen around the tumor. No tumor extensions out of the eye. Lens and cornea are perfectly normal and were removed immediately after the enucleation of the eye.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Aqueous Humor:	Measured at 1.5 mm thick Data converted to 3.0 mm thick
Lens:	Measured at 2.3 mm thick Data converted to 3.2 mm thick
Vitreous Humor:	Measured at 11.7 mm thick Visible pigment contamination

Elapsed time between enucleation and measurements.

Direct Transmittance:	15 to 95 minutes
Total Transmittance:	105 to 160 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Aqueous:	Direct Transmittance:	± 2.2% transmittance
Lens:	Direct Transmittance:	± 2.1% transmittance
	Total Transmittance:	± 2.9% transmittance
Vitreous:	Direct Transmittance:	± 1.6% transmittance
	Total Transmittance:	± 1.8% transmittance

TABLE VI (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220			0.0				
240			1.4				
260			2.2				
280	< 0.1	< 0.1	3.2				
300	0.5	9.5	28.			0.0	0.0
320	12.	42.	46.			5.5	22.4
340	18.	53.	47.5			7.4	33.5
360	24.	61.	48.			8.9	40.
380	29.	69.5	48.5	0.0	0.0	10.	46.
400	32.5	73.5	46.	0.2	0.4	9.3	36.5
420	33.0	72.	47.5	8.5	10.5	8.7	27.5
440	38.	81.5	52.	22.	33.5	9.3	45.
460	42.	87.5	53.	33.	44.5	10.	53.5
480	44.5	88.5	53.5	47.5	56.	10.5	60.
500	47.	89.5	53.5	62.5	70.5	11.5	67.5
550	51.	91.	54.5	76.5	89.	13.	73.
600	54.5	94.	57.	81.5	94.5	14.5	81.5
650	57.	94.5	57.5	84.	96.5	15.5	85.5
700	59.	95.	59.	86.	96.5	17.	85.5
750	60.	95.5	59.	86.5	97.	18.5	85.5
800	62.	95.5	59.	87.5	97.	20.5	85.
850	63.	95.5	59.5	88.	96.5	21.5	83.5
900	64.	95.5	59.5	88.	96.	23.	81.5
950	64.	94.5	59.	84.5	90.5	19.	54.
980	63.	93.5	52.	80.5	86.5	14.	48.
1000	64.	94.	53.5	81.	89.	16.	53.
1100	67.	96.	59.	86.	93.	26.	69.
1200	63.	90.	42.5	65.	72.	6.2	16.
1300	64.	89.5	42.5	68.	72.5	7.7	15.
1400	34.	42.	0.5	30.	5.5	0.0	0.0
1445	10.	17.5	< 0.1	0.0	0.0		
1500	17.5	27.	< 0.1	0.0	0.0		
1600	43.	63.5	6.5	11.	13.		
1700	47.5	67.	10.	14.	16.		
1800	40.	55.	3.5	7.5	7.5		
1900	0.5	1.5	0.0	0.0	0.0		
1950	0.0	0.0	0.0				
2000	0.5	0.5	0.0				
2100	9.5	16.	< 0.1				
2200	17.	25.	0.2				
2300	10.	15.	< 0.1				
2400	1.5	4.	0.				
2500	0.0	0.0					

TABLE VII

DATA ON HUMAN EYE, 53 YEARS, FEMALE

March 7, 1960

Age: 53 years Sex: Female Case Number: 940239

Pathological Condition:

Malignant melanoma of the choroid—spindle B cell type—without extensions of the tumor out of the eye. The tumor had developed within the last half year. The retina was partially detached.

The cornea, aqueous, lens and vitreous appeared normal and were removed immediately after enucleation of the eye.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Aqueous Humor:	Measured at 0.42 mm thick Data converted to 3.0 mm thick
Lens:	Measured at 2.4 mm thick Data converted to 3.2 mm thick
Vitreous Humor:	Measured at 3.2 mm thick Data converted to 15 mm thick

Elapsed time between enucleation and measurements.

Direct Transmittance:	35 to 135 minutes
Total Transmittance:	160 to 220 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
	Total Transmittance:	± 1.5% transmittance
Aqueous:	Direct Transmittance:	± 5 % transmittance
Lens:	Direct Transmittance:	± 2.1% transmittance
	Total Transmittance:	No measurements due to lack of proper cell holder
Vitreous:	Direct Transmittance:	± 4 % transmittance
	Total Transmittance:	± 4 % transmittance

TABLE VII (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220			< 0.1				
240			0.8				
260	0.0	0.0	< 0.1				
280	< 0.1	< 0.1	0.1			0.0	0.0
300	1.5	5.0	29.5			< 0.1	0.2
320	18.	43.	84.			31.	50.5
340	24.	53.	86.5			39.5	61.
360	28.5	61.	88.5			41.5	68.
380	33.	65.5	90.	0.0		47.	69.
400	35.5	68.	87.	3.6		47.	67.
420	35.5	66.	87.	23.		48.	69.
440	40.	75.	90.	43.		50.5	75.
460	46.	84.	91.	53.		52.	79.
480	49.	86.5	93.	60.5		54.	82.
500	51.	88.	94.	68.5		56.5	85.
550	55.	90.5	95.	78.		60.	87.
600	59.	94.	96.5	82.5		61.	89.
650	62.	95.	96.	86.		63.	90.
700	64.	95.	95.5	88.		66.5	91.
750	65.5	95.	95.	89.		67.	91.
800	67.	95.	95.	89.5		67.	91.
850	68.5	95.	94.	89.5		66.5	88.5
900	69.5	95.	92.	88.		60.	85.
950	69.5	95.	90.5	85.		49.	54.5
980	66.5	94.	89.	80.		29.	47.
1000	67.5	94.5	90.	82.		32.	50.5
1100	70.	95.5	97.	87.		49.	69.
1200	67.5	91.	64.5	68.		10.	14.
1300	68.5	91.	66.	71.5		10.	14.
1400	40.	45.5	1.5	6.		0.0	0.0
1445	16.5	24.0	< 0.1	0.0		0.0	0.0
1500	25.	37.0	0.2	0.5		0.0	0.0
1600	50.5	68.	10.5	16.		< 0.1	< 0.1
1700	54.5	70.5	17.5	20.		< 0.1	< 0.1
1800	47.5	61.5	6.	12.		< 0.1	< 0.1
1900	0.0	3.	0.0	0.0		0.0	0.0
1950	0.0	1.5	0.0				
2000	1.0	3.5	< 0.1				
2100	14.	21.	< 0.1				
2200	23.	30.5	0.2				
2300	16.	21.5	< 0.1				
2400	4.	8.	< 0.1				
2500	0.0	0.5	0.0				

TABLE VIII

DATA ON HUMAN EYE, 63 YEARS, FEMALE

May 11, 1960

Age: 63 years Sex: Female Case Number: 963117

Pathological Condition:

Malignant melanoma of the choroid—epithelioid cell type—without extensions out of the eye of unknown duration. The retina was totally detached.

