THE VISUAL STANDARDS FOR THE SELECTION AND RETENTION OF ASTRONAUTS

PART II

BY

MERRILL J. ALLEN
JOHN R. LEVENE
GORDON G. HEATH

Prepared under Contract No. NAS 9-9665 by

INDIANA UNIVERSITY
DIVISION OF OPTOMETRY AND
PROGRAM IN PHYSIOLOGICAL OPTICS
BLOOMINGTON, INDIANA

for Manned Spacecraft Center, Houston, Texas
National Aeronautics and Space Administration

May 1972

ACKNOWLEDGEMENT

It is a pleasure to thank Stanley Miller, O.D. for his assistance throughout the project. We thank Mrs. Elizabeth Egan and the Optometry library staff for their continued help.

M.J.A.
J.R.L.
G.G.H.

I. Introduction:

In the Request for Proposal No. BG 721-8-9-319P Exhibit A dated 27 February 1969 it is stated: "The contractor shall (a) conduct a definition study of the problem, (b) isolate and study the components related to space mission tasks, (c) conduct empirical studies of the fundamental factors in binocular vision, (d) search for tests of other visual functions that may be important in determining visual fitness for primary control of spacecraft such as color vision, dark adaptation, contrast threshold, and refractive error."

The above four projects were programmed to be met in 4 years of work, one per year. The first year's work was the definition study centered around a comprehensive literature search. The second year's study, Herewith reported, is divided into four parts as detailed in the following Statement of Work, Exhibit B June 24, 1970.

" A. The contractor shall analyze the visual stimuli involved inside the available space vehicles, and those associated with space docking and moon landings. These will include both normal and space suit clothing conditions.

B. The contractor shall attempt to determine the human capabilities to perform these space related visual tasks by consulting the literature and will thus determine the areas needing further laboratory study.

C. The contractor shall conduct studies to determine the human capabilities in the important specific areas of deficit discovered. Examples of areas that may need further study are as follows:

1. aniseikonia
2. autokinesis
3. cyclorotational eye movements
4. night myopia
5. retinal acaptation

The human characteristics shall be compared to the appropriate visual space tasks and recommendations for visual test standards will be made.

D. The contractor shall make recommendations for vision test standards and procedures where literature information is adequate to establish the human characteristics, and where the relationship between these characteristics and the visual space tasks is clear cut."

II. Analysis of Visual Stimuli in Space Related Tasks.

Extensive laboratory visits and interviews were conducted to determine the visual tasks with in the command module, the lunar module, and during the docking and landing operations. We consider these tasks to be no more difficult visually than those encountered in commercial aviation. It was not possible to see and measure the actual instrumentation and to study their arrangements in the various space vehicles. However, we believe the simulators at N.A.S.A. Houston are representative and these have been visited and examined. Most instrument displays were about 30-60 cm (quite variable) away from the astronauts' eyes and arranged within ± 45-60° of straight ahead. The vertical breadth of the displays was ± 35°. It can be assumed that the most used instruments were directly in front of the face but the amount of time spent on a given cluster of instruments was not learned. Interviews with astronauts and engineers indicated that for long periods of time only a few instruments are monitored. For those critical midcourse corrections and reentry maneuvers the instrumentation is read frequently and carefully, and precise visual localization of controls and switches is important. For lunar landings a combination of both instrument and lunar surface viewing is required. Docking maneuvers also involve visual tasks, both inside and outside the space craft.

Rarely does the astronaut need more than 2 diopters of accomodation to perform his duties in the space craft. The size and contrast of the critical detail of most instrument panels are such that with normal size pupils up to 1 diopter of focus error will still allow legibility. A 1 diopter error is assumed to casue an acuity reduction to 20/40.

The necessity to change vergence of the eyes would likewise be minimal. Convergence for a 50 cm target is 2 meter angles, or 12 prism diopters (6.87°). For a 1 meter target is is one half this. Hence convergence need only change about 10° from the most remote to the nearest target. Versions to scan instruments and controls in the field of view need not exceed about 45° in any direction, assuming minimal normal head movements.

With the exception of the L M "Generic" Decals (GFE), critical detail on all instruments subtended a visual angle of 1.5-3.0 minutes or greater, permitting them to be read by an astronaut with as little as 20/30-20/60 acuity. The L M generic decals required an acuity of $20/25^{+}$ (this is at best an approximation) when viewed at the 50 cm panel distance.

Glare reduces contrast sensitivity and limits retinal adaptation to shaded areas. The ability to perform under glare conditions is a characteristic of the individual; however, individual variability in a healthy human is far less in the author's opinion than the environmental factors producing glare, such as dust on the visor, and internal surface reflections from the visor. Within the confines of the commond module, the lunar module, and the orbiting space laboratory, sources of glare are less common and more easily controlled. Sapce vehicle glare problems will be more or less disabling to an astronaut depending upon the excellence of his visual apparatus. Means are available to him to cover windows or to shade instruments with his hand, therefore only the most severe abnormality in glare resistance would be incapacitating.

III. Human Capabilities to Perform Space Tasks.

In general, none of the visual tasks required of the astronauts is beyond his visual capability is 1) his ametropia has been corrected; 20 he has good binoulcar vision; and 30 he is younger than approximately 45 year os age or wears spectacles.

Specifically the one visual task which is beyond human capability is that posed by glare from direct sunlight on visor dust, or on materials immediately adjacent to shaded materials which a person is trying to see. Such extremes in lighting are beyond known human retinal and perceptual capabilities. The solution is to modify the seeing conditions by casting light into the dark areas and by shading the visor and the eyes from direct sunlight.

IV. Apparatus Completed for Visual Studies.

In preparation for the various studies which were planned for assessing visual capabilities and task in order to set vision standards for astronauts, several pieces of equipment have been assembled and tested. These are described below, under headings A-H.

A. Spectacle Obstruction Measuring Device.

This is a white 6" diameter sphere with polar coordinates laid out on its inner surface and a source of light at its center. A spectacle frame (in the illustrated example, a zyl frame) with lenses is placed at about 17 mm from the bulb filament which represents the pupil of the subject's eye. The bulb will cast light on the spherical screen except where the spectacle frame interferes. The frame's shadow is exactly analogous to the visual field defect which would be produced by that combination of frame and lens. Preliminary observations indicate that high minus prescriptions eliminate frame induced blend zones, whereas high plus prescriptions create a serious scotoma, even without a frame being present (Figs. 1, 2, 3).

B. Glare Susceptibility and Recovery Equipment.

A Biometrics Glare Susceptibility Tester was acquired and subjected to preliminary trials in preparation for quantitative studies of a population sample. The apparatus is shown in Figures 4, 5, 6. The figures show the control unit, the subject in position for testing, and the subject's view of the field.

Additionally, an Oculus Mesoptometer has been acquired by the Division of Optometry, Indiana University, and is available for laboratory confirmation and comparative studies of both glare susceptibility and mesoptic acuity. The apparatus is shown in Fig. 7.

C. Variable Vergence Amplitude Testing Device.

A breadboard model of a variable vergence unit went through considerable changes in design and modification. The breadboard design, shown in Figs. 8, 9, 10, has proved to be highly satisfactory and when motorized, can provide a meaningful study of one of the least known visual functions, i.e. the fusional response to prism power.

