AD NUMBER: AD0488545
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational use; 1 Oct 1961. Other requests shall be referred to Office of Naval Research, Arlington, VA 22203.
AUTHORITY
ONR ltr 27 Jul 1971 - b/3 to a/1

FINAL REPORT

INVESTIGATION AND DEVELOPMENT OF LIGHT RESTRICTIVE VISORS, DEVICES, SYSTEMS, OR LENSES.

CONTRACT #Nonr-3177 (00)

OMNITECH, INC.

- FINAL REPORT -

INVESTIGATION AND DEVELOPMENT OF LIGHT RESTRICTIVE VISORS, DEVICES, SYSTEMS OR LENSES

CONTRACT #Nonr - 3177 (00)

<u>CONTRACTOR</u>

OMNITECH, INC.
Route #131
Dudley, Massachusetts

<u>AGENCY</u>

Department of the Navy
Office of Naval Research

<u>AUTHORITY</u>

NR 145 - 150/1-21-60
(Physiological Psychology Branch)

<u>DATE</u>

October 1, 1961

OMNITECH, INC.

I N D E X

Purpose and Scope

The intensive flash resulting upon detonation of a thermo-nuclear device can cause temporary or permanent blindness in an observer who has no eye protection, even when the observer is sufficiently distant from the explosion to survive the other effects of the blast. It is imperative that air crews be provided with a means for guarding against flash blindness, which can occur at great distances, and which can seriously affect the ability of a crew to properly operate its aircraft.

Under the terms of Contract #Nonr-3177 (00), OMNITECH, INC. performed several assigned tasks, all of which pertained to the design, and or evaluation of retrofit visor assemblies to be used with Pilots Protective Helmet, Model #APH-5, which assemblies were designed to serve as carriers or frames for various light restrictive devices or systems proposed for the suppression or prevention of nuclear flash blindness.

The operation of high performance aircraft requires that air crew members have the utmost in vision capability. A device position before the eyes to protect against flash blindness should therefore have, as a major design criteria, the capacity for preserving in the "open" state, as much of the wearer's natural vision capability as possible. This means providing near-to-normal capability in the following areas:

I. Peripheral Vision
   (a) Horizontal Field of View
   (b) Vertical Field of View

II. Visual Transmittance

III. Visual Acuity
   (a) Definition
   (b) Spherical Power
   (c) Cylindrical Power
   (d) Fogging

IV. Color

V. Comfort
   (a) Prism Imbalance (Horizontal and Vertical)
   (b) Weight
   (c) Fit

The above factors apply to the normal wearing of the device by air crew personnel in the so called "open" position. It does not define other characteristics of a particular restrictive device, such as speed of closure, degree of attentuation, facility for renewal etc., which, are also very important, and which must be considered when evaluating a device for overall efficiency.

Description of Items

I. Light Restrictive Lens Visor Assembly for APH-5 Helmet

Contract #Noas-59-6124C, required the development of a "Light Restrictive Visor for the APH-5 Helmet", which used as its means of attenuation, a pair of ground and polished, 4 base curve, specially absorbing close band pass filter lenses. These lenses are identical in transmittance characteristics to those in the LRFG-58 goggle procured some time ago, except that they are curved and are much thinner, to allow incorporation into a curved visor assembly. Characteristics of these lenses are described in the Final Report, Contract #Noas-58-245-C. The preferred model of the visor assembly developed to contain these lenses was considered by the Bureau as a good structure into which to incorporate possible alternate flash blindness protective devices, and we were requested to improve the anti-fogging characteristics of the device.

The visor assembly as developed in Contract #Noas-59-6124-C comprises a unit fabricated from fiberglas polyester resin, into which is fitted the pair of 4 base, curved, light restrictive lenses. The inner surface of the visor carries a flanged construction, which allows it to nest very firmly within the facepiece opening of the helmet, meanwhile, providing a light seal across the top and down both sides of the helmet opening. The visor is attached to an APH-5 helmet, which is first stripped of conventional visor, tracks and hood. It operates from pivots at each temple, and in the "up" position, rests on the helmet with the bottom edge of the visor at the edge of the facepiece opening. To close, the unit is lowered until the flange engages the helmet opening, whereupon it snaps into position. To raise the visor, it is necessary to pull the top part of the visor forward 1/8" to disengage the flange, whereupon it will snap into "up" position by its spring mechanism.

To provide ventillation, the outer lens retaining member was redesigned to extend upward to the top of the visor, and to provide a hollow chamber in the space above the lenses. The 3/16" diameter holes were drilled into this chamber from the inside, 1/2" above the lenses and venting holes drilled at right angles to these in the outer member. The annular void space was suitably baffled and painted black, so that light could not be transmitted or reflected from the outside.

Upon testing this model, it was found to eliminate most of the fogging difficulty, and application of anti-fogging compounds, such as material complying with Spec #MIL-A-21071, successfully controlled any remaining "fogging" effect exhibited by the visor.

In Appendix:

Enclsoure #1

Assembly sketch of original Visor-Front View

Enclosure #2

Assembly sketch of Vented Visor-Front View

Enclosure #3

Assembly sketch of Vented Visor-Side View

Description of Items

II. Marks Polarized Electro-Optic Light Restrictive System

In September 1960, we were requested by A. E. Merkin, (RAAE-232), BuWeps, to provide a visor design for an "Electro-Optic Shutter" light restrictive device being developed for the Navy by the Marks Polarized Corporation of Whitestone, L.I., New York. Heart of the shutter device is a lens, comprising laminated layers of coated ammonium dihydrogen phosphate crystal sheeting, and optical glass elements. The sandwich, or assembly is relatively transparent under normal conditions, but when activated by high voltage, becomes opaque. Lenses are assembled as units, which can be incorporated into a suitable designed visor. Each lens unit is round, 2 5" diameter, 1 1/16" thick, and for proper use must be mounted 3" in front of the pupil aperture. We were required to design a suitable visor assembly for said lenses; as well as to evaluate the Electro-Optic shutter with and without the side band filter necessary to provide total protection.

