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OCCURRENCE OF LENTICULAR IMPERFECTIONS IN THE EYES OF MICROWAVE WORKERS AND THEIR ASSOCIATION WITH ENVIRONMENTAL FACTORS

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PROGRESS REPORT

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OCCURRENCE OF LENTICULAR IMPERFECTIONS IN THE EYES OF MICROWAVE WORKERS AND THEIR ASSOCIATION WITH ENVIRONMENTAL FACTORS

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with the assistance of

H. Schmidt

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INTRODUCTION

This report describes the status, at nearly the mid-point of the investigation, of our study of the occurrence of lenticular changes in the eyes of microwave workers. This study began in February 1960, and this report covers the progress made until July 1961. It is anticipated that the investigation will continue until the Spring of 1963, by which time sufficient field work will have been completed to permit us to achieve the objectives for which the investigation was undertaken.

These objectives are the following:

1. Establish a standardized method of slit-lamp bio-microscopic examination of the crystalline lens of the eyes.

2. Examine "exposed" and control personnel to determine the extent, if any, of cataract formation and to report all types of lens defects along with their geographic locations.

3. Evaluate environmental data relating to microwave and ionizing radiations as concerns the subjects studied.

4. Advise whether or not an eye health problem exists and provide the nature and scope of such problem if it exists.

5. A detailed description of the methods of surveying for microwave and ionizing radiation exposure in the various establishments participating in our study.

6. A critical review of these procedures.

7. Development of improved methods of characterizing the exposure histories of personnel.

8. Preparation of recommendations which, if adopted, would lead to a more uniform method of performing environmental surveys, a unified procedure for reporting the data, and, hopefully, the establishment of a registry of environmental data which, when correlated with the accumulating clinical information, will assist to interpret the relationships that exist between the environmental and clinical findings.

This investigation is being undertaken under Contract AF30 (602)2215 with the Rome Air Development Center. From its inception, the investigation has been one of several being undertaken under the general guidance of the Tri-Services Microwave Committee, of which Colonel George Knauf is chairman and Mr. Herbert Brownstein is secretary. The continuing interest of Colonel Knauf and Mr. Brownstein and the helpful guidance they have provided to us is deeply appreciated.

Although the original sponsorship has been by the Air Force through the Tri-Services Microwave Committee, this investigation could not proceed without the cooperation of the many industrial companies that have participated in this

study from its inception. To the many individuals of these companies, whose number is too numerous for individual mention, we also express our deep appreciation.

I

DESCRIPTIONS OF INSTALLATIONS SURVEYED

The samples of microwave workers and controls included in the overall study have been selected from eleven separate installations. The work at these installations encompasses a variety of types of microwave operations including research and development, operation, installation, maintenance and test of microwave equipment.

Two of the eleven installations were visited during preliminary stages of the investigation and the data obtained from them has not been included in the statistical analysis presented in this report.

Table I-1 categorizes the nine sites included in this analysis according to type of installation and major functions of each. In some cases detailed descriptive information is not presently available. This information will be obtained for all installations included in the study.

Installation A

Installation A is a large military establishment with operations divided between high-powered radar research and development and aircraft radar maintenance. One-hundred forty-eight microwave workers and 147 controls were examined. The sample selection was performed under the direction of an official at Installation A.

The personnel at Installation A may be divided into two groups, those doing research and development, and those in aircraft maintenance. The research and development work is mainly performed by civilian employees of the government, and due to the nature and requirements of the work this group generally has a higher mean age and more exposure to microwave radiation than the aircraft maintenance group.

The aircraft radar maintenance group, which comprised the majority of the sample, is mainly composed of young service personnel with less microwave experience than the civilian group. Exposures result from testing and aligning procedures on aircraft radar.

Surveying of microwave hazards is handled by an on-site unit whose duties are concerned with microwave measurements of various kinds. This group surveys possible sources of over-exposure on request of on-site operating personnel. The surveying procedure follows a service directive (2) which specifies the delineation of safe distances in regards to the 10 mw/cm^2 limit. The directive also lists the complete specifications of the test equipment and specifies the method of calculation to be used and the procedure to be followed in each survey. The surveying procedure thus appears to be well standardized.

Installation B

This installation is a civilian microwave assembly plant employing approximately 50 microwave workers. Nineteen microwave workers and 20 controls were examined. The microwave worker group was chosen by company supervisors as representing those individuals at Installation B with past and present microwave exposures of varying degrees.

The plant function is mainly design and assembly of microwave modulators. All transmitter tubes are purchased from other manufacturers and incorporated into the assembly at this installation. There is no tube testing done at Installation B.

Airborne radar transmitters and receivers are regularly tested in specially designed environmental rooms constructed to simulate high altitudes. The negative pressure within the rooms limits entry during operation of microwave equipment and decreases the possiblity of personnel exposure. The walls of the chambers are lined with steel plates such that transmission to the environment is minimized.

Test chambers with wire mesh exteriors and nonreflecting interiors (rubberized horsehair mats) are also used to test transmitter performance. There is no restriction on access to these rooms during operation of the radar equipment.

Some work is being done with X band radar indicating the possibility of high power densities in very limited areas (pencil beams).

The majority of the antenna work is restricted to low powers estimated to be in the microwatt region. Higher powered transmitters and antennas have been used in the past, but no radiation surveys were made at that time.

In general the low powers involved and the use of environmental and shielded chambers suggests that high level exposures would not now be expected at this installation.

There is no regular microwave surveying procedure being used. No survey instruments have been designated to check power densities and there is no systematic procedure for requesting surveys or reporting the findings of a survey. In the event of an expected X-ray exposure, film badges are issued. This not done on a routine basis.

Installation C

Installation C is a large military missile tracking facility at which 75 microwave workers and 38 controls were examined. The total number of microwave workers at this site is approximately 100. The sample was chosen partially on the exposure history questionnaire data and partially on the subjective judgement of personnel at Installation C.

The microwave workers may be divided into civilian and military employees. The civilians may be further broken down into two groups. One group consists of workers employed by companies doing contract work for the government. The other group is comprised of civilians directly employed by the government.

The radar equipment is generally medium to high power (i.e. $\geqslant$100 watts average output) and exists in a variety of types which include; tracking radar, mobile van units, airborne radar, radar beacons, radar jammers and shipborne radar.

Due to the great variety in radar types, a quantitative classification of radar exposures for each individual is impossible. Sites of possible exposure are generally around the antennas of the higher powered equipment. Remote radar equipment which is not well supervised or surveyed, appeared to offer the greatest probability of over-exposures. Certain areas in which men worked in close proximity to radiating antennas have been surveyed and found to exceed the maximum acceptable exposure levels of 10 mw/cm^2. Such findings have led to the designation of exclusion areas or relocation of equipment to reduce the power density to safe levels.

Responsibility for the surveying of possible radiation hazards rests with a testing and monitoring group. This group performs microwave power density surveys at the request of the director of the specific operation in question or at the request of the health officer. The survey is performed according to a standard procedure followed in evaluating possible radio frequency hazards at this installation. The areas of power densities greater than 10 milliwatts per square centimeter are specified and all personnel are excluded from such areas. In addition to the microwave survey, X-ray surveys of the transmitters are performed.

A detailed report of each survey is written and distributed to both the group requesting the survey and to the group responsible for overall site safety. In general the surveying and reporting procedure appears adequate to protect the workers from microwave radiation hazards where the surveys are performed. The possibility of over-exposures in unsurveyed areas exists due to the fact that the radar equipment is deployed over a wide area and is in some cases mobile.

Installation D

Installation D is a smaller military missile tracking site. The majority of the microwave workers at this installation work for civilian contractors who install, operate and maintain missile tracking and area clearance radar for the military. Approximately 50 men are employed in microwave work at site D. Of this group 15 were examined along with 8 controls. The microwave workers were selected on the basis of availability rather than on the basis of the microwave history questionnaire.

Many of the radar installations at this site are remotely located and staffed by a small group of men who function more or less independently of other groups. At each of these locations there is the possibility of exposure to ionizing and microwave radiation from the transmitters and microwave exposure from the antennas. Film badges have been issued to all employees at this site. There is no group available on a continuous basis to perform radiation surveys.

Installation E

Operation at Installation E include research and development of advanced radar systems for missile detection. There are also tube producing facilities, antenna development projects, electromagnetic scattering experiments and fabrication of field evaluation models at this installation.

The total number of people employed in microwave work at

Installation E is 800. Thirty-one microwave workers and 25 controls were examined. The exposed group as selected by company representatives as comprised of individuals with varied degrees of microwave exposure.

Although there is a wide variety of possible sources of microwave exposure the generally low powers should tend to minimize the operating hazards.

The testing of microwave components is generally carried out in specially designed rooms lined with rubberized horse hair to reduce power spray. The process of antenna testing is performed out of doors with the antennas mounted on towers. The antenna power outputs are normally of the order of micro-watts and there is small liklihood of overexposures from antenna radiations. Frequencies up to a maximum of 12.5 kilomegacycles per second are used.

In the event of a suspected microwave radiation hazard the supervisor in charge of the equipment requests a hazard survey. The survey is supervised by the head safety engineer. Power densities in excess of 10 milliwatts/cm^2 of microwave radiation (at any frequency from L band and up) are considered hazardous and such conditions are corrected. The surveys are performed with a Ramcor detector.

A survey report is made to the head safety engineer and the supervisor who requests the survey. Such survey results are kept on file by the safety department.

Installation F

Installation F is a civilian company engaged in contract work for the government. Radar defense systems are developed, tested and operated at this site. There are approximately 300 microwave workers at this site. One hundred microwave workers and 37 controls were examined at site F. The microwave workers were chosen by the company as representing those individuals with suspected microwave exposures of varying degrees.

The operation of very high powered radars at Installation F is a source of potential exposure. Such equipment has been provided with safety interlock systems to avoid exposure to the high power densities associated with the antennas.

Installation G

Installation G is a large civilian research and development laboratory engaged in military and civilian microwave work. The military work involves research, development, fabrication and testing of missile guidance systems. The work at this part of the laboratory involves the operation of some high powered (i.e. $\gg$1 Kw average power) radar sets. The number of employees engaged in microwave work at this site is approximately 400.

The civilian work, which is performed at a separate site, is mainly concerned with lower powered communications systems ($<$ 10 watts average power). This work involves research, development and testing of microwave communications networks. There is some communications work on tropospheric scattering being carried out that involves higher power outputs (i.e. $>$ 100 watts average power). The number of employees engaged in microwave work at this site is approximately 100.

The sample of microwave workers examined at Installation G was chosen on the basis of the duration of past microwave exposures. The total number of microwave workers examined was 44. This sample was composed of 35 men from the site engaged in military work and 9 men from the civilian branch.

The company has set up a standard procedure for the evaluation of microwave hazards and for the protection of the workers. In the event there is an operation that may present a hazard, the project engineer directly in charge of the operation assumes the responsibility of avoiding over exposures. On the basis of the known operating characteristics of the equipment, he makes use of standardized calculations to delineate theoretically the hazardous areas. These areas are designated as radiation hazard areas and are fenced off. The power density levels are then checked with survey meters to insure that the calculations are accurate in defining the radiation hazard area.

Since the calculations may be made before the equipment has been turned on, this procedure appears to be safer than commencing operation without knowledge of the possible hazards involved.

The level of 10 milliwatts per square centimeter is specified as being potentially hazardous. A level of less than 1 mw/cm^2 is attained whenever possible since this is considered safe for indefinitely prolonged exposure or permanent assignment.

Installation H

The work at this civilian installation is mainly fabrication and testing of radar equipment.

The total number of employees engaged in microwave work is approximately 400. The sample examined consisted of 40 microwave workers and 41 controls. More detailed information is not presently available.

Installation I

Installation I consists of a civilian complex of operations including research, development and fabrication of radar equipment.

The total number of microwave workers at the installation is approximately 100. The sample consisted of 15 microwave workers and 17 controls. The exposed group was chosen by the company as representing individuals with probable exposure to microwave radiation. More detailed information on Installation I is not presently available.

TABLE I-1

INSTALLATION	TYPE	MAJOR FUNCTION(S)
A	large military base (>1000 employees)	a. research and development of surface radar b. airborne radar maintenance
B	civilian assembly plant	a. design and assembly of microwave modulators b. components testing
C	large military missile tracking facility (>1000 employees)	a. radar operations and maintenance b. systems development
D	smaller military missile tracking facility	a. radar operations and maintenance
E	civilian research development and fabrication facility	a. research and develop- of reconaissance radar b. tube production facilities c. antenna development work

TABLE I-1 (continued)

F	large civilian radar installation	a. research and development of radar defense systems b. radar equipment operation c. testing of radar equipment
G	civilian research laboratory	a. research and development of military and communications type radar equipment b. fabrication and c. testing of radar equipment d. limited operation of radar equipment
H	civilian fabricator of radar equipment	a. fabrication and b. testing of radar
I	civilian complex of radar operations	a. research and development b. fabrication and c. testing of radar systems

II

METHOD OF OPHTHALMOLOGICAL EXAMINATION

The ophthalmological examination included history, visual acuity, slit-lamp examination of the lens and stereophotography of the lens. In addition, other ophthalmological procedures such as tonometry, ophthalmoscopy and outline perimetry were performed when indicated.

Part I Ophthalmological History

The ophthalmological history was oriented towards gathering information relating to hereditary predisposition toward cataract formation and in order to elicit past history of pathological conditions predisposing the patient to secondary cataracts.

Part II Visual Acuity

The visual acuity was recorded without eyeglasses and with eyeglasses where worn in order to determine any loss of vision due to cataracts. Whenever corrected vision was less than 20/20, ophthalmoscopy was performed to determine etiology.

Part III Slip-Lamp Examination

Slit-lamp examination was performed and the results were scored and recorded in accordance with the protocol established to evaluate the sub-clinical microscopic lens defects as noted by the Rome Eye Study Group. Five categories of slit-lamp observation were defined. Minute defects, opacification and relucency describe the microscopic appearance of the total lens volume. Sutural defects and posterior polar defects describe specific regions of the lens.

1. Minute defects - This category included all defects such as granules, vacuoles and tiny opacities which are ordinarily too small to be individually catalogued.

2. Opacification - Before becoming clinically cataractous, the lens undergoes changes in that either an irregularly diffuse cloudiness develops or discrete regions of the lens, bordering macroscopic dimensions, become markedly opacified such as occurs when increased radial markings verge on spoking.

3. Relucency - Optical luminosity occurs when the beam of light from the slit-lamp traverses the lens and the various regions such as the cortex to adult nucleus to fetal nucleus to adult nucleus to cortex may be distinguished from one another by the differing degrees of haziness and the light reflexes created by the light beam.

4. Sutural defects - The sutures of the human lens can usually be observed by slit-lamp examinations. As this region of the lens is prominently involved in experimental microwave cataracts produced in certain laboratory animals, it was mandatory to specifically include this region of the lens as a category for investigation. Thickening, banding and striations of the lens fibers of this region were noted as sutural defects.

5. Posterior polar defects - The posterior subcapsular cortex, especially in the polar region, is a frequent site and apparently a sensitive region in the lens for early changes to occur regardless of the type of injury to the lens. Moreover, in some cases of ionizing radiation injury, it is pathognomonic for a doughnut-shaped subcapsular defect to appear and progress to the stage of polar, subcapsular cataract.

Each of these categories of slit-lamp examination were graded on a relative scale in the following manner: 0 for insignificant numbers or degree, 1 for small numbers or minor degree, 2 for moderate numbers or degree, and 3 for large numbers or major degree short of clinically recognized cataract.

Part IV Stereo-photography

Stereo-photography of every lens by means of the Donaldson camera was performed as part of the routine examination. By this procedure, it was frequently possible to document macroscopic changes in the lens providing the plane of the lens to be photographed was precisely in the focal plane of the camera. The focal plane of the camera was determined by the examiner vertically alligning two verging target lights in the plane of the patient's lens that was to be photographed. This was accomplished by having the patient's head fixed in a chin-forehead rest. He was then instructed to stare directly ahead and to keep his palpebral fissure open. At this time, the camera operator, while viewing the target lights as they entered the patient's eye, adjusted the camera by first visually lining up the axis of the camera to the axis of the eye by moving the pedestal holding the camera to approximately the proper place. Next, the photographer had to adjust the height of the camera so that the target lights were approximately on a level with the axis of the lens. Following this, an adjustment was made in the horizontal meridian to align the camera with the axis of the eye. Finally, the target lights were brought into adjustment for the proper antero-posterior plane of the lens and at this instant the photographer tripped the shutter.

III

ESTIMATION OF EXPOSURE HISTORIES OF MICROWAVE PERSONNEL

The questionnaire which has been described previously (1) was used throughout the past year to approximate the exposure histories of microwave workers. It is intended to enabel one to classify the exposed personnel into several classes according to the relative severity of exposure.

The questionnaire which consists of seven parts is shown in Appendix III-A.