D. Accommodation Speed and Flexibility.

A Biometrics Eye Trac, a device for recording eye movement, was modified by adding a motor driven target in a Badal optometer to control accommodation (Figs. 11-13). Convergence could be measured as the speed and amplitude of accommodation stimulation were varied. A reference accommodation target was also provided to ensure accuracy of accommodation. Preliminary results indicate that this is a difficult experiment, requiring subject training and careful programming. Some preliminary results are shown in the sample records (Fig. 14, Eye Trac) and graphical interpretation (Figs. 15-17).

E. Glare Resistance and Contrast Sensitivity.

The wiring of the 10,000 ft. candle environmental chamber is complete and is ready for studies simulating the extremes of lunar illumination. The room is 24 feet long with a 6 ft. wide ceiling of fluorescent lights, or rearranged it becomes a 24 ft. tunnel with the top and sides of lamps with 1/8" spacing. The room's variable shape permits a wide assortment of experiments to be conducted. Preliminary observations and the results of earlier work with a similar chamber indicate that 6,000 to 8,000 apparent foot lamberts of chamber wall brightness is too high to tolerate without sunglasses. Earlier observations indicated that a bright ganzfeld is less tolerable than a detailed scene of equal luminance.

F. Peripheral Visual Acutiy.

Much of spatial orientation and target recognition depends upon peripheral vision. There is little research none recent on peripheral visual acuity; hence it was planned to run a population study of this important function. The apparatus was constructed (Figs. 18-20) but only preliminary trial runs have been made.

Peripheral visual acuity is seldon if ever ascertained in the routine visual examination of candidate pilots or astronauts. This apparent neglect finds reconciliation in several factors. Firstly, though peripheral acuities have been the subject of numerous investigations for over a century, their findings and significance have been almost exclusively confined to theoretical and psychophysiological consideration. Only a few of the fifty or sixty publications reviewed thus far on this subject (see Appendix) have indicated any clinical significance. Secondly, with few exceptions, all previous research of peripheral acuity required time consuming effort from both the examiner and examinee, an effort which would unequivocally deny application to any clinical vision examination. An immediate consequence of the foregoing is that the total mumber of subjects examined in any single investigation seldom exceeded fifty, and only one investigator attempted to streamline his technique so he could quantitatively examine more than 100 subjects.

Consequently, one should not be surprised to find peripheral acuity deleted from routine clinical consideration, for even if one considers the modicum of expressed clinical significance, there are insufficient quantitative grounds for adoption of any standards.

Aerospace design and performance has changed continuously and considerably in the past fifty years. This is especially true in the case of those vehicles for employment in the NASA program. Accordingly, there is a greater complexity of cockpit instrumentation and general human visual performance required to monitor it. Thus, every avenue which feasibly provides information to the pilot or crew of the space craft warrants serious consideration. The present investigators believe that one of the most exclusive avenues warranting further investigation is that of peripheral acuity, and that it should be assessed routinely in astronaut visual examinations. A bibliography, which does not claim to be completely comprehensive, but which aims to include the major references on the subject, is given as an Appendix following the conclusion of the report.

G. Night Myopia.

One of the most important consequences in very low illumination, or a large unstructured field, is the change of refractive state which can result in a reduction in acuity for targets at a specific distance. The apparatus suitable for acuity measurements at very low luminances is shown in Fig. 4. The apparatus has only recently been installed and only a few preliminary trials have been made.

It is a well established phenomenon that an increased in the refractive power of the human eye occurs under conditions of dardkness or when viewing an empty, lighted visual field. When this occurs in darkness or dim illumination, it is termed "night myopia." In the empty, lighted field, it is called "space myopia." Two of the present investigators (Heath, Levene) have described the various facets of the subjects both experimentally and historically, and the subject was documented in the final report for the first year's work on the present contract.

H. Retinal Adaptation.

Retinal adaptation is certainly important in visual performance, especially under conditions of suddenly changing illumination.

Several studies of retinal adaptation were anticipated, and equipment has been obtained and set up to pursue the investigations. These include the Biometric Glare Recovery Tester (Figs. 4-6), the Mesoptometer (Fig. 7), and the Goldmann Weekers Adaptometer. A separate study has been conducted to explore effects of caffeine and Vitanin A ingestion on dard adaptation. The results have been recently reported (Revuelta).

V. Recommendations for Vision Test Standards and Procedures.

Pertinent comments on pages 5 and 6 of the June 1970 Report under this contract are repeated herewith.

"From the literature it is apparent that many of the vision tests and procedures are inadequate or out dated and that certain physiological aspects of vision that are of importance to aviators and astronauts have been neglected or overlooked. The primary oversight of immediate concern in this report relates to testing for near vision capabilities.

"Testing for distance vision function has been the main concern in the past. Yet in modern aviation and in space flight, near vision has risen to high importance while distance vision has become almost unnecessary. The vision tests indicated in Table I could be passed even by a person with a strabismus at the near point, and hence are grossly incapable of identifying those people who have near point heterophorias of significance or accommodative problems at near. Furthermore, to compound the problem, the maturation of pilots and astronauts ultimately brings them into the age of presbyopia wherein accommodative and related near point heterophoria problems become acute.

"The nature of many of the tests in Table I is such that precoaching by fellow cadets or past experience and common sense can allow an otherwise unqualified person to pass the tests. A need exists therefore to make the testing more objective. Alternatively, greater control over subjective techniques is needed to ensure reliable reporting of the vision status of the examinee.

"It is recommended that for improvements in standards, further investigation and experimental work be carried out on the need for and methods of testing that might be used in the following areas.

a. Fusional amplitudes at distance and near
b. Fixation disparity at distance and near, a test which might be able to supplant the need for fusion tests
c. Visual functions of dynamic acuity and stereopsis
d. Ocular motility and muscle fields
e. Near point of convergence
f. Dynamic accommodation needed for prolonged
g. Amplitude of accommodation needed for prolonged efficient visual performance

"While changes in vision testing are indicated, it is perhaps premature to recommend them at this time. The areas most in need of revision and expansion also need more documentation and research . . ."

As no experimental research has been performed since these conclusions were originally made, they must still be considered valid, until further experimentation has been conducted.

REFERENCES

G. G. Heath, The Time Course of Night and Space Myopia, Rep. No. ANRL-TDR-62-80, Div., Aero. Med. Res. Lab, Wright-Patterson AFB, Ohio, August 1962.

J. R. Levene, "Nevil Maskelyne, F.R.S., and the Discovery of Night Myopia," Notes and Records of the Royal Society, London, vol. 20 (June 1965),

R. Revuelta, "Effect of Caffeine and Caffeine Combined with Vitamin A on Dark Adaptation," M.S. Thesis, Indiana University, 1971.

APPENDIX: BIBLIOGRAPHY RELATED TO PERIPHERAL ACUITY

Aubert, H., and Foester, R.: Beiträge zur Kenntniss des indirekten Sehens. Albrecht von Graefe's Archiv. 3 (1857) 1-67.