The lens appeared normal and was removed immediately after the enucleation of the eye.

Experimental Conditions:

Only the lens of this eye was measured, as it was enucleated 1-1/2 hours after the eye described in table III, and cells were not available for measuring the other components.

Lens: Measured at 2.9 mm thick
Data converted to 3.2 mm thick

Elapsed time between enucleation and measurements

Direct Transmittance: 75 minutes
Total Transmittance: 35 minutes

Accuracy of Measurements:

Lens: Direct Transmittance: ± 1.8% transmittance
Total Transmittance: ± 2.5% transmittance

TABLE VIII (Concluded)

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
200							
220							
240							
260							
280							
300							
320							
340							
360							
380							
400				0.3	0.4		
420				12.4	20.		
440				37.	53.5		
460				48.5	67.5		
480				56.	76.		
500				62.	85.		
550				71.	91.5		
600				76.	94.5		
650				78.	95.5		
700				80.5	96.		
750				81.	96.5		
800				82.	97.		
850				82.	96.5		
900				82.5	96.		
950				79.	87.		
980				77.	88.		
1000					89.		
1100					91.5		
1200					69.5		
1300					74.		
1400					2.7		
1445					0.0		
1500					0.0		
1600							
1700							
1800							
1900							
1950							
2000							
2100							
2200							
2300							
2400							
2500							

TABLE IX

DATA ON HUMAN EYE, 75 YEARS, FEMALE

April 18, 1960

Age: 75 years Sex: Female Case Number: 951219

Pathological Condition:

Malignant melanoma of the choroid—epithelioid cell type—without extensions out of the eye. The tumor had developed in the eye within the last three months. The retina was partially detached.

The cornea, lens and vitreous appeared normal and were removed from the eye immediately following the enucleation of the eye.

Experimental Conditions:

Cornea:	Measured and reported in its entire thickness
Aqueous Humor:	Measured at 0.4 mm thick Data converted to 3.0 mm thick
Lens:	Measured at 2.3 mm thick Data converted to 3.2 mm thick
Vitreous Humor:	Measured at 3.2 mm thick Data converted to 15 mm thick Contained visible pigment contamination

Elapsed time between enucleation and measurements

Direct Transmittance: 70 to 160 minutes

Accuracy of Measurements:

Cornea:	Direct Transmittance:	± 1.2% transmittance
Aqueous:	Direct Transmittance:	± 4.5% transmittance
Lens:	Direct Transmittance:	± 2.1% transmittance
Vitreous:	Direct Transmittance:	± 4.3% transmittance

TABLE IX (Concluded)

Wavelength (millimicrons)	Percent Transmittance					
	Cornea		Aqueous,	Lens		Vitreous
	Direct	Total	Direct	Direct	Total	Direct Total
200						
220			0.0			
240			0.5			
260			0.0			
280	< 0.1		0.1			0.0
300	0.5		21.			< 0.1
320	11.		78.5			25.
340	16.		80.			32.5
360	21.		80.5			37.5
380	25.		81.	0.0		38.5
400	27.		81.	2.		35.5
420	25.5		80.	8.		31.5
440	30.5		80.5	13.5		40.5
460	38.		84.	17.5		43.
480	40.5		84.5	21.5		44.
500	42.5		85.	25.5		46.
550	46.		86.	32.		47.
600	50.5		87.	36.5		48.5
650	53.5		87.	39.		50.
700	56.		87.	41.		51.
750	58.		87.	42.5		52.5
800	60.		90.	43.5		54.
850	61.5		93.	45.		54.
900	63.5		95.	46.5		54.
950	63.		86.5	47.		46.5
980	62.5		85.	45.		31.
1000	64.		86.	47.		33.5
1100	66.		94.	52.		51.
1200	63.5		64.5	41.5		11.5
1300	65.5		66.	44.		13.
1400	35.		3.	4.		0.0
1445	12.5		< 0.1	0.5		0.0
1500	20.5		0.1	0.0		0.0
1600	46.5		8.5	7.		< 0.1
1700	51.		17.5	16.		< 0.1
1800	42.		5.5	9.		< 0.1
1900	0.5		0.0	1.0		0.0
1950	0.0		0.0	0.0		
2000	0.5		< 0.1	0.0		
2100	11.		< 0.1			
2200	19.		0.3			
2300	12.		< 0.1			
2400	2.0		0.0			
2500	0.0					

TABLE X

CALCULATED PERCENT TRANSMITTANCE THROUGH THE WHOLE EYE OF A HUMAN

(Percent of that radiation incident on the eye reaching the various surfaces)