(A) Design of Visor

The visor assembly described in Task #1 was used as the basic structure around which to design the retractable unit. The most difficult requirements, however, was that the lenses be positioned 3 inches in front of the wearer's eyes. This, together with the fact that the lenses are heavy, results in a structure that is awkward, top-heavy, and gives a very narrow limited field of view.

In accordance with instructions, a preliminary design without lenses was completed, and a rough model fabricated from polyester resin-fiberglas. This was demonstrated to Mr. Merkin, who requested we postpone further development until lenses were available for insertion into the unit.

In Appendix:

Enclosure #4

Assembly sketch of Visor with Mark Electro-Optic Shutter Lenses--Side View

Enclosure #5

Assembly sketch of Visor with Marks Electro-Optic Shutter Lenses--Front View

Enclosure #6

Sketch of Marks "Electro-Optic Shutter" Lens

(E) Evaluation of Electro-Optic Shutter

Evaluation of the Marks' Shutter including the use of band pass filters was conducted and was the subject of a Task Report dated 5 January 1961. This report is included as Enclosure #7, reproduced in its entirety. A summary of the pertinent results obtained are as follows:

Open Visual Transmittance (no band pass filter protection)	=	14.6%
Open Visual Transmittance (band pass filter protection)	=	7.3%
Minimum Visual Transmittance closed (no filters) .	=	.176%
Minimum Visual Transmittance closed (filters)	=	.05%
Voltage to obtain minimum transmittance	=	4000
Field of View	=	25°

Definition - poor - equivalent approximately to 20/40 max

In Appendix:

Enclosure #7

Test and evaluation of Marks Polarized Corp. Electro-Optic Shutter

Enclosure #8

EG & G report "The ADP Crystal Goggle as an Electrical Load"

Description of Items

III. Isomet Exploding Mirror Light Restrictive System

The Isomet Corp. has proposed a device for the suppression of nuclear flash blindness which comprises using a highly reflective surface on a suitable di-electric material which can be exploded at the proper time to interrupt a light path to the eye. A model of the device, demonstrated to BuWeps personnel, comprised a mirror, positioned in an optical system so that it directed the optical path to the eye, and permitted normal vision. When a voltage pulse of sufficient amplitude was applied to the mirror, stresses in excess of the mirrors' di-electric strength resulted, and the mirror shattered, effectively removing itself from the optical system, and interrupting the light path.

OMNITECH was assigned a task to investigate various optical systems and designs into which it is possible to incorporated the Isomet Corporations' exploding mirror type of light restrictive device, and to recommend a preferred system based on simplicity, weight, overall dimension, optical image quality and cost.

As design objectives, we were required to provide a design which:

(a) Can be incorporated into a retrofit visor assembly.
(b) Can be contained in a space 2" x 2" x 6", properly positioned before the wearer's eyes.
(c) Has a field of view of at least 35°
(d) Has maximum visible light transmittance, (preferably in excess of 85%).

First order studies were conducted on four (4) possible designs, which comprise the subject matter of the task report dated 20 January 1961, and which is included in its entirety as Enclosure #9 of this report. Further study indicated that two of these configurations (Fig. III and Fig. IV of Enclosure #9) warranted further optical analysis. Further design work is summarized in the report date 9 February 1961, which is included herewith as Enclosure #10.

Ray tracing and 3rd order analysis of the two preferred optical systems demonstrated rather severe deficiencies in optical performance, which are as follows:

(a) Within the space limitations set forth, neither system gives a full 35° field of view. A substantial increase in both size and weight is necessary to accomplish this.

(b) Both systems have a low effective open shutter transmission due to their low N.A. (numerical aperture). Use of the high N.A. objectives are not as feasable in the cylindrical system, while the use of high N.A. optics in the binocular system require the use of a precision binocular-type hinge in order to maintain collimation between the two eyes.

(c) Both systems require further color correction.

In view of parallel development of other light restrictive devices (ELF method), the continued development of the exploding mirror system to a point where it would compare favorably with "ELF" in such areas as field of view, chromaticity, open transmittance, and distortion did not seem feasable. At the instructions of Mr. Merkin, we concluded the task, and awaited further opinions and instruction from the Bureau.

In Appendix:

Enclosure #9

Copy of report "Optical System for Exploding Mirror Light Restrictive Device" Dated - 20 January 1961

Enclosure #10

Copy of report "Optical System for Exploding Mirror Light Restrictive Device" Dated - 9 February 1961.

Description of Items

IV. Sandia "ELF" Explosively Actuated Light Restrictive System

In January 1961, Omnitech was requested by BuWeps (RAAE-232) to cooperate with the Sandia Corporation in its program for the development of an Explosively Actuated Flash Blindness Protective System. Sandia Corporation, in conjunction with NWEF personnel from Kirtland Air Force Base had conducted preliminary work on a device which provides attenuation by the explosive release of a fine carbon black suspension into an annular chamber between two clear optical elements. Adhesion of the carbon black to the clear inner surfaces of the chamber provides the light restrictive capability.

Because of the many desirable characteristics of this device, its high initial "open" transmittance, excellent field of view, good optical properties, together with the fact that a mock up of this device had already been successfully flight tested, BuWeps assigned a high priority to the development and perfection of this unit, and Omnitech was assigned several tasks to assist Sandia in the various phases of this development. These are summarized as follows:

A. Provide designs for complete visor assemblies, to include optical design of lens unit, as well as necessary frame hardware.

B. Fabricate experimental test models and "dummy" lens cells.

C. Supply prototype frame and visor assembly for flight testing.

D. Supply test samples of Lens Cell aperture materials with information on physical and optical characteristics.

E. Supply test blocks on "ELF" techniques structural material with information on physical properties.

F. Evaluate presently available sensing and triggering mechanisms, and recommend what is required for initialing closure.

G. Provide a design and functional breadboard model for sensor-trigger mechanism.

(A) Visor and Lens Design

The basic design criteria established by BuWeps required the following characteristics:

1) Retractability-It is desired that the unit can be raised to a position atop the helmet.