Charpentier, A.: De La Vision Avec Les Diverses Parties De La Rétine. Arch. de Physiol. norm. et path. 4 (1877) 894-945.

Clemmesen, V.: Central and Indirect Vision of the Light Adapted Eye. Acta Physiol. Scand. 9 (1944) Supplementum xxvii 1-206.

Collier, R. M.: An Experimental Study of Form Perception in Indirect Vision. Jour. of Comp. Psychol. 11 (1931) 281-290.

Feinberg, R.: A Study of Some Aspects of Peripheral Visual Acuity. Amer. Jour. of Optom. and Arch. of Amer. Acad. of Optom. 26 (1949) part i, 49-56, parts ii, iii, iv, 105-119.

Fick, A. E.: Ueber Stäbchensehschärfe und Zapfensehschärfe. Arch. f. Ophthal. 45 (1898) 336-356.

Freeman, E.: Anomalies of Peripheral Visual Acuity. Jour. of Exper. Psychol. 12 (1929) 324-339.

Geissler, L. R.: Form Perception in Indirect Vision. Psychol. Bull. 23 (1926) 135-136.

Handel, S., and Christ, R.: Detection and Identification of Geometric Forms Using Peripheral and Central Viewing. Percep. and Psychophysics 6 (1969) 47-49.

Held, H. H.: Peripheral Acuity. Brit. Jour. of Physiol. Optics 16 (1965) 126-143.

Hopkin, V. D.: The Discrimination of Form in the Visual Periphery. IAM Report No. 357, RAF Institute of Aviation Medicine, Farnborough, Hants. (1965) 1-20.

Kleitman, N., and Bler, Z.: Color and Form Discrimination in the Periphery of the Retina. Amer. Jour. of Physiol. 85 (1928) 178-190.

Le Grand, Y.: Form and Space Vision. Bloomington, Indiana (translated by M. Millodot and G. G. Heath) 1967 Indiana Univ. Press 84, 131-139.

Low, F. N.: The Peripheral Visual Acuity of 100 Subjects. Amer. Jour. of Physiol. 140 (1943-1944) 83-88.

Low, F. N.: The Peripheral Acuity of 100 Subjects Under Scotopic Conditions. Amer. Jour. of Physiol. 146 (1946a) 21-25.

Low, F. N.: Some Characteristics of Peripheral Visual Performance. Amer. Jour. of Physiol. 146 (1946b) 573-584.

Low, F. N.: Peripheral Visual Acuity. A.M.A. Arch. of Ophthal. 45 (1951) 80-99.

Ludvigh, E.: Extrafoveal Visual Acuity as Measured with Snellen Test-Letters. Amer. Jour. of Ophthal. 24 (1941) 303-310.

Menzer, G. W., and Thurmond, J. B.: Form Identification in Peripheral Vision. Percep. and Psycho. 8 (1970) 205-209.

Munn, N. L., and Geil, G. A.: A Note on Peripheral Form Discrimination. Jour. of Gen. Psychol. 5 (1931) 78-87.

Randall, H. G., and Brown, D. J., and Sloan, L. L.: Peripheral Visual Acutiy. A.M.A. Arch. of Ophthal. 75 (1966) 500-504.

Riggs. L.: Visual Acuity. In Graham. C. H. (ed.): Vision and Visual Perception. New York, 1966, John Wiley & Sons. 322-327.

Rowland, L. S., and Rowland, W. M.: Individual Differences in the Region of Maximal Acuity in Scotopic Vision: Applications to Night Vision Testing and Training. AAF Report No. 2, AAF School of Aviation Medicine, Randolph Field, Texas. (1945) 1-8.

Wertheim, Th.: Über die indirekte Sehschärfe. Zeitschrift für Psychologie und Physiologie der Sinnesorgane. 7 (1894) 172-187.

Westheimer, G.: Visual Acuity. Ann. Rev. of Psychol. 16 (1965) 367.

Weymouth, F. W., and Hines, D. C., and Acres, L. H., and Raaf, J. E., and Wheeler, M. C.: Visual Acuity within the Area Centralis and its Relation to Eye Movements and Fixation. Amer. Jour. of Ophthal. 11 (1928) 947-960.

Whitmer, C. A.: Peripheral Form Discrimination under Dark-Adaptation. Jour. of Gen. Psychol. 9 (1933) 405-418.

Zigler, M. J., and Cook, B., and Miller, D., and Wemple, L.: The Perception of Form in Peripheral Vision. Amer. Jour. of Psychol. 42 (1930) 246-259.