Wavelength (millimicrons)	Percent Transmittance							
	Aqueous		Lens		Vitreous		Retina	
	Direct	Total	Direct	Total	Direct	Total	Direct	Total
200								
220								
240								
260								
280	< 0.1	< 0.1	0.0	0.0				
300	2.0	8.3	0.3	1.4	0.0	0.0	0.0	0.0
320	26.3	55.5	19.3	40.7	1.3	3.7	0.8	2.7
340	34.1	63.3	26.6	49.3	0.5	1.0	0.3	0.8
360	39.	66.2	31.8	54.	0.1	.3	< 0.1	0.2
380	42.3	67.7	35.7	57.2	0.4	.9	0.3	0.7
400	44.8	62.3	38.5	53.6	4.8	7.5	3.	5.9
420	44.8	61.3	39.4	53.9	22.1	34.5	12.4	27.6
440	52.1	75.	46.6	67.1	33.1	60.3	23.8	56.1
460	56.	83.3	50.9	75.8	37.7	70.5	28.4	67.
480	58.9	85.7	54.5	79.2	41.4	74.1	31.6	71.5
500	60.8	87.2	57.2	82.	44.6	77.1	34.6	74.
550	64.3	89.6	61.7	86.	44.4	81.7	34.4	78.5
600	69.2	90.6	66.4	87.	56.8	82.7	45.4	80.2
650	71.1	91.5	67.9	87.4	59.1	83.9	47.6	81.4
700	73.5	90.6	69.8	86.	61.4	82.6	49.7	80.1
750	75.5	91.1	71.7	86.5	63.4	83.	51.7	77.6
800	76.9	91.5	72.7	86.4	64.7	82.9	52.3	77.5
850	78.4	92.5	74.1	87.4	66.3	83.8	52.	76.3
900	79.4	92.5	74.7	87.	66.8	83.1	50.3	73.1
950	78.9	92.5	68.6	80.5	58.3	72.5	35.	47.8
1000	79.4	91.5	63.5	73.2	51.4	61.5	22.9	34.4
1100	82.8	92.1	70.8	78.8	60.8	69.3	39.5	50.6
1200	77.9	89.	47.1	53.8	30.2	36.0	3.8	7.2
1300	79.8	87.7	49.8	54.8	33.4	38.4	4.2	6.
1400	38.9	57.4	0.2	0.3	0.0	0.0	0.0	0.0
1500	26.8	32.1	0.0	0.0	0.0	0.0		
1600	56.5	66.2	4.9	5.8	0.5	0.8		
1700	61.8	69.2	9.3	10.4	1.1	1.6		
1800	53.5	59.9	2.7	3.0	0.1	0.2		
1900	2.9	4.9	0.0	0.0	0.0	0.0		
2000	1.0	2.9	0.0	0.0				
2100	16.6	21.4	0.0	0.0				
2200	25.8	30.2	< 0.1	< 0.1				
2300	17.5	20.4	0.0	0.0				
2400	5.4	7.8						
2500	0.0	0.5						

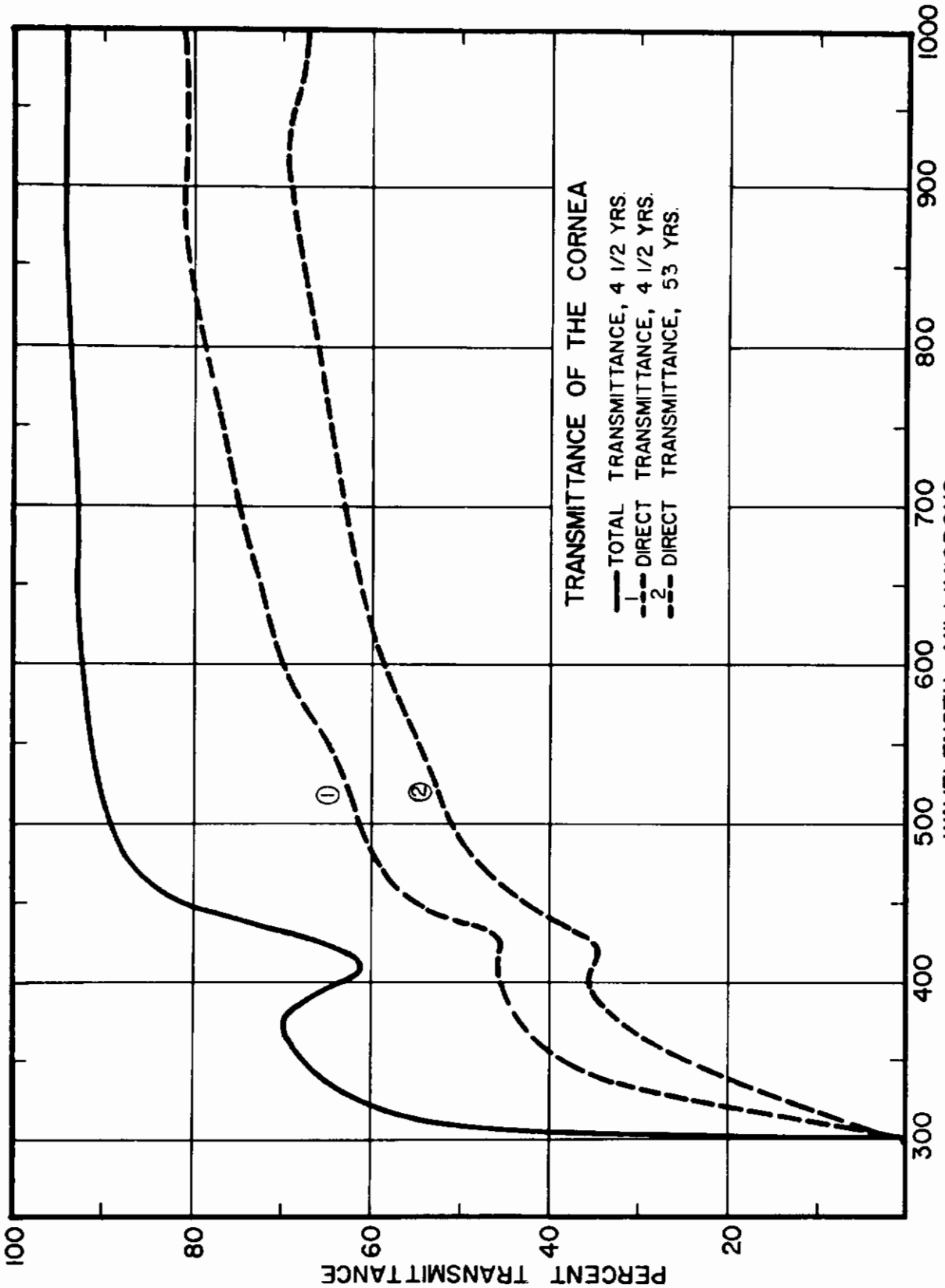

Figure 3A. Transmittance of the cornea, 250-1000 millimicrons.