2) Optics of the "Lens Cell" must be the best attainable in the following vision areas, within the limitations of the materials selected for use.

   (a) "Open" Transmittance
   (b) Horizontal and Vertical Field of View
   (c) Minimum of Spherical and Cylindrical Power
   (d) Maximum Definition
   (e) Neutrality
   (f) Minimum of Horizontal and Vertical Prismatic Imbalance
   (g) Minimum Weight

3) The assembled lens, including the "ELF" explosive section, must be capable of replacement with a single motion of one hand.

4) Assembly to be designed to exclude stray light, and to provide best possible anti-fogging characteristics.

5) Visor assembly to be supplied as a retrofit kit, to be used with an APH-5 Helmet, to replace visor currently supplied with this helmet.

Two designs for the visor assembly were developed. These are described as follows:

1) A retractable unit, designed to completely replace the visor and hardware currently used with the APH-5 Helmet. Design of this assembly is presented as Enclosures #11, 12, and 13. The retractable mechanism used with this design is mechanically identical to that used with the visor described in Item #1. The unit is designed to be attached to an APH-5 Helmet, which is first stripped of its conventional visor and related hardware (slides, hood, lock, etc.). That portion of the frame, made to nest and contain the light restrictive lens element, is fabricated from plastic, and is provided with a flanged construction, which allows it to nest very firmly within the facepiece opening of the helmet, simultaneously providing a light tight seal across the top, and from down both sides of the helmet opening. This is in turn attached to metal hardware, which provides a spring loaded double pivot arrangement that:

   a) Allows the entire frame-lens assembly to be raised to a position atop the helmet such that in the "up" position, the bottom edge of the lens is at the edge of the facepiece opening.

b) When lowered into position before the eyes, the flanged portion of the frame engages with the facepiece opening, and is held in this position by the spring retaining mechanism. To disengage, it is necessary merely to pull the visor forward, which disengages it from the visor, and raise it to its "up" out-of-the-way position.

The disposable "ELF" lens unit shown in Enclosure #13, comprises two sections; the top or "ELF" portion containing the attenuating material, explosive charge, means for detonating the device and suitable contacts. The bottom section, which is the open aperture or lens cell area, comprises two parallel curved sections of optically clear plastic separated by a spacer along the sides and bottom which is cemented to the two elements.

This hollow "Cell" is so constructed to integrate with and be cemented to the top explosive section, and to receive the explosive dispersed suspension of carbon black within its annular chamber. The entire assembly is further strengthened by a stainless steel frame, which firmly ties together the various portions of the assembly.

The lens units and its nesting frame sections are equipped with mating contact points, to complete the firing circuitry.

The unit is provided with a means for activating the device which comprises a sensor, and circuitry to discriminate and identify a nuclear flash; a power supply to provide the necessary firing energy, and a trigger. In the design shown, the sensor is mounted atop the visor, in a position looking outward, and the remaining electronic circuitry, namely the power supply, differentiating and trigger circuitry is shown in a separate container.

In this design, the lens cell elements are fabricated from curved sheets of optical grade, clear Plexiglas, 1/8" thick, separated by a 3/16" spacer. With two such sheets before the eyes, the observer is looking through 1/4" of plexiglas; and in order to provide the best possible optics, a geometric design for the basic lens curvature was selected to minimize prismatic imbalance between the eyes. This design is such that regardless of where the observer is looking, his line of sight is maintained at right angles to a tangent at the lens surface. When the lens is bent from a flat sheet with such curves, both eyes will look through approximately equal thicknesses of plastic, which will result in minimum prismatic imbalance. The method for geometrically determining the base curvature is described in Enclosure #14.

To provide a light tight seal, a molded rubber adapter is provided which can be attached or cemented to the rubber oxygen mask, and which provides a mating surface against which the bottom part of the lens will rest a nest when the lens is in position before the eyes.

In order to provide fast and positive removal of the assembly, this unit is designed such that the first motion is to disengage the lock mechanism and raise the visor to the "open" position. A simple hand snap disengages the lens, and allows it to be removed with one hand. A second lens can be inserted with the visor in the "up" position, locked into place, then lowered and positioned before the eyes.

<u>In Appendix:</u>

<u>Enclosure #11</u>

Light Restrictive Visor Assembly,
Design #1, Retractable Model - Side View

<u>Enclosure #12</u>

Light Restrictive Visor Assembly,
Design #2, Retractable Model - Front View

<u>Enclosure #13</u>

Sketch of "ELF" Lens Cell Assembly,
showing general construction of Lens Unit.

<u>Enclosure #14</u>

Means for determining base curve of an acylindrical lens, bent from flat, optical grade plastic sheeting, to minimize prismatic deviation.

Description of Items

2) A second design was prepared in which the lens nests within a frame held within the facepiece opening. It is so positioned that it can be used in conjunction with the present sun visor assembly unit. This design is shown in Enclosures #15, 16, and 17. This design is not retractable, and cannot be raised to an open position atop the helmet. The lens must be inserted and replaced from its position directly before the eyes. Lenses are fabricated from cylindrical sections, and when made from flat optical sheeting, theoretically have a prism imbalance of approximately one diopter. This is approximately 4 times the amount normally considered tolerable, and if worn for any length of time, will result in excess eye fatigue.

Cylindrical lenses to this basic design can be made optically correct by injection molding. By this method, optical corrections can be introduced in the mold inserts to eliminate the prism imbalance. This assumes the ability to use a material, which has the optical requirements, and which is capable of being molded to have the required strength and resistance to impact.

This second design positions the "ELF" lens very close to the face, because it must be behind the APH-5 sun visor. In this position, excessive "fogging" of the lens is almost certain to occur, unless provision is made to vent the confined air space by a manner such as described in Item #1.