<u>Figures</u>

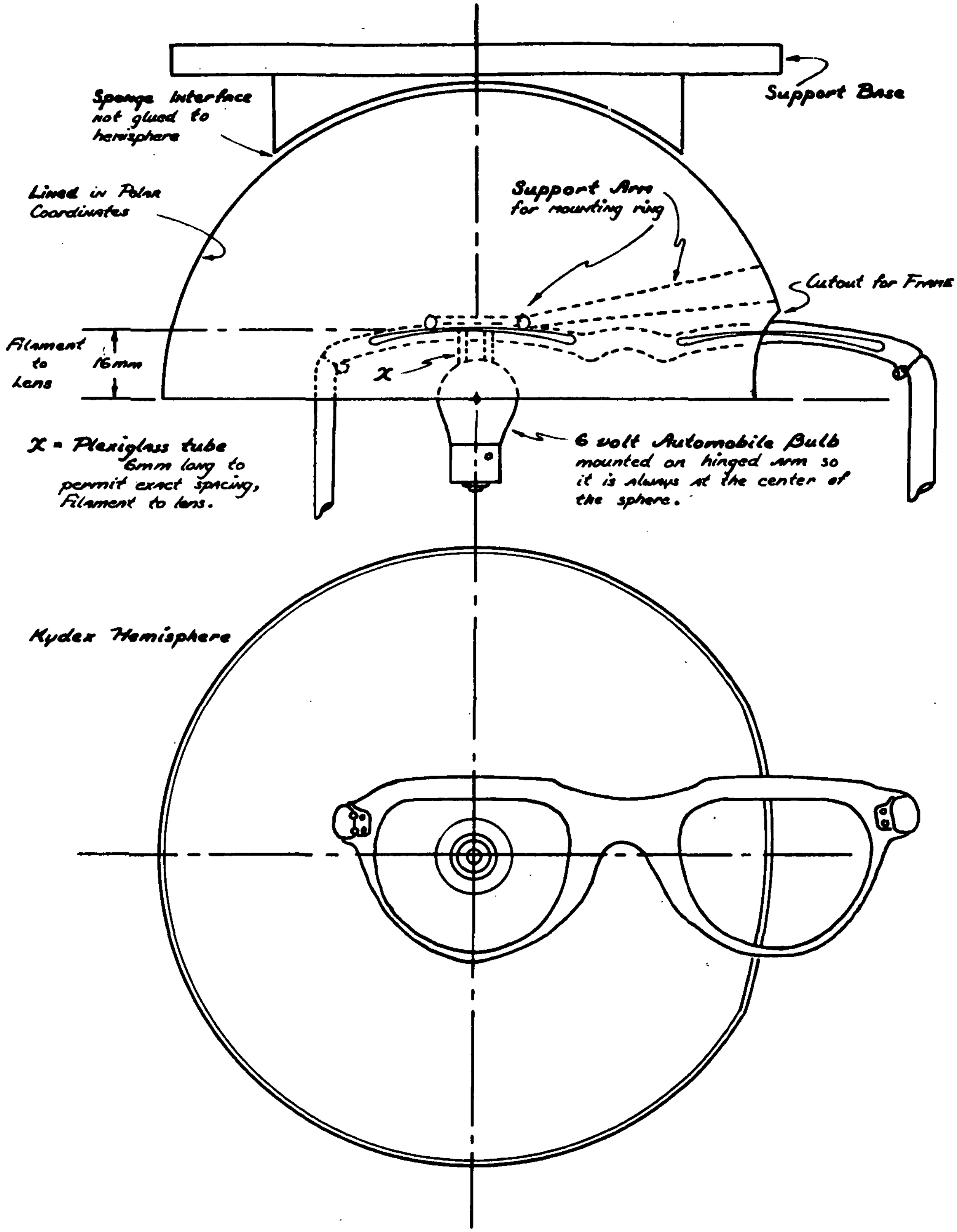


Fig. 1. Diagram of Spectacle Obstruction Measuring Device.

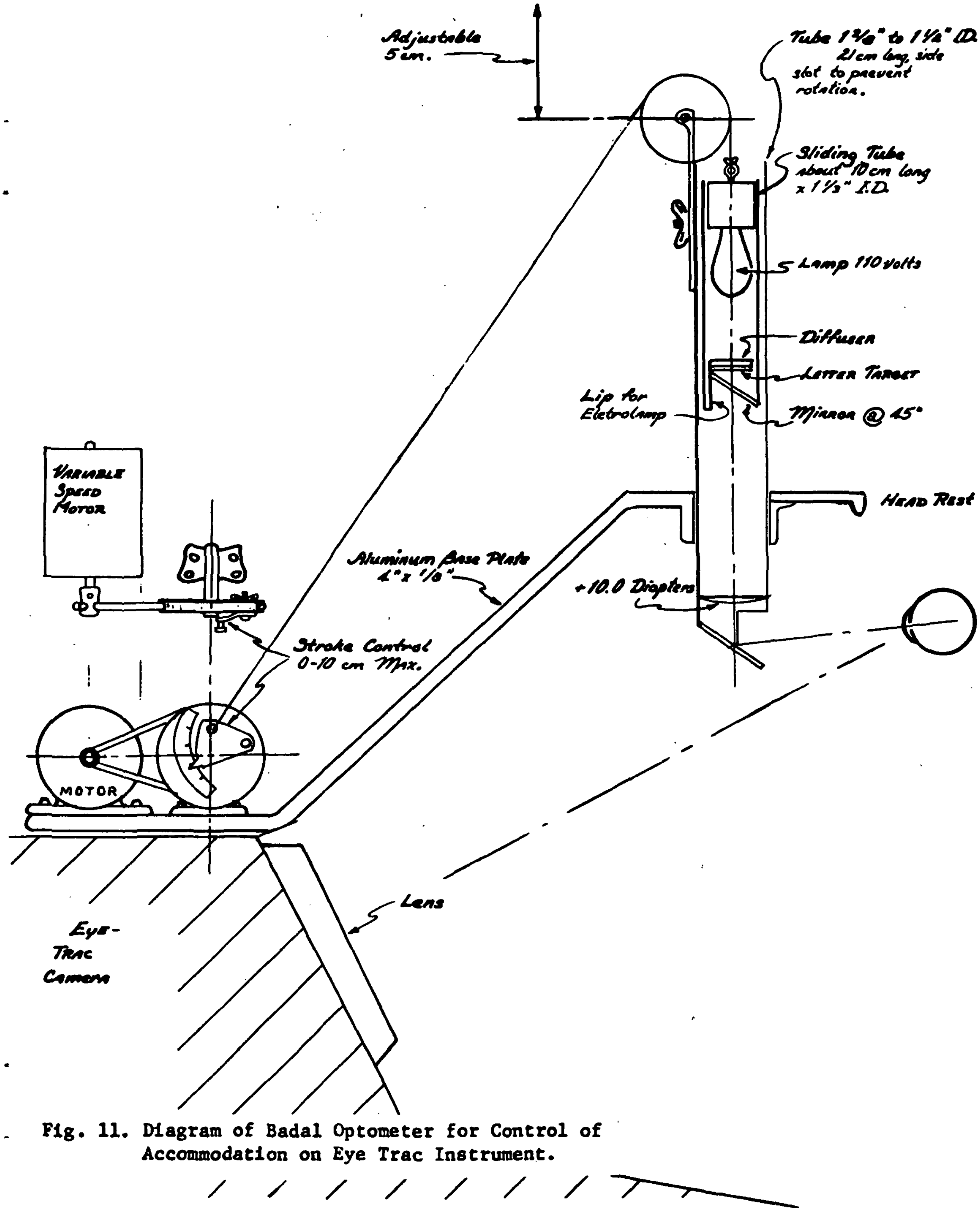


Fig. 11. Diagram of Badal Optometer for Control of Accommodation on Eye Trac Instrument.

