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DEVELOPMENT OF AN AUTOMATED VISUAL SENSITIVITY TESTER

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16. Abstract

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SUMMARY

An automated visual sensitivity tester is described that determines the observer's visual sensitivity within a 30° arc from the fovea as well as the size, shape, and location of the blind spot. A modified super 8-mm movie, back screen projector is used to present the dynamic visual stimuli in conjunction with an infinity collimating lens, a head positioning support, a response button, an electronic control unit, and a two-pen XYY′ response plotter. The present tests use a 10 arc-minute diameter, dim, white spot of light, which is made to travel slowly across the screen along each of 12 meridians, 30° apart. This spot disappears at unexpected locations and for each of several preselected durations. The observer is instructed to press the response button each time the spot disappears and release the button when the spot reappears. These responses are recorded by one of the two pens. The second pen records the on-off status and movements of the visual stimulus. Various retinal dysfunctions are assessed by comparing the locations of stimulus and response plots. Preliminary results from administering the device to observers having normal and abnormal visual capabilities indicate that the automated visual sensitivity tester is easy to operate and maintain, is sensitive to the presence of such dysfunctions as scotoma, glaucoma, and changes in retinal sensitivity, and adequately controls the illumination level, image velocity and other stimulus characteristics required.

INTRODUCTION

Impetus for the development of an automated visual sensitivity tester (AVST), which is self-administered, yields valid and reliable data, and can be easily maintained, came from the need for monitoring man's visual capabilities during long-term space missions (refs. 1-4). The primary performance criteria for such a vision tester include: *adequate sensitivity* to changes in visual performance that accompany the various stressors encountered in spaceflight, *sufficient comprehensiveness* to detect the possibility of changes in visual functions other than those expected, and *adequate diagnostic* value – the tester should not only detect a dysfunction, but should provide an indication of the extent of its development.

The two visual functions chosen for measurement by the present AVST are retinal sensitivity and blind spot mapping. A test of visual sensitivity was chosen because of the possibility of occurrence of the following events during long duration spaceflight.: (1) changes in the transparency of the eye's optic media due to the impingement of various ionizing radiations, foreign matter, or cataract development; (2) changes in the neural, biochemical, and/or photochemical processes which underlie visual sensitivity; or (3) changes in visual perception due to a wide range of retinal and central nervous system dysfunctions which affect sensitivity. Armaly (ref. 5) for instance, conducted a 10-year study of the various methods of detecting early glaucoma and summarized his findings as follows: "A skillful thorough examination of the central visual field must be the cornerstone of any attempt at early detection of glaucoma."

Mapping the size, shape, and location of the observer's blind spot was chosen as the second test for the present AVST because of its value not only in determining the state of retinal (thus visual) function near the perimeter of the blind spot but in providing an indication of changes in intraocular pressure. It is well known that intraocular pressure change may indicate such things as the presence of ocular inflammation, changes in blood pressure, elasticity of retinal vessels, body temperature, alkalinity and osmotic pressure of the cardiovascular system, closure or clogging of the anterior ocular chamber, or variation of the volume of any of the intraocular areas (ref. 6).

As a result of his extensive investigation of changes in glaucomatous visual field sensitivity over time, Armaly (ref. 5) writes,

> The first type [of visual field defect which can indicate incipient glaucoma] is one which is commonly seen in many nonspecific conditions and includes general depression and constriction of the isopter, enlargement of the blind spot, and baring of the blind spot. This type which may well be the earliest change in glaucoma is nevertheless so frequently associated with age, lens changes, refractive changes, pupil size, and conditions of testing that it cannot be seriously considered as a reliable criterion to mark the transition from the normal state to that of definite glaucomatous involvement of visual function.
>
> The second type is one which is most frequently encountered in the advanced state of open-angle glaucoma, yet it may result from obvious fundus lesions such as arterial occlusion, choreoretinal scar, or retrobulbar neuritis, etc. This type [of visual field defect] includes the arcuate scotoma which is an extension of either one or both poles of the blind spot, the paracentral scotoma, arcuate or otherwise, which does not connect with the blind spot and the nasal step.
>
> Defects of the second type are called glaucomatous when there is no history of retrobulbar neuritis nor evidence on fundus examination of any lesion that could account for these defects. In other words it is by exclusion of any evident etiology that they are called glaucomatous ...

Armaly used defects of the second type as criteria for the existence of glaucoma. The testing techniques he developed (ref. 5) are:

1. Outline the blind spot of each eye using standard perimetric techniques on at least eight meridians.

2. Determine the light sensitivity to a small (approximately 5 arc min diameter), white dim (10 mL), 1 sec test spot imaged at each of 72 locations in the visual field. These locations are on three circles surrounding the fovea at 5°, 10°, and 15° arc-radius distance. 24 points per circle.

3. Plot the boundary of the nasal visual field at 7 locations, 5° apart and falling on and between meridians 15° above and 15° below the horizontal. Two additional points are marked on meridians 30° above and 30° below the horizontal.

4. Plot the boundary of the temporal visual field on two meridians, one 15° above and one 15° below the horizontal.

With practice, this series of tests requires about 8 minutes to administer per eye. Since the test spot was moved manually across the observer's visual field, it is impossible to know how fast or with what constancy it was moved. However, Armaly does state that special attention was paid to the speed of movement of the targets so that it was not too fast for the reaction time of the individual (ref. 5, p. 29). Since the observers in Armaly's investigations, as in most clinical testing situations, tap on a surface or verbally indicate when the test spot disappears (or reappears) and the experimenter must then stop and mark the test spot's position, the reaction time of both individuals must be accounted for. These "measurement errors" can be quite large for relatively high test spot angular velocities which vary from trial to trial. In the present AVST, these errors are reduced through the use of a filmed presentation of the test spot's movement and automatically recorded plot of the response.

STIMULUS PRESENTATION DEVICE

General Description

The prototype AVST uses a modifed, rear projection, cartridge loading, super 8-mm movie projector. The Fairchild Mark IV S was chosen because all of its controls and the film cartridge insertion slot were located at the front. This projector presents both black and white color movies on a semitransparent, semidiffuse projection screen. Since the film within each cartridge is a continuous loop, no rethreading is required, and the film can be stopped and the catridge removed from the AVST at any time. (Film preparation is described in appendix A.)

The AVST described here was designed for use within a confinement chamber having a relatively high O_2 content (50 percent) and a pressure of 1/2 atmosphere (ref. 7). Consequently, the following modifications were made to the projector: (1) All wires were replaced with Teflon-coated wire; (2) all flammable parts were replaced with metal parts or with nonconductive, nonflammable material; (3) a new aluminum cabinet was constructed to house a number of spare-part storage boxes and easy-access panels; (4) the loud-speaker, magnetic audio pick-up head, and amplifier were removed; (5) the viewing screen was masked to a 7.5-inch diameter; (6) eight photocells were added, two in each corner of the screen to sense coded stimulus-position information photographed on each film; (7) a light shield was added that also served to support the viewing lens, filter rack, and eye-positioning plate; (8) a horizontally and vertically adjustable bite board was added as well as an adjustable forehead rest; (9) a 6-diopter, 2.12-inch diameter, biconvex viewing lens was added so as to place the projection screen images at optical infinity; and (10) three visual fixation cross projectors and a panel control switch were added. The first four of these modifications are not required if the device is to be used under normal laboratory conditions.

Figure 1 is a schematic, cutaway drawing of the AVST. All items shown, except the film projector's lens, mirror system, and film drive system, were added to the standard projector.

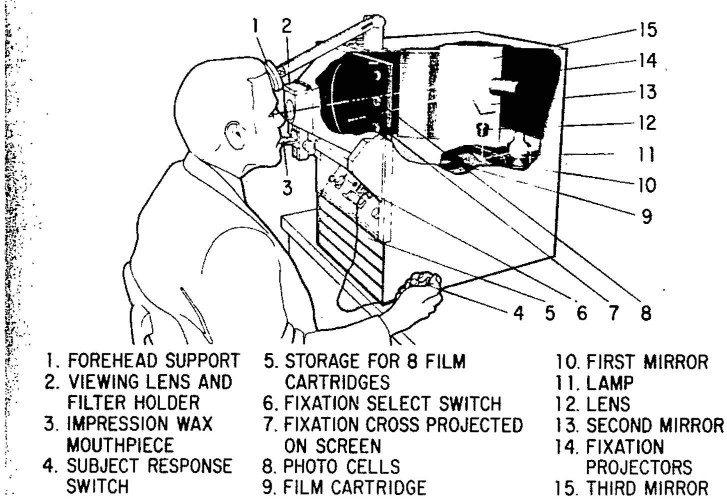


Figure 1.– Schematic drawing of the Automated Visual Sensitivity Tester.

Figure 2 is a photograph of the completed AVST; a spare parts storage box and subject bite board rack is also shown at the right. A film cartridge is shown in the lower right of this figure.

Also shown in figure 2 are the lockable horizontal slides which permit the AVST to be pulled forward from its benchtop location for easy access and maintenance.

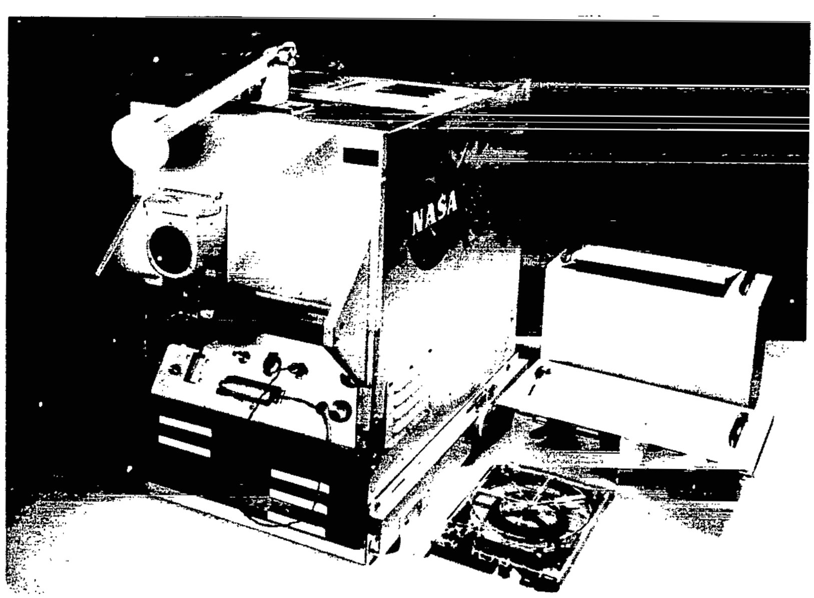


Figure 2.– Photograph of completed AVST (left) spare parts storage box (right rear), bite board rack (right center), and film cartridge (right front).

Figure 3 is a rear view of the AVST with the aluminum case removed to show the three fixation projectors (cylindrical tubes at upper left), and three spare projection lamps (at right), and the structural members that were added to increase rigidity. The rear side of the projection screen

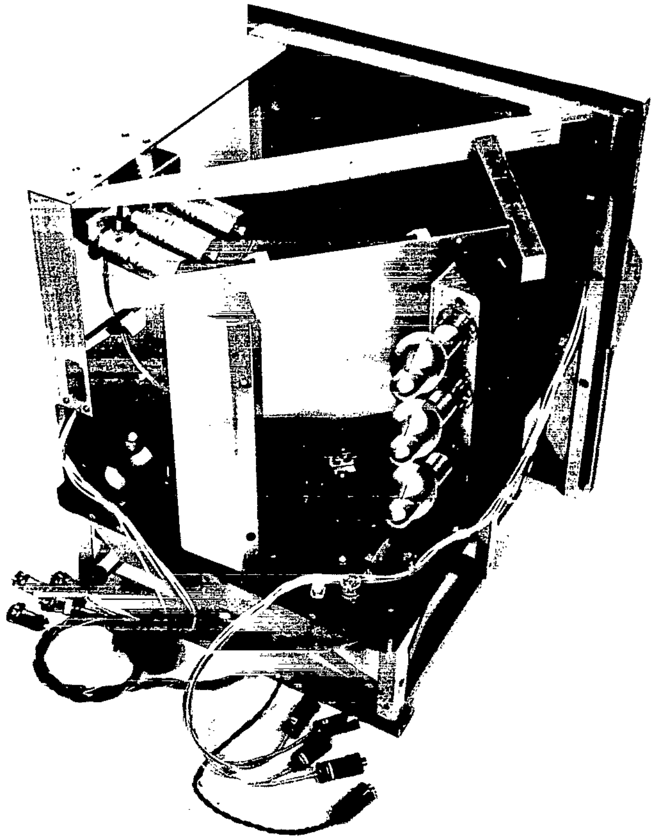


Figure 3.– Rear view photograph of the AVST with the case removed.

can also be seen behind the circular mask. Each of the eight photocells is located within a black rectangle (with a round hole in the center) seen on the screen.

Cabinet and Interior Framework Construction

The cabinet constructed for the AVST was made of 0.0625-inch-thick 6061T6 aluminum. The seams were either welded, riveted, or hinged. Although the cabinet provided some structural rigidity, the existing framework was strengthened by adding aluminum channel as shown in figure 3.

A vertical opening is located at the rear of the cabinet. A removable, spare-parts container sets at the bottom of this opening. It measures 13 X 6 X 9 inches and has a hinged lid and lifting handles. It is shown at the right middle in figure 2. It contains such items as spare drive belts, fuses, projector lamps, bite plates, fixation cross lamps, response button, etc. The tray (shown just in front of this box) holds four bite boards. It also forms the top of the cabinet when in place.

The front of the aluminum cabinet (fig. 2) has four shelves at the bottom, each holding two film cartridges. The slanted control panel, shown schematically in figure 4, is located just above the

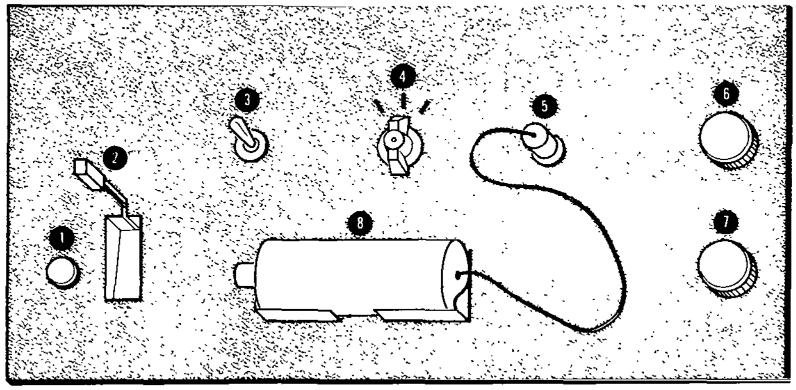


Figure 4.– Diagram of AVST control panel.

film cartridge shelves. The name and the function of each control shown are: (1) *Off button*, turns projector off; (2) *on lever*, turns projector on; (3) *fixation projector control toggle*, allows the fixation projectors to be turned on without the stimulus projector being on; (4) *fixation cross selector knob*, a three-position switch that turns on each of the free fixation projectors; (5) *cable plug*, connects response button to device; (6) *image focus knob*; (7) *projector framing control knob*, adjusts the stimulus' vertical screen position; (8) *response button* (resting in its holding tray) used by the observer to respond to the visual stimulus.

The adjustable bite board support and forehead rest can be seen in figures 1 and 2 along with the viewing lens. A filter rack is located just in back of the lens and is accessible by a hinged cover. A total of three 2 X 2 inch neutral-density and/or chromatic optical filters may be placed in this rack if necessary. A removable eye-positioning plate is also inserted in this rack. Its function is to reduce the viewing aperture to 1/8 inch diameter, centered on the lens, while the bite board and forehead rest are being adjusted. The observer merely positions his head so that he can see the appropriate fixation cross through this eye-positioning aperture. The aperture plate is then removed for the test administration.

Viewing Screen and Photocell Assembly

The standard Fairchild Mark IV S viewing screen is used. An aluminum mask, located on the observer's side of the screen, produces a 60° arc-diameter field of view. The eight photocells are located outside this field of view on the observer's side of the screen.

Clairex, type CL 905 L photocells are used. The amplifiers and associated electronic controls are described in appendix B. The stimulus films contain (1) an image of the moving, white spot of light, and (2) small, fixed spots of lights appropriately coded to indicate test spot position on each of the 12 meridians.

Miscellaneous Interior Details

Three fixation projectors, mounted above the second mirror shown in figure 1, are used to project 10-min-arc bar length, red crosses upon the viewing screen. Each projector consists of a 6.3 V (No. 44) lamp, opal glass diffuser, photographic negative of a cross, focusable achromat lens and a red No. 24 Wratten (Kodak) filter. Lamp luminance is controlled by adjustable resistors.

The loud speaker, accompanying the Fairchild Mark IV S projector was removed, as was the magnetic pick-up head and amplifier, because of the flammability control requirements of the AVST's chamber test application. These particular items could be useful in other applications of the device, however; for example, voice instructions could be recorded on each film.

Easy access to the projector's interior is gained by removing two screws and a single aluminum plate shown at the top of the AVST in figure 2.