In Appendix:

Enclosure #15

Light Restrictive Visor Assembly.
Design #2 - Non Retractable Model - Side View

Enclosure #16

Light Restrictive Visor Assembly.
Design #2 - Non Retractable Model - Front View

Enclosure #17

Light Restrictive Visor Assembly.
Design #2 - Non Retractable Model - Sectional View

Description of Items

B) Fabricate Experimental Test Models and Model Lens "Cells"

Design #1, as described above, and also in Enclosures #11 and 12 was selected by BuWeps (RAAE-232) and ACEL as the basis to proceed with this development. We were requested to fabricate experimental test models of frame, "ELF" and lens sections, and to provide model lens cells for preliminary optical inspection and evaluation.

Patterns, temporary molds, bending fixtures and cementing jigs were made to produce the 3 "lens cell" components, namely the front and rear lenses, and the spacer, from optical grade PLEXIGLAS II. Patterns and temporary molds were made to produce the "ELF" section, and the Frame section from high impact castable epoxy resins.

The following items were produced and supplied as requested:

1) Twelve model lens cell units from Optical Quality UVA Plexiglas #II, in accordance with design shown in Enclosures #13, and 14. Outside and inside lens components were 1/8" thick, and the spacer was 3/16" thick.

2) Twelve model "ELF" sections were prepared. The method used to fabricate these was to make a dimensional wooden pattern, around which was cast a reinforced mold of RTV Silicone Rubber. From this mold, castings of the "ELF" section were produced using high impact epoxy resins.

3) Several complete Lens Assemblies each comprising a lens cell unit attached to an "ELF" model top section were prepared. Units were submitted for study and evaluation to:

NAMC	Johnsville, Pennsylvania	Dr. J.H. Hill
NWEF	Albuquerque, Kirtland AFB	LCDR P.E. Beck
Sandia	Albuquerque, New Mexico	Mr. Frank Goss
ACEL	Philadelphia, Pennsylvania	Mr. Frank Catroppa

4) Ten Frame sections were prepared. The method used was to form a dimensional wooden pattern of the frame, and use this pattern to prepare a reinforced, flexible mold from RTV Silicone Rubber. Using this mold, frame parts were cast from high impact epoxy resins. These frames were used in subsequent model work, and samples were also submitted to the four destinations mentioned in (3) above.

Description of Items

C) A complete mock up of the Light Restrictive Visor Assembly, in accordance with Design #1, and Enclosures #11, 12, 13, and 14 was fabricated and delivered to NWEF, Kirtland AFB in Albuquerque for flight testing and evaluation. Prior to submission of this unit to NWEF, it was demonstrated for fit and basic design at the Air Crew Equipment Laboratory, Philadelphia, to a meeting of personnel from:

Air Crew Equipment Laboratory	- Philadelphia, Pa.
Air Crew Systems Branch	- BuWeps, Washington, D.C.
AMAL, NAMC	- Johnsville, Pennsylvania

The basic design structure, and optical characteristics of the lens design was adjudged to be satisfactory by this group.

This unit comprised the following:

1) A retractable frame assembly, complete with metal hardware, pivots, lock and retaining springs, attached to a large size APH-5 helmet, which had been previously stripped of its standard sun visor and accompanying hardware.

2) A dummy "ELF" Lens Unit, assembled as previously described in B-(3).

3) A light seal, comprising a polyester-resin fiberglas oxygen mask retainer, enlarged in top section to provide a seat or nest for the bottom of the lens, when it is in the "as worn" position.

In Appendix:

Enclosure #18

Light Restrictive Visor Assembly, Design #1, Front and Side View, Complete Assembly.

Enclosure #19

Light Restrictive Visor Assembly, Design #1-Top View of Complete Assembly, and Exploded View of Lens Cell, Lens Cell Holder, and Hinge Plate Assembly.

Enclosure #20

Photographs of complete Assembly, in (a) as worn position, and (b) in retracted position.

Description of Items

D) Supply Test Samples of Lens Cell Aperture Materials with Information on Physical and Optical Characteristics.

To assist the Sandia Corporation in its effort to evaluate materials suitable for use in the lens section, OMNITECH was requested to search for possible materials, procure samples of same, and supply samples to Sandia for evaluation, together with all pertinent technical information available on these materials.

The characteristics required of the materials to be used in the lens cells are as follows:

(a) The material must have resilience, or impact strength capable of withstanding the explosive shock generated by firing the "ELF" unit.

(b) The material must be capable of being formed, or fabricated into a lens, to provide optical clarity, high visual transmittance, and freedom from distortion.

(c) The materials must have good abrasion resistance or surface hardness.

In our survey, materials of the following types were investigated, and samples submitted to Sandia for evaluation and tests.

1) Castable Materials: These substances are prepared by polymerizing liquid monomers, or mixtures of monomers between highly polished mold faces, or between highly polished sheets of plate glass. In general, these materials are cast to finished shape or curvature, and cannot be substantially reshaped or formed by subsequent heating. Excellent optical characteristics can be attained with such materials. The following were obtained and sent to Dr. Leslie at Sandia for his evaluation:

Trade Name	Chemical Composition	Impact Strength Notched Izod ft.lb./in.	Tensile Strength psi x 10^3	Flexural Strength psi x 10^3	Thickness ins.
CR-39	Allyl Diglycal Carbonate	0.35	5.5	10	.062
CR-39	"	0.35	5.5	10	.125
CR-39	"	0.35	5.5	10	.188
CR-39	"	0.35	5.5	10	.250
CR-39 M	"	0.35	5.5	15.2	.125
HT-CR-39	"	0.35	8.6	10.0	.125
Homolite-100 CR-39	"	0.35	5.5	10.0	.125
Homolite-100 CR-39	"	0.35	5.5	10.0	.250
SAF-T-LITE	CR-39 laminated with polyvinylbutyral	-	-	-	.250
SAF-T-LITE	"	-	-	-	.125
Duralite	Modified Acrylic	-	-	-	.125
Duralite	-	-	-	-	.250
Tuffak	Stretched Acrylic	-	-	-	.050
Tuffak	"	-	-	-	.080

2) Extruded Materials, press polished to achieve optical clarity:

Trade Name	Chemical Composition	Izod Strength Impact ft.lbs./in.	Tensile Strength psi x 10^3	Flexural Strength	Thickn ins
Celanese S-700	Cellulose Acetate	1.1	8.0	8.5-11	.040
Celanese S-701	"	1.1	8.0	8.5-11	.060
Celanese S-702	"	1.1	8.0	8.5-11	.150
Kodapak II	Cellulose Acetate Butyrate	1-2	5-6	-	.040
Kodapak II	"	1-2	5-6	-	.060
Kodapak II E-461	"	1-2	5-6	-	.080
Tenite Butyrate 205-A-969- MH	"	2.1	5-6	6.2	.115
Kodapak IV F401 - R8	Cellulose Triacetate	-	-	-	.045
Lexan	Polycarbonate	12-16	9-10.5	11-13	.062
Lexan	"	12-16	9-10.5	11-13	.125

Description of Items

E) Supply Test Samples of ELF Structural Plastic Materials, with Information on Physical Characteristics.

To assist Sandia Corporation in its efforts to evaluate plastic materials suitable for use in the "ELF", or top section of the lens assembly, OMNITECH was requested to search for materials available, and submit samples to Sandia together with pertinent information on same.

Characteristics required were very high impact resistance; and ability to fabricate to the required shape. The following materials were submitted to Sandia:

Trade Name	Chemical Composition	Izod Impact ft.lb./in.	Tensile Modulus psi x 10^3	Flexural Modulus psi x 10^3	Thickness ins.
Marlex Type 2	High Density Polyethylene	14	85-160	90-150	.250
Cycolac C-4015	ABS Copolymer	4-5	340	270	.250
Cycolac L-15575	"	6-8	200	210	.250
Boltaron 6100	"	8	200	238	.250
Boltaron 6500	"	3	125	216	.250
Teflon Virgin Grade	Tetrafluoro Ethylene	3	-	50-90	.250
Polytet HA-17-M	Glass Filled Teflon	-	-	-	.250
Lexan	Polycarbonate	12-16	320	375	.250
Cymel	-	8-10	-	9	.250
Hetron 92	Rigid Polyester Glass Cloth	-	-	-	.250
Hetron 32-A	Semi-Rigid Polyester Glass Cloth	-	-	-	.250
Zytel 101	Nylon 6	.9-2.5	200-450	50-250	.250
Delrin 500 x	Acetal	2-3	400	400	.250
PVC	Polyvinyl Chloride	-	-	-	.250
Polypropylene	Polypropylene	.5-11	150	150	.250

Description of Items

F) Evaluate Presently Available Sensing and Triggering Devices, and Recommend What Is Necessary for Initialling Closure.

At the beginning of this development, engineers from BuWeps had assumed that a sensing and triggering device was already in existance to sense, differentiate and activate the device. This unit had been developed and produced by E.G. & G. in Boston, under contract from BuWeps, to be used with the Marks Polarized Electro-Optic Shutter previously mentioned in this report.

Upon investigation, it was found that several basic differences existed between the Electro-Optic shutter closure requirements,and the "ELF" closure requirements, which precluded use of the already existing unit. The E.G. & G. device was a larger unit, approximately 4" x 5" x 8", weighing several pounds, and needed ship power for operation, eliminating the feature of portability.

To fire the "ELF" unit, requires from the trigger circuit a condenser discharge through a low resistance of less than an ohm. The E.G. & G. trigger provided for an initial high voltage pulse of 4000 volts followed by a secondary maintained or holding voltage of 4000 volts at very low currents for extended periods of time. The "ELF" requirements, and the E.G. & G. trigger capabilities were completely at odds. It was recommended that a completely new unit be developed, to be completely miniaturized, with its own power supply to make it completely portable.

Description of Items

G) Provide a Design and Functional Breadboard Model for Sensor-Trigger Mechanisms.

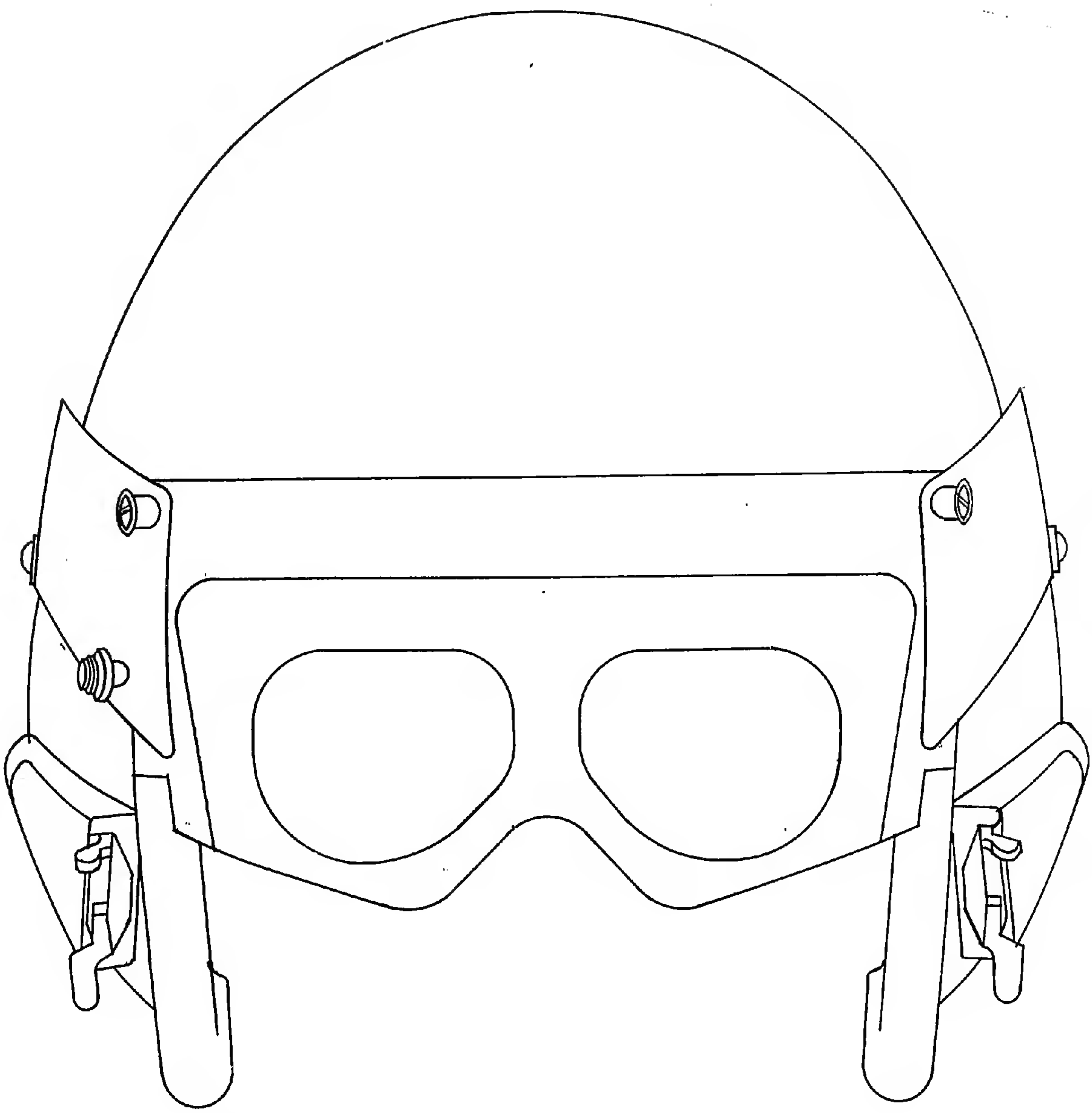
As a result of the investigation made in (F), we were requested to provide the initial design of a mechanism to fire a 5 ohm detonator, supplied to us be Sandia Corporation. To fire this detonator required a condenser discharge of 50,000 ergs.