Part I

Part I is an employment record. A complete account of the places of employment in which microwave work was involved and the duration of employment at each job is requested. The types of work are divided into five categories and the examinee indicates the number of months spent working in each category. The total duration of microwave work as well as more detailed information on specific periods and types of employment are recorded.

Part II

Part II attempts to determine the existence and location of film badge records of ionizing radiation exposure to the examinee.

Part III

Part III is included to take into account the possibility of X-ray exposure from high voltage microwave generating tubes. It is requested that the examinee indicate any work experience involving generating tubes from which X-ray shielding had been removed. An indication of the time periods involved and transmitter tube voltages is requested to give a general idea of the magnitude of the possible exposure.

Part IV

In Part IV detailed information regarding the principal types of microwave generating equipment with which the examinee has worked is requested. It was judged that the important parameters of microwave exposure from generating equipment are:

a. type of equipment

b. average power generated

c. operating frequency or frequency band

d. duration

e. date of first exposure

f. mode of power termination

g. distance from equipment

h. type of work

Part V

Part V regards the practice of looking into energized microwave waveguides. Since this practice may result in direct exposure of the lens to microwave radiation it is considered important in this survey. The extent of this practice as well as the average power being generated and the method of viewing the waveguide is recorded by the examinee.

Part VI

Part VI is a record of the approximate number of times the examinee has physically sensed exposure to microwave radiation from the antennas of generating equipment. The number of exposures at different positions in relation to the antenna as well as powers, frequencies, distances and heating sensations are recorded in this section.

In addition to recording exposure histories the questionnaire has been used to assign a semi-quantitative exposure index to each examinee for purposes of dividing the exposed subject into two or more classes according to the severity of their exposures. The scoring system is shown in Table 3-1. The exposure index assigned to each employee is obtained by taking the product of items 1 x 2 x 3 x 4 and adding this to the product of 5 x 6 x 7. By this system it is possible to attain a maximum score of 81.

As a result of experience with the questionnaire and the exposure index it is now possible to critically evaluate its effectiveness for the gathering and categorization of microwave exposure histories.

<u>Questionnaire Evaluation</u>

The main difficulty encountered in the use of the questionnaire may be attributed to the inherent difficulties in an attempt to obtain information of the type sought. In many instances the employee was not able to supply detailed information regarding the equipment worked with because of a lack of knowledge, security restrictions, or inability to remember past working experiences. This was particularly true of nonprofessionals such as technicians and operators.

Inconsistencies were noted in the answers to certain related questions. In some cases ambigious wording in the questionnaire led to confusion and errors in the answers to some of the questions. A list of explanatory remarks which has been used to clarify the questionnaire is shown in Appendix III-B.

It became apparent after working with the questionnaires that in most instances extensive personnal interviews would be required to get more accurate and complete information. In many cases interviews were conducted in order to supplement the information obtained by use of the questionnaire.

The data from the completed microwave history questionnaire as well as from the separate eye scoring form were transferred to a master code sheet. The details of the coding system used are given in Appendix III-C. In this process it was not possible to transfer all of the information from the history questionnaire. Therefore, in certain cases the information from the questionnaire was categorized and then coded.

The information was then transferred from the code sheets to IBM cards to facilitate subsequent statistical analysis by means of a computor or a tabulator.

Table 3-1

METHOD OF CALCULATING MICROWAVE EXPOSURE INDEX*

Factor	Weight 1	Weight 2	Weight 3
1. Power output (av. watts)	<100	100-1000	>1000
2. Distance from tube or transmission line (feet)	>10	< 10	-
3. Looked into energized waveguide (no. of times)	1-10		>10
4. Felt heat from waveguide	<10	Hands only >10	Head or whole body >1
5. Antennae exposure (location and time)	Rear or sides	Front (seconds or minutes)	Front (hours)
6. Antennae heat (time)	Seconds	Minutes	>Hour
7. Antennae power (av. watts)	< 100	100-1000	> 1000

* Exposure Index = (1 X 2 X 3 X 4) + (5 X 6 X 7).

IV

RELATIONSHIP BETWEEN EYE SCORE, AGE, AND ENVIRONMENTAL FACTORS

I Sample Analysis

A. Age Frequency Distribution

A comparison of the age frequency distribution of the exposed and control groups of the total sample is shown in Table 4-1 and Figure 4-1. The general agreement in the frequency distribution and mean ages of the two groups indicates that they are reasonably well matched.

B. Eye Score Frequency Distribution

The distributions of eye score for the exposed and control groups are given in Table 4-2 and Figure 4-2. Although the distributions are generally similar, a peak is present in the exposed group at a score of eight. This peak is less prominent in the control group. The greater mean eye score of the exposed group most likely can be attributed to this peak rather than to a number of individuals with very high scores (i.e., >10).

C. Exposure Score and Duration of Microwave Work Frequency Distributions

The frequency distributions of exposure score and duration of microwave work are given in Tables 4-3 and 4-4, and Figure 4-3 and Figure 4-4. They appear to be somewhat similar in shape as would be expected since there should be a relationship between the relative severity of exposure and the length of time spent working with microwaves. The mean duration of microwave work is approximately five years.

D. Job Classification Distribution

The frequency distribution of types of microwave work is given in Table 4-5. The three main job classifications encountered in this survey are (1) operation of microwave equipment plus installation maintenance and test 25.45%, (2) installation and maintenance 29.9%, and (3) research and development 18.11%.

Since these three categories of employment include the main types of microwave work which could be expected to result in microwave radiation exposure, it appears that the sample is well balanced in regard to the types of workers examined.

It is not yet possible to state that this frequency distribution is representative of the general microwave population since the overall job category frequency distribution for the total microwave population is not presently available. Further work is planned to determine if the sample studied is representative of the total microwave population. This will involve a determination of the job classification distribution of microwave workers.

Correlations between job classification and eye score have not yet been completed. Any differences in eye score that correlate with specific types of microwave work will be a clue in the determination of the types of exposure which contribute most significantly to increased frequencies of lenticular imperfections.

E. X-Ray Exposure

The fact that an individual did or did not wear a film badge is not necessarily an indication of whether he was exposed to ionizing radiation. It is well known that microwave workers have worked near inadequately shielded generating tubes without their having been provided with film badges. It is also well known that conservative managements provide film badges in many instances where minimal or no possibility of X-ray exposure exists.

Of the total sample, about 17% indicated that they had worn film badges at one time or another. A total of 43% had histories which suggested the likelihood of exposure to ionizing radiation.

An effort will be made in the coming year to sort out and study groups who have had concommitant ionizing and microwave exposure and a group who had microwave exposure but no ionizing radiation exposure.

II Statistical Analysis of Microwave Data

A. Total Eye Score in Relation to Various Factors

Preliminary statistical analysis of the data obtained from the eye examinations and environmental histories indicate there is a small but statistically significant difference between mean eye scores of the total exposed and control groups when adjusted for age. The differences are not significant clinically.

The method of analysis has thus far been restricted primarily to a linear regression analysis of five subgroups. A linear model was selected because of an apparent linear relationship between eye score and age noted in a pilot study (1). This provides a convenient method of comparison at the present time.

B. Selection of Groups for Analysis

Five groups were selected for separate statistical analysis in an attempt to investigate the effects of such factors as microwave exposure, exposure score, duration of microwave work and bias on the part of the examiner. The group designations are summarized in Table 4-6.

Group I is the total samples with the exception of Installation A. It consists of 212 controls and 327 microwave workers with varying degrees of exposure. The sample is not age-matched on an individual basis but the mean ages of the exposed and control groups were controlled to be approximately equal (i.e. mean age exposed group = 36.28, mean age control group = 36.73).

The data from this group was subjected to multiple linear regression analysis to estimate the relationship of age, exposure score and duration of microwave work to eye score.

Group II is the total of the samples from Installation A through I. It includes 475 microwave workers with varied microwave experience, and 359 controls. The mean age of the microwave workers is 33.36 years and that of the controls is 32.6 years.

Group III and IV are composed of the microwave workers and controls who were examined at Installation A and G respectively.

These groups were chosen for separate analysis because they represent two installations at which the eye examinations were well controlled "blind" examinations. Unbiased examinations of this type were performed whenever possible at other installations but due to restrictions regarding work schedules an undetermined number of "non-blind" examinations were performed. It is estimated that this type of "non-blind" examination procedure occurred in less than 15% of the total number of examinations.

As a result of this possible element of bias in the overall sample (Group II), Groups III and IV were singled out as being completely "blind" samples and unbiased indicators of the relationships between the eye score of the microwave workers and the controls.

Group V is a sample of 50 exposed personnel and 50 age-matched controls selected from installations B through I. These individuals were the most heavily exposed microwave workers on the basis of exposure score, each member in this group having received a total exposure score of 25 or greater. The control for each of the exposed was chosen from the same installation as the exposed and is the same age as the exposed worker.

C. Analysis of Data

The data from each of the above groups has been analyzed by means of a linear regression analysis in order to establish a relationship between mean eye score and age. In one case an attempt was made to determine the relationship of age, exposure score, and duration of microwave work, to eye score.

1. Group I

The following multiple linear regression model was proposed to represent the regression of eye score on age, exposure score and duration of microwave work for the microwave workers of Group I.

$$\mu = \beta_{o_E} + \beta_{1_E}(X_{1_E} - \bar{X}_{1_E}) + \beta_2(X_{2_E} - \bar{X}_{2_E}) + \beta_3(X_{3_E} - \bar{X}_{3_E}),$$

where the value of μ (expected value of Y are given X_{1_E}, X_{2_E}, X_{3_E}) was estimated from the sample data by $\hat{Y}_E$ as follows:

$$\hat{Y}_E = b_{o_E} + b_{1_E}(X_{1_E} - \bar{X}_{1_E}) + b_2(X_{2_E} - \bar{X}_{2_E}) + b_3(X_{3_E} - \bar{X}_{3_E}).$$

where X_{1_E} = age

X_{2_E} = exposure score

X_{3_E} = duration of microwave work.

The regression equation was found to be:

$$\hat{Y}_E = 8.4159 + 0.1228(X_1 - 36.2782) + 0.004172(X_2 - 18.3180) + 0.00024945(X_3 - 86.0581)$$

Both b_2 (= .004172) and b_3 (=.00024945) were not significantly greater than zero ($P > .05$) and were omitted from the regression equation.

The fact that the estimated regression coefficients b_2 and b_3 were not found to be significantly greater than zero when adjusted for b_1 (age), still leaves open the possibility that some combination of X_2 and X_3 may significantly reduce deviations from the exposed group regression.

The lack of correlation between eye score and exposure score when adjusted for age suggests that the exposure score as presently determined does not properly estimate the severity of microwave exposure.

The revised equation is:

$$\hat{Y}_E = 3.8884 + 0.1248\ X_E$$

The equation for the control group is:

$$\hat{Y}_C = 2.9853 + 0.13370\ X_C$$

where X now represents age.

The values of b_{1_E} (= 0.1248) and b_{1_C} (= 0.13370) were tested to determine if they were statistically significantly different from each other. It was found that a 5% level of significance these coefficients were not different.

A joint regression coefficient (b_1) was then calculated for the two groups (b_1 = 0.1284) and the regression equations were redetermined as follows:

$$\hat{Y}_E = 3.7578 + 0.1284\ X_E,$$

and

$$s = \text{standard error of estimate } (\hat{Y}_E) = \pm 1.429 \sqrt{\frac{1}{n_E} + \frac{(X_E - \bar{X}_E)^2}{S_{xx}}}$$

$$= \pm 0.07905 \text{ (at } X_E = 36.2782 = \bar{X}_E).$$

$$\hat{Y}_C = 3.1799 + 0.1284\ X_C,$$

and

$$s = \pm 1.429 \sqrt{\frac{1}{n_C} + \frac{(X_C - \bar{X}_C)^2}{S_{xx}}}$$

$$= \pm 0.09817 \text{ (at } X_C = 36.7311 = \bar{X}_C).$$

The above equations have been plotted in Figure 4-5. There is a statistically significant ($P < .05$) constant difference between the exposed group and the control group. This difference in eye score units is 0.5779. Use of this simple linear model describing the regression of eye score on age disregards any more complicated relationship that may exist between eye score and age. Hence, though it may be inferred that this difference in the two groups is significant in the vicinity of the mean age, how far these relationships may be extrapolated is not clear at present because the numbers of subjects are small at the ends of the curves. This constant difference in eye score does not necessarily hold for the entire age range shown in Figure 4-5 (i.e. 20 to 60 years).

2. Group II

The data from group II, the total sample to date, has been analyzed by means of simple linear regression of eye score on age.

The linear model, used for both exposed and control groups, is:

$$\text{Expected value of } Y = \mu = \beta_o + \beta_1(X-\bar{X})$$

$$\text{Estimated value of } \mu = \hat{Y} = b_o + b_1(X-\bar{X})$$

The following equations were obtained:

a. Exposed Group

$$\hat{Y}_E = 1.4242 + 0.1784\ X_E$$

and

$$s = \text{standard error of estimate } (\hat{Y}_E) = \pm 1.603\sqrt{\frac{1}{n_E} + \frac{(X_E - \bar{X}_E)^2}{S_{xx}}}$$

$$= \pm 0.07355 \text{ (at } X_E = 33.3621 = \bar{X}_E)$$

b. Control Group

$$\hat{Y}_C = 0.7980 + 0.1784\ X_C$$

and,

$$s = \pm 1.603\sqrt{\frac{1}{n_C} + \frac{(X_C - \bar{X}_C)^2}{S_{xx}}}$$

$$= \pm .09467 \text{ (at } X_C = 32.6017 = \bar{X}_C).$$

The equations have been plotted as shown in Figure 4-6. The regression equations again show a common regression coefficient ($b_1 = 0.1784$) and a highly significant constant difference (d) in mean eye score of 0.6262 ($P < .005$). The 95% confidence interval for the true difference δ is given as:

$$0.41 \leq \delta \leq 0.85$$

On the basis of the results of the analysis of the total sample to date (i.e. Group II) it is apparent that there is a statistically significant detectable difference in the number of minor lens defects in the exposed and control groups.

3. Group III

The data from Group III has been analyzed according to the model:

$$\text{Expected value of } Y = \mu = \beta_o + \beta_1(X-\bar{X}),$$

and the data is used to estimate the regression coefficients as follows:

$$\text{Estimated value of } \mu = \hat{Y} = b_o + b_1(X-\bar{X}),$$

where

Y = eye score

b_o, b_1 = estimated regression coefficients

and

X = age

The same model has been used for both the exposed and the control groups resulting in the following equations:

a. Exposed Group

$$\hat{Y}_E = 0.8400 + 0.1573\ X_E$$

and

$$s = \text{standard error of estimate } (\hat{Y}_E) = \pm\ 1.2725 \sqrt{\frac{1}{n_E} + \frac{(X_E-\bar{X}_E)^2}{S_{xx}}}$$

$$= \pm\ 0.1046 \ (\text{at } X_E = 26.9189 = \bar{X}_E)$$

b. Control Group

$$\hat{Y}_C = .5704 + 0.1573\, X_C$$

$$s = \pm 1.2727 \sqrt{\frac{1}{n_C} + \frac{(X_C - \bar{X}_C)^2}{S_{xx}}}$$

$$s = \pm 0.1049 \text{ (at } X_C = 26.6463 = \bar{X}_C)$$

These relationships are shown in Figure 4-7. Again, there is a small, statistically significant difference between the exposed and control groups ($P < .05$), but the difference in mean eye scores is less than Group I (i.e. 0.2696 compared to 0.5779 for Group I) and the common regression slope is somewhat greater (i.e. b_1(Group III) = 0.1573, b_1(Group I) = 0.1284).

It should be noted that this group had a mean age which was ten years less than that of Group I. The Group III eye scores at a given age are in general lower than for Group I. This difference so far as the exposed groups are concerned could be due to differences in exposure to microwave radiation. Thus if the exposed members of Group I at a given age, on the average received greater amounts of exposure than the average of Group III microwave workers of the same age, it would be expected that the eye score might be greater for Group I. There is some evidence (based on the microwave history questionnaires) which indicates that this may be true to some extent. However the differences in control scores cannot be explained in this way. It is possible that systematic differences exist from site to site or that they are due to slight differences in the technique of examination and scoring.

This should have no effect upon the validity of the survey if it can be shown that the relative differences between the exposed and non-exposed personnel are unaffected. This aspect must be studied further.

There is also a possibility that this difference in estimated eye scores of the controls of Groups I and III may be due to limitations in the linear model chosen to represent the regression of eye score on age. It has been mentioned in the preceding section that the regression equations do not necessarily apply over the entire age range from 20 to 60 years of age. Therefore, if we compare the mean eye score of the controls of Group I at age 26 with the mean eye score of the controls of Group III at age 26 the indicated difference may have no statistical significance since the regression equation for Group I may not be valid at age 26.