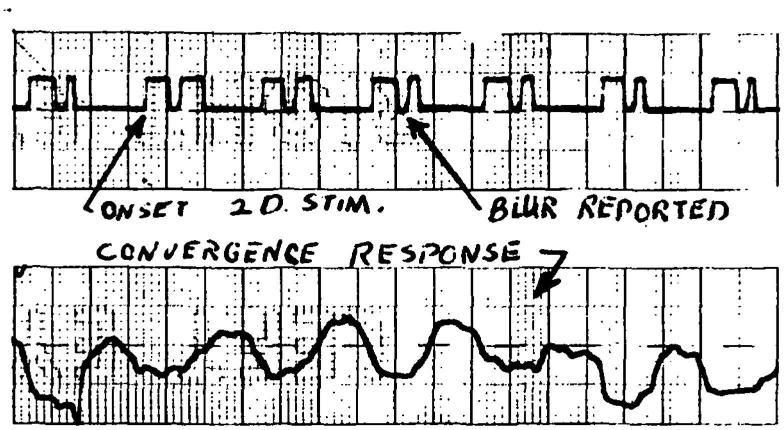
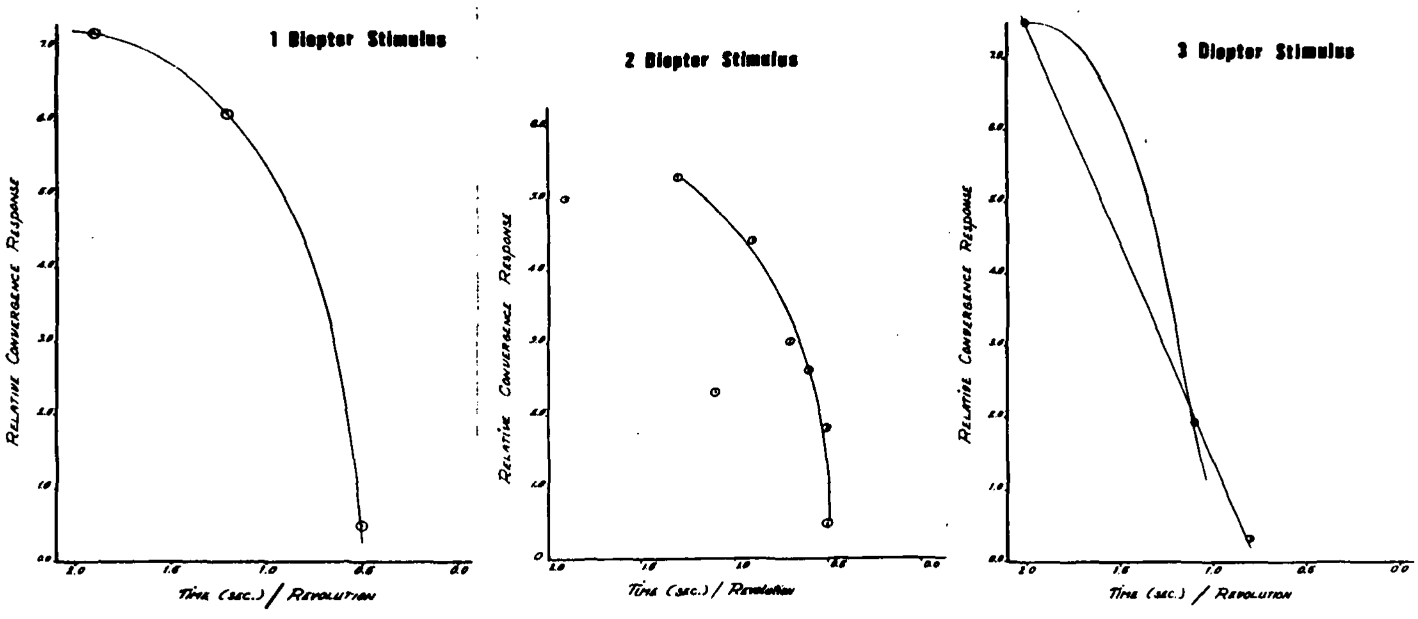


Fig. 14. Sample Eye Trac Record.



Figs. 15, 16, 17. Graphical Analysis of Eye Trac Recording for Three Different Stimulus Alternation Levels.

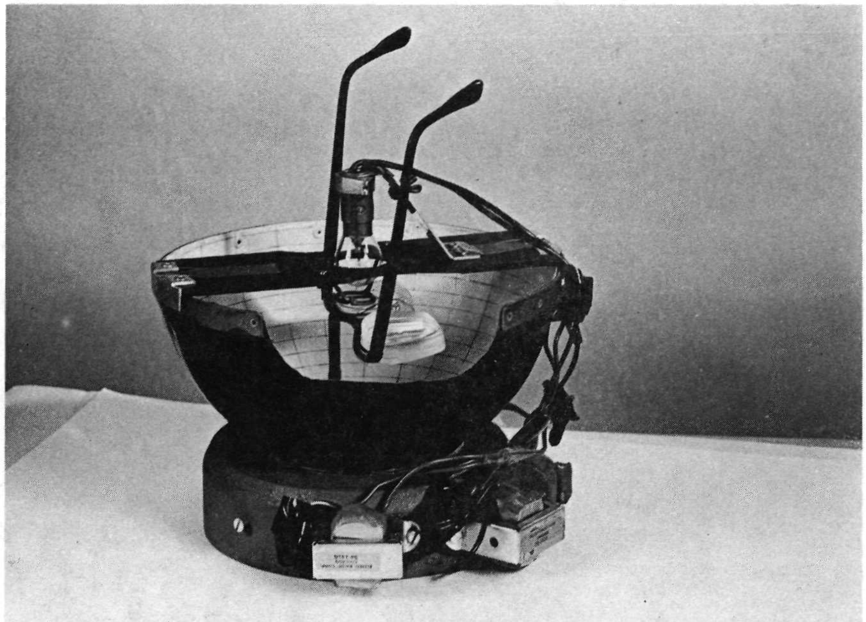


Fig. 2. Photograph of Spectacle Obstruction Measuring Device, with Spectacle in Place.

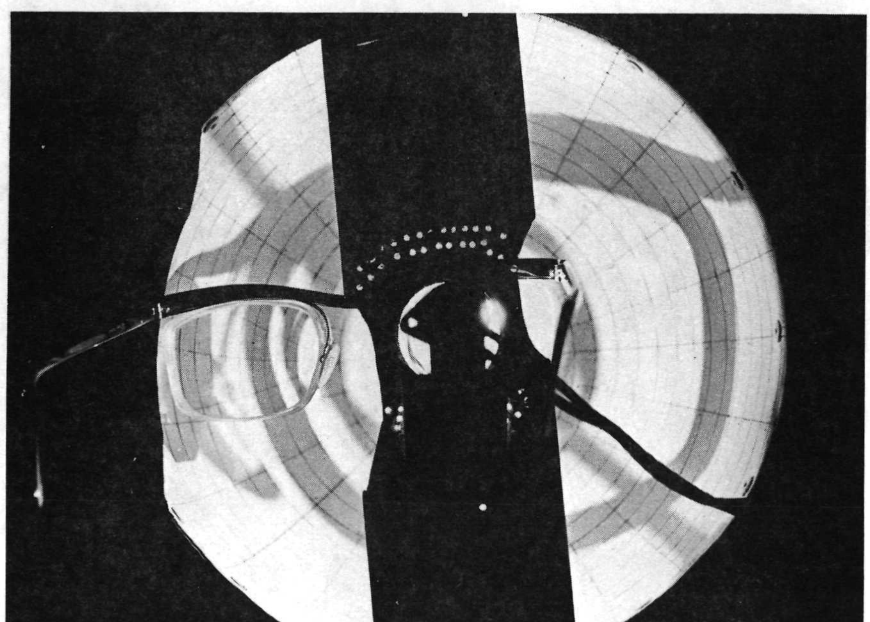


Fig. 3. Projection of Spectacle Frame Obstruction on Spherical Screen.