RESPONSE PLOTTER

A two-pen Honeywell Model 540 XYY′ recorder (fig. 5) is used to record the stimulus and response. It was modified so that the pens could be dropped onto the graph paper independently. The lower pen remained connected to the original solenoid; the upper pen control bar scale was tied, by a roller and arm, to a new solenoid and bar running across the top rear of the plotter (fig. 5,

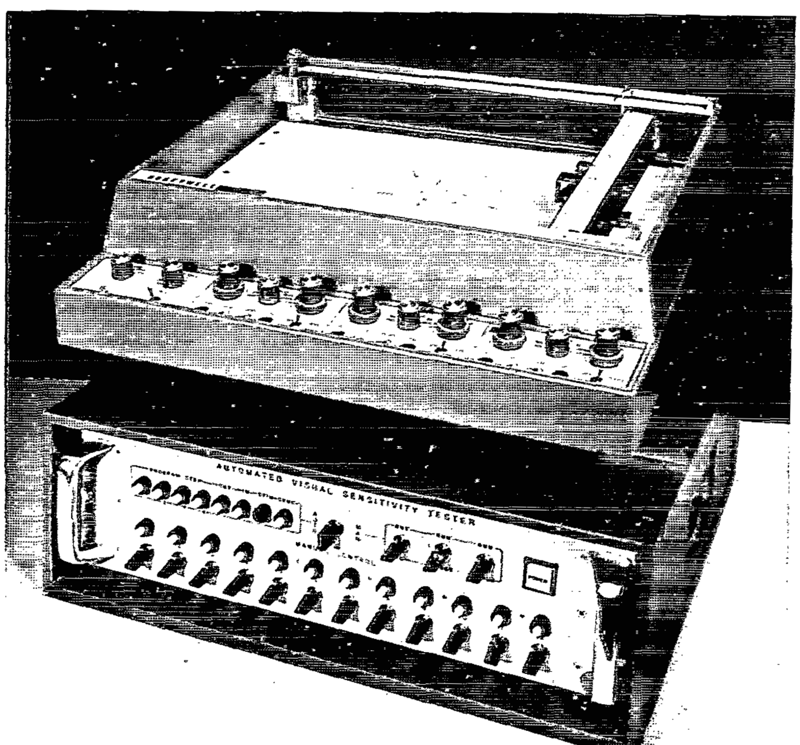


Figure 5.– Response plotter (top) and electronic control unit (bottom).

upper left). Green ink is used in the stimulus pen and red ink in the response pen. The plotter is operated in accordance with the manufacturer's instructions. Because the pens move over the same line on an IN and an OUT portion of a trial, the ink flows together so that the start of an IN response is difficult to distinguish. Therefore, the experimenter draws a short line across the pen's line at the spot the pen drops onto the paper for an IN response. The distance between the end of the OUT response line to the small line drawn across the inked line (indicating the start of an IN response) represents the OUT plus the IN response time. The midpoint between these two locations is taken as the actual (mean) blind spot boundary.

ELECTRONIC CONTROL UNIT

Function

The primary function of the electronic control unit, shown in figure 6, is to drive the response plotter pens in accordance with the position of the viewing screen image. This is accomplished by means of eight small spots of light projected from each film, through the screen, and onto eight photocells.

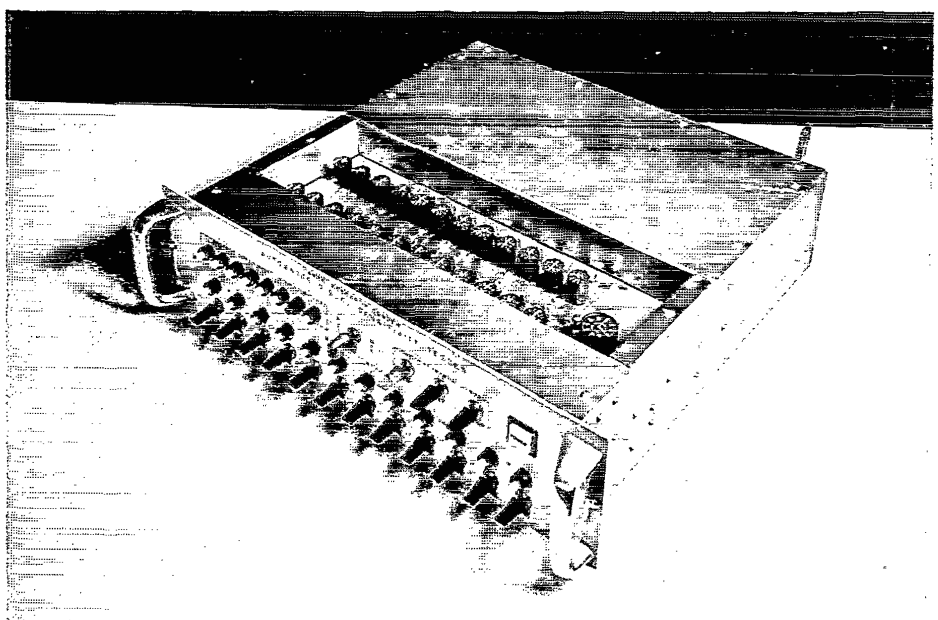


Figure 6.— Electronic control unit.

Modes of Operation

The design of this control unit makes it possible to operate the response plotter in each of three modes: (1) automatically from screen images that operate the photocells; (2) manually from the front face of the control unit; and (3) from an external device such as a digital computer.

Figure 7 is a block diagram of the electronic control unit circuitry. Stimulus-position information is derived from the output of each of the photocells. Within the signal-conditioning chassis mounted in the projector cabinet, the photocell signals are converted to ON/OFF (0 to +15 V) signals. (Drawing 1, appendix B is a schematic illustration of this unit.)

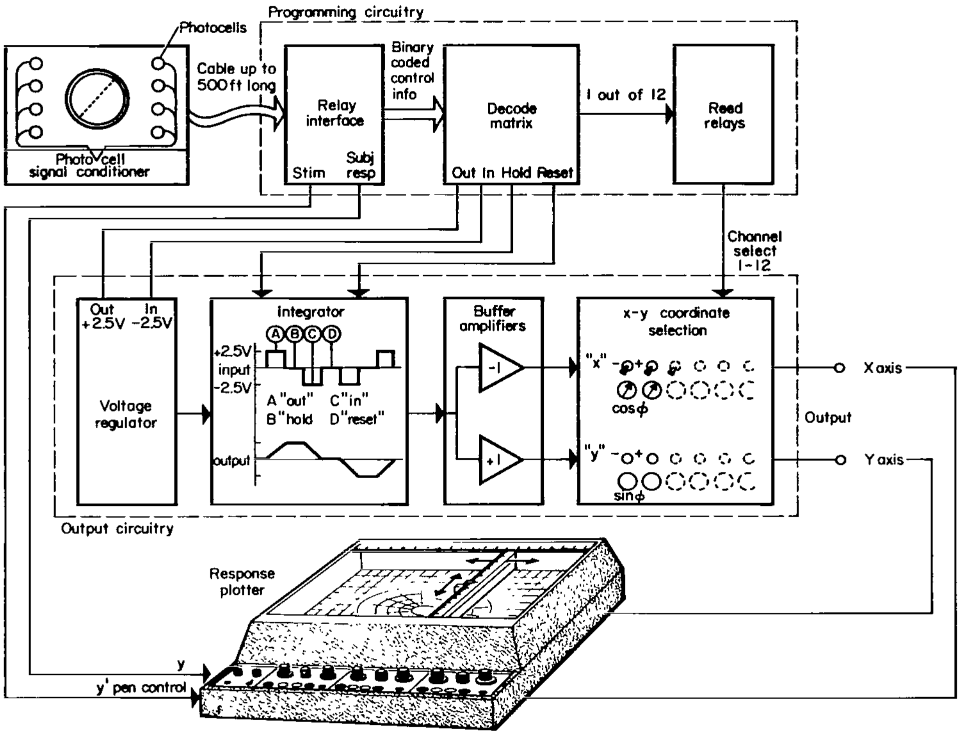


Figure 7.— Block diagram of the electronic control unit circuitry.

The photocell output information includes: (1) four binary-coded bits denoting one of 12 preset stimulus meridians, (2) two bits, denoting stimulus direction of travel (IN or OUT) along a given meridian, and a hold or reset command; (3) one bit to denote stimulus condition (light ON or OFF); and (4) a "sync" bit which indicates whether the projector's lamp is on or off.

In the present confinement chamber application of the AVST, the observer was located 100 feet from the experimenter at the response plotter. In order to minimize the problems associated with "noise" pick up, the signal cable was terminated at the control chassis in mercury-wetted contact relays. These contacts effectively isolated the observer's AVST power supply from the electronic control unit. (Drawing 2 in appendix B presents a schematic illustration of the programming circuitry used.)

The binary coded stimulus information is decoded and drives reed relays to control an analog voltage. The output signals to the response plotter are generated by using an integrator (drawing 3, appendix B). As shown in figure 7, stimulus direction of travel (IN or OUT) signals allow a plus or minus regulated voltage to drive the integrator toward +5 V or back to 0 V. The present design actually allows for four voltage excursions. If the first command is OUT, the output of the integrator will, initially, travel toward +5 V. This command would be followed by a HOLD command, then by an IN command. The "ramp" output voltage would then move toward the 0 voltage condition. If the sequence is reversed (an IN comand followed by a HOLD, followed by an OUT command), output voltage of the integrator will move from 0 V toward -5 V followed by a HOLD condition then back toward 0 V. The result of using both of these sequences is 24 unique radial pen excursions, using the 12 preprogrammed meridians.

The "ramp" output voltage of the integrator is buffered by two amplifiers. This creates a plus and a minus version of the ramp voltage. Two potentiometers per meridian are used to preset each of the X and Y coordinates of pen travel. They can be seen in figure 6 within the depression on top of the device. The toggle switches, located above each potentiometer (see fig. 6), select the sign of the sine or cosine functions for locating the meridian within any of the four quadrants. For example, if the response plotter is supposed to move along the 30° meridian (all meridians are measured from the 12 o'clock position in the clockwise direction), the X channel potentiometer is set for +0.866 and the Y potentiometer for +0.500. These values represent the cosine and sine of 30°, respectively. An OUT command, initially, will cause the pen to move out from the center along the 30° meridian. If, however, an IN command is initiated first, the pen would travel along a 210° meridian (i.e., 180° from the 30° meridian).

The response plotter's pens are driven in parallel from the Y output; however, the subject's response switch and the stimulus OFF/ON information cause the pens to drop onto the paper independently.

Operation of the Electronic Control Unit

The front panel controls provide two control functions (see fig. 8). When the AUTO-MANual switch is in the MANual position, the twelve front-panel switches and the OUT/IN, RUN-RESET,

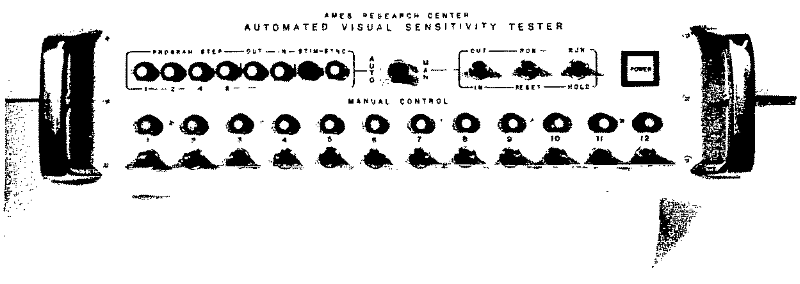


Figure 8.– Front panel of the electronic control unit.

and RUN/HOLD switches are operational. This provides for local control of pen travel for calibration purposes. Initial calibration of pen travel is achieved by depressing the CAL button (located on the right-hand side of the depression on top of the electronic control unit) and adjusting the X, Y, Y′ sensitivity controls on the plotter until both pens are at the desired maximum radial paper location. The RATE control, located within the depression in the top, is used to match the pen's angular velocity to the screen stimulus' velocity.

In the AUTO position the functions are automatically controlled by externally generated control signals from the viewing screen photocells. The eight lights on the front of the panel display the programming information from each of the eight viewing photocells.

If it is desired that an oscilloscope be used to display the stimulus, the X and Y inputs of the scope can be connected in parallel with the X and Y plotter inputs. Control information may then be generated from an external programmer, such as multilevel stepping switch, or computer, or by the experimenter operating the manual, front-panel controls.

OPERATING PROCEDURE FOR THE STIMULUS PRESENTATION DEVICE

Positioning the Head

The observer's anterior cornea must be properly centered behind the viewing lens for these tests to be valid. The present AVST design uses an adjustable dental impression bite board and forehead rest for this purpose; however, a chin rest and a curved, padded support at the temples could also be used.

The following steps are taken for proper positioning of the observer's head and viewing eye: (1) insert the blackened metal, eye positioning plate into the vertical slot just behind the viewing lens; (2) turn the fixation cross selector knob (fig. 4) to the top left position if the blind spot of the right eye is being tested, to the middle position if the visual sensitivity of either eye is being tested, or to the top right position if the blind spot of the left eye is being tested; (3) place the fixation projector control toggle (item 3 on fig. 4) in the right position; (4) bite onto the bite board (or place the chin into the chin rest) and loosen the horizontal and the vertical adjustment knobs; (5) slide the bite board or chin rest horizontally and vertically until the red fixation cross is seen through the small hole in the eye-positioning plate, then tighten each adjustment knob finger-tight; (6) remove the eye positioning plate; (7) place the fixation projector control toggle in the left position. The remaining test administration details are described below.

Visual Fixation During Test

It is important that visual fixation (i.e., direction of gaze) be maintained on the small, red fixation cross on the screen throughout the test. As some observers may find this difficult at first, it is recommended that the observer be allowed to look into the AVST (without a film running) for several minutes both with and without the red fixation cross present. He then will be less likely to move his fixation from the cross during a test due to curiosity or transient visual distractions.

Observer Instructions for the Visual Sensitivity Test

The observer is handed the response button and told to hold it in whichever hand he prefers, and rest his thumb on the button. He is given the following instructions *before* each of the first several administrations of the visual sensitivity test film.

> When I turn the device on you should be biting onto the bite board [or resting chin in the chin rest] and your head should be resting against the forehead rest. At first you will see a black and white checkerboard pattern. This is a film leader telling you that the test is about to begin. Because we are using a continuous loop film, you will see this same checkerboard pattern reappear in several minutes at the conclusion of the test. When this happens, please reach up and press the OFF button here [point out the OFF button].
>
> After the pattern has been on for about ten seconds it will gradually fade out; thereafter you will only see the red fixation cross on the darkened screen. Please keep your gaze directly upon this red cross throughout the entire test. If at any time you realize that you have momentarily shifted your gaze away from this cross merely look back at it as soon as possible and continue with the test. Soon you will see a small, white, spot of light travel slowly across your field of view in various directions. From time to time it will disappear. You are merely to press your finger button just as soon as the white light disappears and release it the instant it reappears. Speed is important so try to do this as fast as you can. Do you have any questions? Please press your finger button now to check its operation.

Observer Instructions for the Blind Spot Mapping Test

The following instructions are given to each observer for the first several administrations of the blind spot mapping test. He again should hold the response button in his preferred hand.

> Just as in the previous test, I will turn the device on after you have become properly centered behind the viewing lens and have tightened the bite board adjustment knobs and forehead rest knob. You will see the same black and white checkerboard pattern as before as a leader. After it fades from view the same white spot of light will appear. As long as you keep your gaze upon the small, red cross the white spot will become invisible at certain locations in your visual field. Merely press the finger button, as before, whenever it [the spot] disappears and let it go when it [the spot] reappears. Remember that speed is important in this test as well, so try to press and release the button as fast as you can.
>
> You will notice that the red cross is to one side of the center of the viewing screen. Make sure that you have centered your head position so that this cross appears as sharply focused as possible.
>
> There is one more thing you are to do. At the beginning of the test the white spot will travel horizontally just under the red cross you are looking at. Please press the button very briefly the instant it [the spot] reaches the point directly under the

red cross while traveling to the right and again when it passes underneath the red cross traveling to the left. Do you have any questions?

PRELIMINARY DATA FROM THE AVST

Both tests of the AVST were administered to a group of observers having normal visual capabilities and also to a group who possessed various kinds of visual dysfunctions. These tests provided an indication of the reliability, validity, and maintainability of the AVST. Test data are given in figures 9 through 33 as discussed in this section.

In each figure the various observer identification information is only repeated when it is necessary to maintain clarity. Thus, if no entry is found on a figure, that information will have been entered on a previous figure for the same observer.

The normal group of observers consisted of 15 males (ages from 18 to 40 years) and 10 females (ages from 18 to 47 years). All had 20:20 vision, normal and full visual fields, normal color perception as determined by the Ishihara plates, and normal tracking and fixation ability.

The location of the fixation point on the present visual sensitivity test results is at the center of the polar coordinate grid. The location of the fixation point on the blind spot mapping test results is indicated by the dashed line just below the vertical arrow.

Representative data from the normal group are presented in figures 9 through 15 for two observers. Each test was administered to the viewing eye noted on each figure. Comments related to each figure are also noted after the words AVST Results. The right and left eyes are referred to by OD and OS, respectively, in keeping with standard optometric practice. The test administration order, day, time of day, and, for the blind spot mapping test results, the mean blind spot area and linear distance between the foveal center and mathematical centroid of the mean blind spot (f.c.d.) are also noted.

Applanation tonometry was performed on observer JS within 15 minutes of the time the data of figures 12 and 13 were obtained. This observer's intraocular pressure was within the normal range in both eyes in all cases. The data from the visual sensitivity test shown in figures 11, 14, and 15 are also considered to be normal.

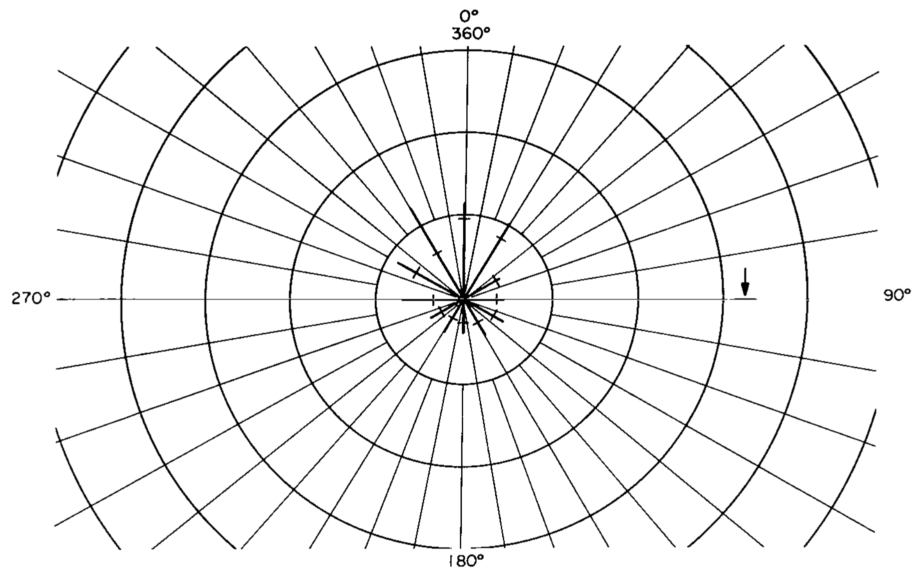
In the visual sensitivity test results presented here the solid lines indicate where the white spot of light disappeared; the dashed lines indicate when the observer pressed his response button to indicate that the spot had disappeared from sight.