4. <u>Group IV</u>

The linear model used for the microwave workers and controls of Group IV is:

Expected value of $Y = \mu = \beta_o + \beta_1(X-\overline{X})$

Estimated values of $\mu = b_o + b_1(X-\bar{X}) = \hat{Y}$

The following equations were obtained:

a. Exposed Group

$$\hat{Y}_E = 3.3556 + 0.1311\ X_E$$

$$s = \text{standard error of the estimate} = \pm 1.55\sqrt{\frac{1}{n_E} + \frac{(X_E-\bar{X}_E)^2}{S_{xx}}}$$

$$s = \pm 0.2364 \ (\text{at } X_E = \bar{X}_E = 46.0698)$$

b. Control Group

$$\hat{Y}_C = 3.0715 + 0.1311\ X_C$$

$$s = \pm 1.55\sqrt{\frac{1}{n_C} + \frac{(X_C-\bar{X}_C)^2}{S_{xx}}}$$

$$s = \pm 0.30411 \ (\text{at } X_C = \bar{X}_C = 45.8077)$$

The age corrected difference in the estimated values of the average eye scores for the exposed and control groups is d = 0.28405. This difference is not statistically significant at the 5% level, due in part to the small size of the sample. A difference of d = 0.2695 for Group III which is less than d for Group IV, was statistically significant at the 5% level. Group III was composed of 148 microwave workers and 147 controls as compared to 43 microwave workers and 26 controls in Group IV.

If the d for Group IV had been statistically significant it would have been further evidence that the d for the overall sample (Group III) is not due to bias on the part of the examiner since, as previously mentioned, Group IV was a completely non-biased sample.

Since the exposed individuals of Group IV had a higher estimated mean eye score than the controls, and the difference apparently would be statistically significant if the d applied to a larger sample, the results of this analysis are inconclusive although concordant with the hypothesis that exposed workers have a higher mean eye score than controls.

5. Group V

The linear model chosen to represent the regression of eye score on age for the exposed group is:

$$\text{Expected value of } Y = \beta_{o_E} + \beta_{1_E}(X_1 - \bar{X}_1) + \beta_{2_E}(X_2 - \bar{X}_2) = \mu$$

where;

μ = expected value of y, the eye score, for a given X_1 and X_2.

$\beta_{o_E}, \beta_{1_E}, \beta_{2_E}$ = regression coefficients

X_{1_E} = age

$\bar{X}_{1_E}$ = mean age

X_{2_E} = exposure score

$\bar{X}_{2_E}$ = mean exposure score

Estimated value of $\mu = \hat{Y}_E = b_{o_E} + b_{1_E}(X_{1_E} - \bar{X}_{1_E}) + b_{2_E}(X_{2_E} - \bar{X}_{2_E})$,

where

$b_{o_E}, b_{1_E}, b_{2_E}$ = estimated regression coefficients.

The analysis yielded the following regression equation:

$$\hat{Y}_E = 9.12 + 0.0994(X_{1_E} - \bar{X}_{1_E}) - 0.0144(X_{2_E} - \bar{X}_{2_E})$$

It was determined that b_{2_E} (= -0.0144) was not significantly greater than zero at the 5% level of significance.

The revised regression equation is therefore:

$$\hat{Y}_E = 9.12 + 0.101(X_E - 40.52)$$

or,

$$\hat{Y}_E = 5.03 + 0.101\ X_E$$

s = standard error of estimate $(\hat{Y}_E) = \pm 1.609 \sqrt{\frac{1}{n_E} + \frac{(X_E - \bar{X}_E)^2}{S_{xx}}}$

$= \pm\ 0.2280$ (at $X_E = 40.52 = \bar{X}_E$)

An analysis of the control group data was made according to the model:

$$\hat{Y}_C = b_{o_C} + b_{1_C}(X_C - \bar{X}_C)$$

the resulting regression equation is:

$$\hat{Y}_C = 1.59 + 0.18\ X_C$$

$$s = \pm\ 1.385 \sqrt{\frac{1}{n_C} + \frac{(X_C - \bar{X}_C)^2}{S_{xx}}}$$

$= \pm\ .1958$ (at $X_C = 40.52 = \bar{X}_C$)

The equations for the exposed and control group have been plotted in Figure 4-8. Although the exposed group has a higher mean eye score at ages less than about 44, the greater slope of the control group regression reverses this effect and the control group assumes the higher mean eye score at ages greater than 44.

The seemingly contradictory results of this analysis have not been considered of great importance due to the inherent limitations of linear regression techniques when based upon as small a sample as this. These limitations could result in the erroneous determination of the slope of the regression line as a result of the relatively few observations at the extremes of the age range being considered. In this case the data does indicate such an effect since a small group of exposed individuals with unusually low eye scores, appears at the extreme upper end of the age range.

The fact that the exposure score, (when adjusted) does not correlate with eye score also suggests that this exposed group chosen solely on the basis of exposure score, may not actually represent the most highly exposed individuals.

Although these two factors greatly reduce the importance of the results of this analysis its possible implications will not be neglected in future work.

III Individual Eye Score Category Frequency Distributions

The total eye score has been broken into its five components and the frequency distributions of each have been determined as shown in Table 4-7. There is some indication of differences in the distributions of some of the classes of lens defects, indicating that the five types of recorded lenticular imperfections may be associated with microwave exposure to varying degrees.

It should be noted that due to the limitations of the scoring system (i.e., only four possible scores: 0,1,2,3) a detailed statistical analysis, of the type used above, to determine the significance of these differences in individual category scores may not be too meaningful. Therefore, the data were subjected to a chi square analysis in which the significance of differences in the exposed and control group scores in each category is determined. The chi square values for the five lens categories are shown in Table 4-8. This procedure, it is hoped, will lead to more insight regarding the etiology of the minor lens changes produced by microwave radiation.

A. Minute Defects

The mean minute defects score for the exposed group is greater than for the control group (i.e., mean score exposed group = 1.777 mean score control group = 1.630). The chi square value is 5.21 with 3 degrees of freedom. This value is not significant at the 5% level ($P > .05$); therefore, there does not appear to be a significant difference in minute defects between the exposed and control groups.

B. Opacification

The mean opacification scores for the exposed and control groups are 1.821 and 1.622 respectively. The chi square value is 23.20 which indicates that there is a difference in opacification scores which is significant at the .5% level ($P < .005$). Since the exposed group has the greater mean opacification score, this difference appears to be very suggestive of specific effects of microwave radiation on opacification changes in the lens.

C. Relucency

The mean relucency score for the exposed group is 1.709 compared to 1.591 for the control group. The chi square value for relucency is 8.96. This value is not significant at the 0.5% level, but it is significant at the 5% level ($P < 0.05$).

D. Sutural Defects

The frequency distributions of sutural defects for the exposed and control groups show no obvious differences in shape. This is also noted in reference to the mean scores which are very nearly equal. The mean sutural defects scores are 1.208 and 1.193 for the exposed and control groups respectively. The chi square value is 0.59 which is not significant at the 5% level. It appears that sutural defects are not sensitive indicators of microwave exposure.

E. Posterior Polar Defects

The shapes of the posterior polar defects frequency distribution histograms indicate that there may be a more appreciable difference in the relative number of posterior polar defects between the exposed and control groups as compared to the other minor lens defect categories. The exposed group is more centrally distributed than the control group, which shows a maximum frequency of score zero. The skewed distribution of posterior polar defects among the controls is the only distribution of this configuration noted among any of the lens categories. The increased frequency of zero suggests that posterior polar imperfections occur relatively infrequently in comparison to the other types of lens changes noted in this study.

Thirty-three per cent of the exposed group and 52% of the control group received posterior polar scores of zero. The sutural defects category, which has the next highest percentage of zero scores, shows 8% and 9% zero scores for the exposed and control group respectively. This indicates that on the average at least four times as many individuals (either exposed or controls) will have insignificant numbers of posterior polar defects as compared to the number having insignificant numbers or degrees of other lens changes (i.e., minute defects, relucency, sutural defects, opacifications).

There also appears to be a marked difference in the posterior polar defects of the exposed and controls. The percentage of exposed individuals with posterior polar defects scores of two or greater is 20% compared to 4% for the controls. Therefore, it is on the average five times more probable that an individual who receives a posterior polar defects score of two or greater is a member of the group exposed to microwave radiations.

The chi square value is 53.83. This value is highly significant ($P < .005$) and is very strongly suggestive of a relative degree of specificity of this type of lens change for microwave radiation exposure.

TABLE 4-1

TOTAL SAMPLE

Number of Exposed = 475

Number of Controls = 362

Total 837

Age Frequency Distribution Group II

	EXPOSED GROUP			CONTROL GROUP		
Age Group	Number Individuals	%	Cumulative %	Number Individuals	%	Cumulative %
16-20	28	5.8	5.8	37	10.22	10.22
21-25	70	14.74	20.54	76	20.99	31.21
26-30	115	24.21	44.75	59	16.30	47.51
31-35	91	19.16	63.91	58	16.02	63.53
36-40	70	14.74	78.65	51	14.09	77.62
41-45	45	9.47	88.12	38	10.50	88.12
46-50	19	4.00	92.12	22	6.08	94.20
51-55	20	4.21	96.33	12	3.32	97.52
56-60	16	3.37	99.70	8	2.21	99.73
61-65	1	.21	99.91	1	.28	100.01

TABLE 4-2

EYE SCORE FREQUENCY DISTRIBUTION

TOTAL SAMPLE

Total Eye Score	EXPOSED GROUP Number Individuals	%	Cumulative %	CONTROL GROUP Number Individuals	%	Cumulative %
0	0	0	0	0	0	0
1	2	.42	.42	1	.28	.28
2	2	.42	.84	10	2.76	3.04
3	9	1.90	2.74	16	4.42	7.46
4	69	14.53	17.27	75	20.72	28.18
5	42	8.84	26.11	37	10.22	38.40
6	32	6.74	32.85	21	5.80	44.20
7	60	12.63	45.48	55	15.19	59.39
8	107	22.53	68.01	63	17.40	76.79
9	76	16.00	84.01	47	12.98	89.77
10	39	8.21	92.22	19	5.25	95.02
11	18	3.79	96.01	8	2.21	97.23
12	10	2.10	98.11	8	2.21	99.44
13	7	1.47	99.58	2	.55	100.00
14	1	.21	99.79	0	0	100.00
15	1	.21	100.00	0	0	100.00

TABLE 4-3

EXPOSURE SCORE FREQUENCY DISTRIBUTION

TOTAL SAMPLE

No.	Exposure Score	Number Individuals	%	Cumulative %
1	1-5	32	6.74	6.74
2	6-10	160	33.68	40.42
3	11-15	92	19.39	59.81
4	16-20	74	15.58	75.39
5	21-25	46	9.68	85.07
6	26-30	22	4.63	89.70
7	31-35	5	1.05	90.75
8	36-40	11	2.32	93.07
9	41-45	15	3.16	96.23
10	46-50	3	.63	96.86
11	51-55	2	.42	97.28
12	56-60	3	.63	97.91
13	61-65	2	.42	98.33
14	66-70	4	.84	99.17
15	71-75	3	.63	99.80
16	76-80	0	0	99.80
17	81-85	1	.21	100.00

TABLE 4-4

FREQUENCY DISTRIBUTION OF DURATION OF MICROWAVE WORK

TOTAL SAMPLE

No.	Duration (months)	Number Individuals	%	Cumulative %
1	0-19	87	18.32	18.32
2	20-39	76	16.00	34.32
3	40-59	74	15.58	49.90
4	60-79	54	11.37	61.27
5	80-99	49	10.32	71.59
6	100-119	36	7.58	79.17
7	120-139	36	7.58	86.75
8	140-159	18	3.79	90.54
9	160-179	9	1.89	92.43
10	180-199	10	2.11	94.54
11	200-219	12	2.53	97.07
12	220-239	1	.21	97.28
13	240-259	6	1.26	98.54
14	260-279	1	.21	98.75
15	280-299	1	.21	98.96
16	300-319	3	.63	99.59
17	320-339	0	0	99.59
18	340-359	0	0	99.59
19	360-379	1	.21	99.81
20	560-579	1	.21	100.00

TABLE 4-5

MICROWAVE WORKERS

JOB CLASSIFICATION

FREQUENCY DISTRIBUTION

Job Classification*	Number Individuals	%
0	86	18.11
1	7	1.47
2	36	7.58
3	142	29.90
4	2	.42
5	1	.21
6	121	25.47
7	10	2.11
8	59	12.42
9	11	2.32

* see Appendix III-D for designations

TABLE 4-6

GROUP DESIGNATIONS

Group Number	Description	Exposed		Controls	
		No.	Mean Age (years)	No.	Mean Age (years)
I	Total personnel from (Installations B thru I)	327	36.28	212	36.73
II	Total sample (Installation A thru I)	475	33.36	359	32.6
III	Installation A	148	26.92	147	26.65
IV	Installation G	43	46.07	26	45.80
V	Microwave workers from Installations B thru I with exposure score >25 plus age matched controls	50	40.46	50	40.46

TABLE 4-7

MINUTE DEFECTS FREQUENCY DISTRIBUTIONS GROUP II

Minute Defects Score	Number Exposed	Number Controls
0	9	7
1	148	141
2	258	173
3	60	41
Mean minute defects score =	1.777	= 1.630

OPACIFICATION FREQUENCY DISTRIBUTION GROUP II

Opacification Score	Number Exposed	Number Controls
0	1	6
1	130	148
2	297	185
3	47	23
Mean opacification score =	1.821	= 1.622

RELUCENCY FREQUENCY DISTRIBUTION GROUP II

Relucency Score	Number Exposed	Number Controls
0	3	7
1	163	153
2	278	183
3	31	19
Mean relucency score =	1.709	= 1.591

TABLE 4-7 (continued)

SUTURAL DEFECTS FREQUENCY DISTRIBUTION GROUP II

Sutural Defects Score	Number Exposed	Number Controls
0	37	31
1	313	241
2	114	79
3	11	11
Mean sutural defects score =	1.208	= 1.193

POSTERIOR POLAR DEFECTS FREQUENCY DISTRIBUTION GROUP II

Posterior Polar Defects Score	Number Exposed	Number Controls
0	157	186
1	225	162
2	89	14
3	4	0
Mean posterior polar defects score	= 0.874	= .525

TABLE 4-8

Lens Category	Mean Score Exposed Group	Mean Score Control Group	χ^2 Chi Square Value	Level of Significance (P)
Mihute Defects	1.77	1.63	5.21	$>.05$
Opacification	1.82	1.62	23.20	$<.005$
Relucency	1.71	1.59	8.96	$<.05$
Sutural Defects	1.21	1.19	0.59	$>.05$
Posterior Polar Defects	.87	.53	53.83	$\ll.005$

TABLE 4-9

MEAN EYE SCORE AND MEAN AGE AT INSTALLATIONS IN GROUP II

TOTAL SAMPLE

	Control Group			Exposed Group		
Installation	Number Individuals	Mean Age	Mean Total Eye Score	Number Individuals	Mean Age	Mean Total Eye Score
A	147	26.65	4.76	148	26.92	5.07
B	20	33.00	6.8	19	33.68	7.947
C	38	38.316	8.03	75	36.0	8.57
D	8	26.375	8.00	13	26.38	7.69
E	25	33.96	7.36	29	30.48	8.21
F	37	29.92	7.27	96	33.64	7.68
G	26	45.81	9.08	43	46.07	9.40
H	41	40.44	8.268	40	40.83	9.55
I	17	38.53	8.30	12	37.83	8.08