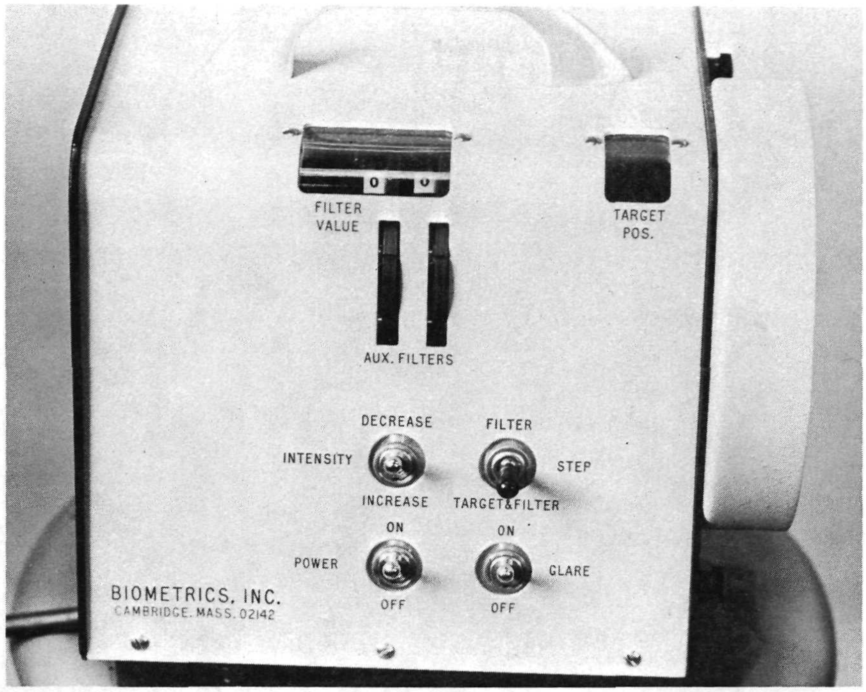


Fig. 4 Glare Susceptibility Tester. Control Unit.

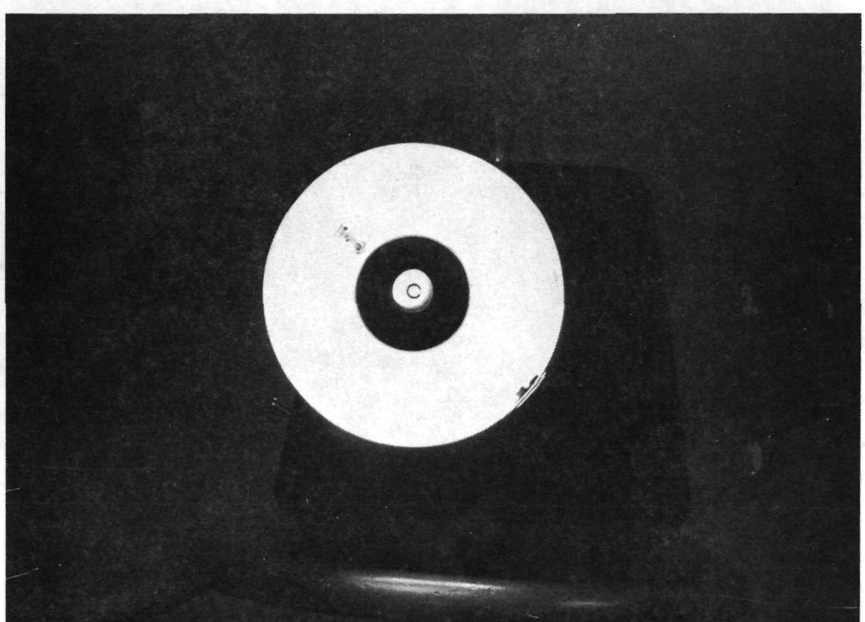


Fig. 5. Subject's View of Glare Susceptibility Tester Field.

Fig. 6. Subject in Position for Testing on Glare Susceptibility Tester.

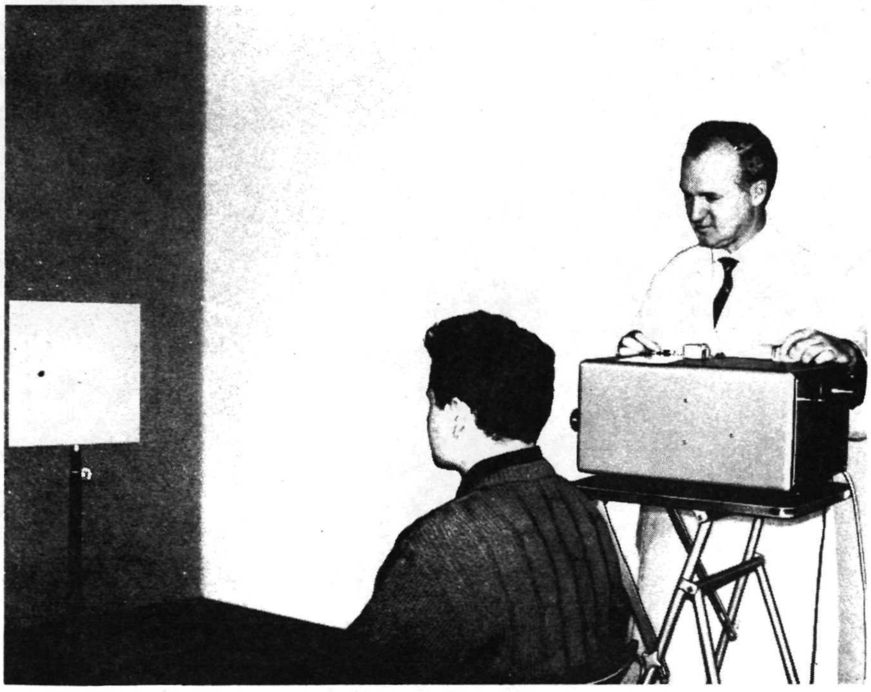


Fig. 7. Oculus Mesoptometer.

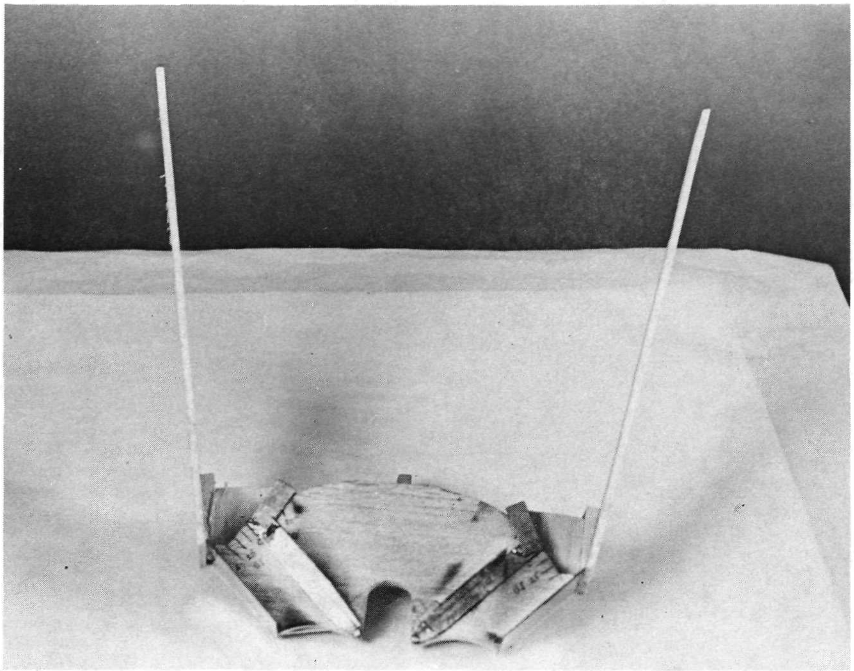


Fig. 8. Variable Vergence Amplitude Testing Device.