A total of 12 observers (10 males, ages from 37 to 64 years; 2 females, ages 45 and 67 years) were tested in the group possessing various visual dysfunctions; four had glaucoma, two had cataracts, two had relatively small (local) scotomas, three had had detached retinas, and one had a scarred cornea. Whenever possible, both AVST tests were administered to both eyes of each observer. Figures 16 through 30 present the results from three observers whose visual dysfunctions

Age: 32
Sex: Male
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results: Normal size, shape, and location of blind spot from the fovea

(First Administration)
Day 1
8:10 AM
Area = 8.03 cm^2
f.c.d. = 7.36



(Second Administration)
Day 1
8:15 AM
Area = 7.96 cm^2
f.c.d. = 7.15

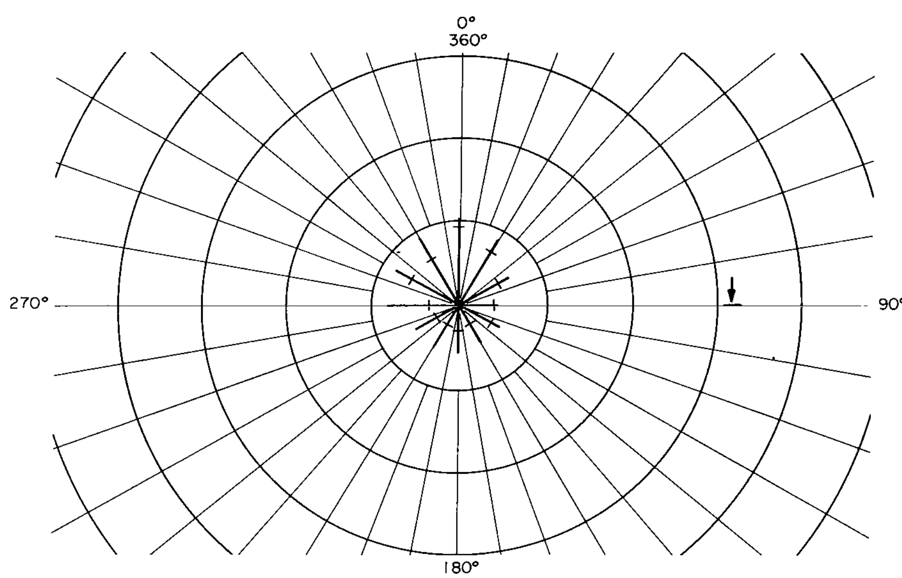
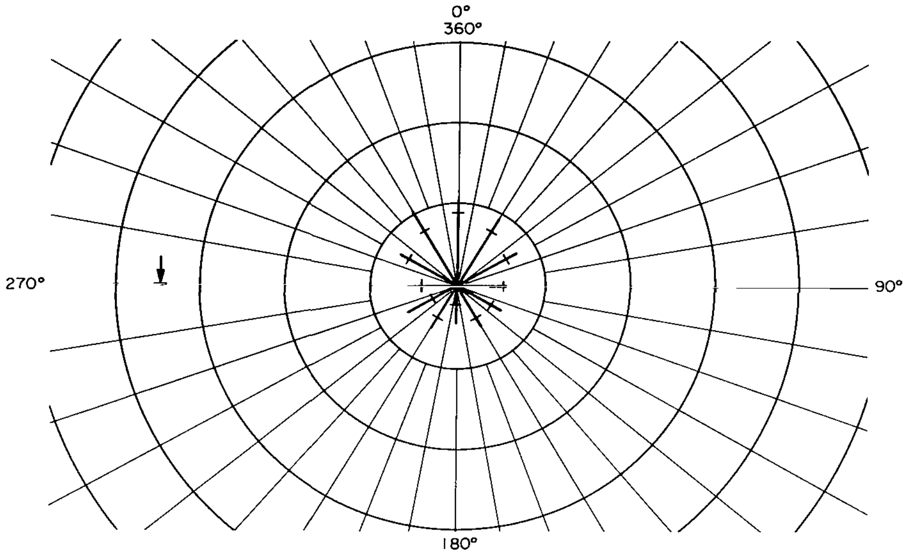


Figure 9.— Blind spot mapping test result for observer RH, left eye.

Age:
Sex:
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results: Normal size, shape, and location of blind spot

(Third Administration)
Day 1
8:21 AM
Area = 8.22 cm²
f.c.d. = 7.43



(Fourth Administration)
Day 1
8:26 AM
Area = 7.66 cm²
f.c.d. = 7.43

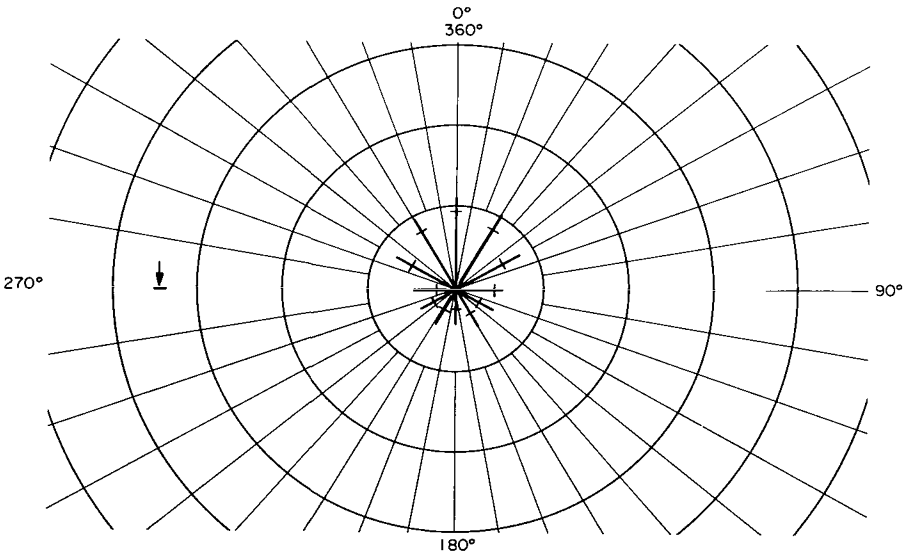


Figure 10.– Blind spot mapping test result for observer RH, right eye.

Age:
Sex:
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results: This observer possessed normal visual sensitivity and reaction times to the disappearance and reappearance of the spot

Day 1
2:21 PM

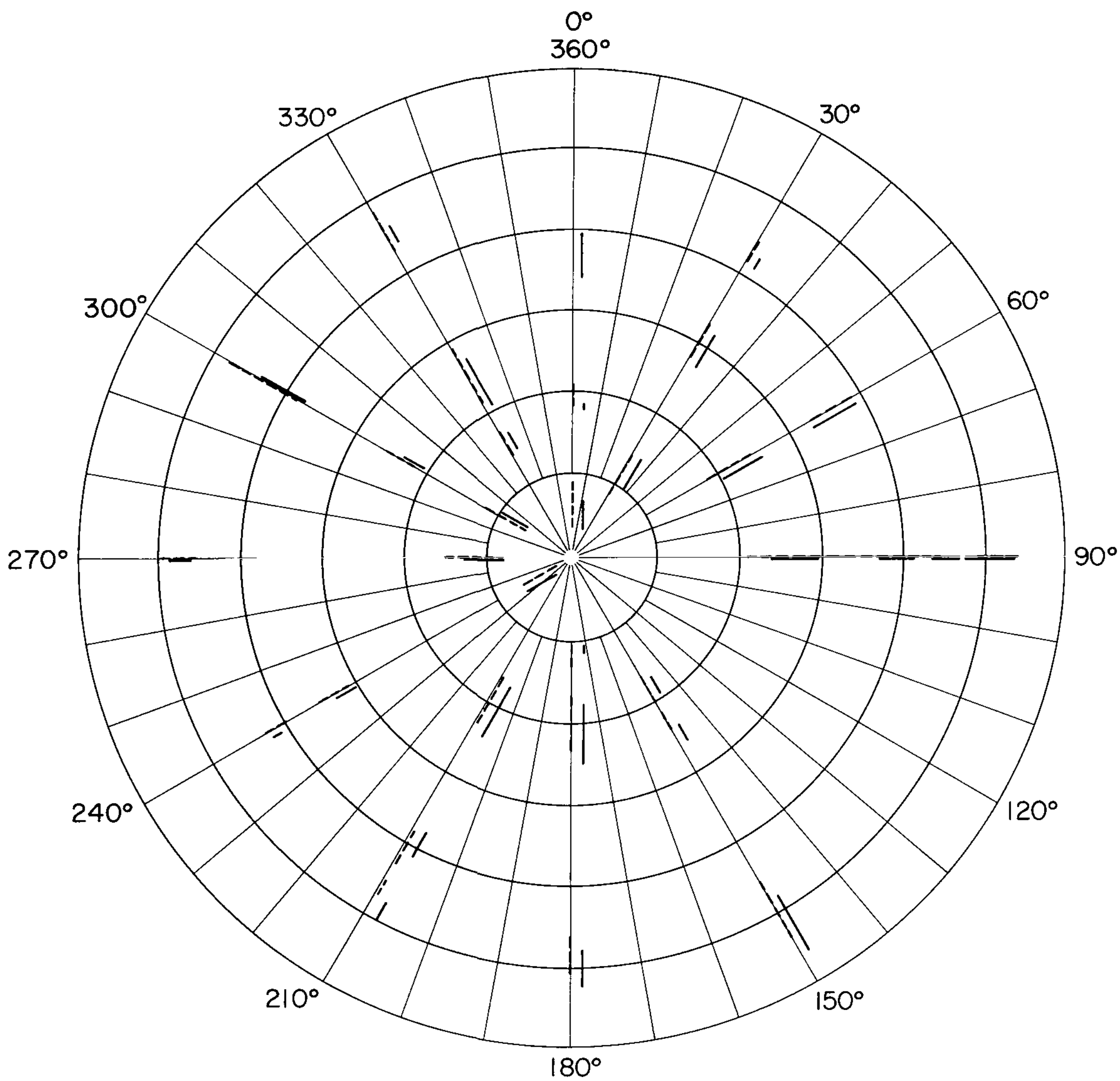
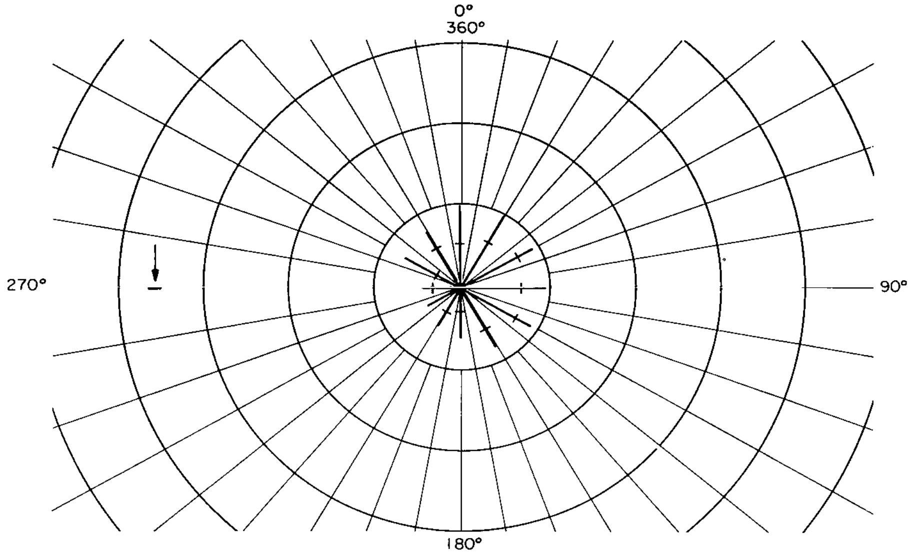


Figure 11.— Visual sensitivity test results for observer RH, right eye.

Age: 43
Sex: Male
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results:

(First Administration)
Day 1
10:50 AM
Area = 10.00 cm^2
f.c.d. = 7.88



(Second Administration)
Day 2
3:02 PM
Area = 9.60 cm^2
f.c.d. = 8.12

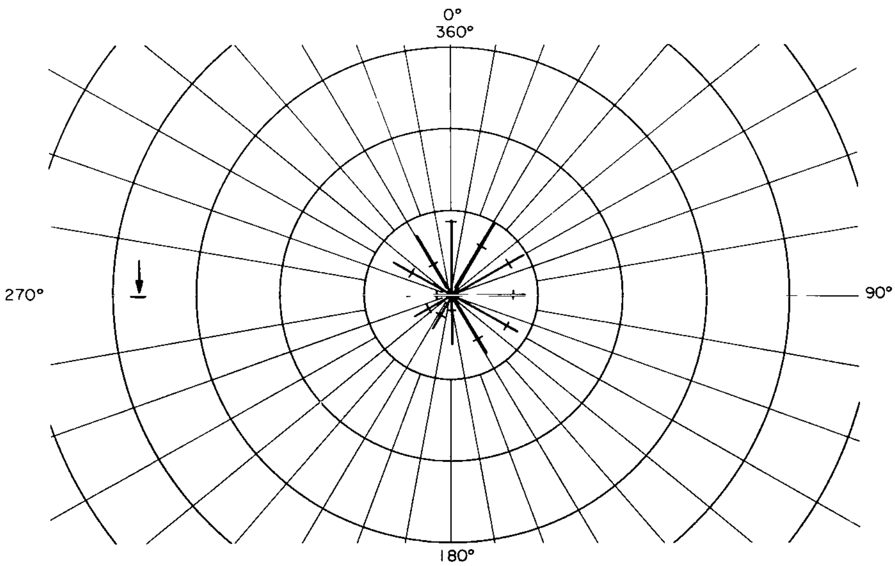
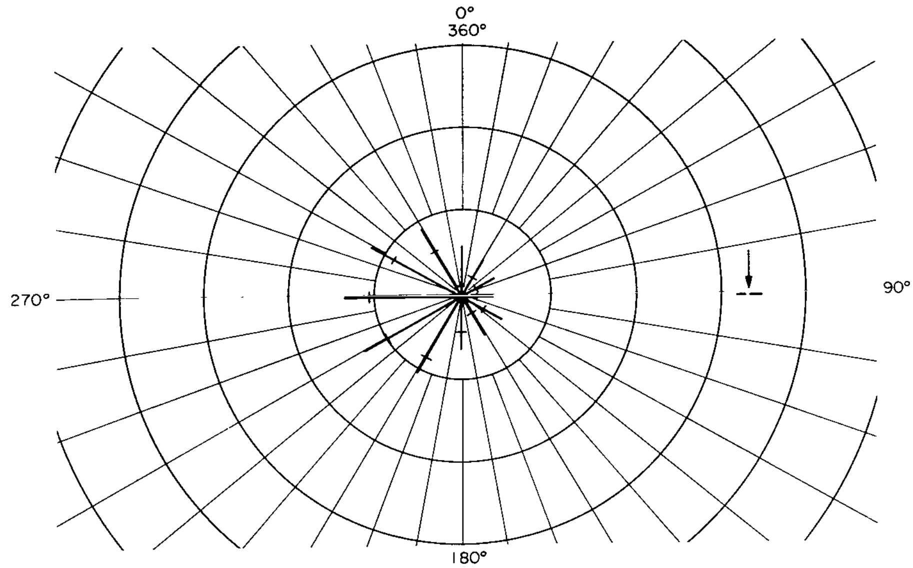


Figure 12.– Blind spot mapping test result for observer JS, right eye.

Age:
Sex:
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results:

(Third Administration)
Day 2
3:08 PM
Area = 11.07 cm^2
f.c.d. = 8.00



(Fourth Administration)
Day 3
8:10 AM
Area = 9.56 cm^2
f.c.d. = 7.55

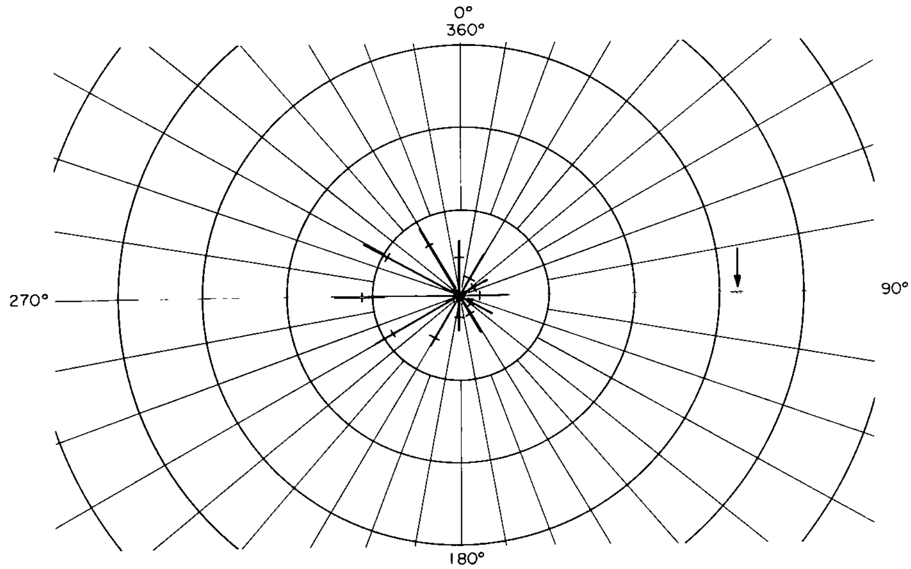


Figure 13.– Blind spot mapping test result for observer JS, left eye.