Figure 4-1-a

AGE FREQUENCY DISTRIBUTION

Total Exposed Group

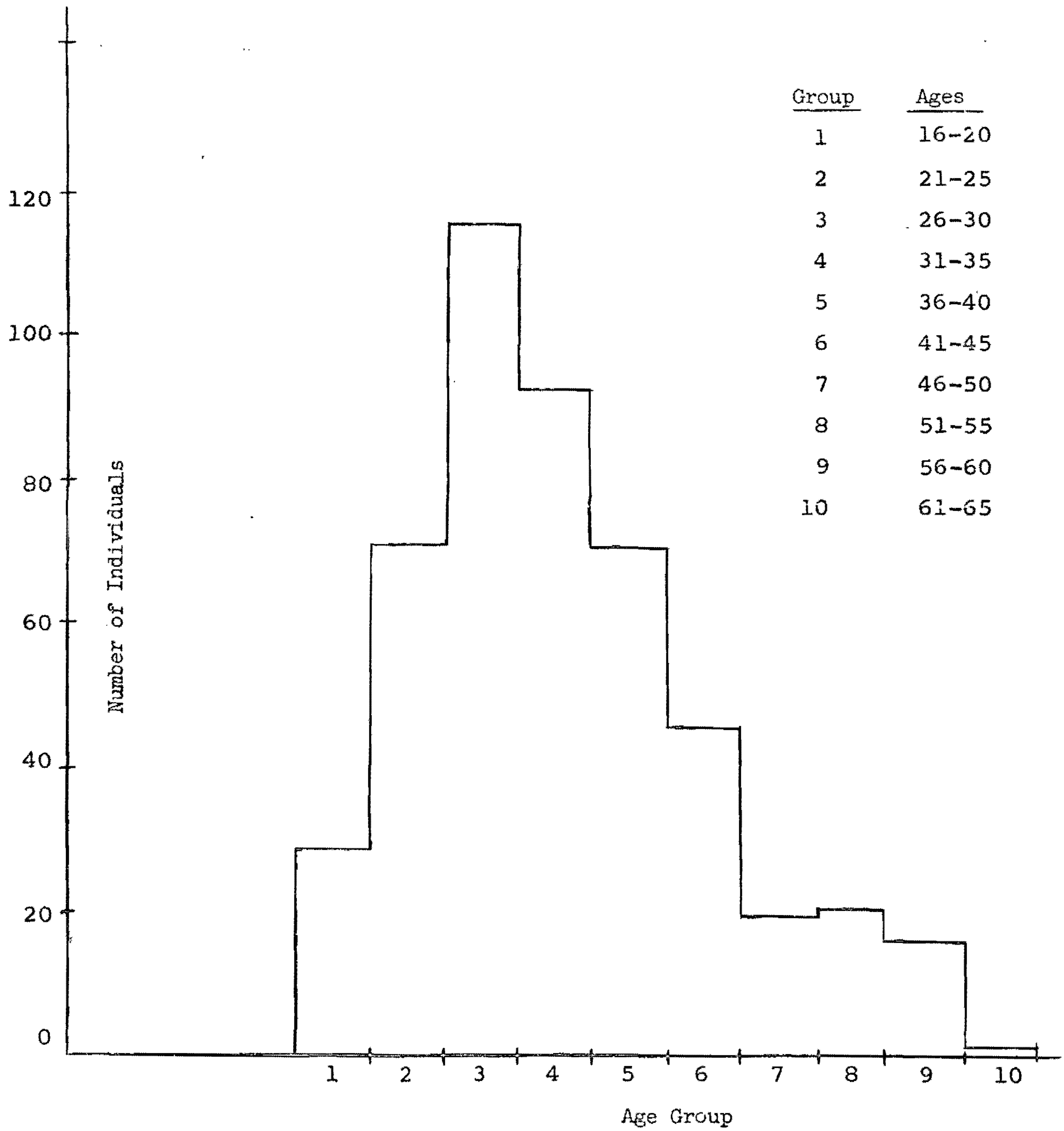


Figure 4-1-b

AGE FREQUENCY DISTRIBUTION

Total Control Group

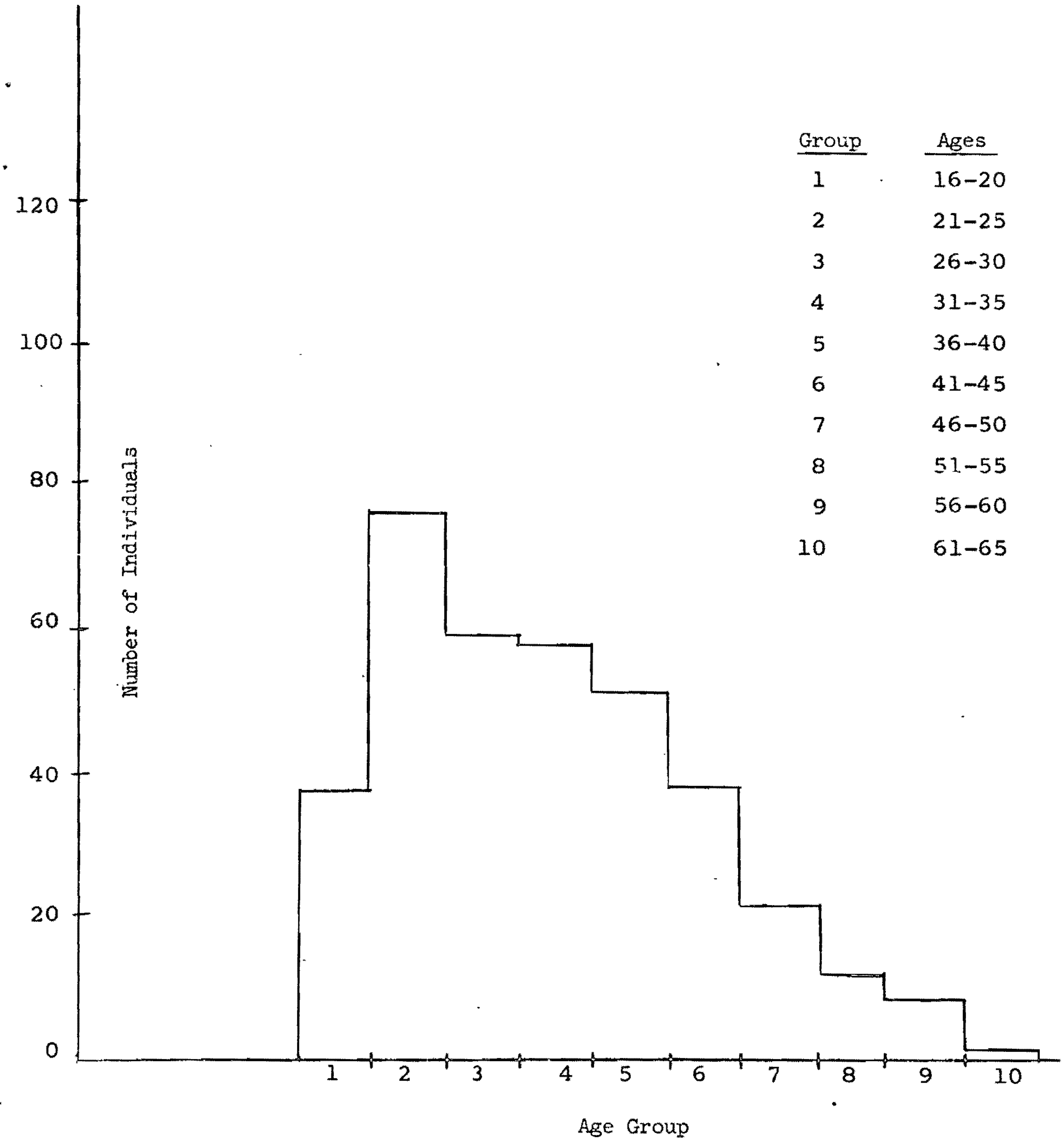


Figure 4-2-a

EYE SCORE FREQUENCY DISTRIBUTION

Total Exposed Group

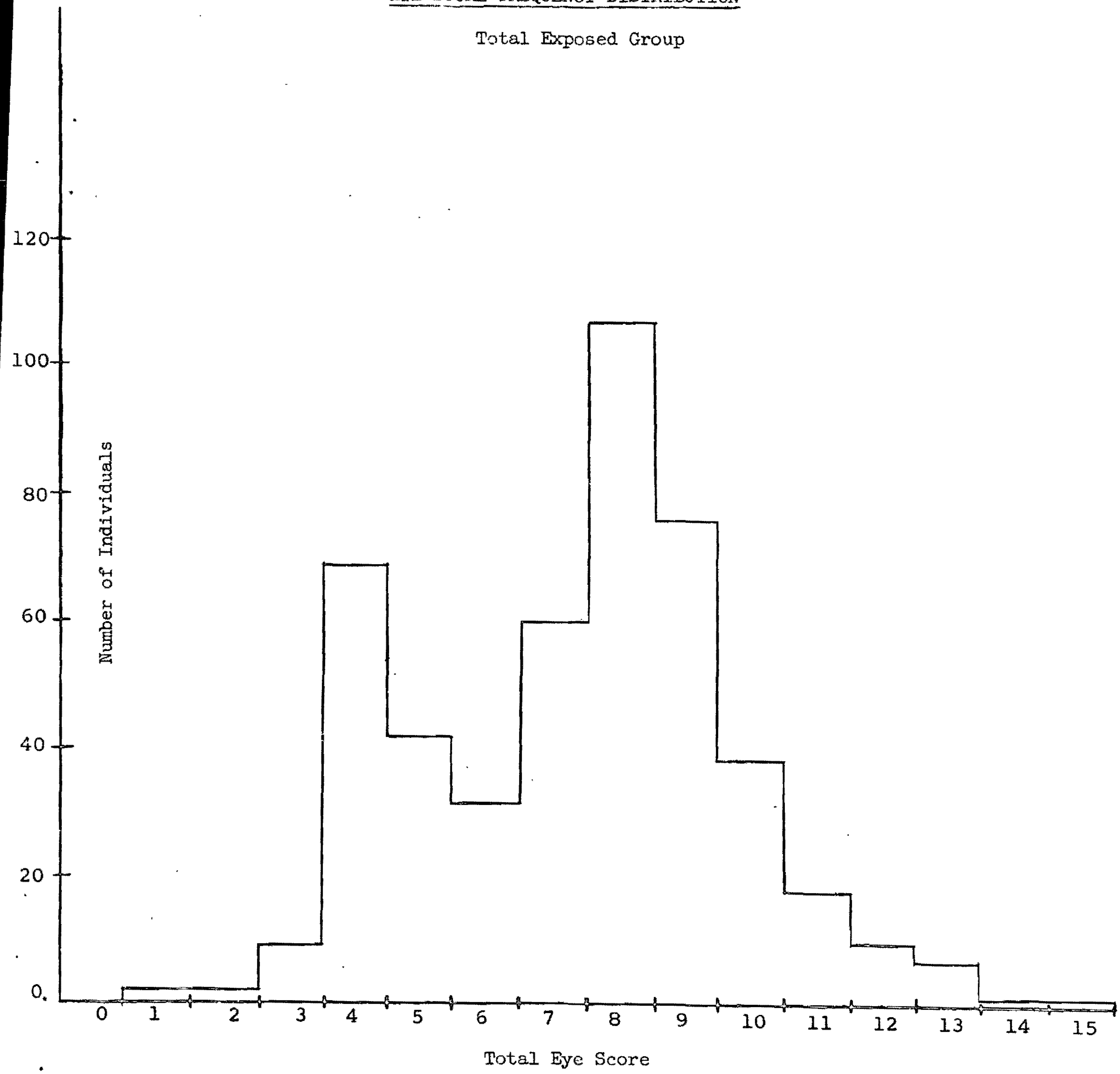


Figure 4-2-b

EYE SCORE FREQUENCY DISTRIBUTION

Total Control Group

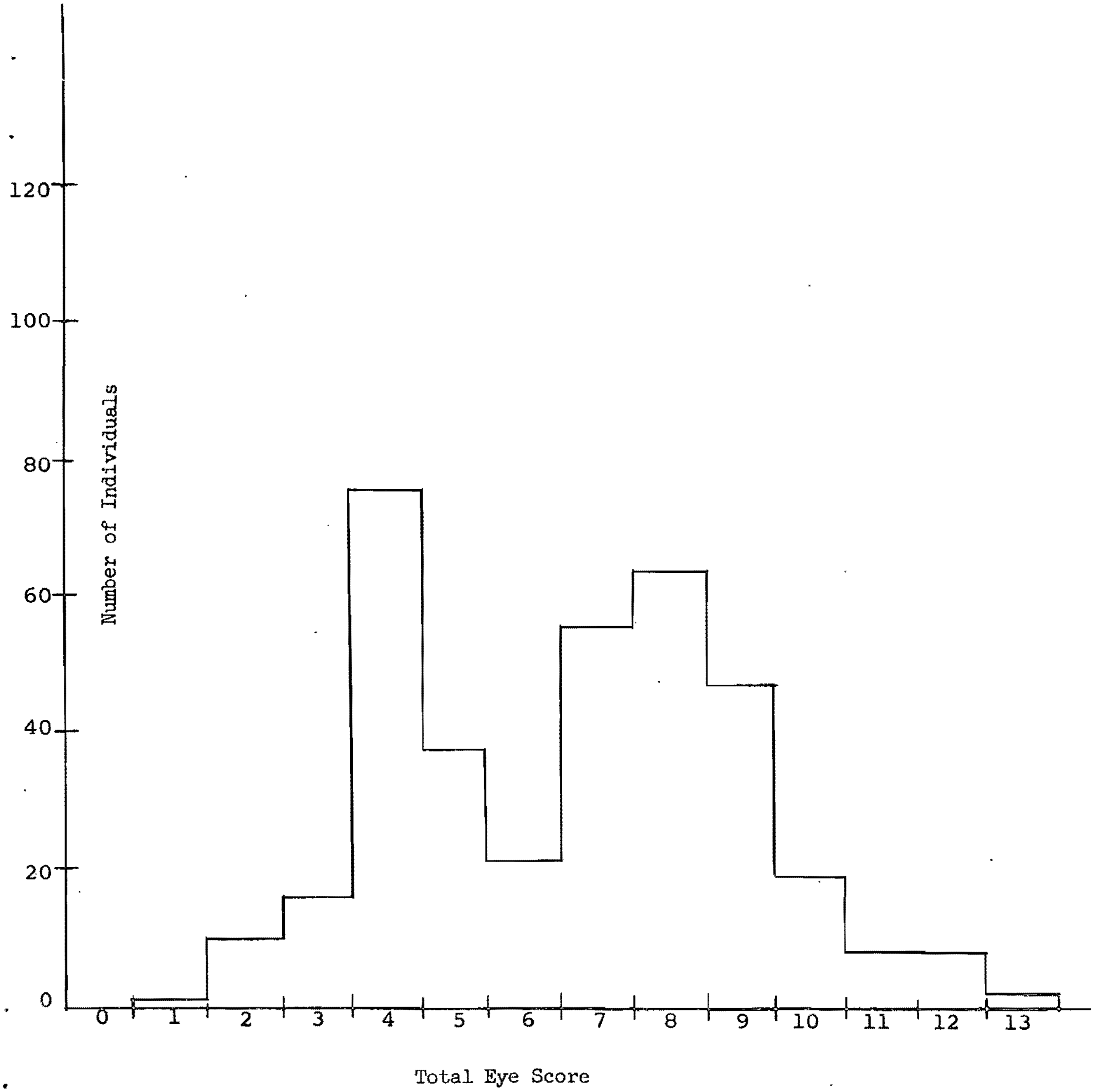
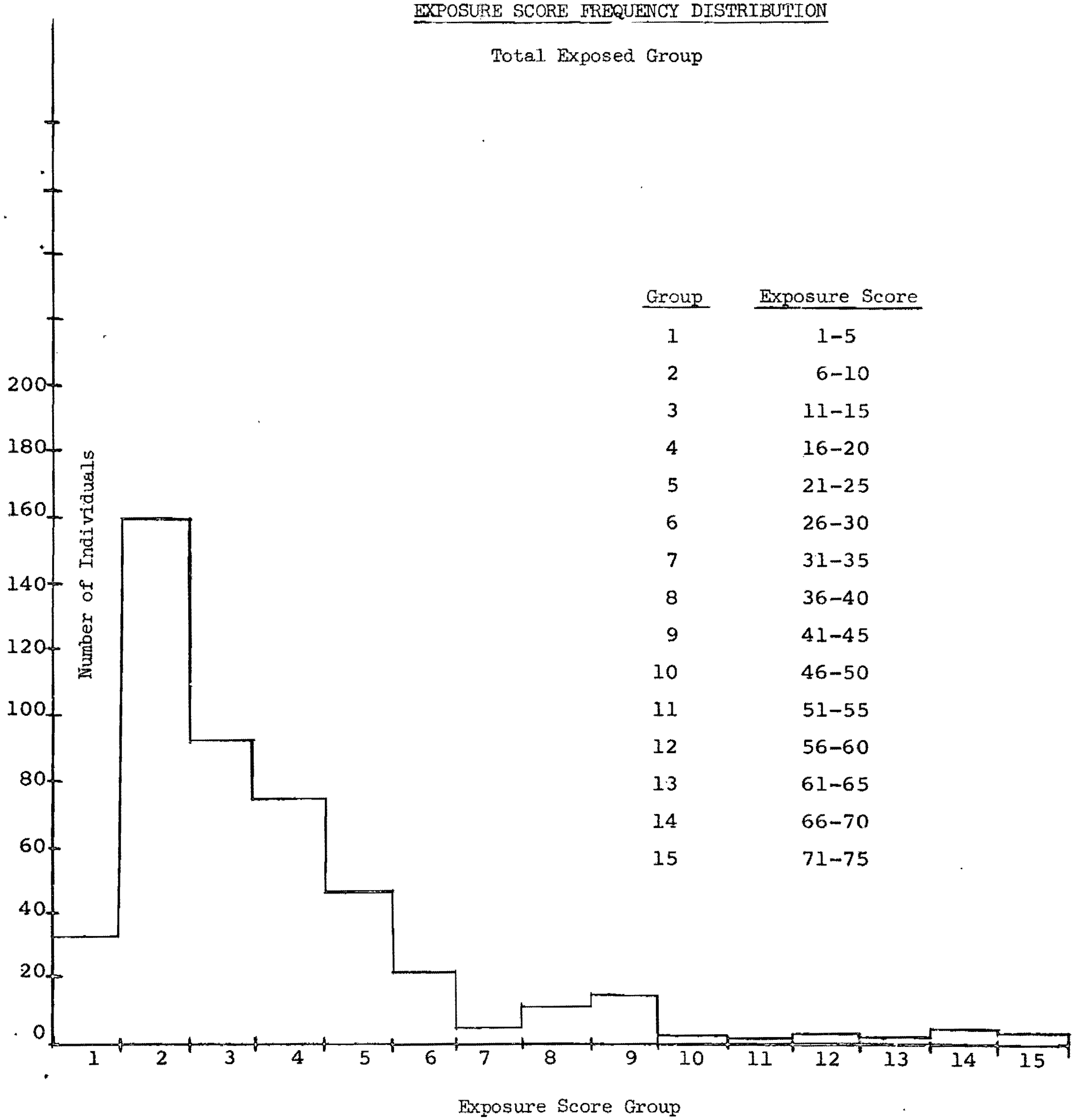