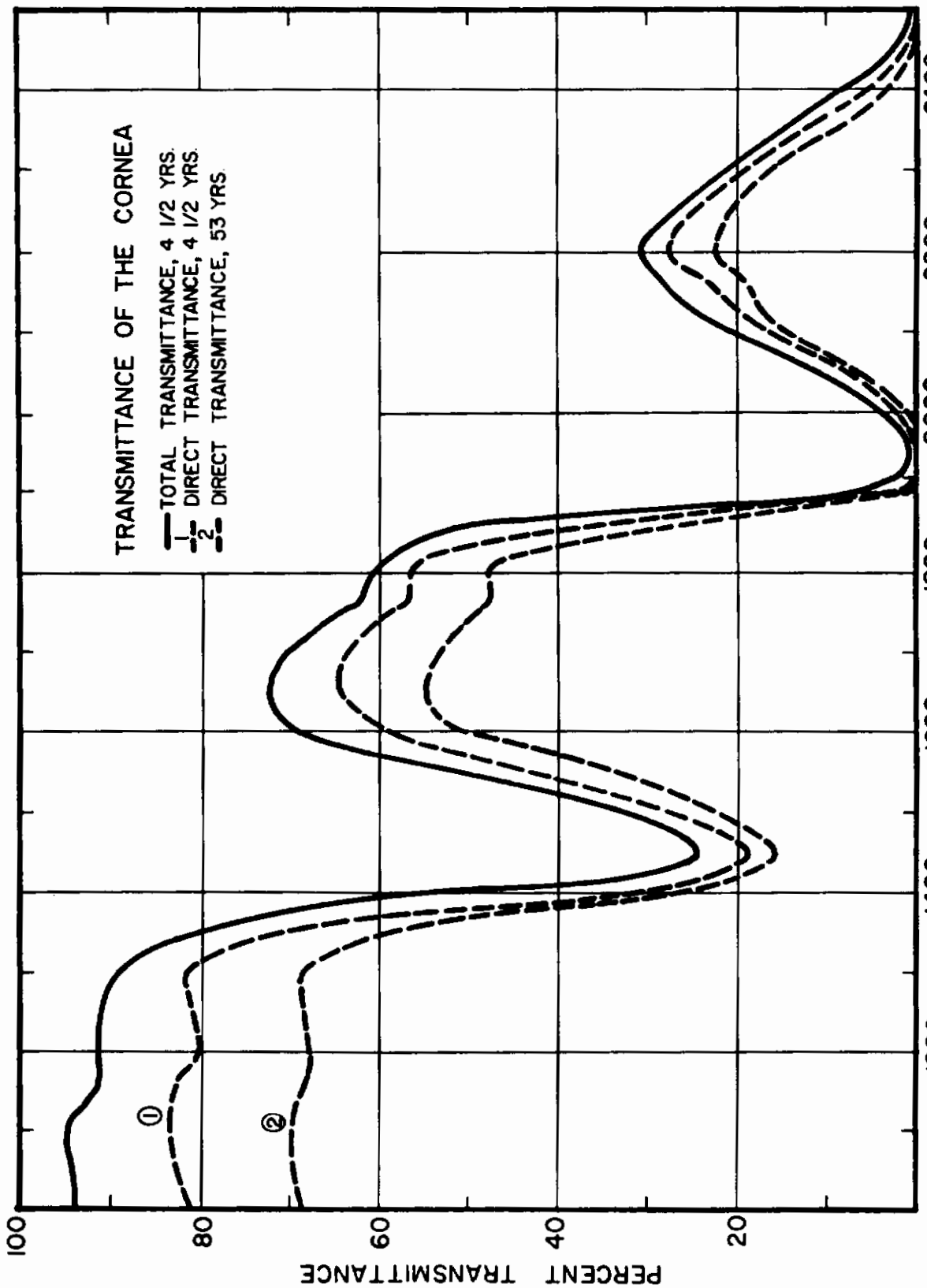

Figure 3B. Transmittance of the cornea, 1000-2500 millimicrons.