A breadboard model was made, the design of which is presented in Enclosure #21. This unit used a silicon cell as the photoelectric sensor, and was activated by a light source having a rise time of approximately 20 microseconds. It was demonstrated to Sandia Personnel, and successfully fired a bridge wire and detonator upon a flash from the light source.

In Appendix:

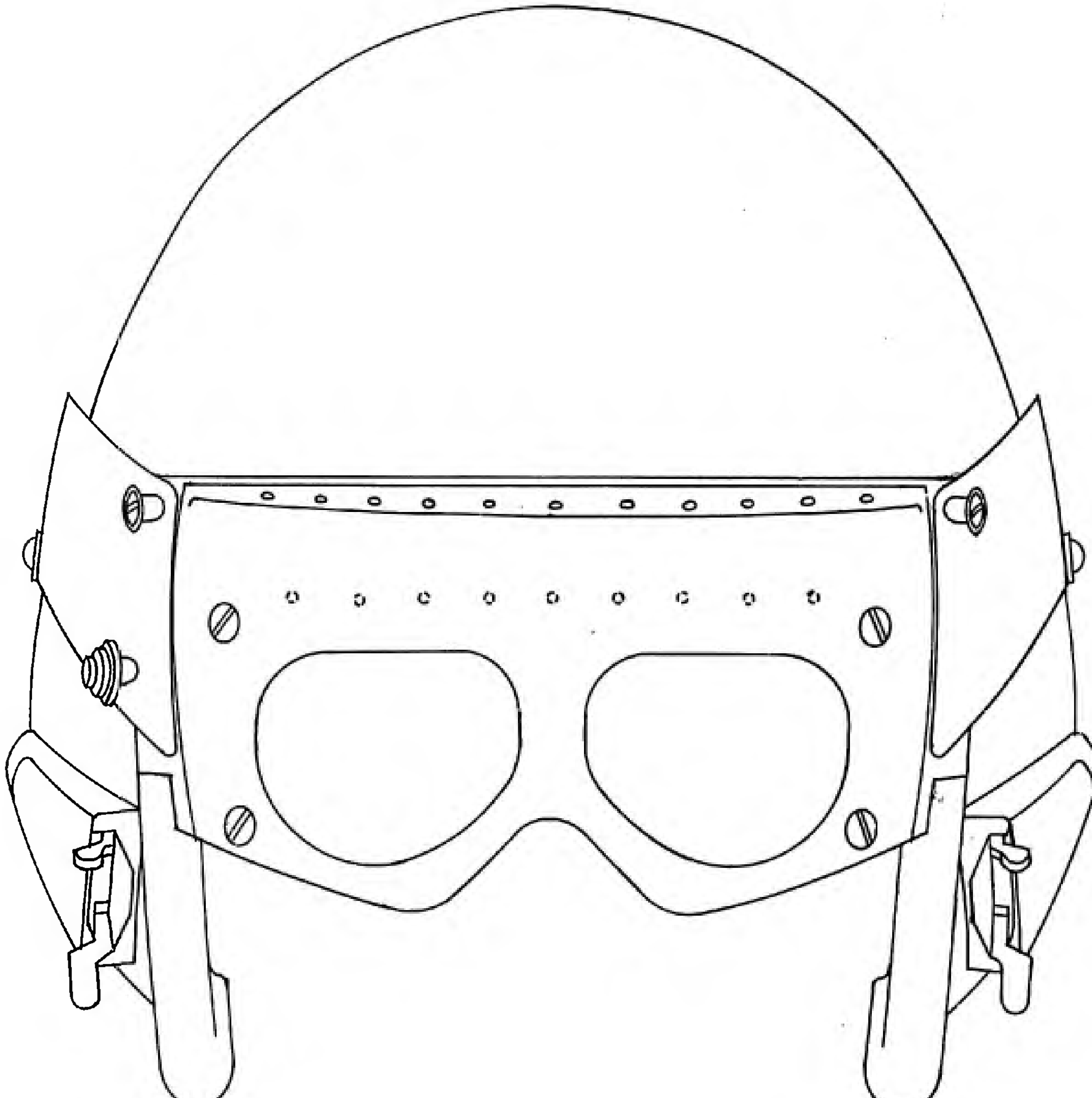
Enclosure #21

Sensor and Trigger Circuitry



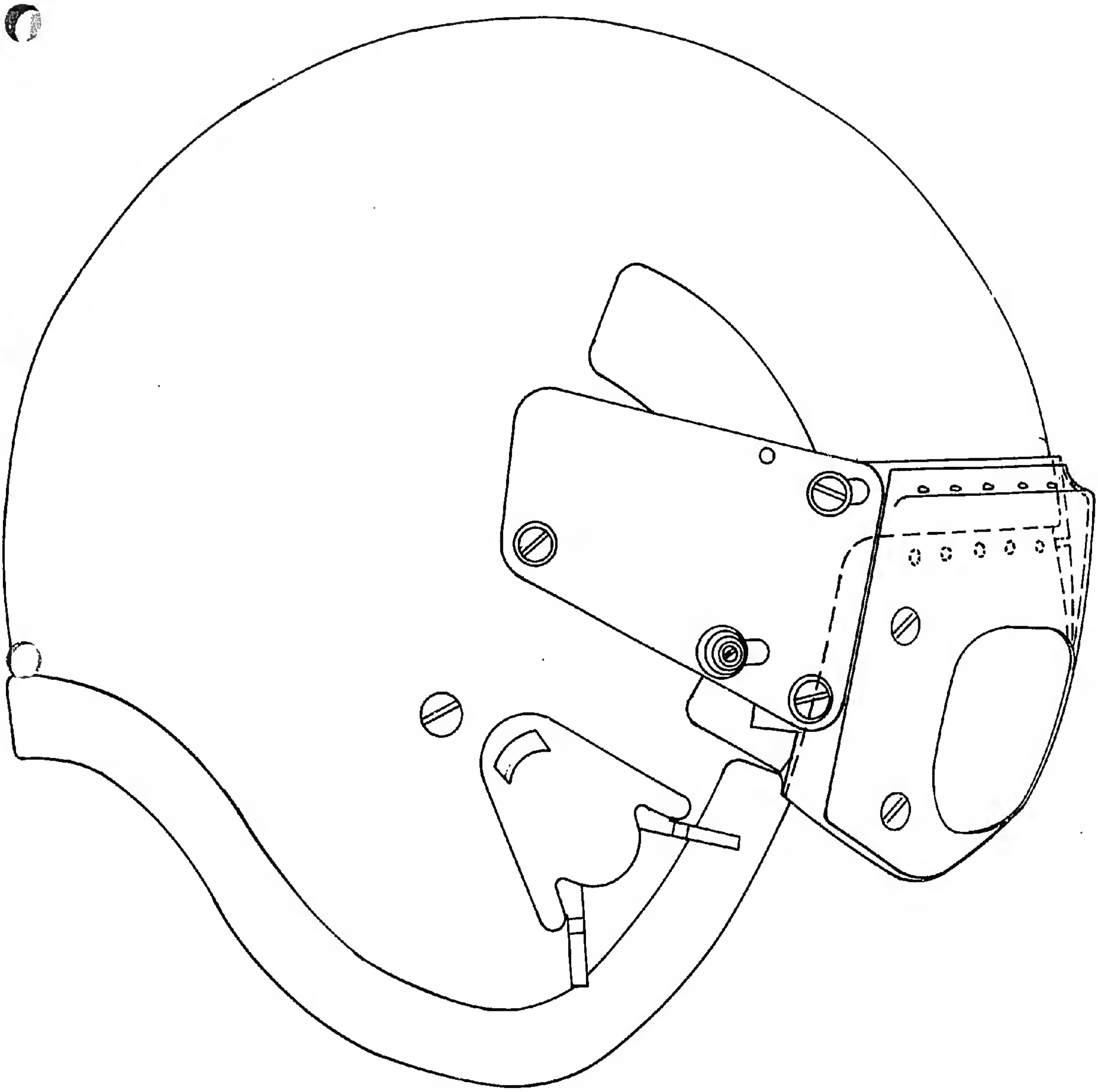
Assembly Sketch of Original Visor-Front View