Figure 4-3

EXPOSURE SCORE FREQUENCY DISTRIBUTION

Total Exposed Group



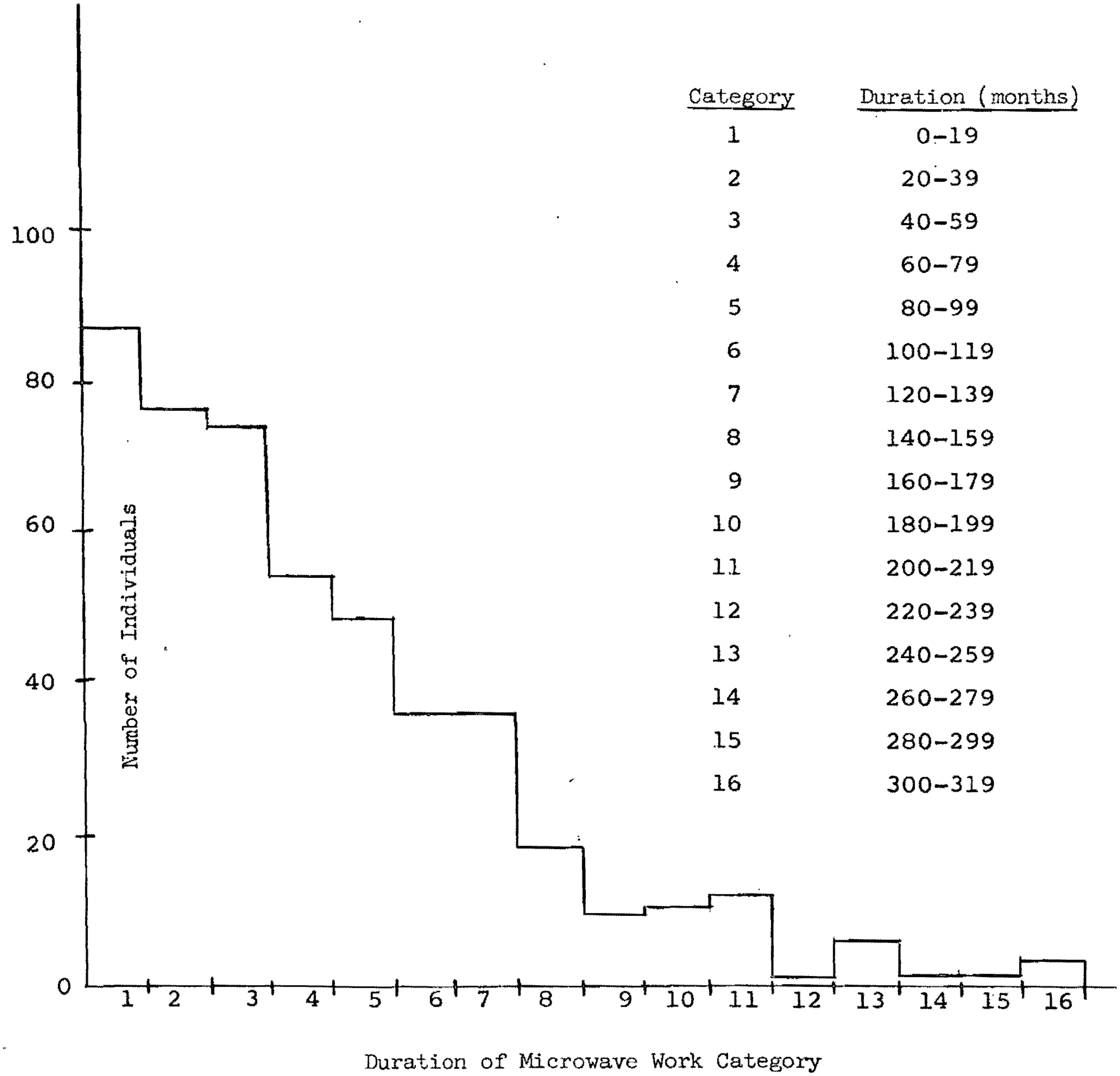
Group	Exposure Score
1	1-5
2	6-10
3	11-15
4	16-20
5	21-25
6	26-30
7	31-35
8	36-40
9	41-45
10	46-50
11	51-55
12	56-60
13	61-65
14	66-70
15	71-75

Figure 4-4

DURATION OF MICROWAVE WORK

FREQUENCY DISTRIBUTION

Total Exposed Group



Category	Duration (months)
1	0-19
2	20-39
3	40-59
4	60-79
5	80-99
6	100-119
7	120-139
8	140-159
9	160-179
10	180-199
11	200-219
12	220-239
13	240-259
14	260-279
15	280-299
16	300-319

Figure 4-5

EYE SCORE VS AGE

Group I

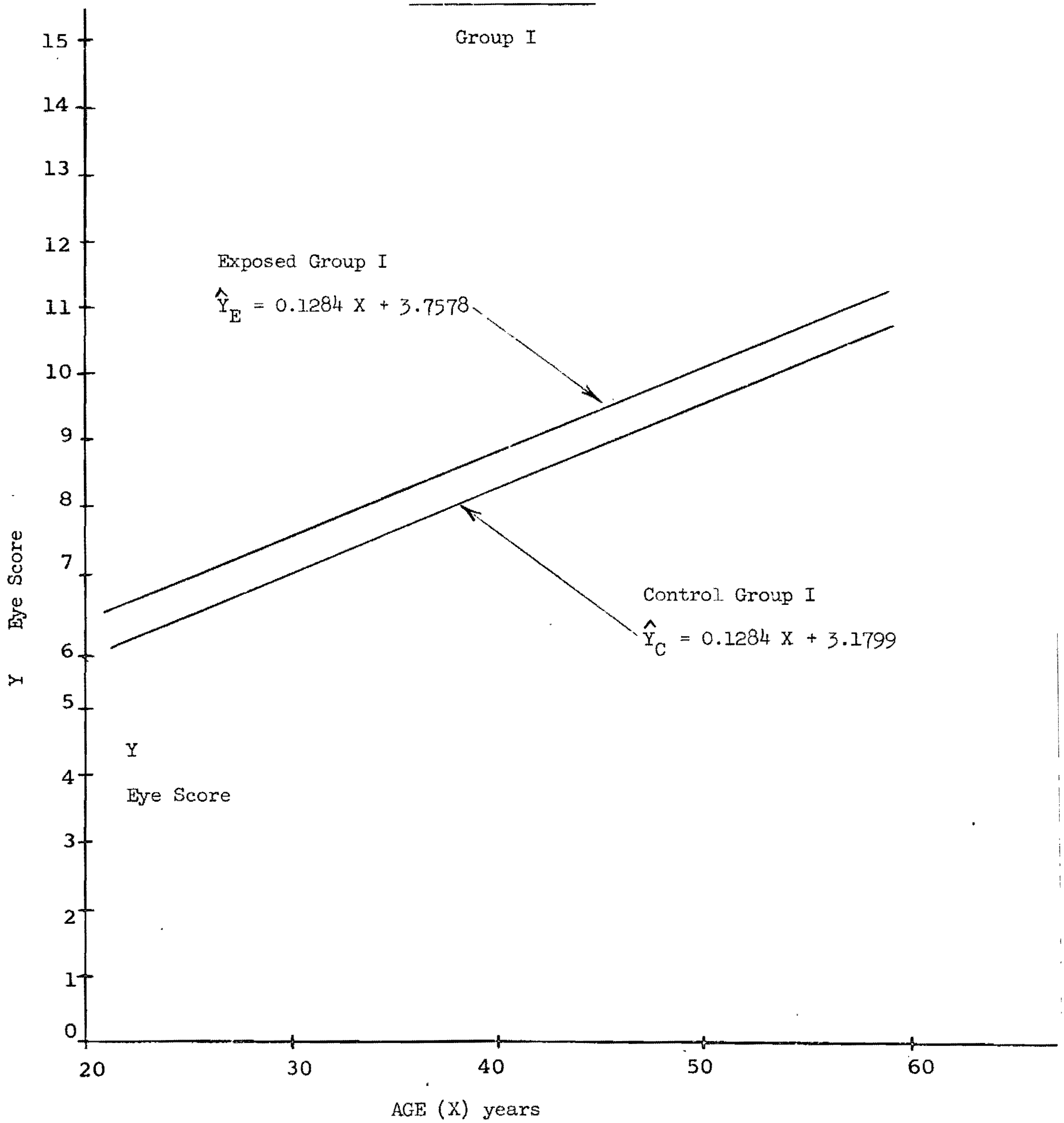
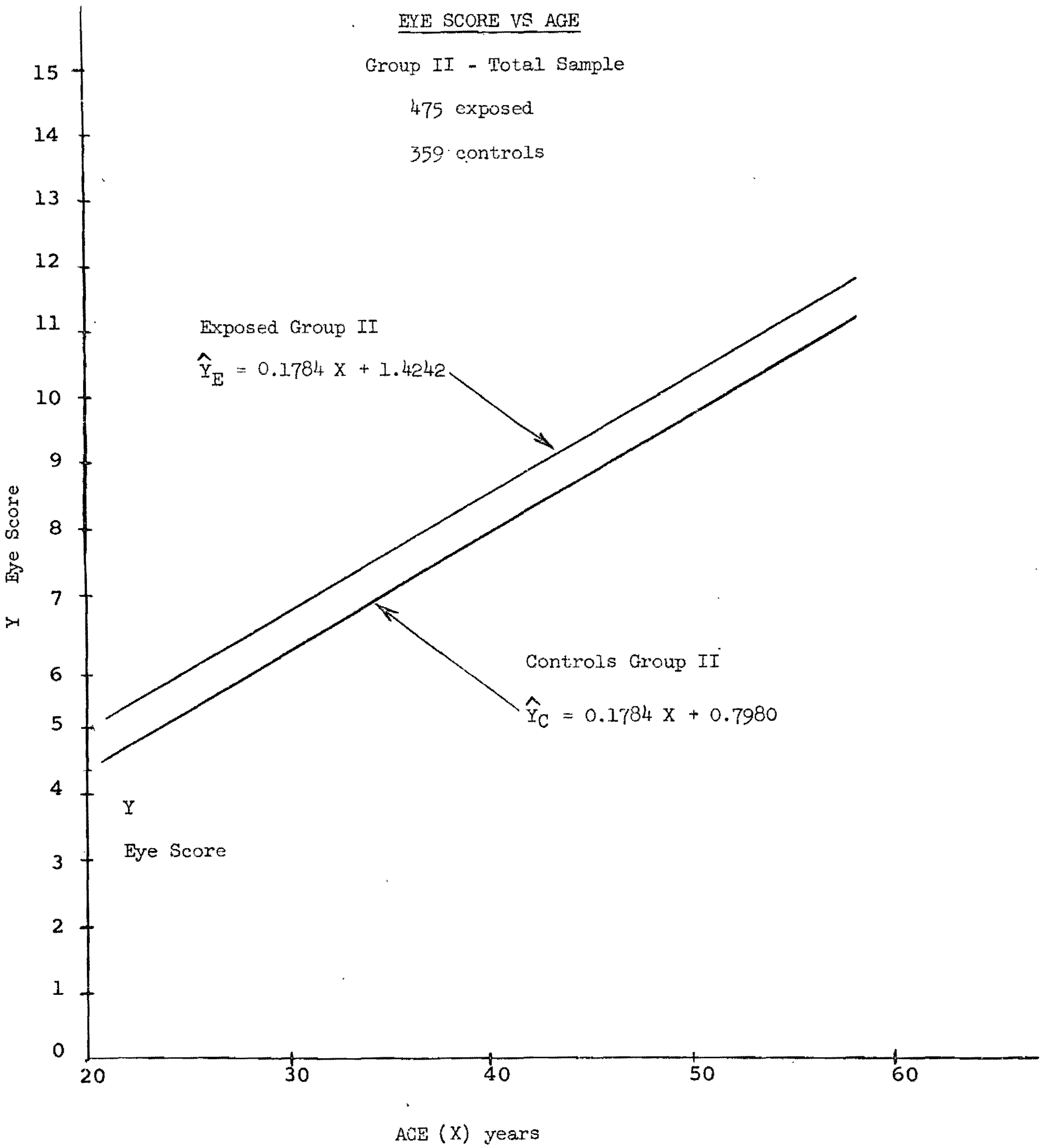


Figure 4-6



EYE SCORE VS AGE
Group II - Total Sample
475 exposed
359 controls
Exposed Group II
$\hat{Y}_E = 0.1784 X + 1.4242$
Controls Group II
$\hat{Y}_C = 0.1784 X + 0.7980$
Y Eye Score
Y
Eye Score
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
20
30
40
50
60
AGE (X) years