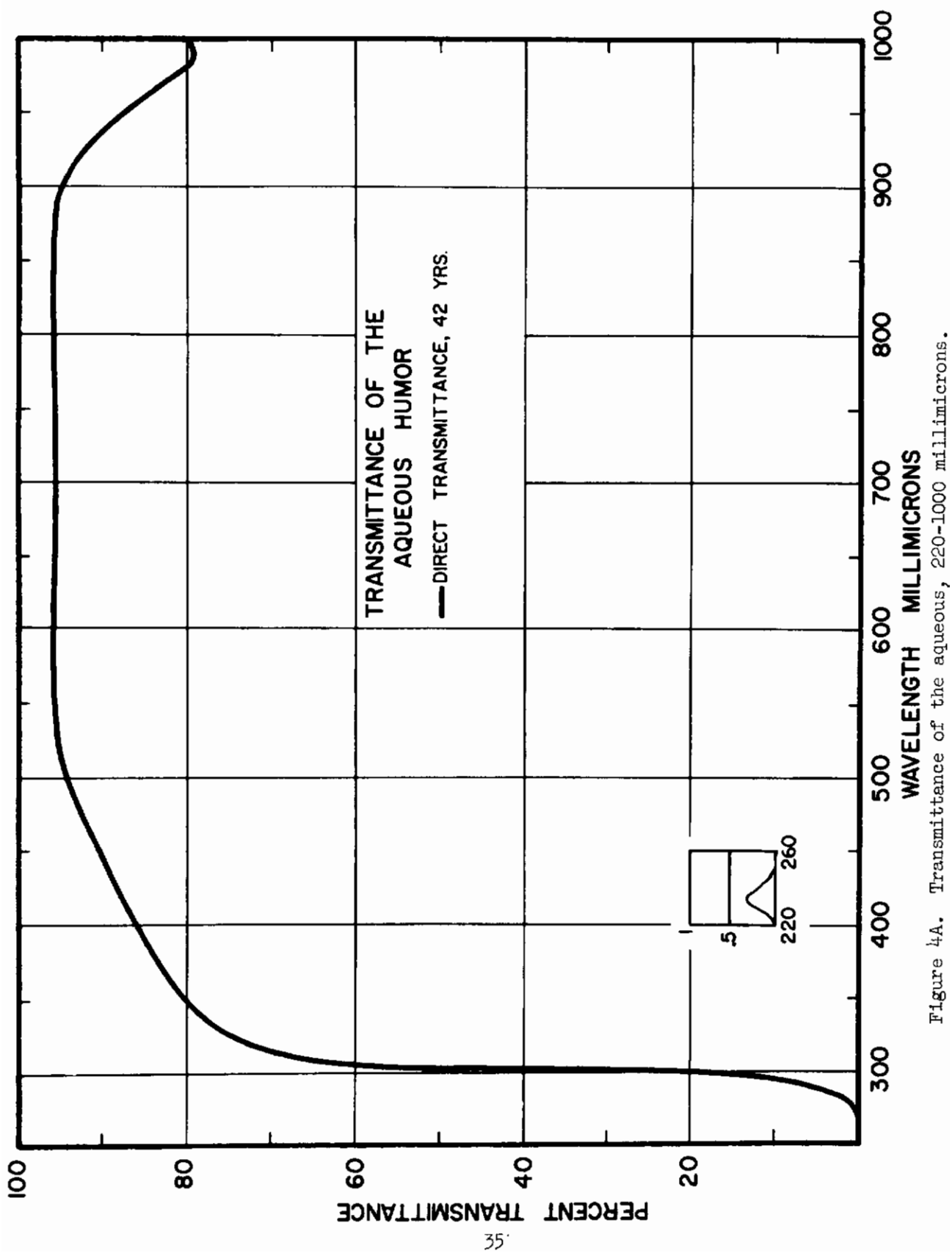

Figure 4A. Transmittance of the aqueous, 220-1000 millimicrons.

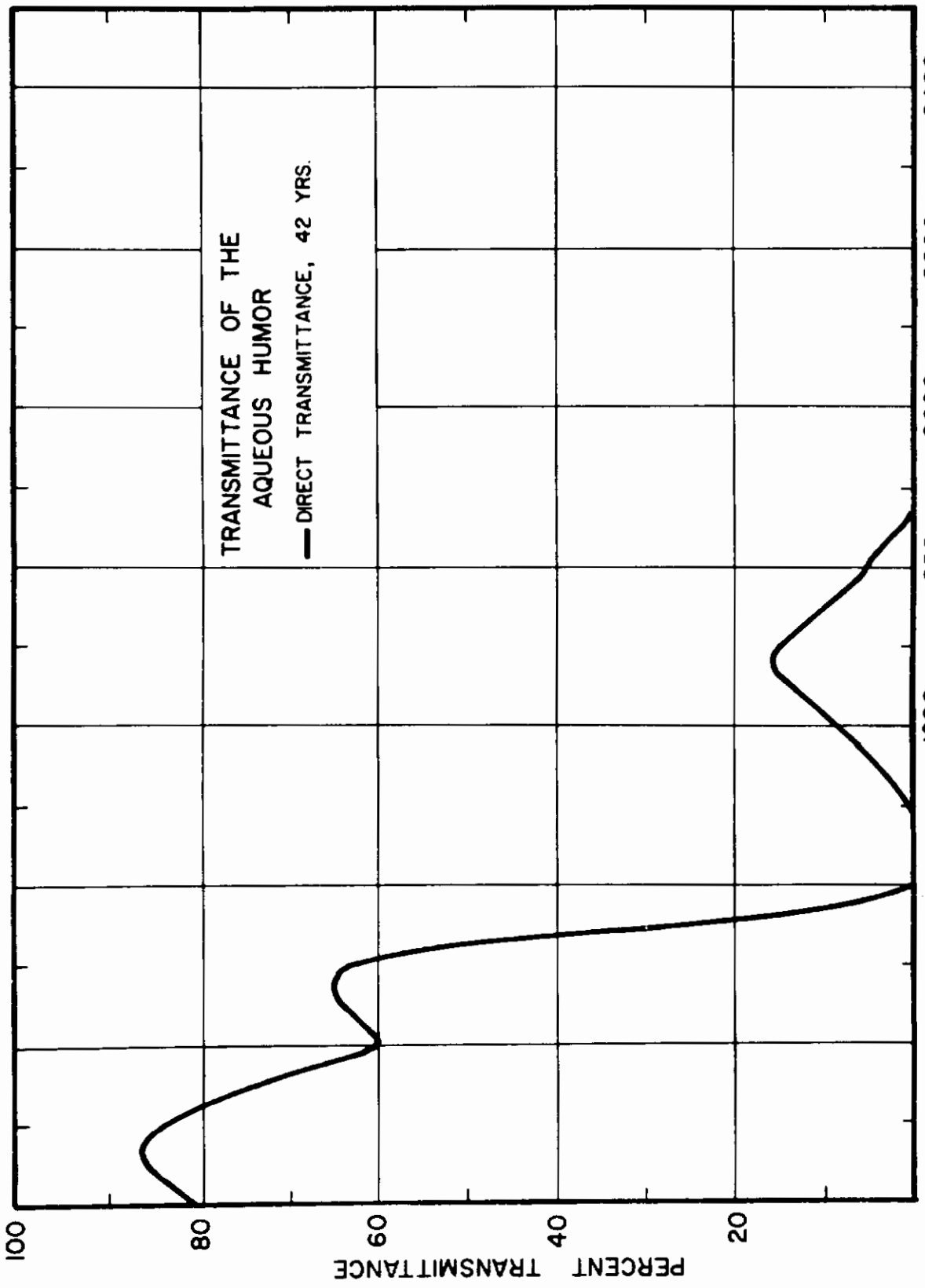

Figure 4B. Transmittance of the aqueous, 1000-2500 millimicrons.