Age:
Sex:
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results:

Day 3
9:54 AM

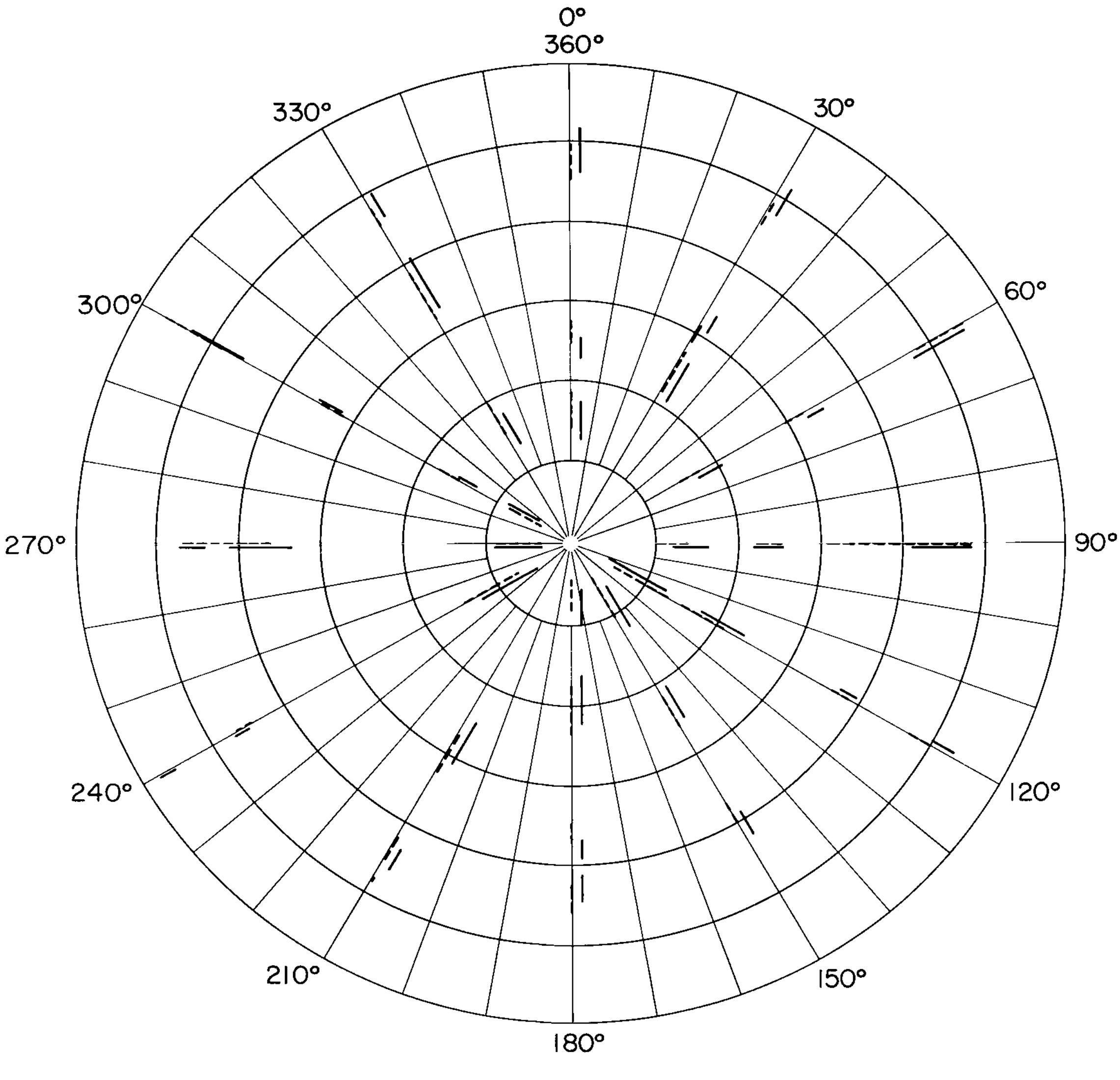


Figure 14.— Visual sensitivity test result for observer JS, right eye.

Age:
Sex:
Nature of Dysfunction: None

Duration:
Treatment:
AVST Results:

Day 3
10:05 AM

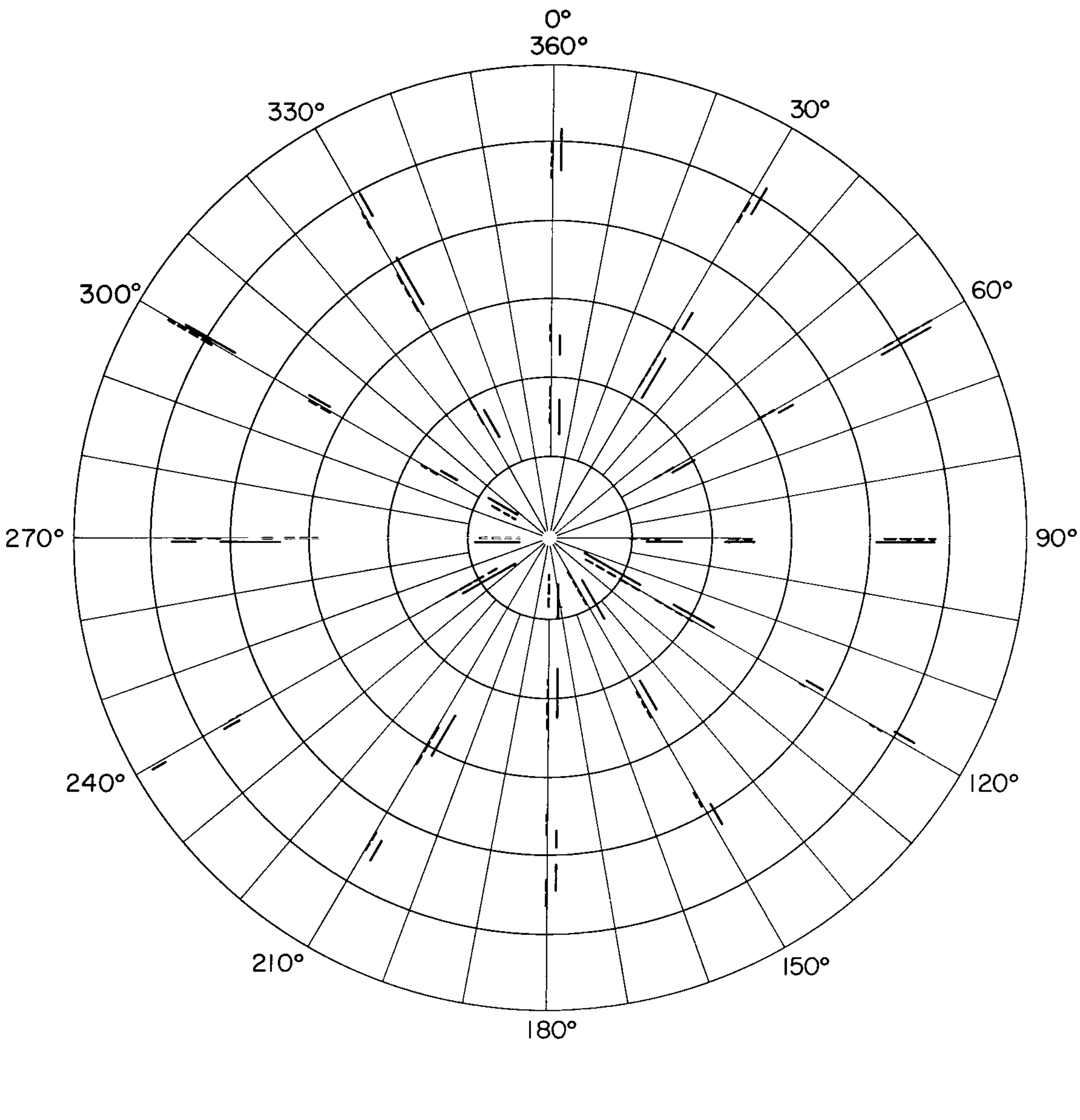


Figure 15.– Visual sensitivity test result for observer JS, left eye.

had been clinically diagnosed as chronic glaucoma. The visual field defects presented in figures 16 through 30 are the same as those noted by Armaly (ref. 5) as indicators of chronic glaucoma.

Figures 16 and 17 show how, for the right eye of observer LF, the blind spot is enlarged in the lower hemisphere with an arc radius of about 12°; this is about twice the arc radius of a normal blind spot.

The visual sensitivity test of the right eye of this observer indicated an extensive loss of vision in the lower right field with macular sparing (see figs. 18 and 19).

Data for observer IP in figures 20 through 22 show a slightly larger blind spot in the right eye than in the left eye. His visual sensitivity test results are also of interest because they indicate an almost complete arcuate scotoma of varying width in the right eye (figs. 23 and 24) extending from the 240° to the 90° meridian and no such scotomas in the left eye (see fig. 25). The majority of his foveal vision has also been lost in the right eye.

The data for observer FD in figures 26 through 28 show a larger blind spot in the right eye than in the left. His visual sensitivity test results are shown in figures 29 and 30. These data indicate a bilateral loss of vision along the 30°, 60°, and 90° meridians in the right eye and along the 0° and 180° meridians in the left eye. Bilateral macular sparing is also indicated.

Figures 31 through 33 are data from observer PD whose right eye had a cataract. Although the blind spot is slightly smaller than normal, the visual sensitivity test results are normal in his left eye. The visual sensitivity test of his right eye, however, indicated an extensive loss of vision from the center of the fovea to the limit of the test field (30° arc radius) along the 150° to the 180° meridian and from the center of the fovea to about 16° arc distance along the 210° and 240° meridians. These data are consistent with the size, shape, and location of the opacity on this observer's cornea.

COMPUTER CALCULATIONS PERFORMED

The following data reduction and computation procedures were used to analyze the blind spot mapping data. The blind spot ink tracings (raw data) were digitized into X,Y coordinates using a magnetic tape-storage, X, Y coordinate plotting board. These data were then processed by a computer program that determined: (1) the area inside the polygon bounded by straight lines connecting the ends of each of the 12 meridians (OUT responses); (2) the area inside the polygon bounded by straight lines connecting the small cross lines on each of the 12 meridians (IN responses); (3) the location of the mathematical centroid of area (1) and (2); and (4) the distance from each centroid to the foveal fixation point. Table 1 presents the mean blind spot area results for the normal and the clinical groups.

Age: 63
Sex: Male
Nature of Dysfunction: Glaucoma

(First Administration)
Day 1
1:15 PM
Area = 66.49 cm^2
f.c.d. = 7.75

Duration: 40+ years
Treatment: Iridectomy 8 years ago; 4 percent pilocarpine 4X daily; 2 percent epinephrine 2X daily
AVST Results: Blind spot enlargement in lower hemisphere with radius of about 12° arc radius

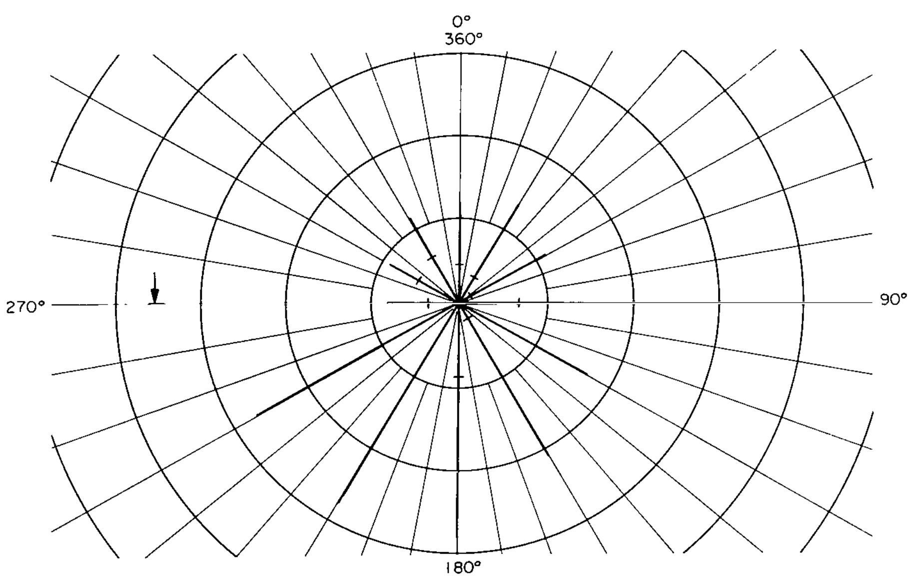


Figure 16.— Blind spot mapping test result for observer LF, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma
(Second Administration)
Day 1
1:22 PM
Area = 37.79 cm^2
f.c.d. = 7.72

Duration:
Treatment:
AVST Results: Similar to that shown in figure 16 except for 90° and 180° meridians

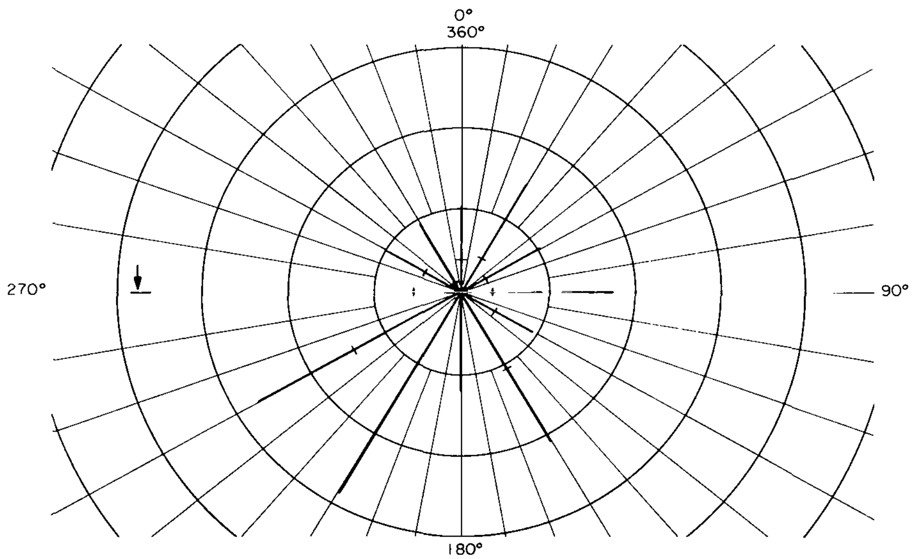


Figure 17.– Blind spot mapping test result for observer LF, right eye.

Age: Sex: Nature of Dysfunction: Glaucoma (First Administration) Day 1 1:34 PM	Duration: Treatment: AVST Results: Total insensitivity for test spot in lower hemisphere between 120° and 240° meridians from macular boundary to 30° arc radius. Macular sparing

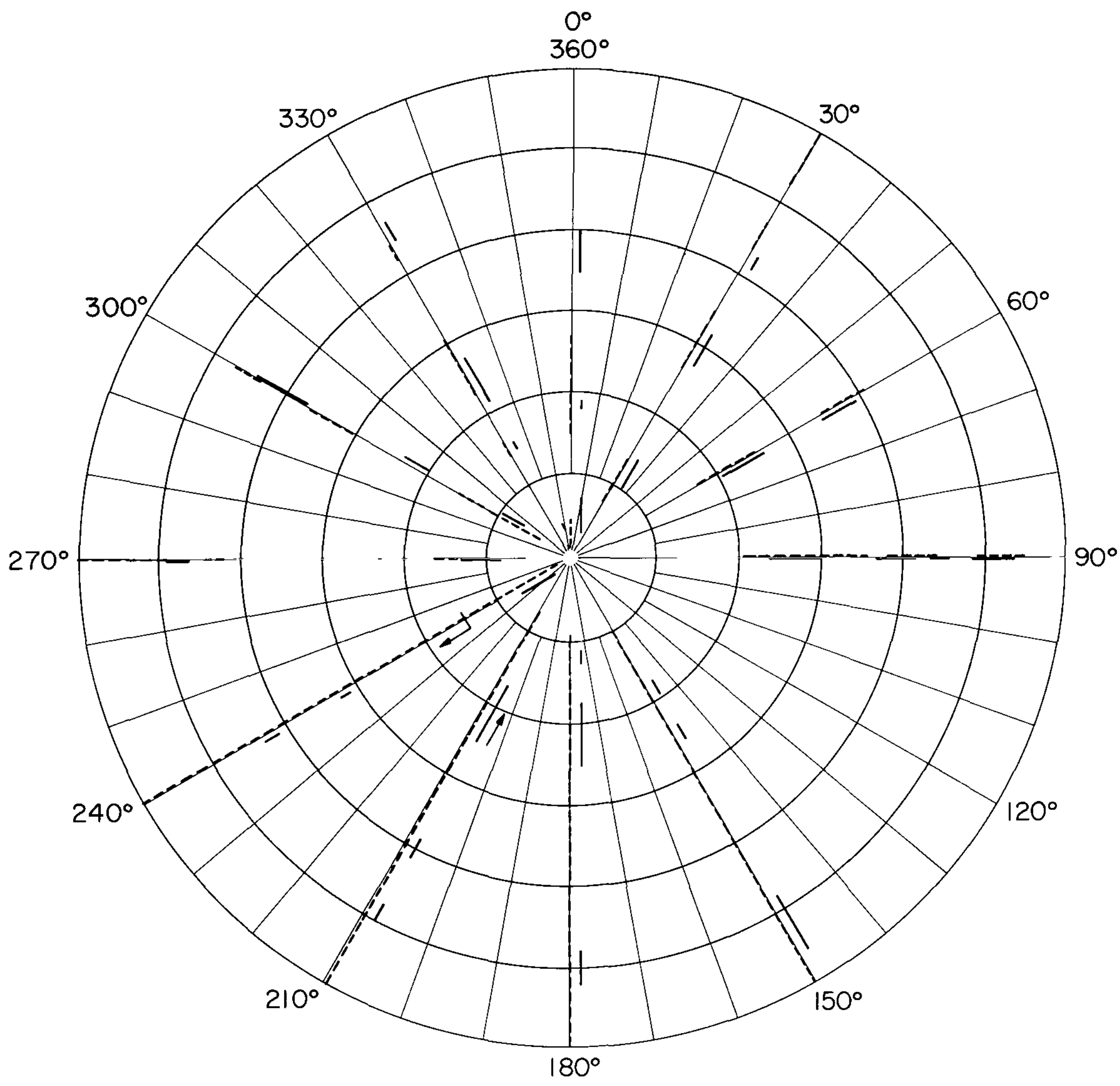


Figure 18.– Visual sensitivity test result for observer LF, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma
(Second Administration)
Day 1
1:44 PM