Figure 4-7

EYE SCORE VS AGE

Group III

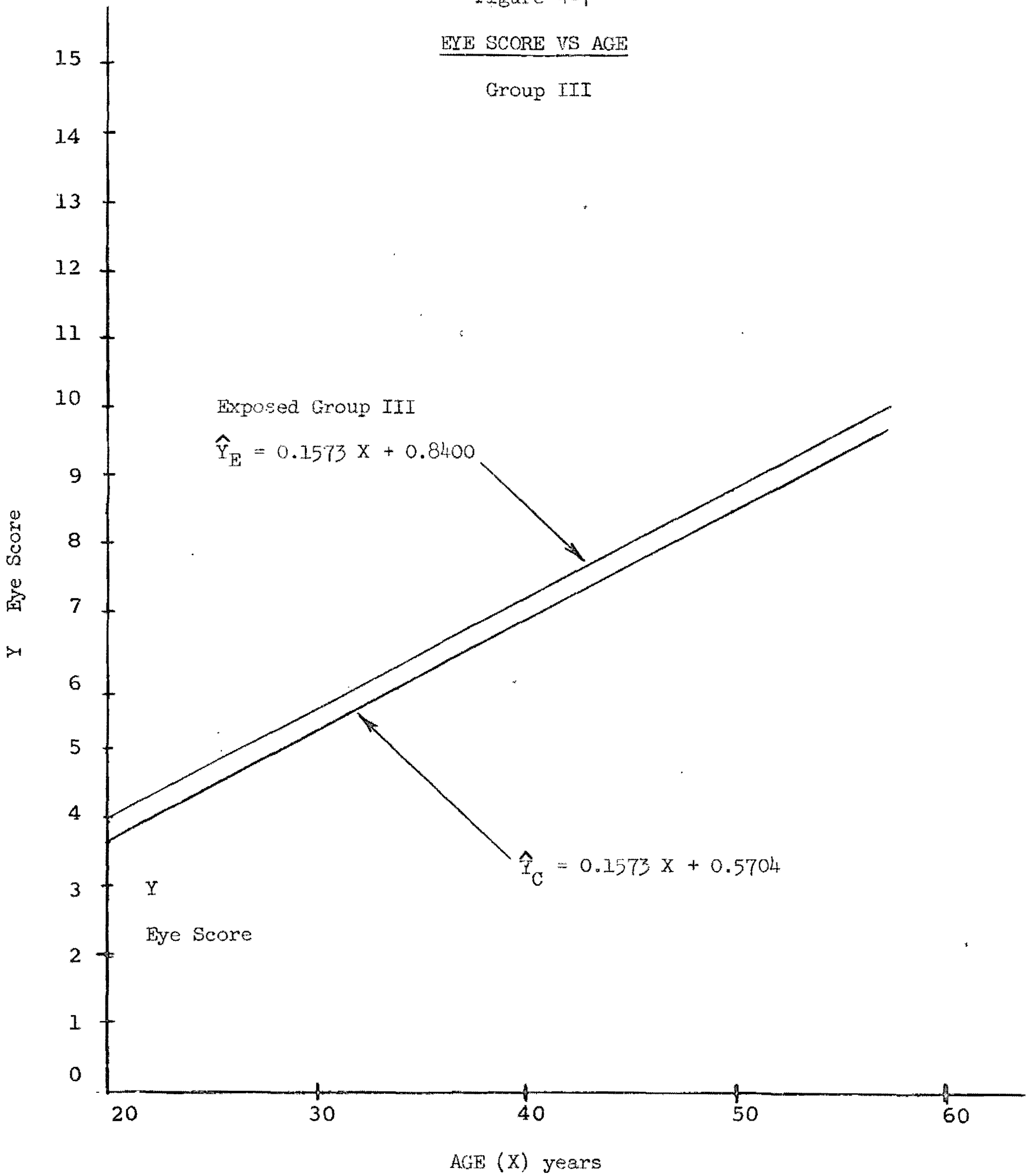


Figure 4-8

EYE SCORE VS AGE

Group V

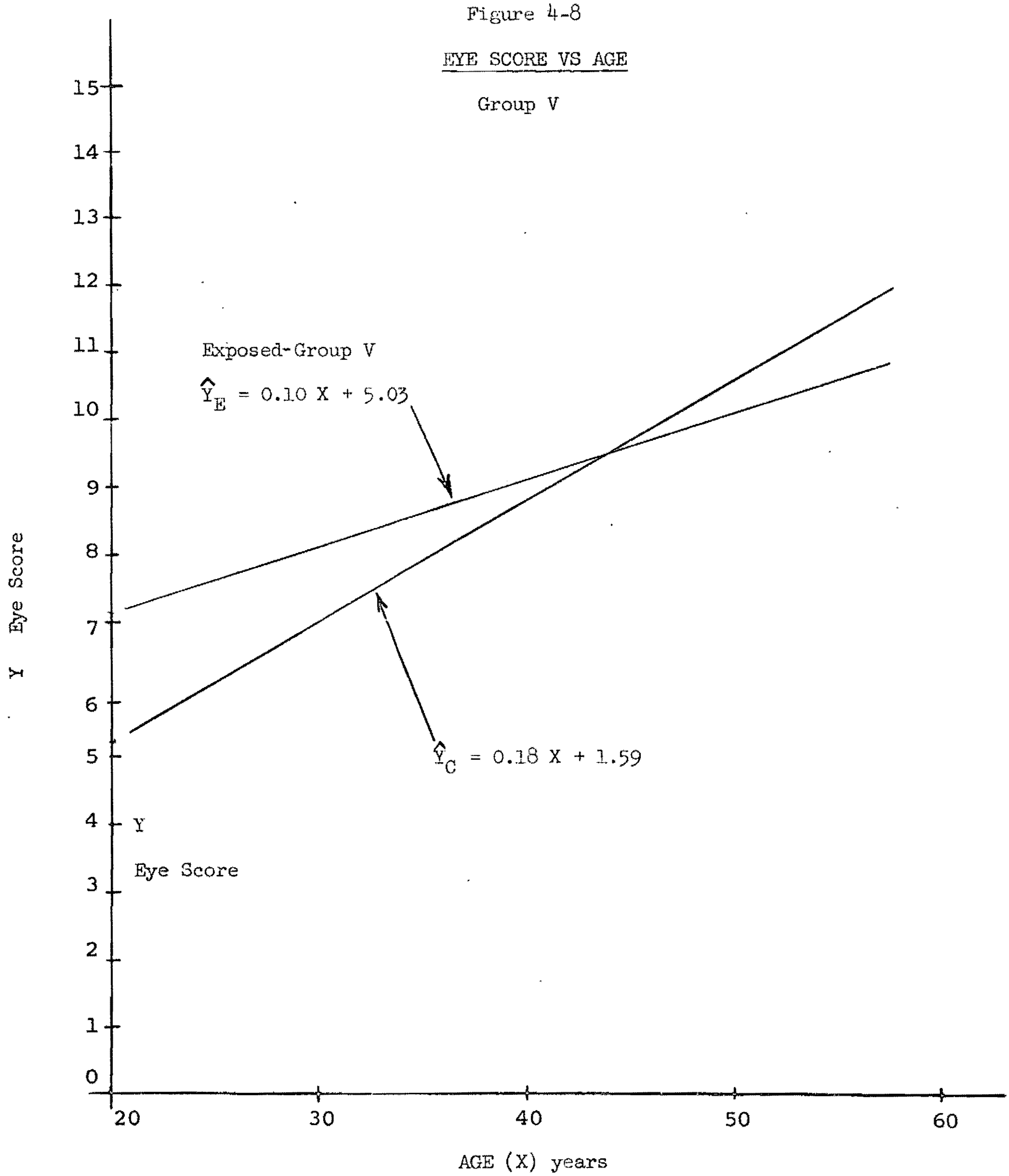


Figure 4-9

RELATIVE FREQUENCY DISTRIBUTION

MINUTE DEFECTS

Total Sample - Group II

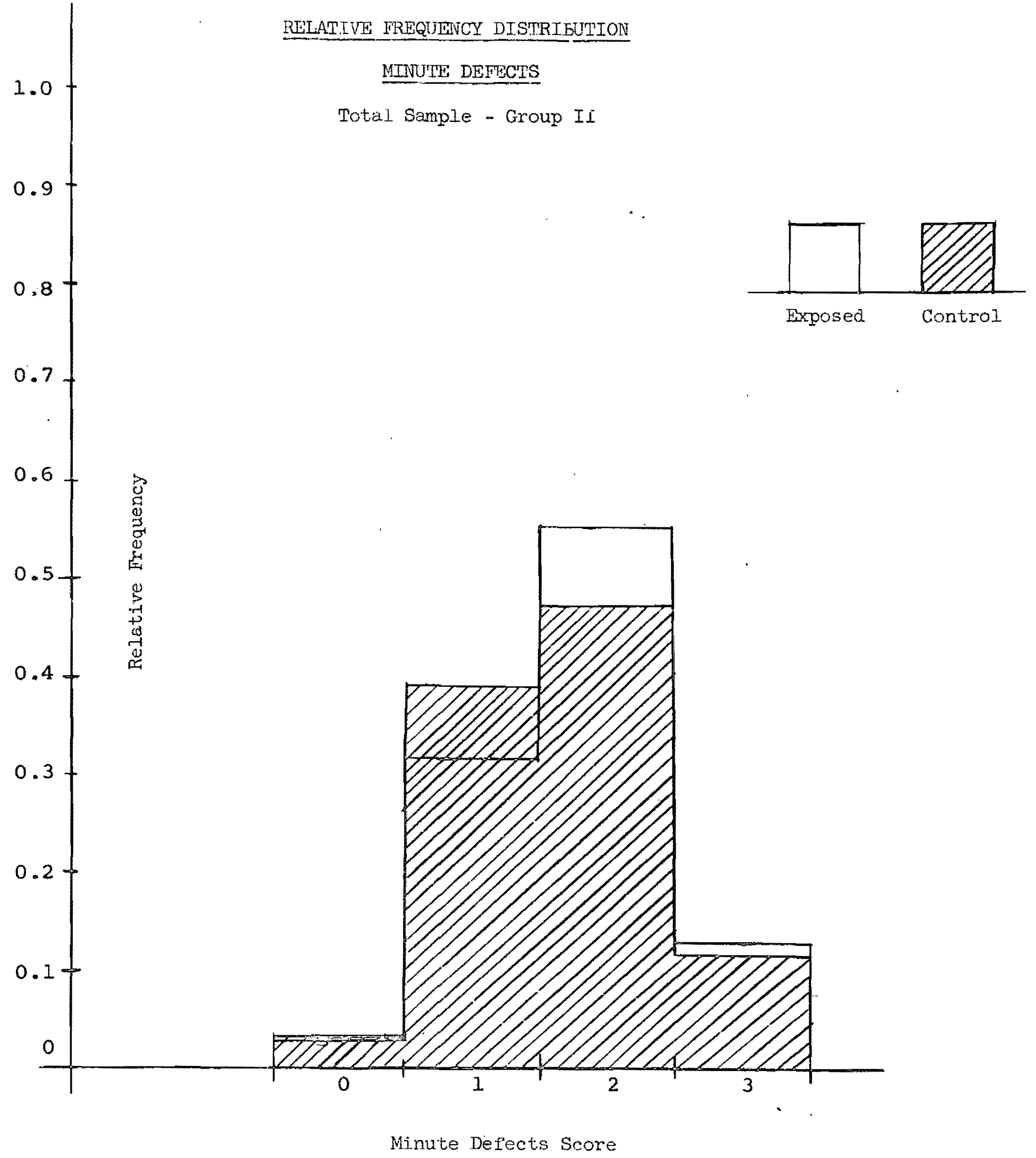


Figure 4-10

RELATIVE FREQUENCY DISTRIBUTION

OPACIFICATION

Total Sample - Group II

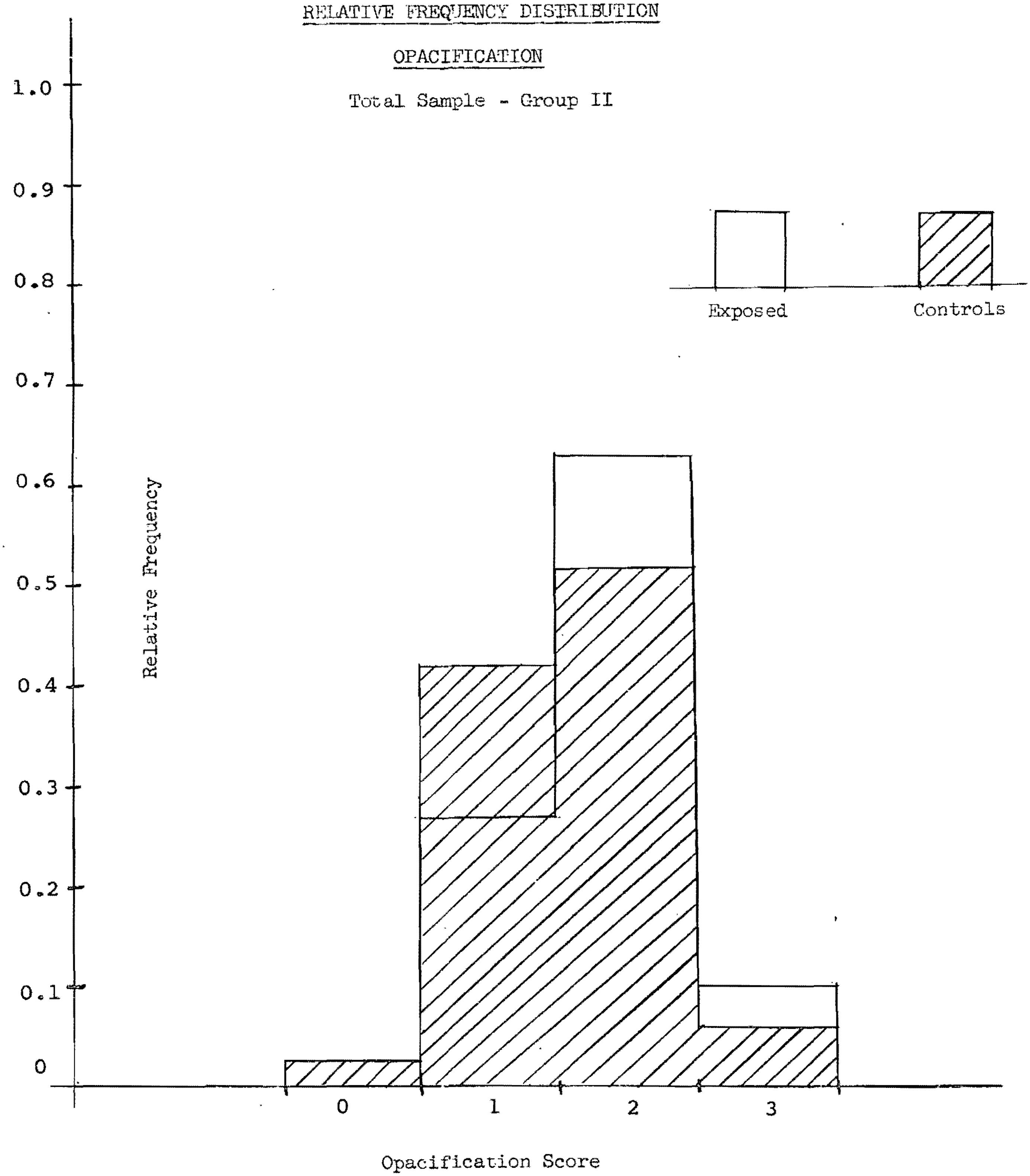


Figure 4-11

RELATIVE FREQUENCY DISTRIBUTION

RELUCENCY

Total Sample - Group II

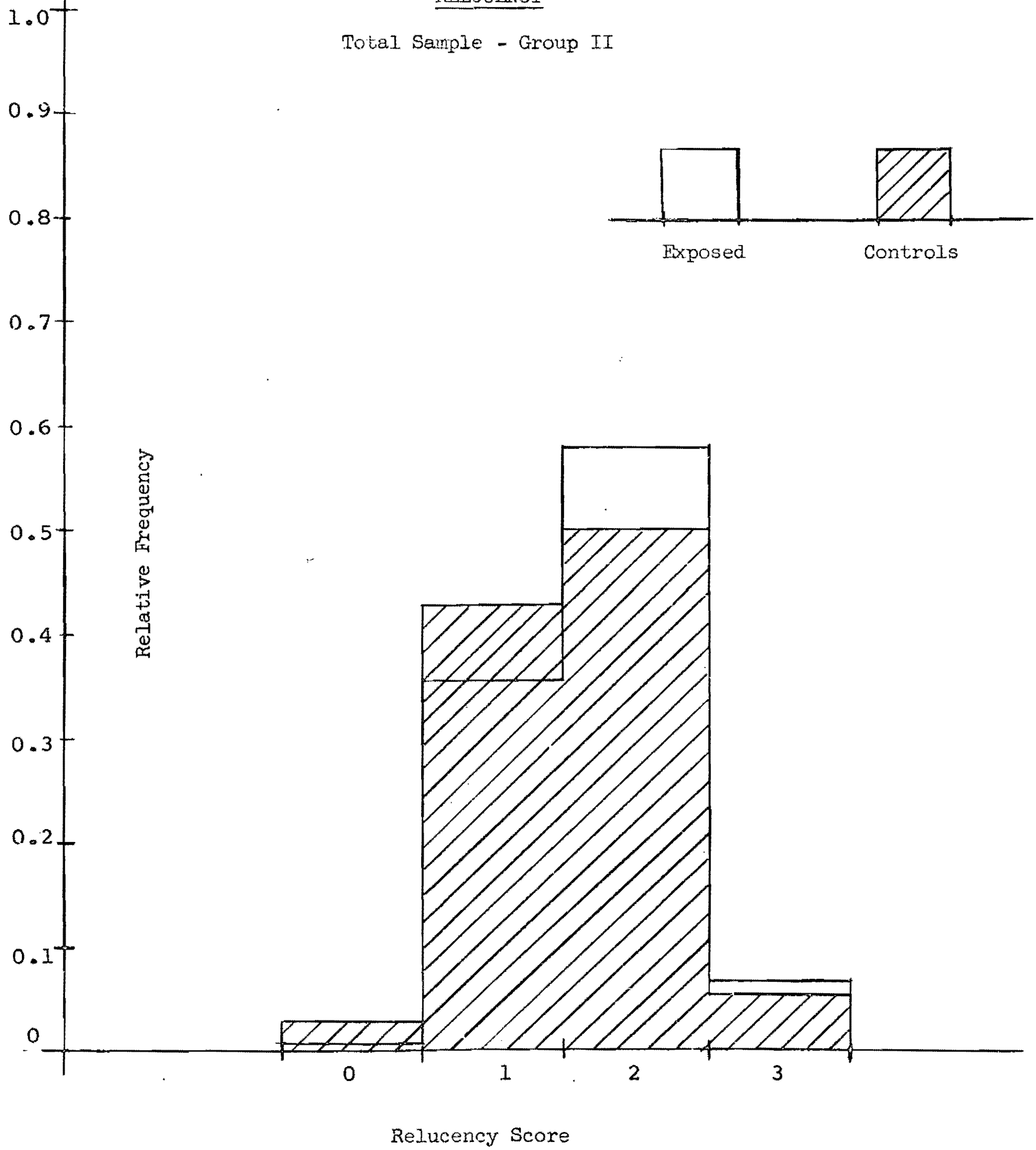


Figure 4-12

RELATIVE FREQUENCY DISTRIBUTION

SUTURAL DEFECTS

Total Sample - Group II

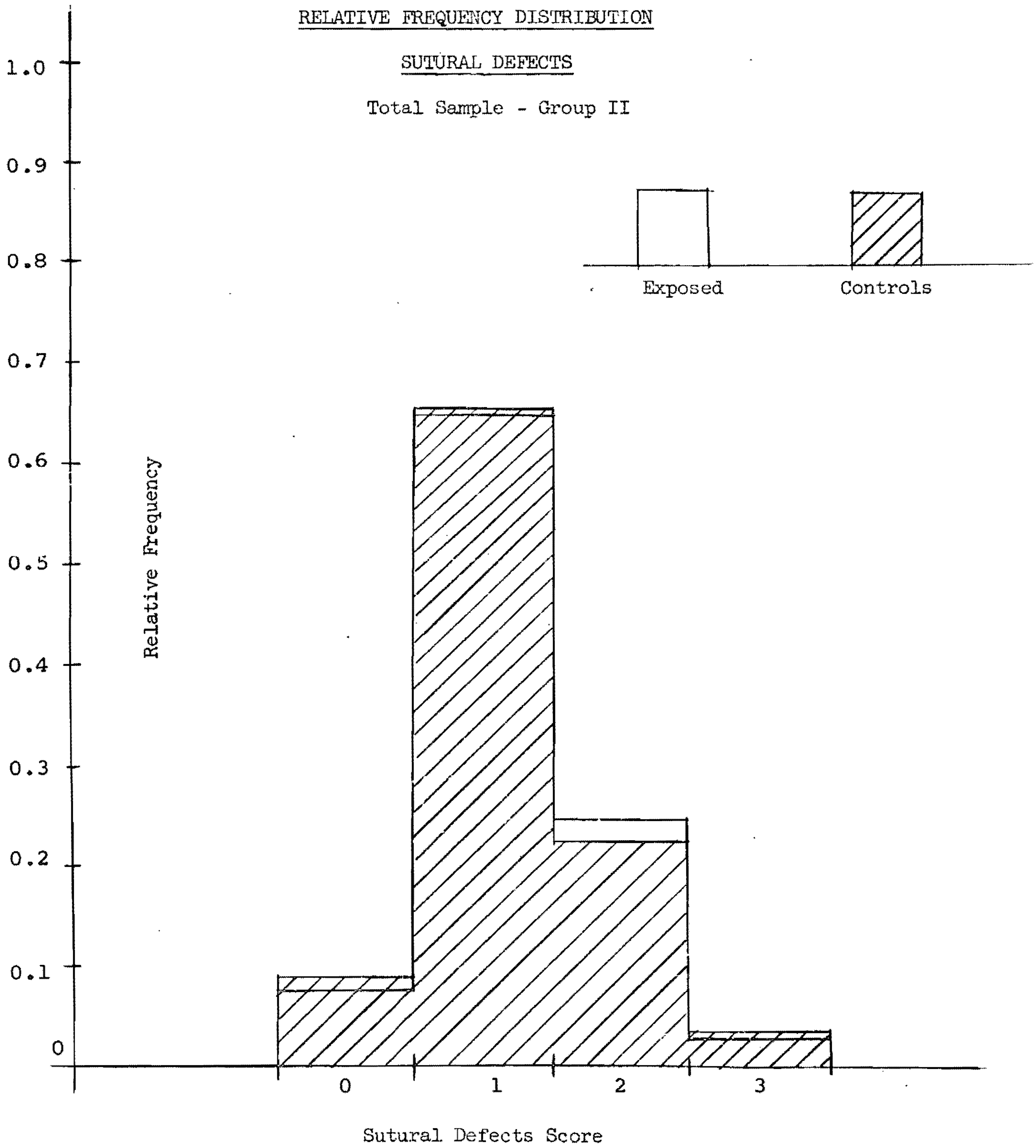
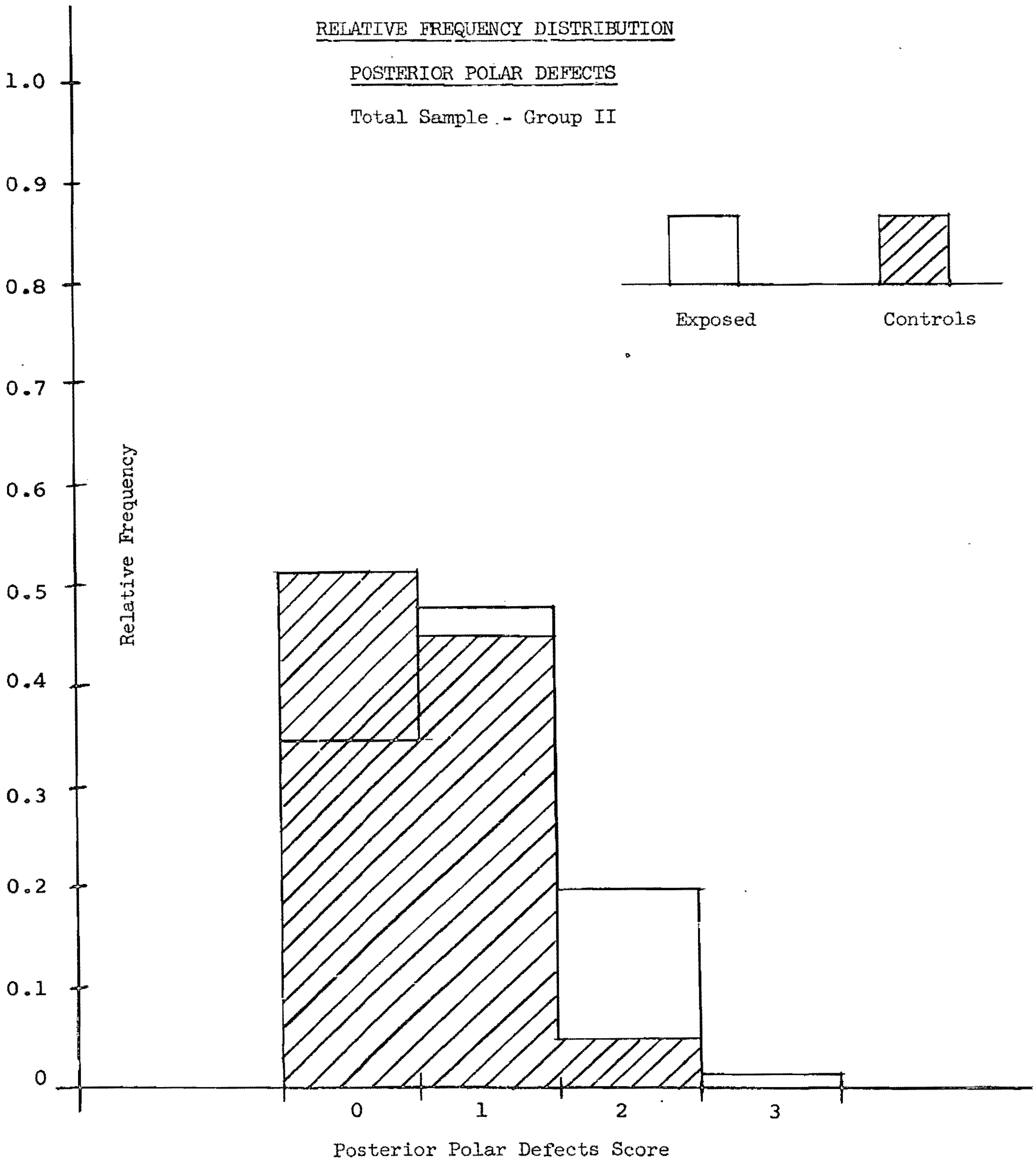


Figure 4-13

RELATIVE FREQUENCY DISTRIBUTION

POSTERIOR POLAR DEFECTS

Total Sample - Group II



V

OPHTHALMOLOGICAL OBSERVATIONS OF SPECIAL CLINICAL SIGNIFICANCE

During the course of performing the slit-lamp examinations, several patients exhibited findings meriting special consideration because the lens appearances were of an unusual nature and were not fully defined by the standard method of expression delineated in this study.

A. Metabolic Lens Changes

One patient in the control group and one in the exposed group had marked equatorial region changes indicative of metabolic derangement of the lens. Careful inquiry into past history elicited the information that the "control" patient had previously worked for several years in an ionizing radiation laboratory where one of his job responsibilities was to adjust targets in a cyclotron.

The other patient with similar lenticular findings, was a juvenile diabetic whose diabetes mellitus could not be brought under adequate medical control and the patient died in diabetic coma several months prior to the scheduled re-examination of his lenses.

B. Intumescent Lenses

Two patients in the exposed group exhibited bilateral swelling of the lenses at the time of slit-lamp examination.

In both cases, there was no other evidence of disease and the patients were asymptomatic.

This finding indicated acute lens injury which probably occurred within two weeks of the eye examination. In each instance, interrogation revealed the probability that these patients had been exposed to levels of microwave radiation substantially exceeding 10 milliwatts per square centimeter.

C. Localized Regions of Lens Opacification

Two patients in the exposed group exhibited an unusual, monocular macroscopic lens defect. Both of these were similar and each appeared as a peripheral, sharply circumscribed irregular and opacified tract extending from the capsule of the lens into the substance of the cortex and adult nucleus in a non-radial and non-axial random fashion.

D. Microwave Cataract

A patient seen in consultation and, therefore, not included in this statistical study was examined and found to have microwave cataracts, the right eye more advanced than the left.

This patient's employment involved bench-testing of experimental r-f tubes. He was specifically concerned with visually checking the tube grids during periods of malfunction. Good records exist concerning ionizing radiation and his cumulative exposure was less than 1 roentgen. No records of microwave exposure exist, however, the possibility exists of repeated short duration exposures to several hundred milliwatts per square centimeter levels of r-f radiation.

VI

RETROSPECTIVE STUDY OF CATARACT INCIDENCE AMONG MILITARY PERSONNEL

The National Academy of Sciences-National Research Council, Division of Medical Sciences, has agreed to undertake a joint study with the Institute of Industrial Medicine to determine if Veterans Administration records indicate an association between the incidence of cataracts among military personnel and their microwave radiation exposure.

A roster of Veterans Administration hospital discharges in 1959, representing a 20% sample of Veterans with primary or associated diagnosis of cataract, Code 385 in the International List (i.e., excluding cataracts assotiated with diabetes or considered to be congenital for veterans of World War II or later), has been received. From this group a sample of forty-three representative medical records is being reviewed. Information on job-title, assignment, and duties is being obtained along with additional diagnostic review and selection in order to eliminate, through error, a few diabetics and traumatic cataracts. Essential to any sampling plan, whether prospective or retrospective, is a structuring of the military environment as to exposure. As soon as the procedures for obtaining more detailed occupational histories has been established, and a more refined methodology for investigating the problem is developed, the size of the sample will be greatly increased.

VII

DISCUSSION

The sampling procedure used in the survey appears to have provided a partially representative population of microwave workers, including individuals of various ages and with varying kinds and degrees of microwave exposure. We say partially representative, because we know that certain types of exposure, notably, shipboard operation and certain types of missile tracking operations have not yet been covered but will be included during the coming year.

The selection of the control group was generally satisfactory and the mean age of the control group was approximately the same as that of the exposed group.

A total of 834 personnel have now been examined at 11 military and civilian installations. This total includes 475 exposed and 359 controls. In confirmation of earlier findings, a slight but statistically significant difference has been observed in the eye scores of exposed and control populations. Four of the five types of lenticular defects recorded - posterior polar defects, opacification, minute defects, and relucency - appear to be related to microwave exposure. The fifth classification, sutural defects, appears to bear no relationship to exposure. Of these five types of lenticular imperfections, the posterior polar changes appear to be most markedly associated with microwave exposure, as it is in this classification that the greatest difference exists between the exposed and control groups.

A peculiar finding is that the difference in eye scores appears to be constant for all age groups. It is not possible to explain why this is so at the present time, but among the reasons which must be considered are:

a) that the relatively small number of subjects of young age (less than 25 years) and of older ages (older than 50 years) results in the shape of the regression curve of eye score on age being somewhat uncertain,

b) that the difference is constant because a repair mechanism is operating which results in an equilibrium difference that remains constant regardless of duration of exposure.

Due to a number of factors, the present method of computing exposure score does not serve as an entirely valid method of determining the relative degree of microwave exposure. The practice of taking the sum of the products of several factors can lead to large errors if the information is not accurate or if it is improperly interpreted. However, even if the exposure information obtained was known to be reliable, it would not at present be possible to properly