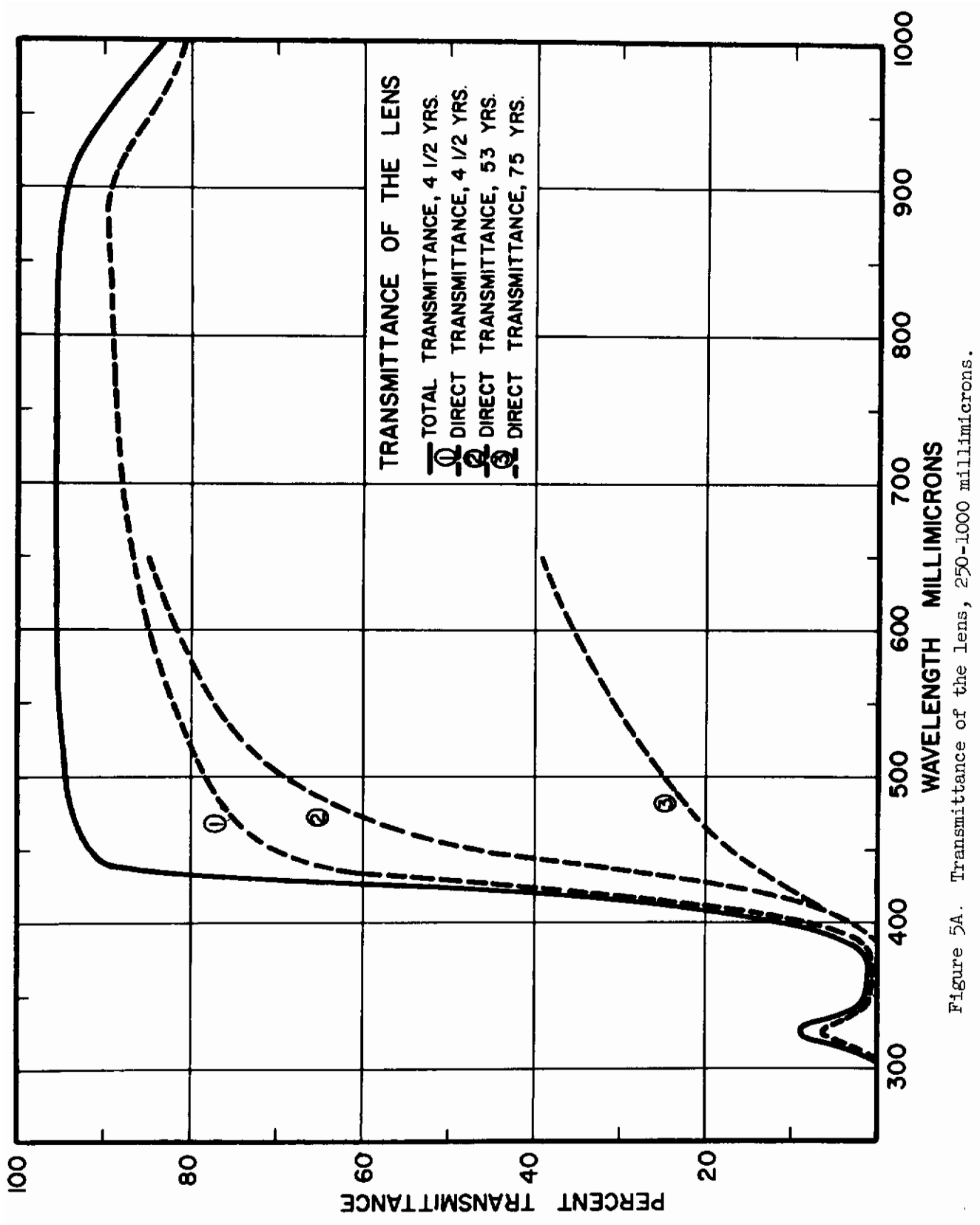

Figure 5A. Transmittance of the lens, 250-1000 millimicrons.

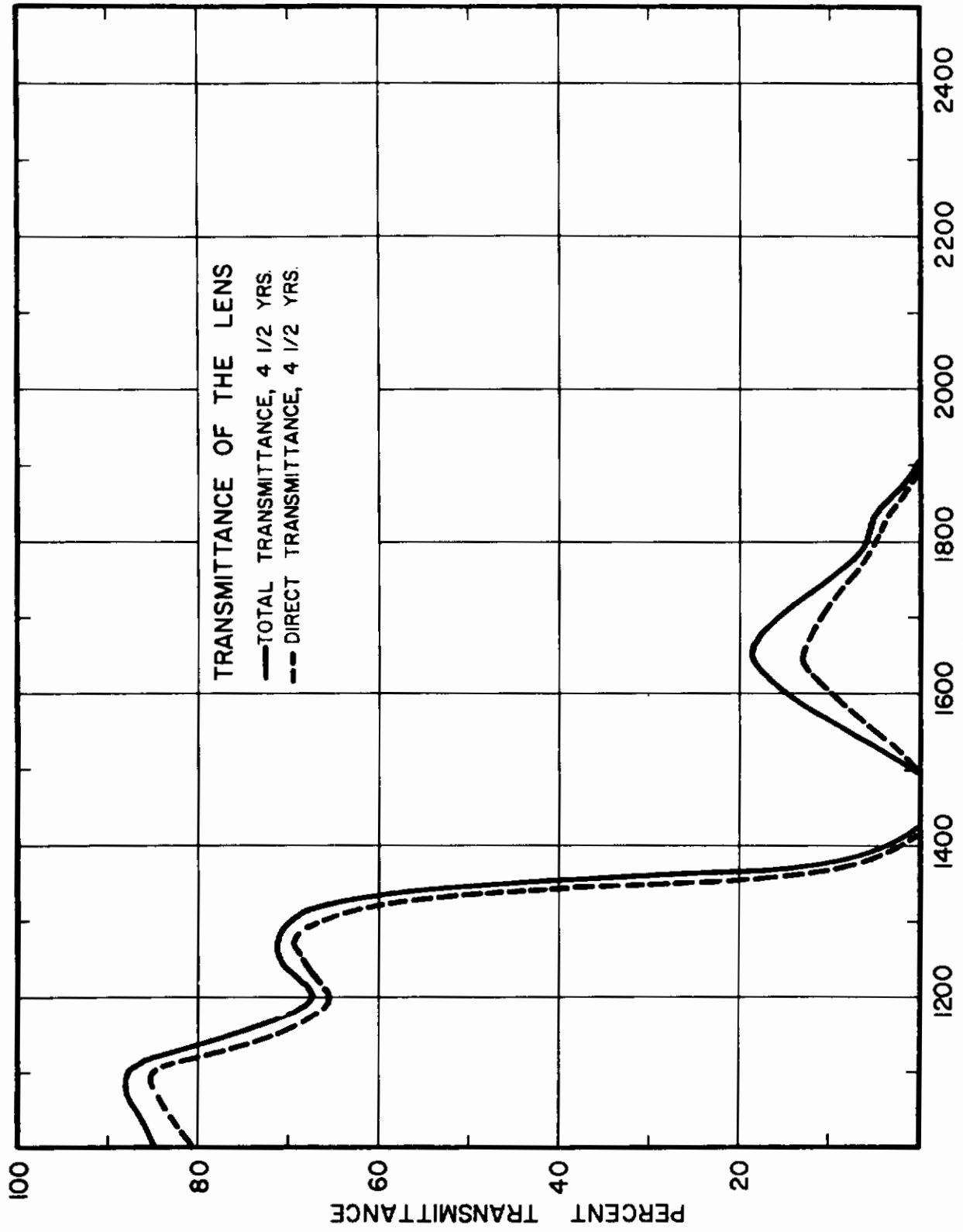

Figure 5B. Transmittance of the lens, 1000-2500 millimicrons.