Duration:
Treatment:
AVST Results: Essentially the same results as reported in figure 18

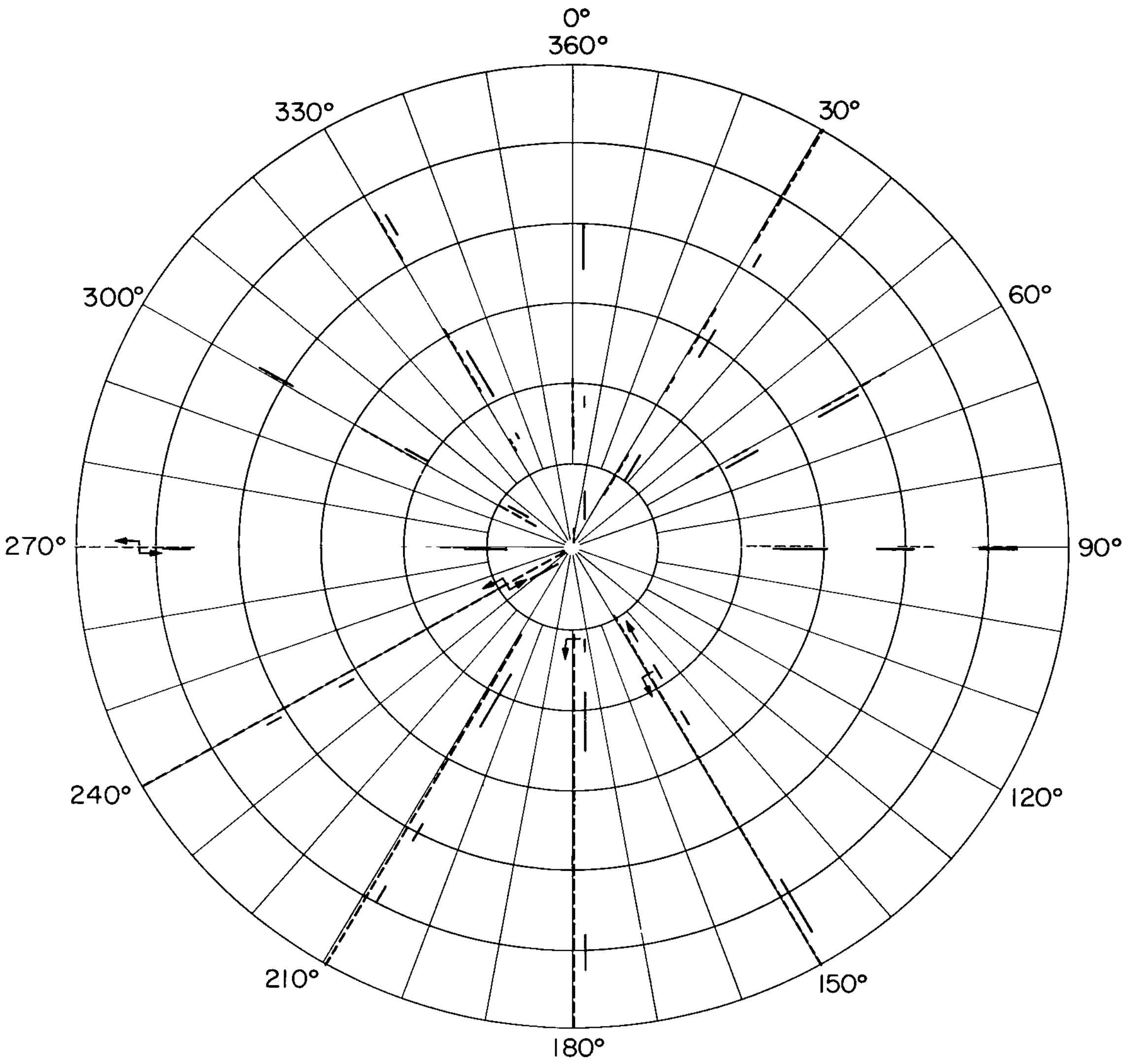


Figure 19.– Visual sensitivity test result for observer LF, right eye.

Age: 46
Sex: Male
Nature of Dysfunction: Glaucoma

(First Administration)
Day 1
3:17 PM
Area = 34.21 cm^2
f.c.d. = 7.55

Duration: 12+ years
Treatment: 5 percent pilocarpine 1X daily; epinephrine 2X daily; observer also wears prescription
AVST Results: Enlargement of blind spot in upper hemisphere between 330° and 360° meridians extending to a limit of about 14° arc radius

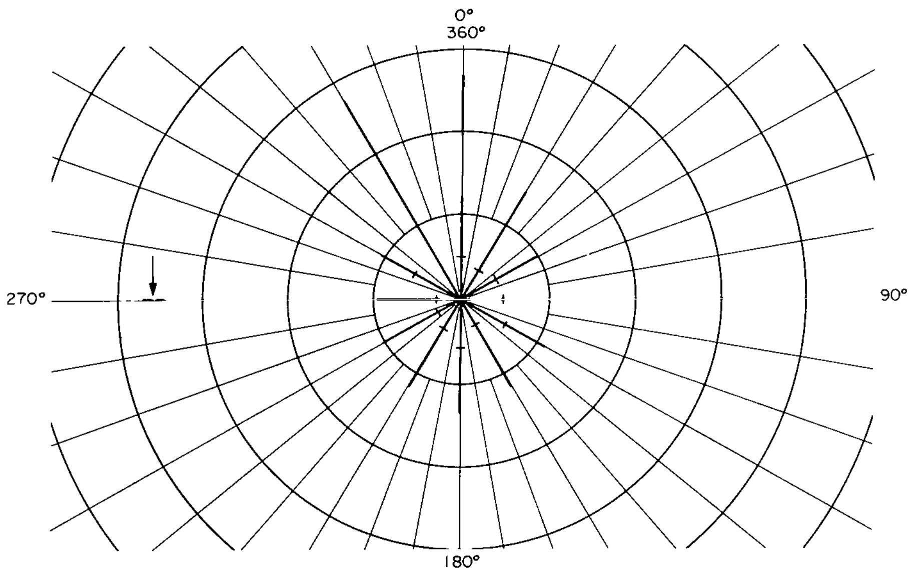


Figure 20.— Blind spot mapping test result for observer IP, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma
(Second Administration)
Day 1
3:24 PM
Area = 37.33 cm^2
f.c.d. = 7.79

Duration:
Treatment:
AVST Results: Similar to that shown in figure 20

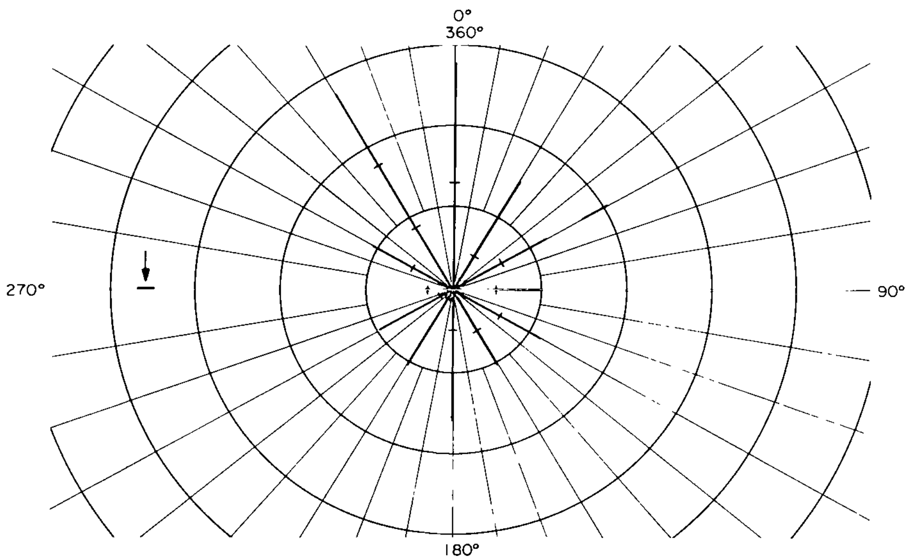


Figure 21.– Blind spot mapping test result for observer IP, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma
(Third Administration)
Day 1
3:31 PM
Area = 18.35 cm^2
f.c.d. = 7.45

Duration:
Treatment:
AVST Results: Blind spot size, shape, and distance from fovea normal

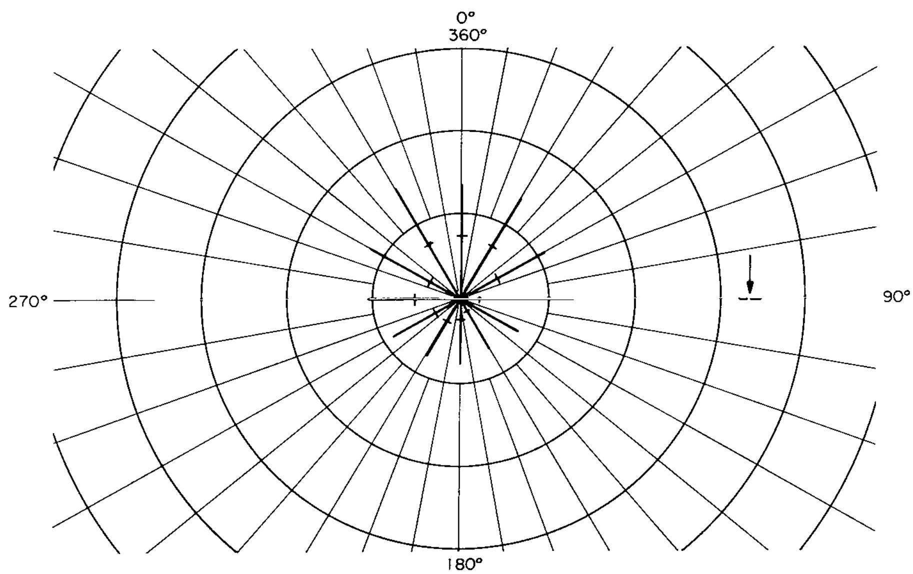


Figure 22.– Blind spot mapping test result for observer IP, left eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma

Day 1
3:39 PM

Duration:
Treatment:
AVST Results: Large region of insensitivity as shown by long (response) lines radiating from the fovea along the 30°, 270°, 310°, 330°, and 360° (vertical) meridians, a distance of about 30° arc radius

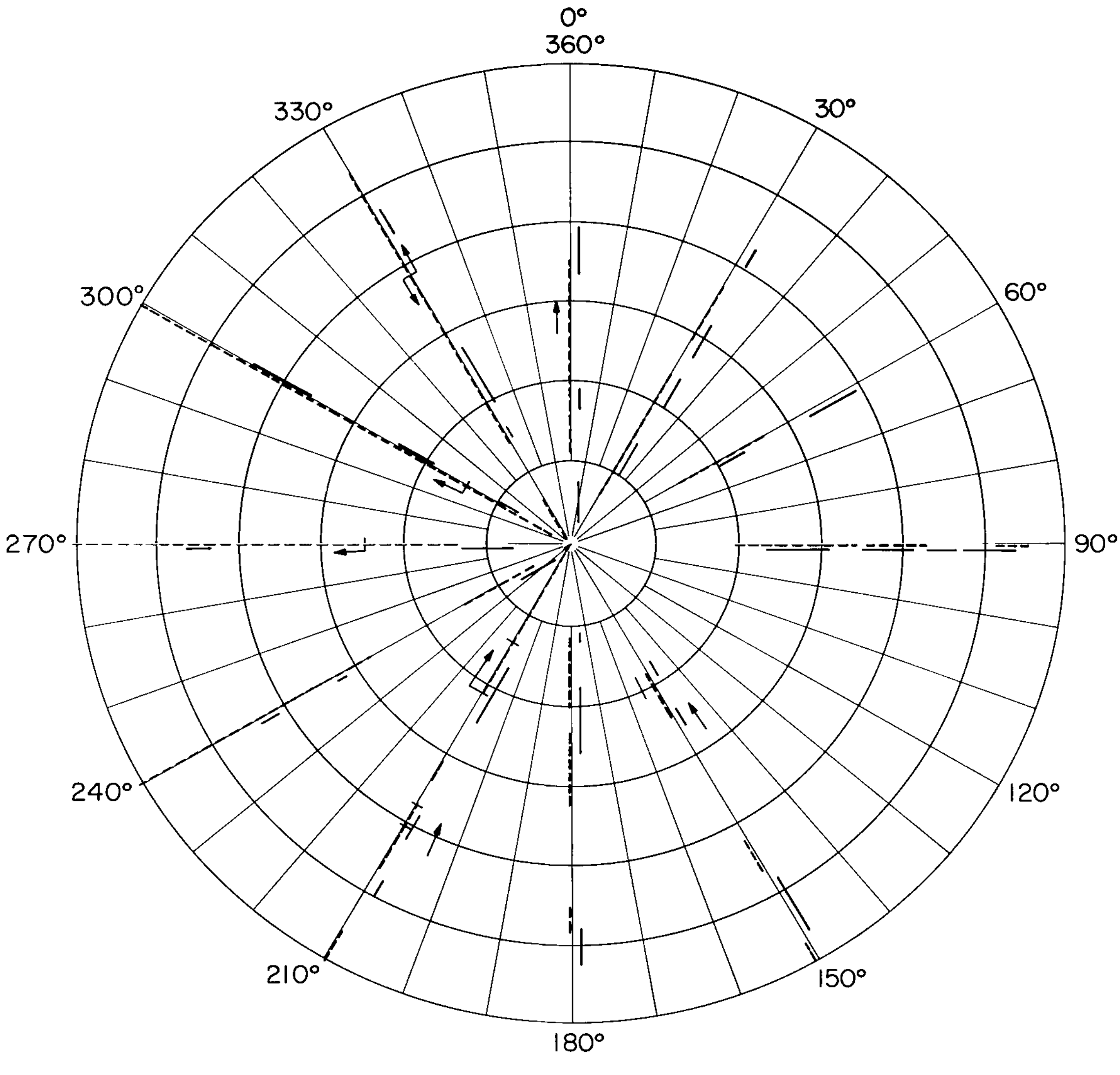


Figure 23.— Visual sensitivity test result for observer IP, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma
Day 1
3:46 PM

Duration:
Treatment:
AVST Results: Essentially the same results as for figure 23 except for the 0° (vertical) and 210° meridians. In both figures macular sparing is evident

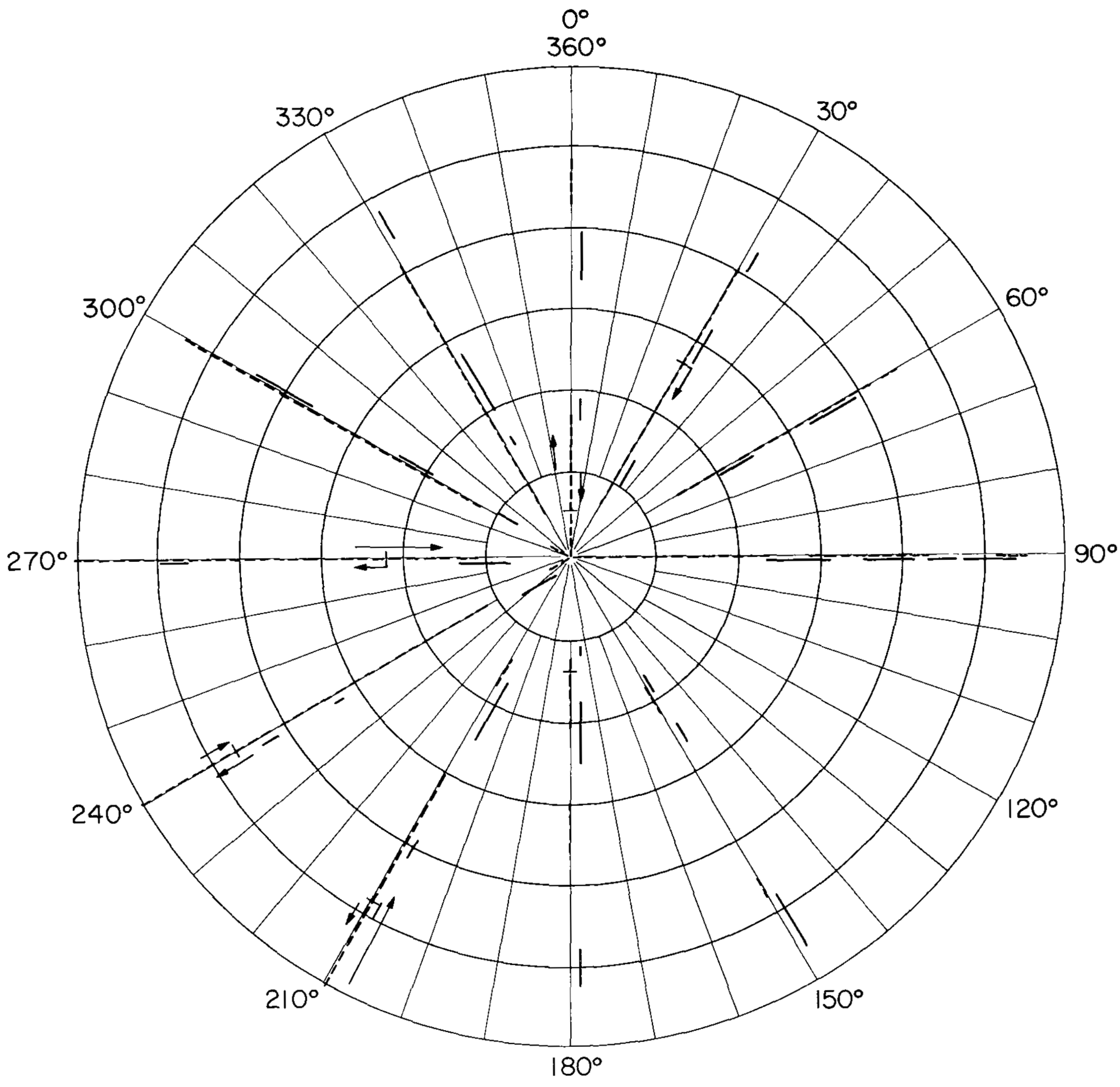


Figure 24.– Visual sensitivity test result for observer IP, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma