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weigh the various factors as we do not know how they contribute to lenticular changes.

In grading an answer, if a value of two rather than one is assigned, the value of the total exposure index can be significantly increased since this factor is a multiplicand. If a summation procedure is used to determine an exposure index instead of the combined multiplication summation method, the errors due to inaccurate information and judgement will be decreased. An attempt to obtain the desired correlations will be made by changing the scoring method in this way. It may also be desirable to incorporate a duration of exposure term in the form of a multiplicand or by some other combination procedure.

The present exposure index does not depend upon the microwave radiation frequency since the relationship between the production of lens defects and frequency is not known. It has been suggested that there is a frequency effect, but at present this is not well enough documented to enable use of frequency in the determination of an exposure index. Additional knowledge regarding the specific frequency dependence of lenticular changes could greatly add to the significance of an exposure index.

In the future, the exposure index will be separated into two factors: one accounting for exposure from the microwave generator and another for antenna exposure. It is hoped that in this way we may sort out the effects of ionizing radiation exposure to the minor lens defects noted, since one index would be associated with possible X-ray exposure (generator exposure), whereas the antenna index would not involve X-ray exposure.

The clinical impression gained from the detailed, microscopic lenticular examinations is that the defects present in the lens are not generally an indicator of cumulative, chronic exposure to r-f radiation. However, the effect of microwave exposure is demonstrable by standard statistical treatment of the data. End

The Donaldson stereo-camera did not adequately photograph the principal lens defects under study. The disadvantages of the fixed distance (film to plane of focus) of this camera as related to the resultant complicated focusing procedure has been described previously. Moreover, this fixed distance feature of the camera provides very little depth of focus in the photographs. In addition to the variations in reproducibility of the photographs caused by inexact realigning of the axis of the orbit, the axis of the eye and the axis of the camera, other variations are due to differences in vertical opening of the palpebral aperture and pupil size. The latter alter the character of the illumination as does the eyebrow configuration and the size, shape, and skin color of the nose, because it is not uncommon to have a relection of the brow, cilia, and nose appear superimposed on the lens. Moreover, the light reflexes are also superimposed on the lens, frequently obscuring the posterior polar region. In addition, the curvature and transparency of the cornea may also affect the quality of the photographs.

Mechanical malfunction of the camera occurred occasionally but was not a serious problem. The electronic circuitry was found to be critical, as variations in the capacitor charge affect reproducibility of color tone in the film. The latter was also found to vary with different techniques of developing processes when an alternate film developing laboratory was used.

REFERENCES

1. Zaret, M.M. and Eisenbud, M.: Preliminary Results of Studies of the Lenticular Effects of Microwave Among Exposed Personnel; Biological Effects of Microwave Radiation, 1:293, Plenum Press, New York
2. Radiation Frequency Radiation Hazards Handbook T.O. 31-1-80

NEW YORK UNIVERSITY MEDICAL CENTER
550 First Avenue
New York 16, N.Y.

Institute of Industrial Medicine
Environmental Radiation Laboratory

HISTORY OF WORK WITH MICROWAVES

You are being asked to fill out this questionnaire as part of a large study in which we are one of a number of participating industrial and military organizations.

We appreciate the fact that in some cases a great many years may have elapsed since you first began to work with microwaves and that it may be difficult for you to recollect all of the detailed information we have asked you to provide. All we request is that you be patient with this questionnaire and fill it out to the best of your ability. If there are any parts of it which are not clear to you, your supervisor will attempt to assist you.

Name ______________________________ Age _________ Badge No. ___________
(Please print)

Address ___________________________

____

I. List only those places of employment in which you worked with radar or other microwave equipment. List present employer first and work backwards.

a. Employer's Name ___________________________

Employed from _______ to ________

Job Titles: 1. ______________

2. ______________

3. ______________

Total Number of Months Employed in the Following Categories

a. Research and development of microwave components ___________

b. Microwave components assembly for production ___________

c. Operation of radar or other microwave apparatus ___________

d. Installation, maintenance, and test of microwave apparatus ___________

e. Other _____________

Total _______

b. Employer's Name ____________________

Employed from ________ to ________

Job Titles: 1. ____________________

2. ____________________

3. ____________________

a. Research and development of microwave components ____________

b. Microwave components assembly for production __________

c. Operation of radar or other microwave apparatus __________

d. Installation, maintenance, and test of microwave apparatus __________

e. Other ______________

Total ________

c. Employer's Name ____________________

Employed from ________ to ________

Job Titles: 1. ____________________

2. ____________________

3. ____________________

a. Research and development of microwave components ____________

b. Microwave components assembly for production __________

c. Operation of radar or other microwave apparatus __________

d. Installation, maintenance, and test of microwave apparatus __________

e. Other ______________

Total ________

d. Employer's Name ____________________

Employed from ________ to ________

Job Titles: 1. ____________________

2. ____________________

3. ____________________

a. Research and development of microwave components ____________

b. Microwave components assembly for production __________

c. Operation of radar or other microwave apparatus __________

d. Installation, maintenance, and test of microwave apparatus __________

e. Other ______________

Total ________

II.

a. Did you ever wear a film badge? Yes _____ No _____

b. If yes, on which job and during what period of time?