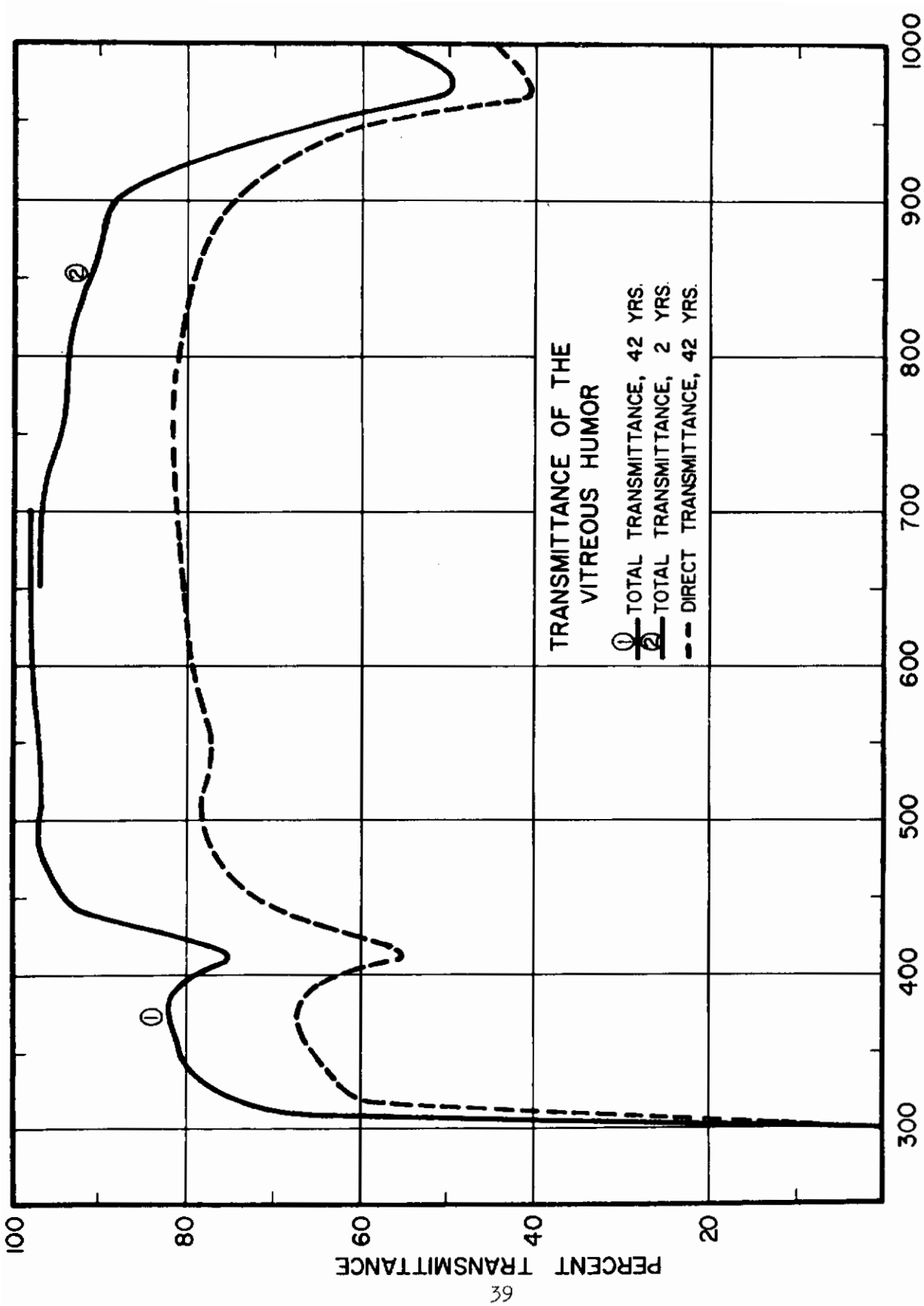

Figure 6A. Transmittance of the vitreous, 250-1000 millimicrons.