Day 1
3:57 PM

Duration:
Treatment:
AVST Results: The visual sensitivity appears normal within 30° arc radius of the fovea

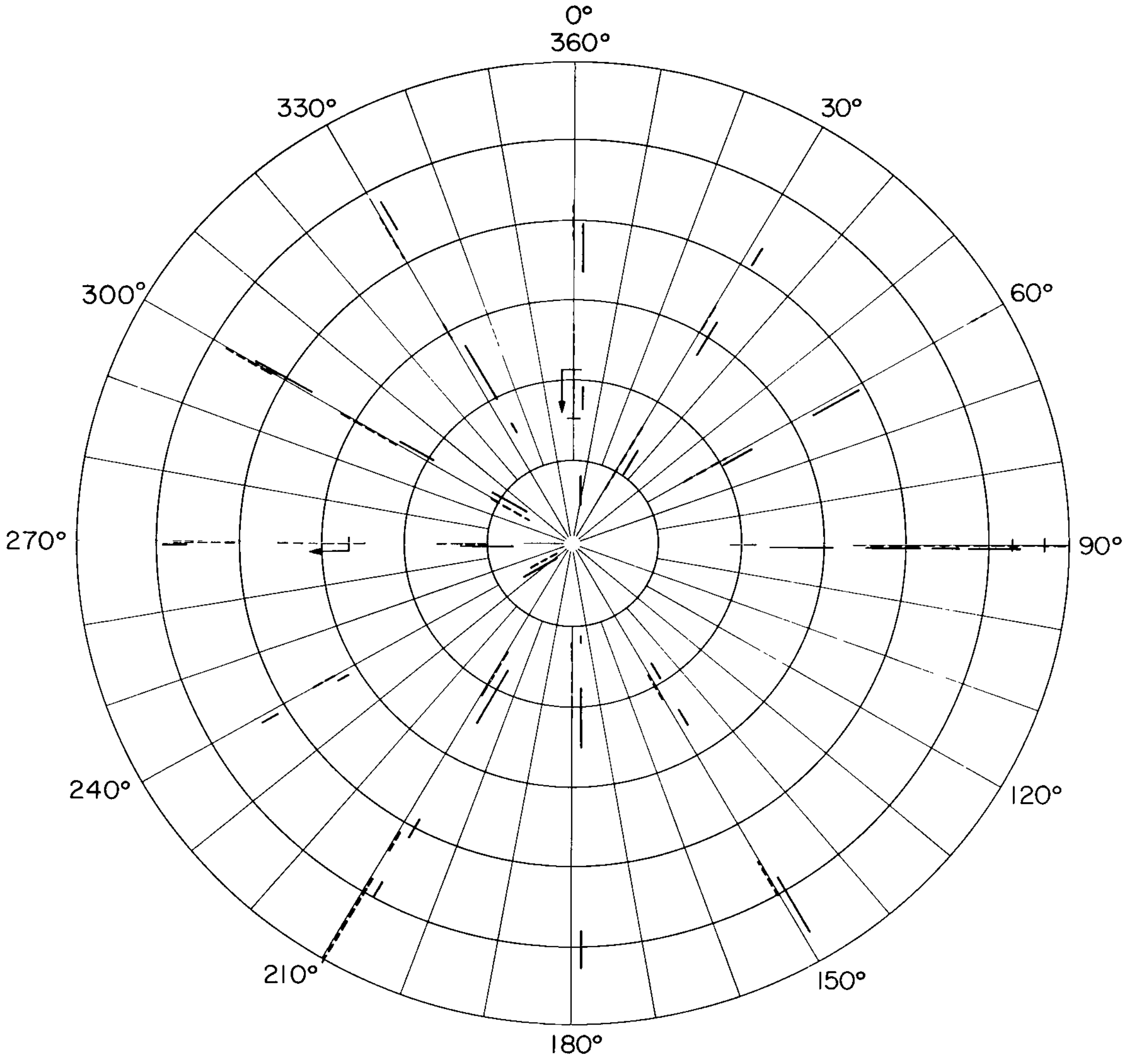


Figure 25.– Visual sensitivity test result for observer IP, left eye.

Age:	49	Duration:	2-1/2 years
Sex:	Male	Treatment:	None
Nature of Dysfunction:	Glaucoma	AVST Results:	Normal size, shape, and location from fovea

(First Administration)
Day 1
3:12 PM
Area = 12.77 cm^2
f.c.d. = 7.68

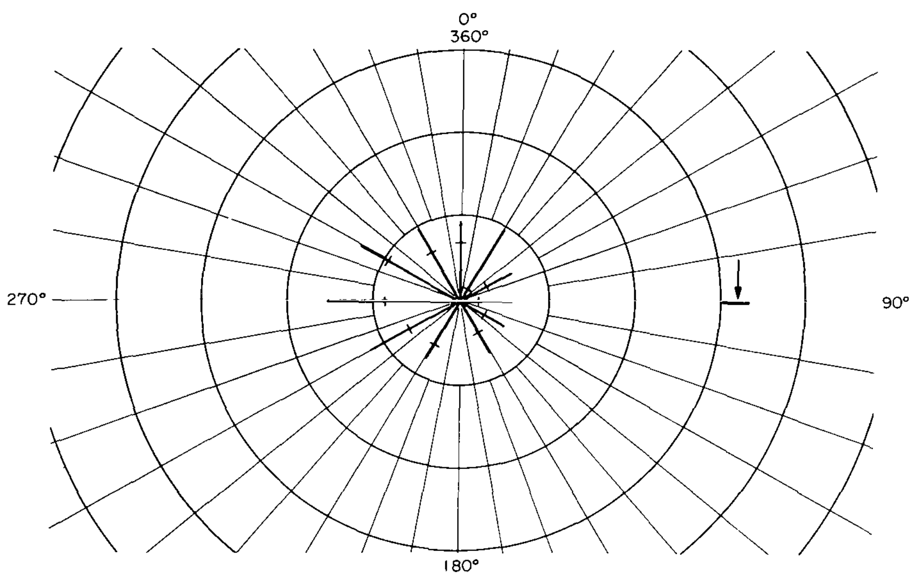


Figure 26.– Blind spot mapping test result for observer FD, left eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma

(Second Administration)
Day 1
3:19 PM
Area = 91.18 cm^2
f.c.d. = 7.75

Duration:
Treatment:
AVST Results: Enlarged blind spot in entire upper hemisphere to a distance of about 14° arc radius and moderately large scotomas within 12° arc distance from blind spot in lower hemisphere

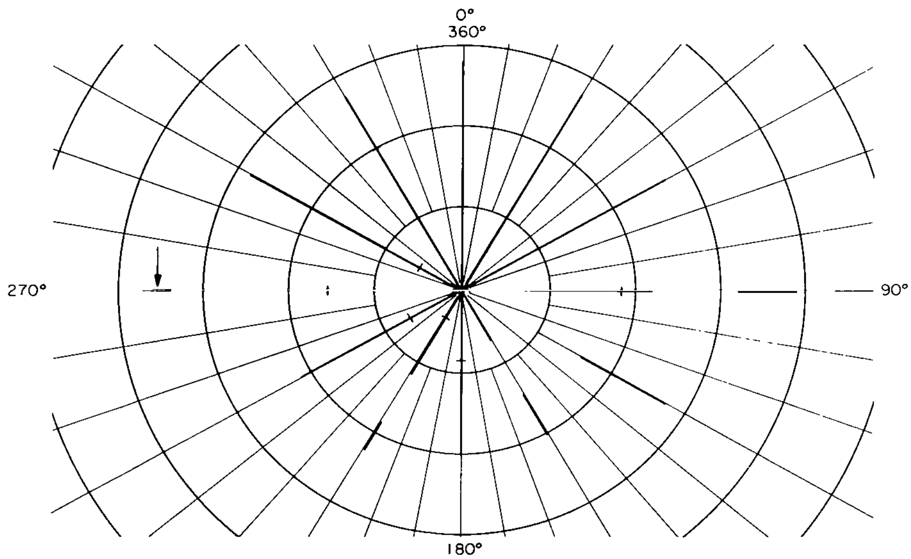


Figure 27.– Blind spot mapping test result for observer FD, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma

(Third Administration)
Day 1
3:26 PM
Area = 80.57 cm^2
f.c.d. = 7.98

Duration:
Treatment:
AVST Results: Similar size, shape, and location of enlarged blind spot for upper hemisphere and slightly different lower scotomas than are shown in figure 26

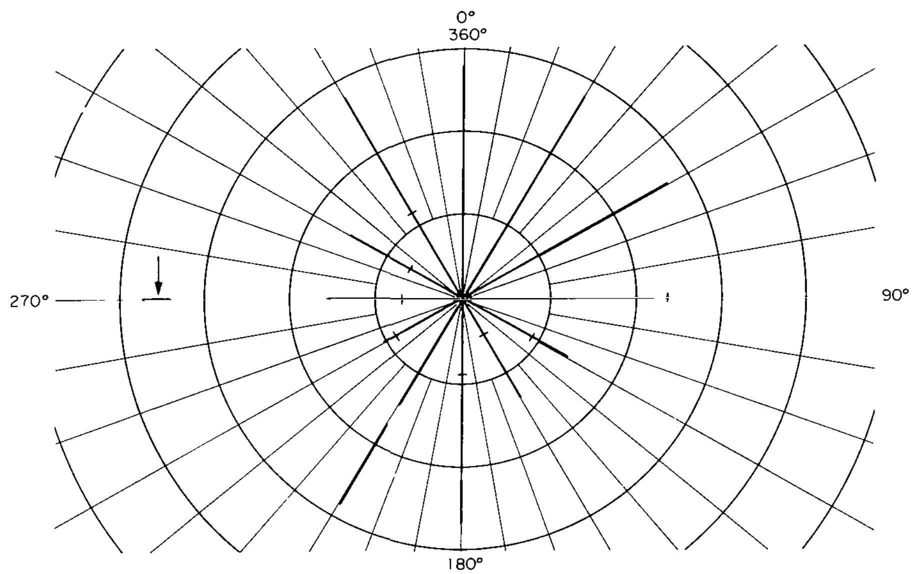


Figure 28.– Blind spot mapping test result for observer FD, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma

(Fourth Administration)
Day 1
3:39 PM

Duration:
Treatment:
AVST Results: Large scotoma located in upper right-hand visual field along 30°, 60°, and 90° meridians from foveal boundary to 30° arc radius. This figure corroborates data shown in figure 28 for the blind spot enlargement. The fovea has been spared.

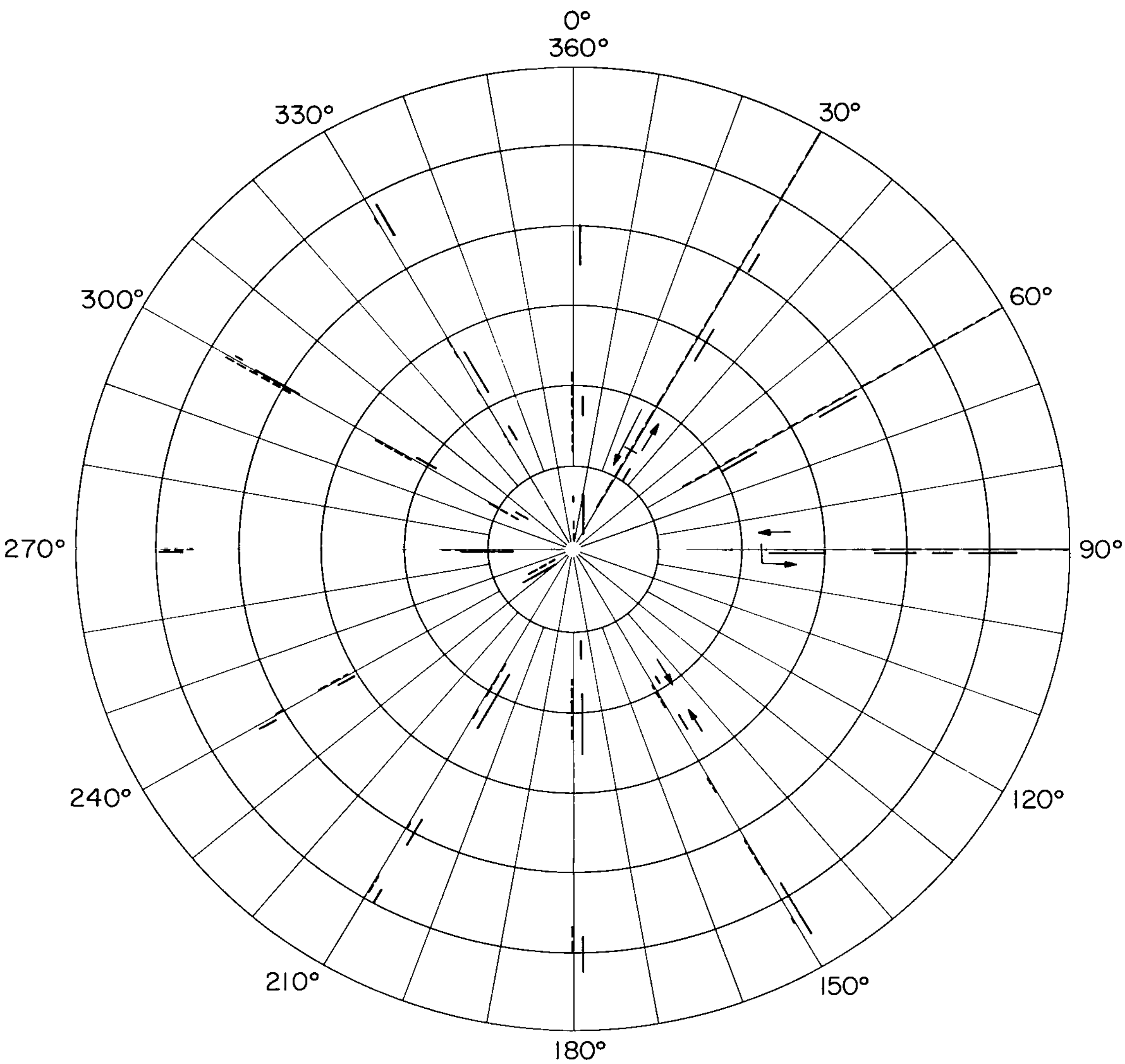


Figure 29.— Visual sensitivity test result for observer FD, right eye.

Age:
Sex:
Nature of Dysfunction: Glaucoma

(Fifth Administration)
Day 1
3:47 PM

Duration:
Treatment:
AVST Results: Large scotoma located in upper right-hand quadrant of visual field similar to that shown in figure 29 for the right eye. The fovea has been spared

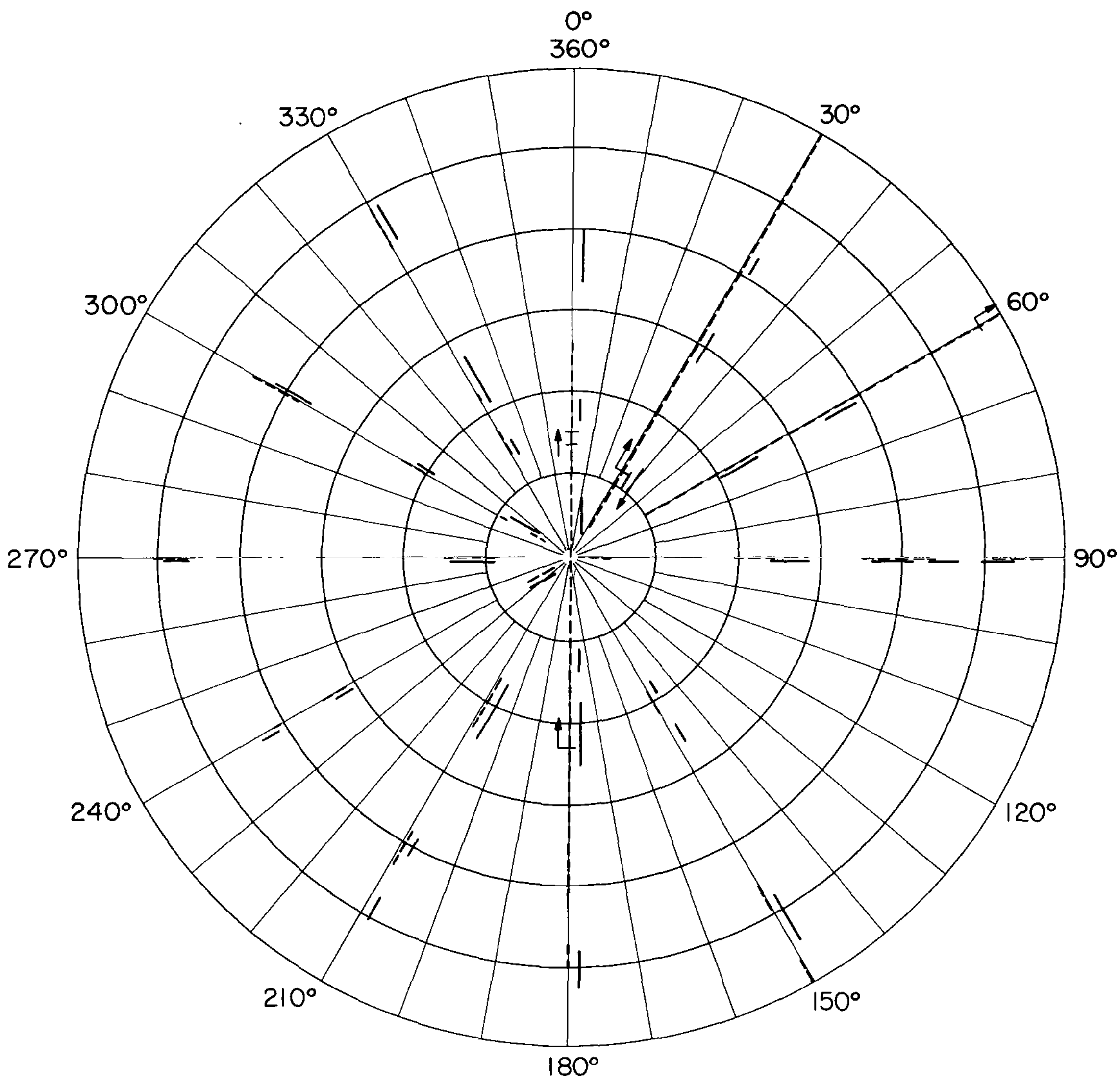


Figure 30.– Visual sensitivity test result for observer FD, left eye.