Places of Employment	From	To
a. ____________	______	______
b. ____________	______	______
c. ____________	______	______
d. ____________	______	______

III.

a. Did you ever work near a transmitter tube from which the shielding was removed while the high voltage was on? Yes _____ No _____

b. If yes, fill out the following:

Tube Type	Aver. Power	Peak Voltage	Check Total Time Elapsed (approx.) Sec.	Min.	Hrs.	Longer

IV. List the principal types of microwave generating equipment with which you have worked.

	a.	b.	c.	d.
Type of Equipment				
Average Power				
Freq. or Band				
Number of months				
Date of first exposure				
Power terminated (Use check mark)				
Dummy load				
Outside antenna				
Within room				

IV. (Continued)

Distance from equipment

Less than 10 ft.	____	____	____	____
10 - 20 ft.	____	____	____	____
Greater than 20 ft.	____	____	____	____

Your work was:

a. research and development	____	____	____	____
b. assembly of microwave components	____	____	____	____
c. operation of microwave equipment	____	____	____	____
d. Installation, maintenance, and test of microwave equipment	____	____	____	____

V. a. Did you ever look into a transmission line such as a wave guide while it was energized? Yes ____ No ____

If yes:

How many times?			Average Power?	How Viewed?	
1-3	4-10	over 10		Viewing Bend	Open Wave Guide
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____

VI. a. Did you ever feel heat from microwaves coming from a wave guide or transmission line? Yes ____ No ____

b. If yes, how many times?

	1-3	4-10	Over 10
Hands only	____	____	____
Whole body	____	____	____
Head only	____	____	____

c. What types of equipment were involved?

Average Power	____	____	____
Freq. or Band	____	____	____

VII.

a. Have you ever worked near an antenna while it was radiating?

Yes ____ No ____

b. If yes, fill in the following:

	1-3	4-10	Over 10	Average Power	Freq. or Band	Distance from Radiating Surface
1. Front Surface						
few seconds	___	___	___	___	___	___
few minutes	___	___	___	___	___	___
over an hour	___	___	___	___	___	___
2. Rear Surface						
few seconds	___	___	___	___	___	___
few minutes	___	___	___	___	___	___
over an hour	___	___	___	___	___	___
3. Sides						
few seconds	___	___	___	___	___	___
few minutes	___	___	___	___	___	___
over an hour	___	___	___	___	___	___

4. How many times did you feel heat from microwaves coming from the antenna?

few seconds	___	___	___
few minutes	___	___	___
over an hour	___	___	___

APPENDIX III-B

EXPLANATORY REMARKS ON

"HISTORY OF WORK WITH MICROWAVES" QUESTIONNAIRE

Part I:

In addition to civilian employment, microwave experience during military duty should be included.

Part III:

This entire question is included to determine if there has been any exposure to ionizing radiation. Therefore, any work done in close proximity to any high voltage tube, even if it was not specifically a microwave transmitter tube, should be included in the answer. Any tube in the kilovoltage range should be specified. The reference to shielding in this question refers to X-ray shielding, not r-f shielding. The term "near" in this question may be defined as within the same room as the unshielded tube.

Part IV:

In specifying the mode of power termination (i.e. dummy load, outside antenna, or within room) for cases a,b,c,d, it would be helpful, if more than one mode of termination was used, to approximate the fraction of the time that each mode was used.

The distance from equipment refers only to the distance during operation of the equipment.

In specifying the job category, when more than one classification applies, the principal one should be used.

When possible (i.e. in case of surveyed exposures) the exact power density and length of exposure should be included. Any exposure other than those occurring as a result of employment should be included; this would apply to home experimentation, etc.

Part V:

Average power is here to be considered as the average power of the transmitter or in the waveguide.

Part VI:

This question refers only to effects of transmitter, transmission lines, and waveguides; it does not refer to antenna exposures which are covered in question VII. If an exposure is reported here as due to local termination of a waveguide with a horn, it should not be reported in the answer to question VII.

Part VII:

Exposure to radiating, rotating antennae should also be included in the answer to this question. In "a" the word near refers to a distance at which the power density is greater than or equal to one milliwatt per square centimeter.

APPENDIX III-C

MICROWAVE SURVEY

Epidemiological Data

Details of Coding Procedure

1. Job Classification (column 18)

In specifying the job classification of an individual in the case where more than one category applies, that category will be chosen which represents twice the period of time spent on any other job listed if the latter is less than six months. If the other jobs listed were worked at for more than six months (each) or were more than one half the period of the major job classification the data will be given another code number signifying combinations of microwave jobs.

Controls will be coded with a 5 signifying non-microwave work.

2. X-Ray Exposure

0 will be used for individuals with no reported work on high voltage tubes and no film badge record.

1 will designate individuals who have worked with unshielded generating tubes of greater than one kilovolt peak voltage for periods of minutes or more with no film badge record of possible exposure.

2 will be used to designate those individuals who note severe exposure to ionizing radiation but did not wear a film badge during the exposure.

3 will designate persons exposed to ionizing radiation while wearing film badges.

3. Power Termination

In any instance in which more than one mode of power termination is used for one power, the most significant mode will be chosen. Thus if power is terminated by a dummy load, an outside antenna and also within the room the latter case will be designated on the card (i.e. by a 2 punch). If both dummy load and outside antenna termination is specified a 3 punch will be used indicating this combination.

4. Age at first exposure will be the age at which the first work with a principal type of microwave generator is listed in the questionnaire.

5. In the case of an individual who has been included as a control but who actually has had some radar experience and does not specify the equipment used, a total score of two will be assigned, to distinguish them from controls.

6. In the event that exposure to microwaves coming from an antenna is listed for two different antennas (different powers and frequencies) the higher powered one will be coded except where the duration of work on the high powered antenna

is specified as being a few seconds and the duration of work on the lower power is hours. In this case the exposure to the lower power will be recorded.

Calculation of Approximate Average Power from Peak Power

Average P = (Peak Power) (Pulse Width) (Pulse Repetition Rate)

= watts x sec x sec^{-1}

Let Pa = average power

Pp = peak power

W = pulse width

R = pulse repetition rate

Pa = Pp WR

$$\frac{Pa}{Pp} = WR$$

An average value of WR will be used to convert from peak power to average power

Assume:

$W \cong 1.0\ \mu sec$

$R \cong 10^{3}\ sec^{-1}$

therefore,

$$\frac{Pa}{Pp} = WR = (10^{-6} \times 10^{3}) = 10^{-3}$$

$$\boxed{Pa \cong \frac{Pp}{1000}}$$

MICROWAVE SURVEY IBM CARD CODE DESIGNATION

APPENDIX III-D

Column Number	Field
1-2	Site Identification
	0 - Rome Air Development Command, Rome, New York
	1 - RCA, BEMEWS, Greenland
	2 - Sperry Rand Company, Lake Success, New York
	3 - DuPont, Wilmington, Delaware
	4 - Sylvania, Waltham, Massachusetts
	5 - Pacific Missile Range, Point Mugu
	6 - Pacific Missile Range, Point Arguello
	7 - Sylvania, Mountainview, California
	8 - RCA, Moorestown, New Jersey
	9 - A.T. & T., Bell Labs., Whippany, New Jersey
	10 - Western Electric, Winston Salem, North Carolina
	11 - Raytheon, Waltham, Massachusetts
	etc. to
	99 -
3-6	Individual Identification
	Each individual that has been examined will be assigned a number which he will keep throughout the survey regardless of the site at which he is located. A master sheet will be kept to relate the number to the individual.

Column Number	Field
7-8	<u>Age of Individual</u>
9-14	<u>Date of Eye Examination</u> Month - columns 9-10 Day - columns 11-12 Year - columns 13-14
15-17	<u>Number of Months of Microwave Work</u> Approximate total months - 0-999 months
18	<u>Job Classification</u> 0 - research and development 1 - assembly of microwave components 2 - operation of radar equipment 3 - installation, maintenance 4 - research and development plus operation of radar equipment 5 - non-microwave work 6 - operation of microwave equipment plus installation, maintenance and test

Column Number	Field
	7 - research and development plus installation, maintenance and test of radar equipment
	8 - combinations of job classifications
	9 - research and development plus operation of microwave equipment
19	<u>X-Ray Exposure</u>
	0 - no known exposure
	1 - possible exposure
	2 - severe exposure
	3 - film badge worn
20-39	<u>Average Power Output of Microwave Generators</u>
	columns 20-24 - 0-10W data
	columns 25-29 - 11-100W data
	columns 30-34 - 101-1000W data
	columns 35-39 - greater than 1000W data
	columns 20, 25, 30, 35 - approximate duration of microwave work at the specified average power levels (i.e. 0-10W, 11-100W, 101-1000W, $>$1000W)

Column Number	Field
	0 - 0 to 2 months
	1 - 3 to 4 months
	2 - 5 to 8 months
	3 - 9 to 16 months
	4 - 17 to 32 months
	5 - 33 to 64 months
	6 - 65 to 128 months
	7 - 129 to 256 months
	8 - 257 to 512 months
	9 - 513 to 1024 months
	columns 21, 26, 31, 36 - approximate frequency band for specified power levels
	0 - l + s bands (1 to 4 kmc/sec)
	1 - c band (4 to 6 kmc/sec)
	2 - x band (5 to 20 kmc/sec)
	3 - k band (18 to 37 kmc/sec)
	4 - q + v band (37 to 57 kmc/sec)
	5 - w band (57 to 100 kmc/sec)
	6 - greater than 100 kmc/sec
	7 - 0 to lkmc/sec
	8 - l + s + c + x band combinations
	9 - other combinations of the above bands

Column Number	Field
	columns 22, 27, 32, 37-mode of power termination at indicated power level 0 - dummy load 1 - outside antenna 2 - within room 3 - combination of dummy load and outside antenna columns 23, 28, 33, 38 - distance from microwave generating equipment during operation at the specified power levels 0 - 0 to 10 feet 1 - 11 to 20 feet 2 - greater than 20 feet columns 24, 29, 34, 39 - job designation while working with the microwave generator at the indicated power levels. 0 - research and development 1 - assembly of microwave components 2 - operation of radar equipment 3 - installation, maintenance and test

Column Number	Field
	4 - research and development plus operation of radar equipment
	5 - non-microwave work
	6 - operation of microwave equipment plus installation, maintenance and test
	7 - research and development plus installation, maintenance and test of radar equipment
	8 - combinations of job classifications
	9 - research and development plus operation of microwave equipment
40-41	<u>Age of Individual at First Indicated Microwave Work</u>
	0-99 years
42-44	<u>Looked Into Energized Waveguide</u>
	column 42 - number of times individual indicated he looked in energized waveguide
	0 - 1 to 3 times
	1 - 4 to 10 times
	2 - greater than 10 times

Column Number	Field
	column 43 - average power being generated at the time of viewing 0 - 0-10 watts 1 - 11-100 watts 2 - 101-1000 watts 3 - greater than 1000 watts 4 - combination from 0 to 1000 watts column 44 - method of viewing the waveguide 0 - viewing bend 1 - viewing open waveguide 2 - other viewing method 3 - combination of viewing bend and viewing open waveguide 4 - viewing feedhorn (no antenna)
45-48	<u>Felt Heat From Microwave Generator</u> Column 45 - hands only 0 - 1 to 3 times 1 - 4 to 10 times 2 greater than 10 times

Column Number	Field
	column 46 - whole body
	0 - 1 to 3 times
	1 - 4 to 10 times
	2 - greater than 10 times
	column 47 - head only
	0 - 1 to 3 times
	1 - 4 to 10 times
	2 - greater than 10 times
	column 48 - frequency band being generated which resulted in the indicated perception of heat
	0 - 1 + s bands (1 to 4 kmc/sec)
	1 - c band (4 to 6 kmc/sec)
	2 - x band (5 to 20 kmc/sec)
	3 - k band (18 to 37 kmc/sec)
	4 - q + v band (37 to 57 kmc/sec)
	5 - w band (57 to 100 kmc/sec)
	6 - greater than 100 kmc/sec
	7 - o to 1kmc/sec
	8 - 1 + s + c + x band combinations
	9 - other combinations of the above bands

Column Number	Field
49-60	Antenna Work

antenna locations

columns 49-52 - work data in front of antenna

columns 53-56 - work data in rear of antenna

columns 57-60 - work data at side of antenna

columns 49, 53, 57 - duration of work at specified antenna locations while antenna was radiating

0 - seconds

1 - minutes

2 - greater than an hour

columns 50, 54, 58 - antenna power output during work at specified antenna locations

0 - 0 to 100 watts (average power)

1 - 101 to 1000 watts (average power)

2 - greater than 1000 watts (average power)

columns 51, 55, 59 - microwave frequency during work at indicated locations

0 - 1 + s bands (1 to 4 kmc/sec)

1 - c band (4 to 6 kmc/sec)

2 - x band (5 to 20 kmc/sec)

Column Number	Field
	3 - k band (18 to 37 kmc/sec)
	4 - q + v band (37 to 57 kmc/sec)
	5 - w band (57 to 100 kmc/sec)
	6 - greater than 100 kmc/sec)
	7 - 0 to 1kmc/sec
	8 - l + s + c + x band combinations
	9 - other combinations of the above bands
	columns 52, 56, 60 - distance from radiating antenna at indicated antenna locations
	0 - 0 to 10 feet
	1 - 11 to 20 feet
	2 - 21 to 100 feet
	3 - greater than 100 feet
61	Antenna Heat
	column 61 - period during which heat was perceived by the individual working near radiating antennas
	0 - seconds
	1 - minutes
	2 - hours

Column Number	Field
62-63	Exposure Scores columns 62-63 - total exposure score
64	Family History of Eye Disease 0 - mother 1 - father 2 - children 3 - maternal grandmother 4 - maternal grandfather 5 - paternal grandmother 6 - paternal grandfather 7 - combinations of above
65	Change of Distance Glasses in the Past 10 Years 0 - x 1 - 1 2 - 2 3 - 3 4 - 4 5 - 5 6 - 6 7 - 7

Column Number	Field
	8 - 8
	9 - 9 or more
66	Evidence of Eye Defects or Illnesses
	0 - glaucoma
	1 - cataract
	2 - uveitis (iritis, cyclitis, choroiditis)
	3 - retinal detachment
	4 - congenital defects
	5 - keratitis
	6 - ptyrigium (growth on eyelid)
	7 - combinations of the above
	8 - acute symptoms of exposure

67-68	Vision	
	Right Eye	Left Eye
	0 - 20/20	0 - 20/20
	1 - 20/30	1 - 20/30
	2 - 20/40	2 - 20/40
	3 - 20/50	3 - 20/50
	4 - 20/70	4 - 20/70
	5 - 20/100	5 - 20/100

6 - 20/200	6 - 20/200
7 - >20/200	7 - >20/200

69-74 Lenticular Changes

69 - minute defects

70 - opacification

71 - relucency

72 - sutural defects

73 - posterior polar defects

74 - photographic findings

0 - insignificant

1 - minor

2 - moderate

3 - major

75-76 Summation of Lens Defects - 69 + 70 + 71 + 72 + 73

00 - 0	07 - 7
01 - 1	08 - 8
02 - 2	09 - 9
03 - 3	10 - 10
04 - 4	11 - 11
05 - 5	12 - 12 etc.
06 - 6	

IBM - Card Layout - Microwave Data

1-2	SITE IDENTIFICATION		
3-6	INDIVIDUAL IDENTIFICATION		
7-8	AGE OF INDIVIDUAL (YEARS)		
9-10	MONTH	DATE OF EYE EXAMINATION	
11-12	DAY		
13-14	YEAR		
15-17	DURATION OF MICROWAVE WORK (MONTHS)		
18	JOB CLASSIFICATION		
19	X-RAY EXPOSURE		
20	MONTHS	0-10	AVERAGE POWER OUTPUT OF MICRO-WAVE GENER-ATOR (WATTS)
21	FREQ.		
22	TERM.		
23	DIST.		
24	JOB		
25	MONTHS	11-100	
26	FREQ		
27	TERM.		
28	DIST.		
29	JOB		
30	MONTHS	101-1000	
31	FREQ		
32	TERM		
33	DIST.		
34	JOB		
35	MONTHS	>1000	
36	FREQ.		
37	TERM.		
38	DIST.		
39	JOB		

40-41	AGE AT FIRST EXPOSURE (YEARS)		
42	#OF TIMES	LOOKED INTO WAVEGUIDE	
43	AVG. POWER		
44	HOW VIEWED		
45	HANDS	FELT HEAT FROM GENERATING EQUIPMENT	
46	BODY		
47	HEAD		
48	FREQ.		
49	DURATION	FRONT	ANTENNA WORK
50	POWER		
51	FREQ.		
52	DISTANCE		
53	DURATION	REAR	
54	POWER		
55	FREQ.		
56	DISTANCE		
57	DURATION	SIDES	
58	POWER		
59	FREQ.		
60	DISTANCE		
61	ANTENNA HEAT		
62-63	TOTAL EXPOSURE SCORE		
64	EYE DISEASE HISTORY		
65	CHANGE OF GLASSES		
66	EYE DEFECTS		
67	LEFT	VISUAL ACUITY	
68	RIGHT		
69	MINUTE DEFECTS	LENTICU-LAR CHANGES	
70	OPACIFICATION		
71	RELUCENCY		
72	SUTURAL DEFECTS		
73	POSTERIOR POLE		
74	PHOTO. FINDINGS		
75-76	SUMMATION OF EYE FINDINGS		
77-80			

UNCLASSIFIED

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