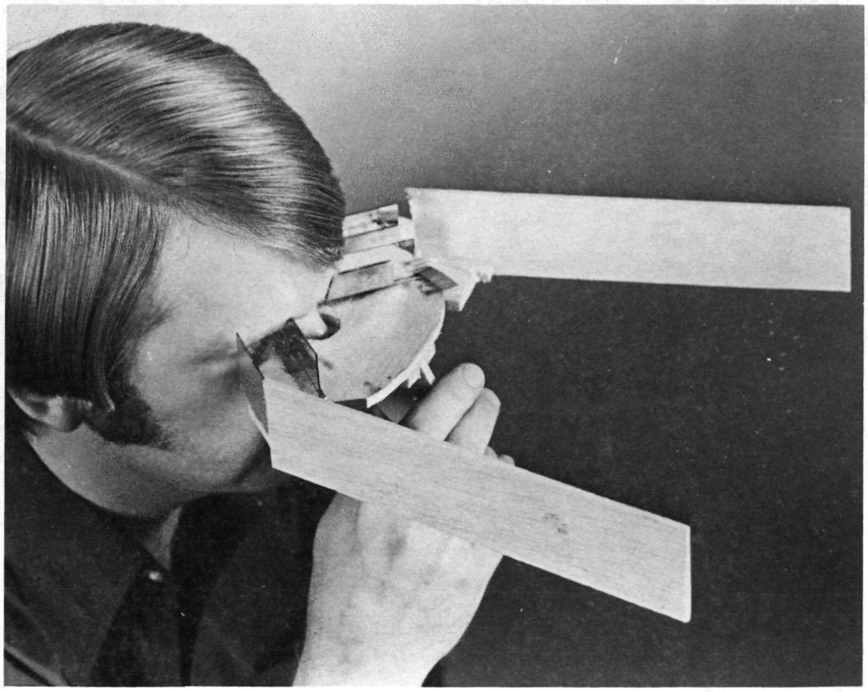


Fig . 9. Subject Holding Variable Vergence Amplitude Testing Device.

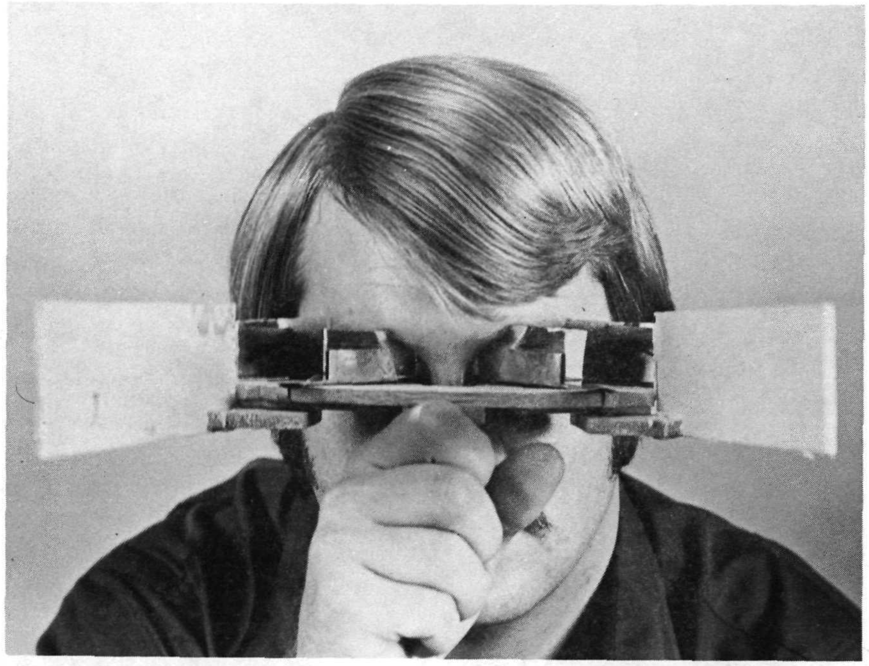


Fig 10. Subject Holding Variable Vergence Amplitude Testing Device.

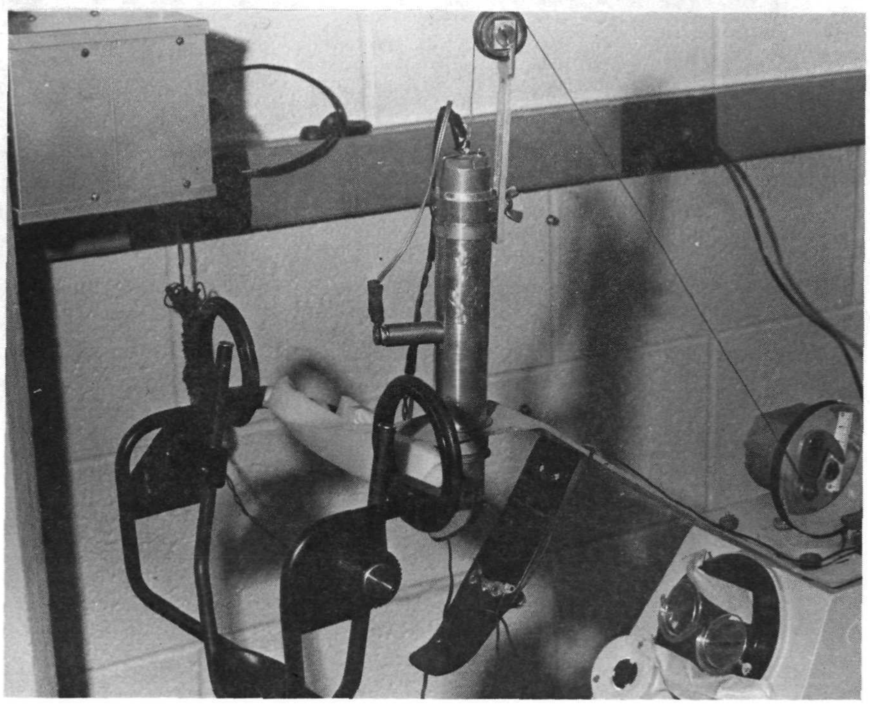


Fig. 12. Photograph of Badal Optometer Modification for Control of Accommodation on Eye Trac Instrument.

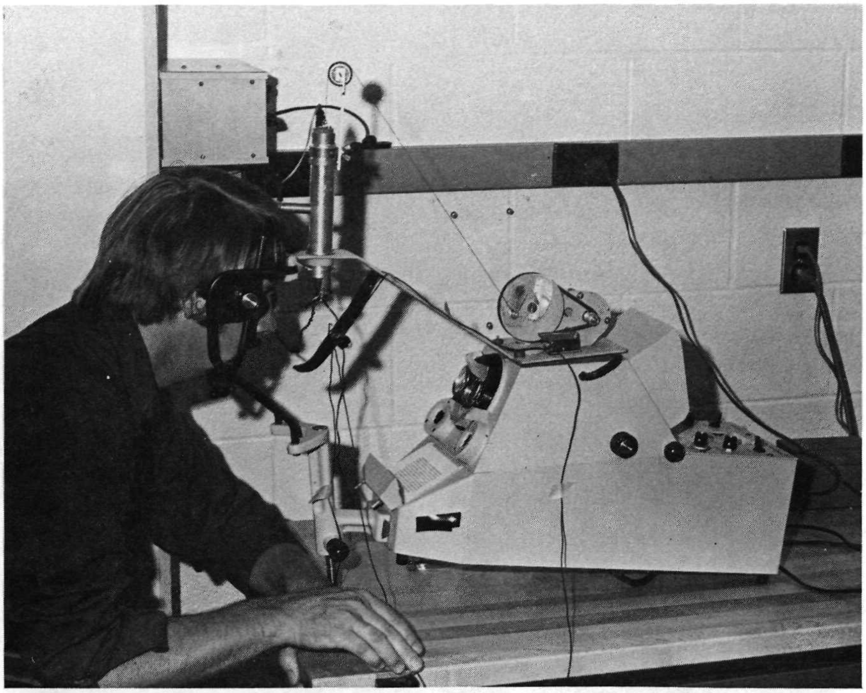


Fig. 13a, Modified Biometric Eye Trac Eye Movement Device with Subject in Place.