Age: 42
Sex: Male
Nature of Dysfunction: Cataract, right eye

(First Administration)
Day 1
3:12 PM
Area = 5.08 cm^2
f.c.d. = 7.18

Duration: 36+ years
Treatment: Two surgical operations. Right eye developed exophoria 3 months ago, left eye dominant, wears prescription for slight left eye myopia and astigmatism. Right eye has whitish opacity in cornea and anterior lens
AVST Results: Slightly smaller blind spot than normal and slightly smaller angular separation from fovea than normal

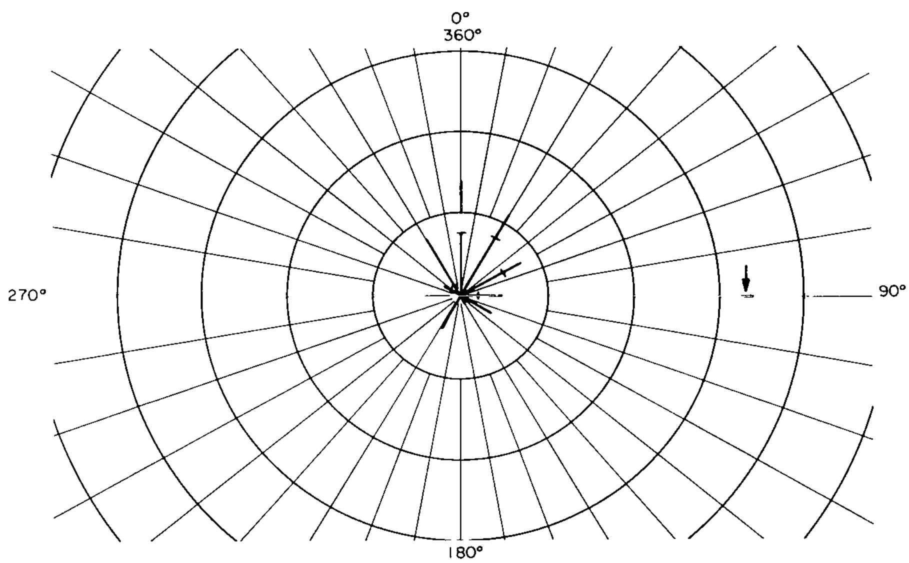


Figure 31.– Blind spot mapping test result for observer PD, left eye.

Age:
Sex:
Nature of Dysfunction: Cataract, right eye

Duration:
Treatment:
AVST Results: Normal visual sensitivity within 30° arc radius of fovea for all meridians tested

(First Administration)
Day 1
3:30 PM

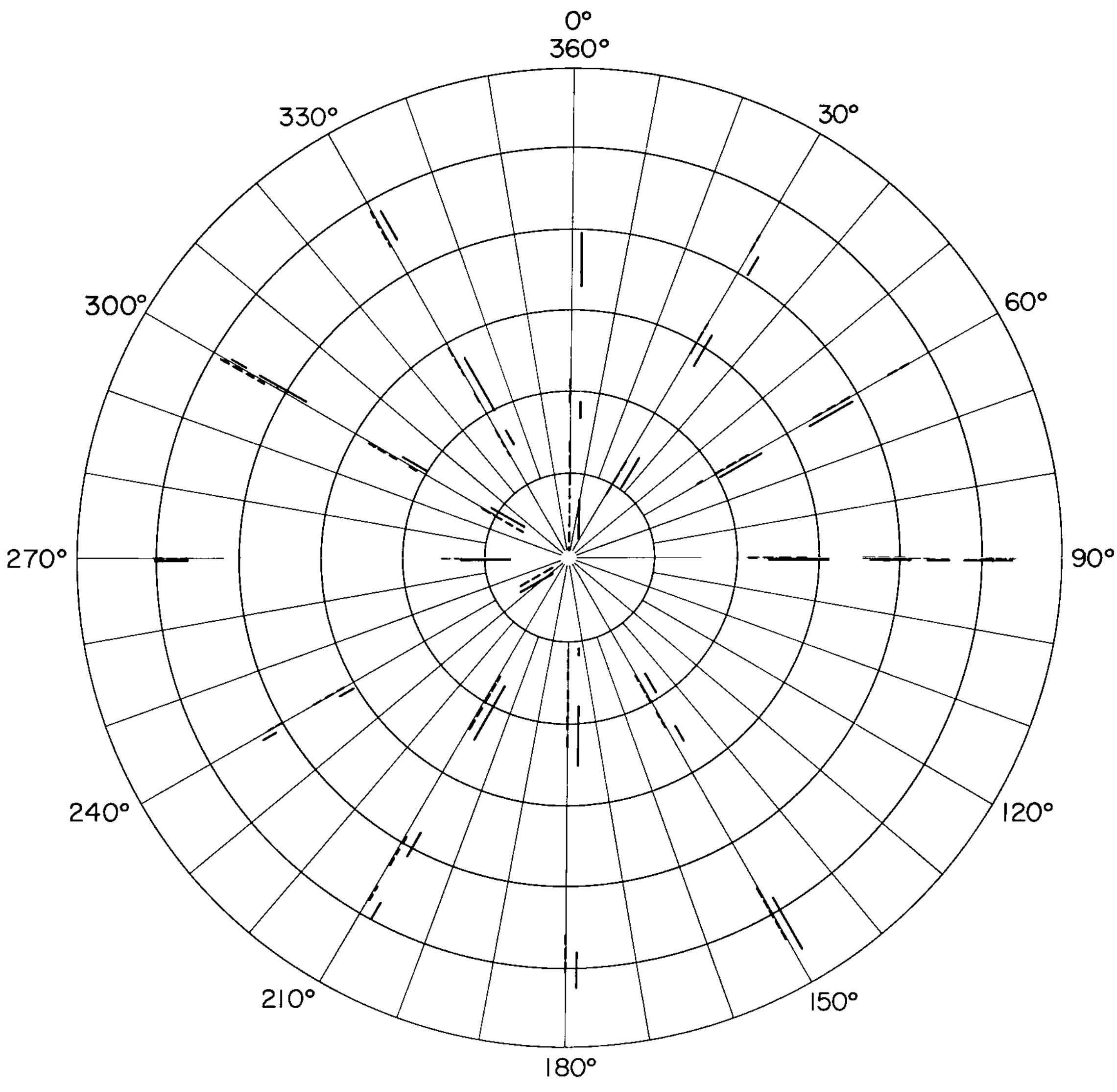


Figure 32.– Visual sensitivity test result for observer PD, left eye.

Age:
Sex:
Nature of Dysfunction: Cataract, right eye

(Second Administration)
Day 1
3:38 PM

Duration:
Treatment:
AVST Results: Relatively large area of insensitivity in lower hemisphere along 150°, 180°, and 240° meridians as shown by long (response) lines

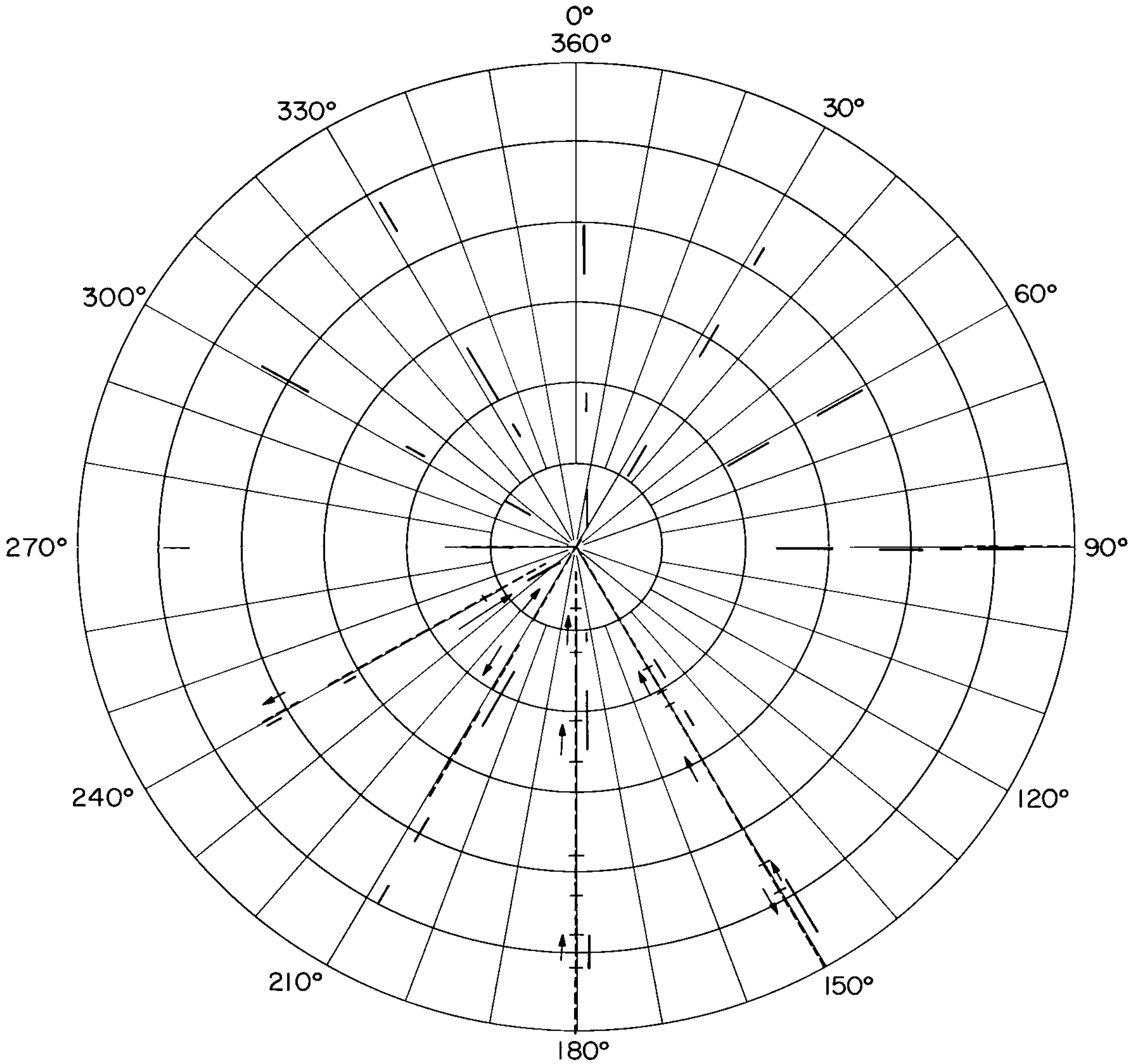


Figure 33.– Visual sensitivity test result for observer PD, right eye.

TABLE 1.- SUMMARY OF MEAN BLIND SPOT DATA

			Normal group	Clinical group
(IN)	OS	Mean[a]	4.822	4.247
		SD	.575	1.566
		N[b]	34	8
		0[c]	17	7
	OD	Mean	4.756	4.680
		SD	.590	1.638
		N	31	11
		0	13	8
(OUT)	OS	Mean	6.915	11.925
		SD	.417	3.992
		N	58	9
		0	20	9
	OD	Mean	6.582	30.413
		SD	.245	26.400
		N	56	16
		0	18	11
(MEAN)	OS	Mean	3.844	7.846
		SD	.884	1.713
		N	25	8
		0	14	8
	OD	Mean	3.825	10.042
		SD	1.001	4.075
		N	22	11
		0	10	8

[a]Each mean is in cm^2 and refers to the area of the various blind spot ink recordings and not to the actual retinal area. Although the retinal blind spot area could be determined, it would be of no more clinical diagnostic significance than the present type of records.

[b]N refers to the number of data points on which each mean and standard deviation (SD) is based.

[c]0 refers to the number of different observers on which each mean and standard deviation is based.

The following determinations were made from the visual sensitivity test data for each of the 12 meridians: (1) the distance between the fixation point and the location at which the observer pressed the response button on an IN and OUT response at the same location; (2) the distance between the fixation point and the location at which the observer failed to detect the disappearance of the test spot; (3) the distance between the ink pen tracing of the test spot's onset and the ink pen tracing of the observer's button-press for that onset (i.e., onset reaction time); and (4) the offset reaction time, as described in (3).

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., 94035, Aug. 5, 1970

APPENDIX A

STIMULUS FILM PREPARATION EQUIPMENT AND PROCEDURE

The basic equipment used to photograph the stimulus film is shown in figure 34. The movie camera used was a super 8 mm with f 1.8, 14-mm lens, operated at 18 frames per second and projected at 24 frames per second.

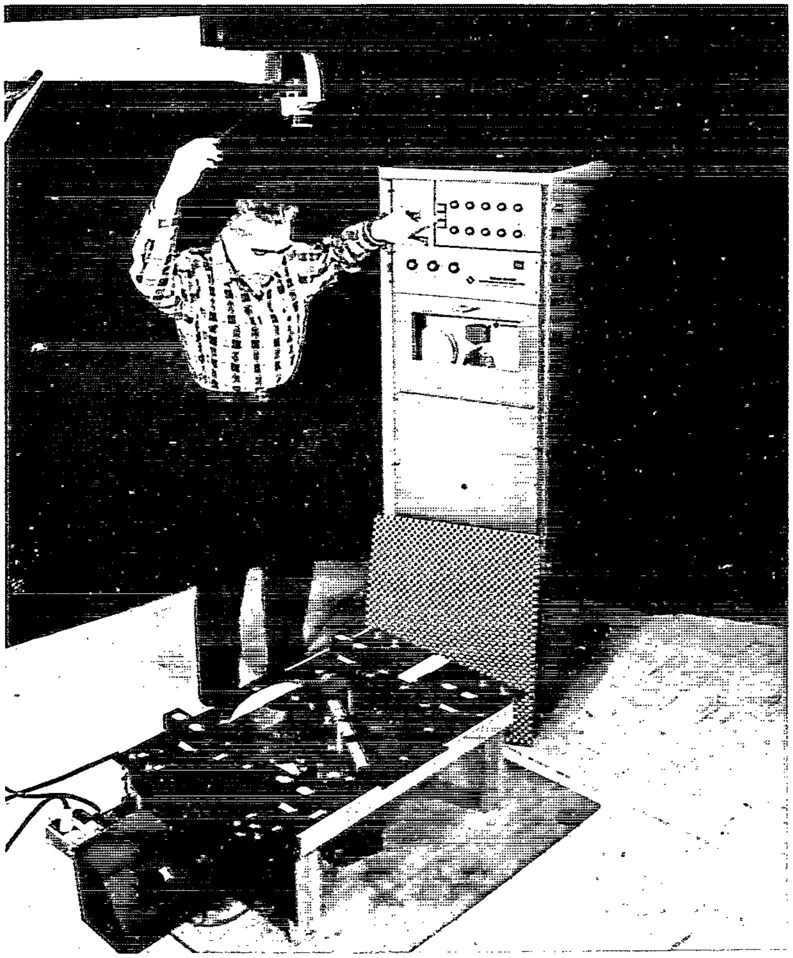


Figure 34.– Stimulus film preparation equipment.

Maximum film image contrast was obtained by using Eastman Kodak Plus-X black and white film and also by choosing the optimal stimulus light to background contrast ratio. A film leader was exposed on each film to aid the observer in determining when to stop the test. This leader was produced by photographing a black and white checkerboard patterned cardboard surface, which was laid on top of the light support fixture shown in figure 34. When projected in the AVST, the side of each square of this pattern subtended about 1° arc. This leader was photographed at a constant, maximum level of illumination for 10 seconds, after which the illumination level was reduced to zero over a 5-second period. This change in apparent contrast signaled the start of the test. Use of a small pattern checkerboard leader helped to reduce visual adaptation problems associated with relatively large, high-contrast scenes.

The various fixed and movable light sources that were photograped were located on a fixture on the floor 7 feet beneath the rigidly suspended camera (fig. 34). The eight (1-1/4 X 1-3/4 in.) lights, used to trigger the photocells and thus drive the plotter, were located at fixed positions on each corner of the fixture shown in detail in figure 35. A stepping motor driven, rotary table was used to move the 0.032-inch-diameter stimulus light over a given meridian at the proper constant velocity. A second stepping motor was used to drive the rotary table into the proper meridian. All of the lights were in the same image plane.