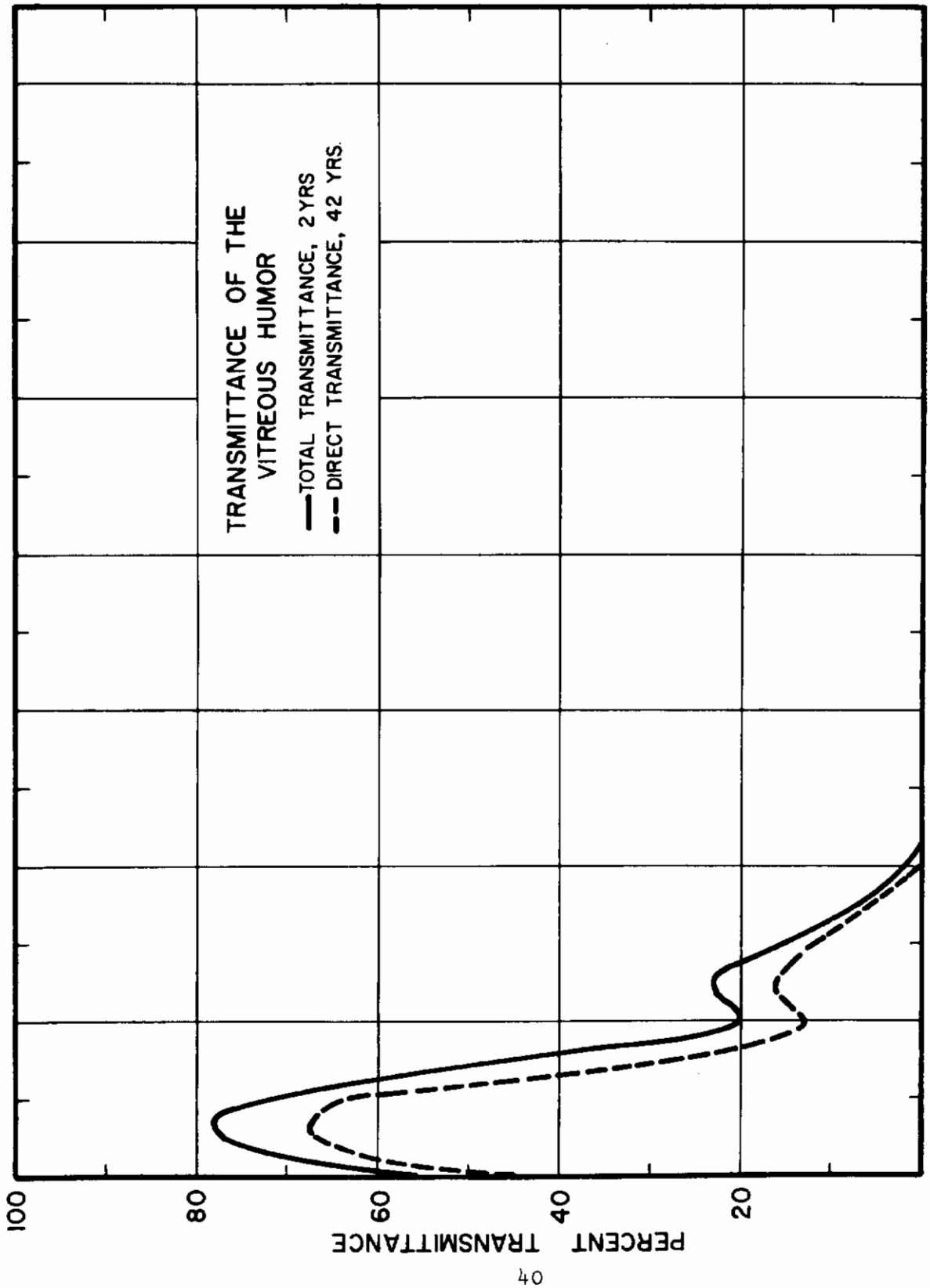

Figure 6B. Transmittance of the vitreous, 1000-2500 millimicrons.

APPENDIX I

MEASUREMENTS ON MONKEY EYES

The transmittance measuring techniques and procedures were developed using the eyes of rhesus monkeys with the result that some data were accumulated on these eyes.

After the mounting cells were prepared, the first measurements on these eyes were made for the purpose of determining the effect of time after enucleation on the transmission. These findings are discussed along with the similar study on human eyes in the section "Evaluation of Data."

Representative transmittance data are tabulated in table XI for the various components of the rhesus monkey eyes. The whole eye transmittances, tabulated in table XII, have been corrected for reflection losses at the air-cornea interface, and like the data in table X are the percent of that radiation incident on the eye reaching the retina.

The transmittance values have been calculated for path lengths corresponding to the thicknesses of the media in the monkey eye. These figures, along with the estimated accuracy of measurement are as follows:

Cornea	0.4 mm	+1.5%	Transmittance
Aqueous	2.6 mm	+4.0%	"
Lens	2.8 mm	+2.5%	"
Vitreous	12.0 mm	+5.0%	"

The relatively poor accuracy of the aqueous and vitreous data result from the use of short measuring paths, making large conversion factors necessary. This situation was corrected later in the program, but no further measurements were made on monkey eye media.

TABLE XI

PERCENT TRANSMITTANCE OF THE MEDIA OF RHESUS MONKEY EYES

Wavelength (millimicrons)	Percent Transmittance						
	Cornea		Aqueous,	Lens		Vitreous	
	Direct	Total	Direct	Direct	Total	Direct	Total
220			0.5				
240			3.0				
260			< 0.1				
280	< 0.1	< 0.1	4.0			< 0.1	< 0.1
300	1.0	2.0	50.	< 0.1	< 0.1	15.	15.5
320	16.	56.	71.	8.0	10.	79.	82.
340	34.	65.	76.	3.0	5.	80.5	85.
360	40.	73.	78.5	0.2	1.0	81.	85.5
380	45.	81.	81.	0.4	1.5	81.5	86.5
400	48.	83.	83.	10.	20.5	82.	88.
420	52.5	86.	85.5	50.5	62.	82.5	89.
440	55.	88.5	87.	80.	90.	83.	90.
460	57.	90.	88.5	82.5	93.5	83.5	91.
480	59.	91.	89.	84.	95.	84.	91.5
500	61.	91.5	90.	85.	95.5	84.	92.5
550	65.	92.	91.	87.	96.	85.	94.
600	68.	94.	93.	88.	96.5	85.5	95.
650	70.5	94.5	94.5	89.	97.	85.5	95.5
700	72.	95.0	95.5	90.	97.	85.5	96.
750	73.5	95.	96	90.5	97.	85.5	96.
800	74.5		96.	91.		85.	
850	75.5		95.5	91.		83.5	
900	76.		95.	90.5		82.	
950	76.		94.	88.		64.5	
1000	76.5		88.	85.5		52.	
1100	79.		90.5	88.		72.5	
1200	75.		70.5	73.		18.	
1300	76.		65.	76.		18.5	
1400	45.		0.5	5.		< 0.1	
1500	32.		0.5	2.5			
1600	57.		12.5	24.5			
1700	61.		19.	28.			
1800	54.		7.5	17.			
1900	0.5		< 0.1	< 0.1			
2000	3.0						
2100	20.5						
2200	30.5						
2300	20.						
2400	6.5						
2500	0.5						
2600	< 0.1						

TABLE XII

CALCULATED PERCENT TRANSMITTANCE

THROUGH THE WHOLE EYE OF A RHESUS MONKEY

Wavelength (millimicrons)	Percent Transmittance	
	Direct	Total
260	0.0	0.0
280	< 0.1	< 0.1
300	< 0.1	< 0.1
320	0.7	3.2
340	0.6	2.1
360	< 0.1	0.5
380	0.1	0.8
400	3.2	12.
420	18.5	40.
440	31.	61.
460	34.5	66.5
480	36.	69.
500	38.5	71.
550	43.	74.
600	46.5	78.5
650	50.	81.
700	52.	83.
750	53.5	83.
800	54.	
850	54.5	
900	52.5	
950	39.5	
1000	29.	
1100	44.5	
1200	6.8	
1300	6.8	
1400	< 0.1	
1500	0.0	