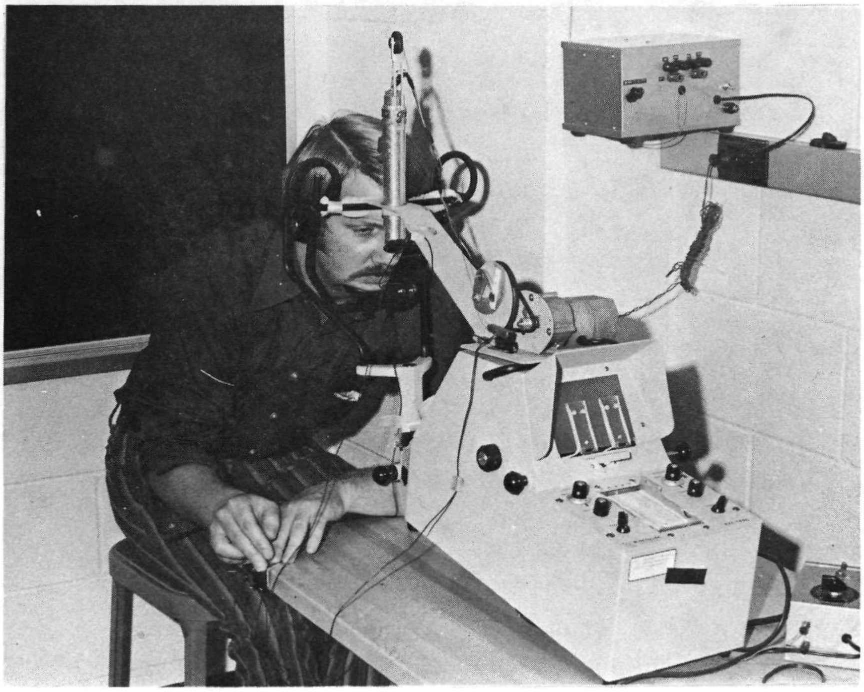


Fig. 13b. Modified Biometric Eye Trac Eye Movement Device with Subject in Place.

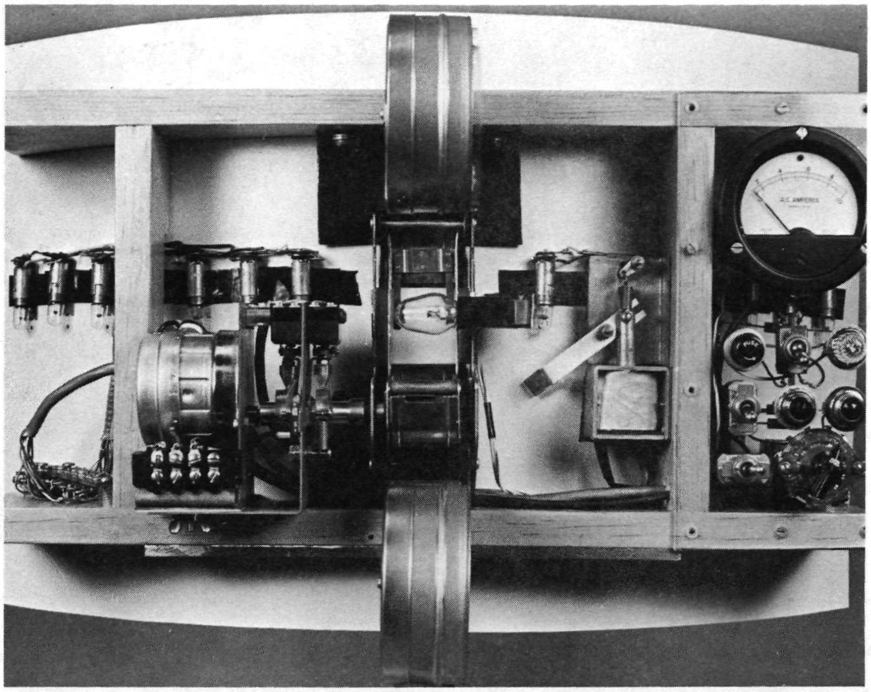


Fig. 18. Peripheral Visual Acuity Apparatus. Rear View.

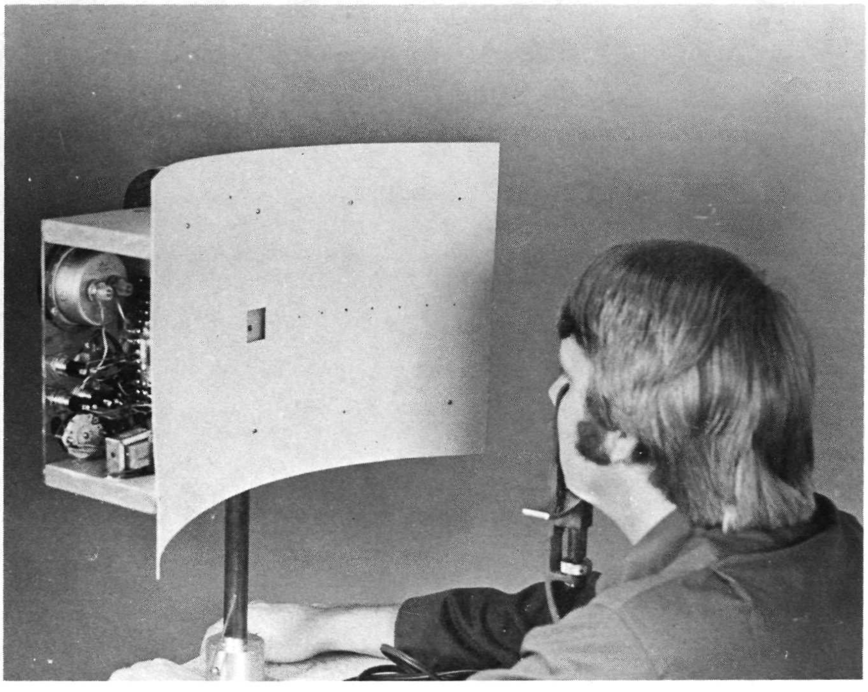


Fig. 19. Subject's View of Peripheral Acuity Apparatus.