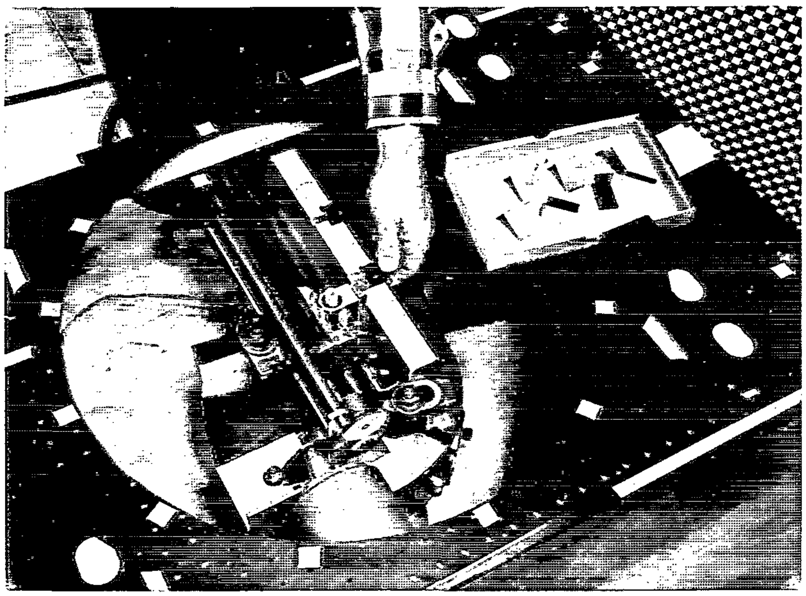


Figure 35.— Photograph of modified machine tool fixture used to move the stimulus light during film preparation.

VISUAL SENSITIVITY TEST PREPARATION

The movable stimulus light was automatically turned on and off by means of a microswitch located on the traveling carriage. This switch touched various length interrupter strips (see fig. 35) located on the rail. Thus, the stimulus light could be turned on and off at different positions and for preselected durations on each meridian. The following five stimulus light off durations were used: 0.5, 0.75, 1, 1.25, and 1.75 seconds. The movable stimulus light traveled away from and toward the center of the rotary table; the center position served as the stimulus light's starting position on each meridian. This light was turned off either once or twice per direction per meridian on a random basis for the visual sensitivity test. The light was never turned off at the same location on an IN or OUT movement on the same meridian, however.

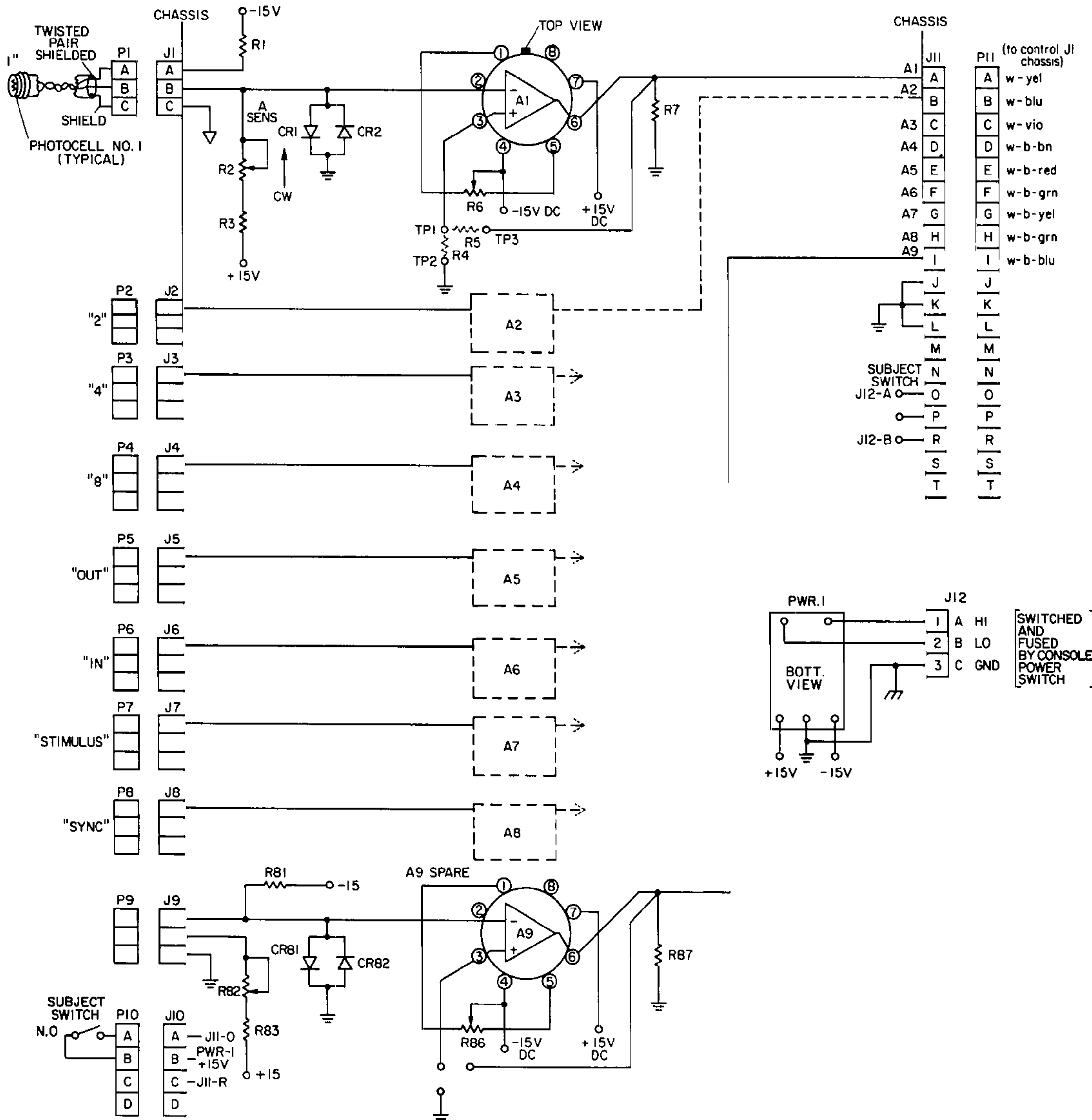
The presentation order of the 12 meridians was randomized. A total of four stimulus films was made of the visual sensitivity test. Different meridian presentation orders and stimulus light on and off locations and durations were used in each film to help reduce learning effects. The locations at which the movable stimulus light was off was photographed so that all of the 30° arc radius of travel was administered by presenting any two films.

BLIND SPOT MAPPING TEST PREPARATION

The blind spot mapping film was made as follows. The movable light was left on continuously, and the same checkerboard leader was used as before. On its first pass, the stimulus light traveled 10° arc out and back on both the 90° and 270° meridian. This was done so that the observer would be able to press the finger button the instant the stimulus light reached the point directly under the peripherally located, red fixation cross. Thereafter, the stimulus light traveled 5° arc from the center along each of the 12 meridians, which were presented in random order.

APPENDIX B

AMPLIFIERS AND ASSOCIATED ELECTRONIC CONTROLS

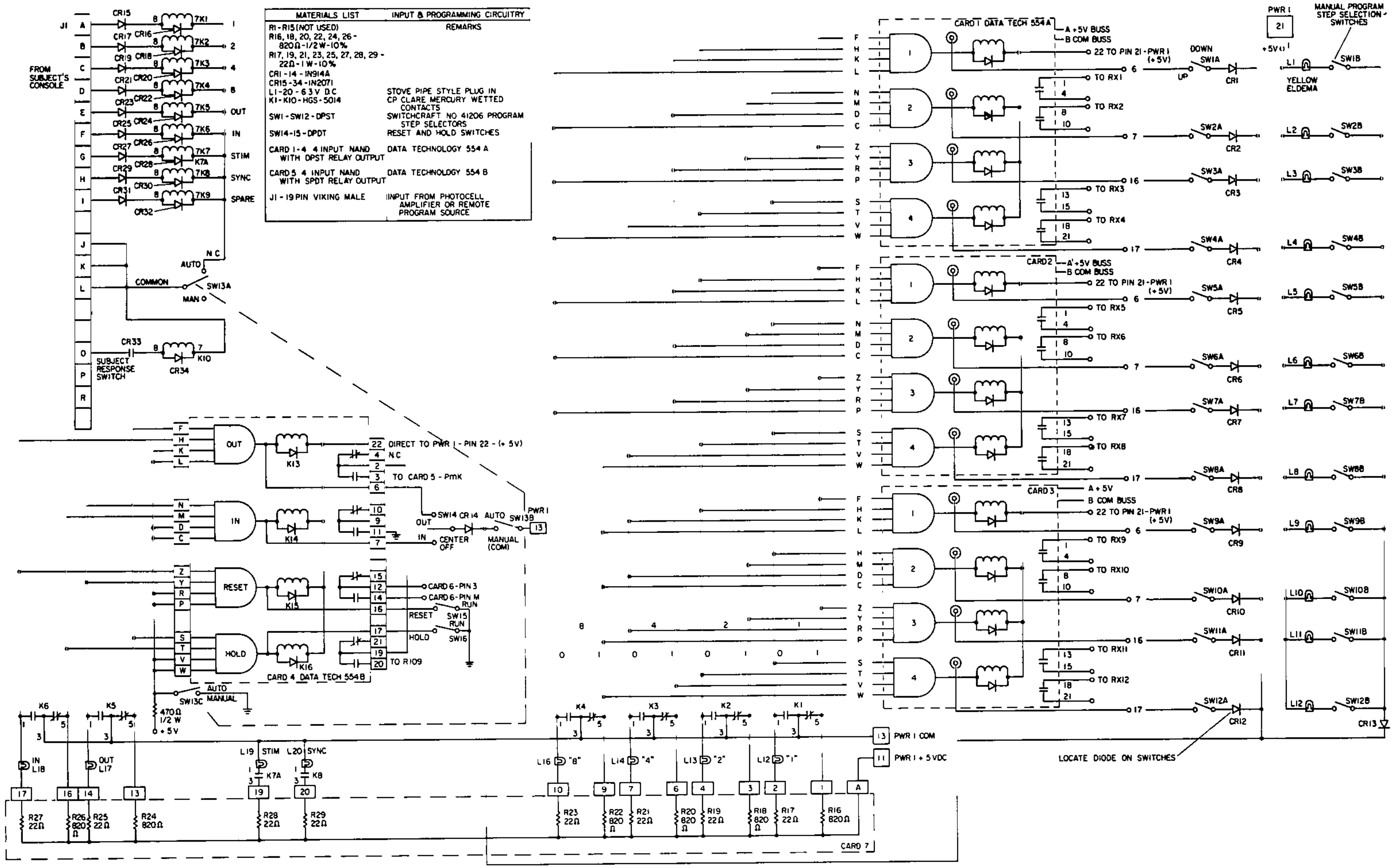


ITEM NO.	QTY.	PART NAME	SPECS	REF. DES
1	18	RESISTOR	10KΩ 1/2 W 10%	R1, 3, 11, 13, 21, 23, 31, 33, 41, 43, 51, 53, 61, 63, 71, 73, 81, 83
2	9	SENSITIVITY POT	50K 10% BOURNS ETC. TRIMPOT	R2, 12, 22, 32, 42, 52, 62, 72, 82
3	9	RESISTOR	4.7K 1/2 W 10%	R7, 17, 27, 37, 47, 57, 67, 77, 87
4	9	BAL. POT	10K 10% TRIMPOT	R6, 16, 26, 36, 46, 56, 66, 76, 86
5	18	SILICON DIODE	IN914	CR_1-18
6	9	OP AMP	FAIRCHILD μA 741 C	A1 - A9
7	9	INPUT RECPT.	VIKING 3 PIN FEMALE VR-3	J1 - J9
8	1	OUTPUT CONN.	VIKING 19 PIN FEMALE VR 19/2AG17	J10
9	1	110V AC CONN. MALE	CANNON 3 PIN MALE	J12
10		POWER SUPPLY	±15V ANALOG DEV. 903 100 mA	PWR-1
11	9	INPUT PLUG	VIKING 3 PIN M VP3/4AB13	P1 - P9
12	1	OUTPUT PLUG	VIKING 19 PIN M VP19/12AA13 WITH V5723C4 HOOD	P11
13		SUBJECT PLUG	VIKING 4 PIN MALE	P10
14		SUBJECT RECPT.	VIKING 4 PIN FEMALE	J10

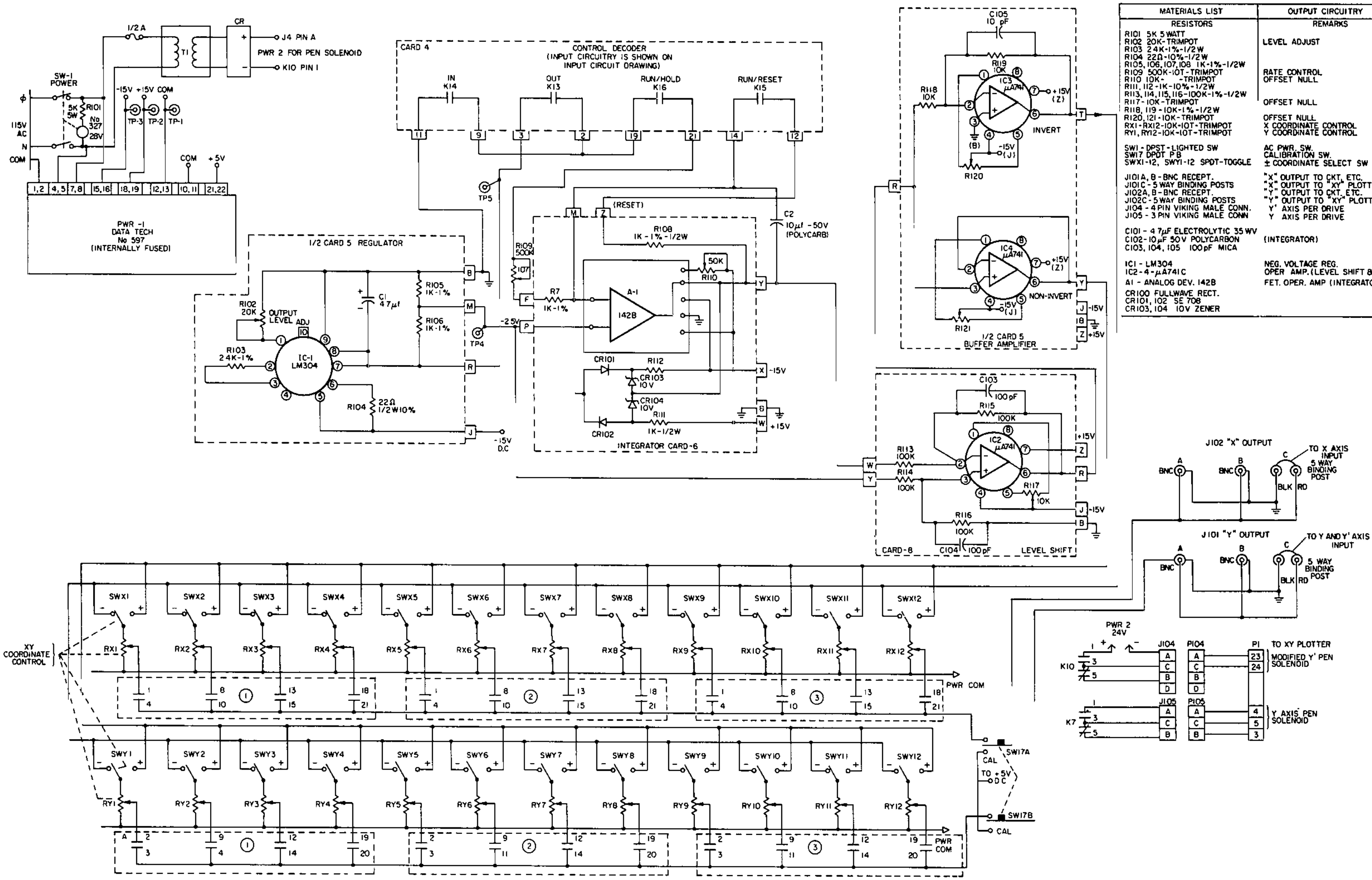
NOTES:

1 SENS POTS ON REAR PANEL
2 BAL POTS INTERNAL
3 R4, 5 ETC. ARE OPTIONAL - USE TO INCREASE HYTERESIS IF R4, 5 NOT USED TP1-3 OPEN; TP1-2 SHORTED

Drawing 1.— Photocell signal conditioner.



Drawing 2.– Input circuitry.



MATERIALS LIST	OUTPUT CIRCUITRY
RESISTORS	REMARKS
R101 5K 5 WATT	
R102 20K-TRIMPOT	LEVEL ADJUST
R103 24K-1%-1/2W	
R104 22Ω-10%-1/2W	
R105, 106, 107, 108 1K-1%-1/2W	
R109 500K-10T-TRIMPOT	RATE CONTROL
R110 10K- -TRIMPOT	OFFSET NULL
R111, 112-1K-10%-1/2W	
R113, 114, 115, 116-100K-1%-1/2W	
R117-10K-TRIMPOT	OFFSET NULL
R118, 119-10K-1%-1/2W	
R120, 121-10K-TRIMPOT	OFFSET NULL
RX1-RX12-10K-10T-TRIMPOT	X COORDINATE CONTROL
RY1, RY12-10K-10T-TRIMPOT	Y COORDINATE CONTROL
SW1-DPST-LIGHTED SW	AC PWR. SW.
SW17 DPDT PB	CALIBRATION SW.
SWX1-12, SWY1-12 SPDT-TOGGLE	± COORDINATE SELECT SW
J101A, B-BNC RECEPT.	"X" OUTPUT TO CKT. ETC.
J101C-5 WAY BINDING POSTS	"X" OUTPUT TO "XY" PLOTTER
J102A, B-BNC RECEPT.	"Y" OUTPUT TO CKT. ETC.
J102C-5 WAY BINDING POSTS	"Y" OUTPUT TO "XY" PLOTTER
J104-4 PIN VIKING MALE CONN.	Y' AXIS PER DRIVE
J105-3 PIN VIKING MALE CONN	Y AXIS PER DRIVE
C101-4.7μF ELECTROLYTIC 35 WV	
C102-10μF 50V POLYCARBON	(INTEGRATOR)
C103, 104, 105 100pF MICA	
IC1-LM304	NEG. VOLTAGE REG.
IC2-4-μA741C	OPER AMP. (LEVEL SHIFT & BUFFERS)
A1-ANALOG DEV. 142B	FET. OPER. AMP (INTEGRATOR)
CR100 FULLWAVE RECT.	
CR101, 102 SE 708	
CR103, 104 10V ZENER	

Drawing 3.– Output circuitry.

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