Enclosure #1



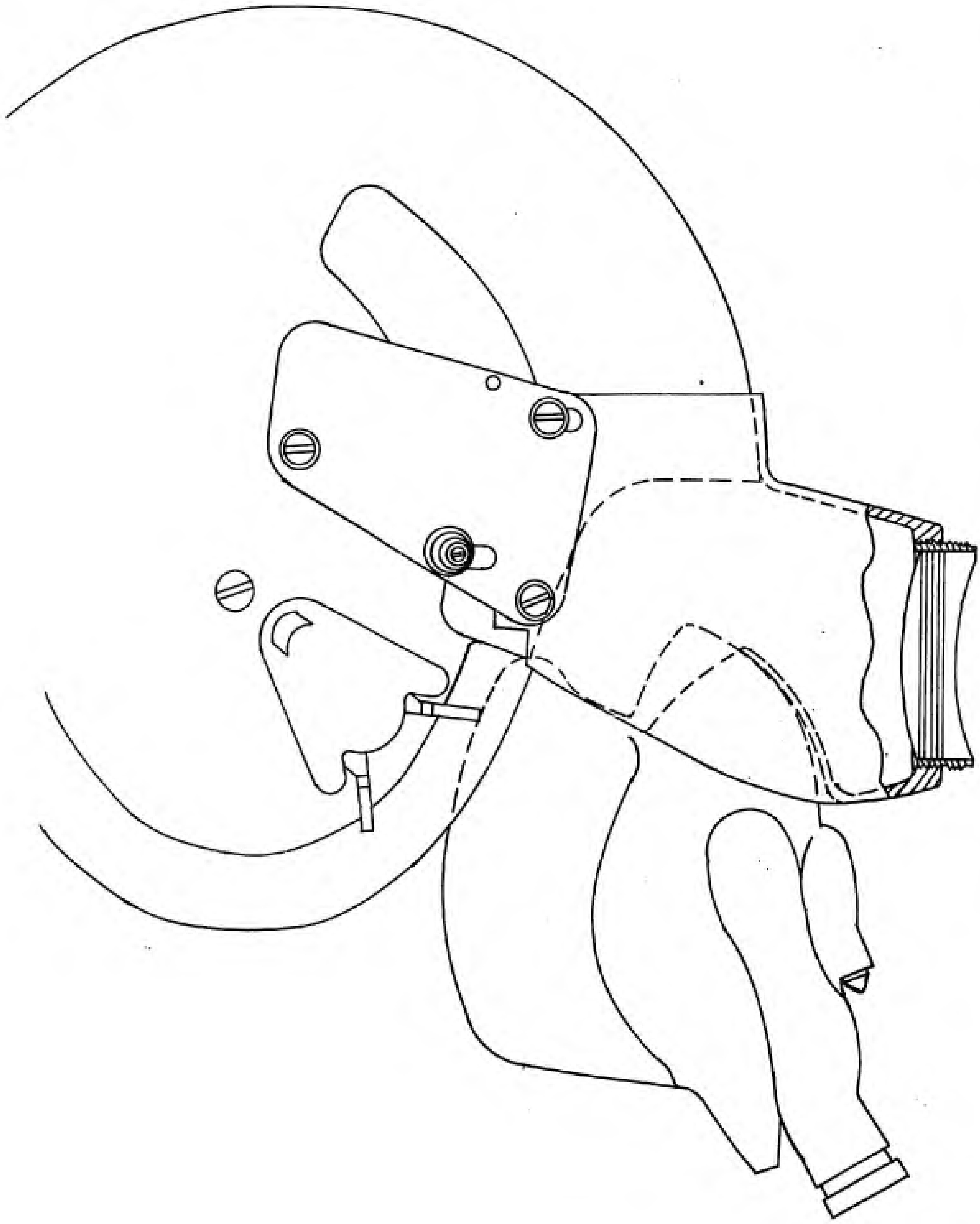
Assembly Sketch of Vented Visor-Front View

Enclosure #2



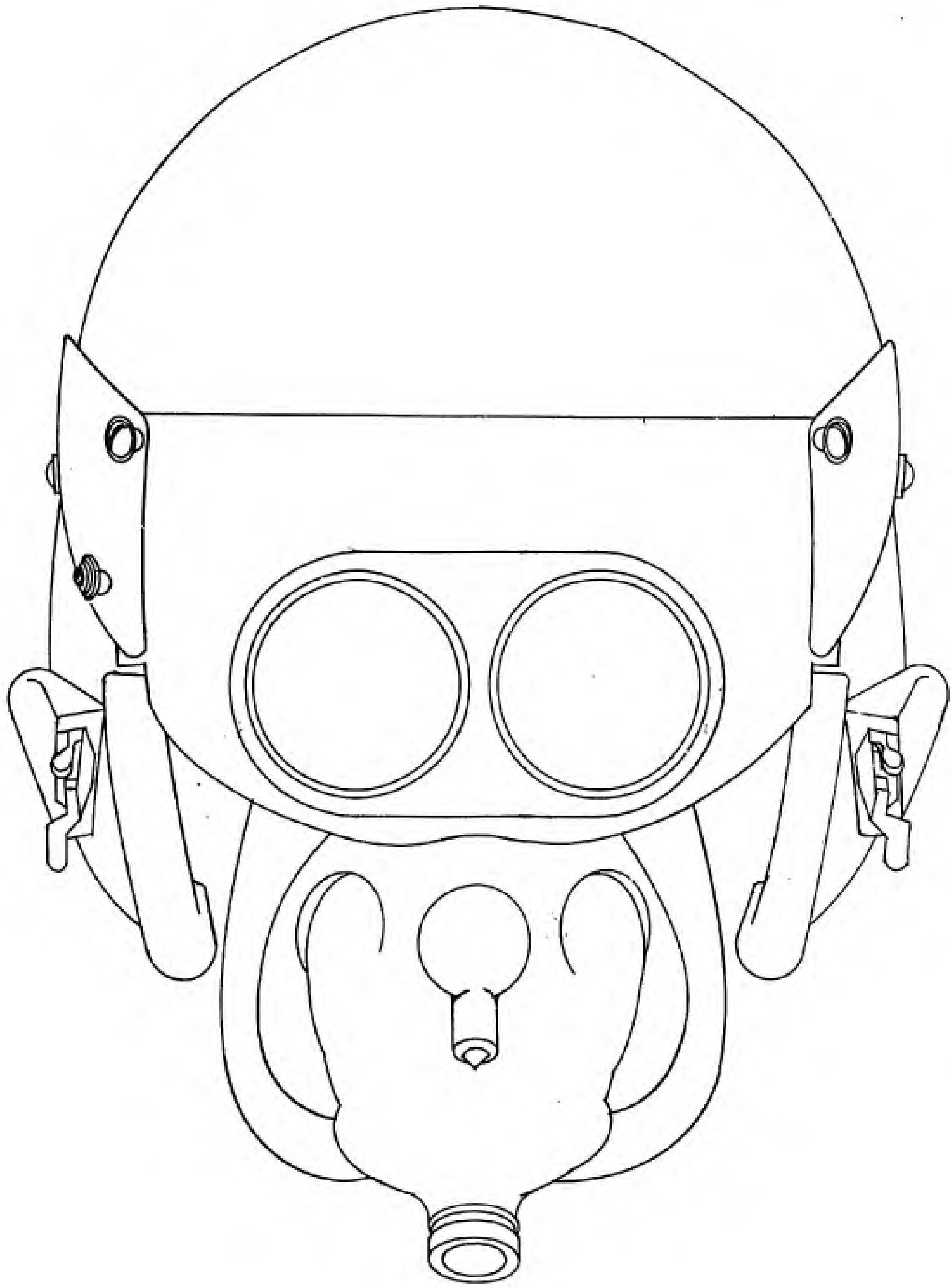
Assembly Sketch of Vented Visor-Side View

Enclosure #3



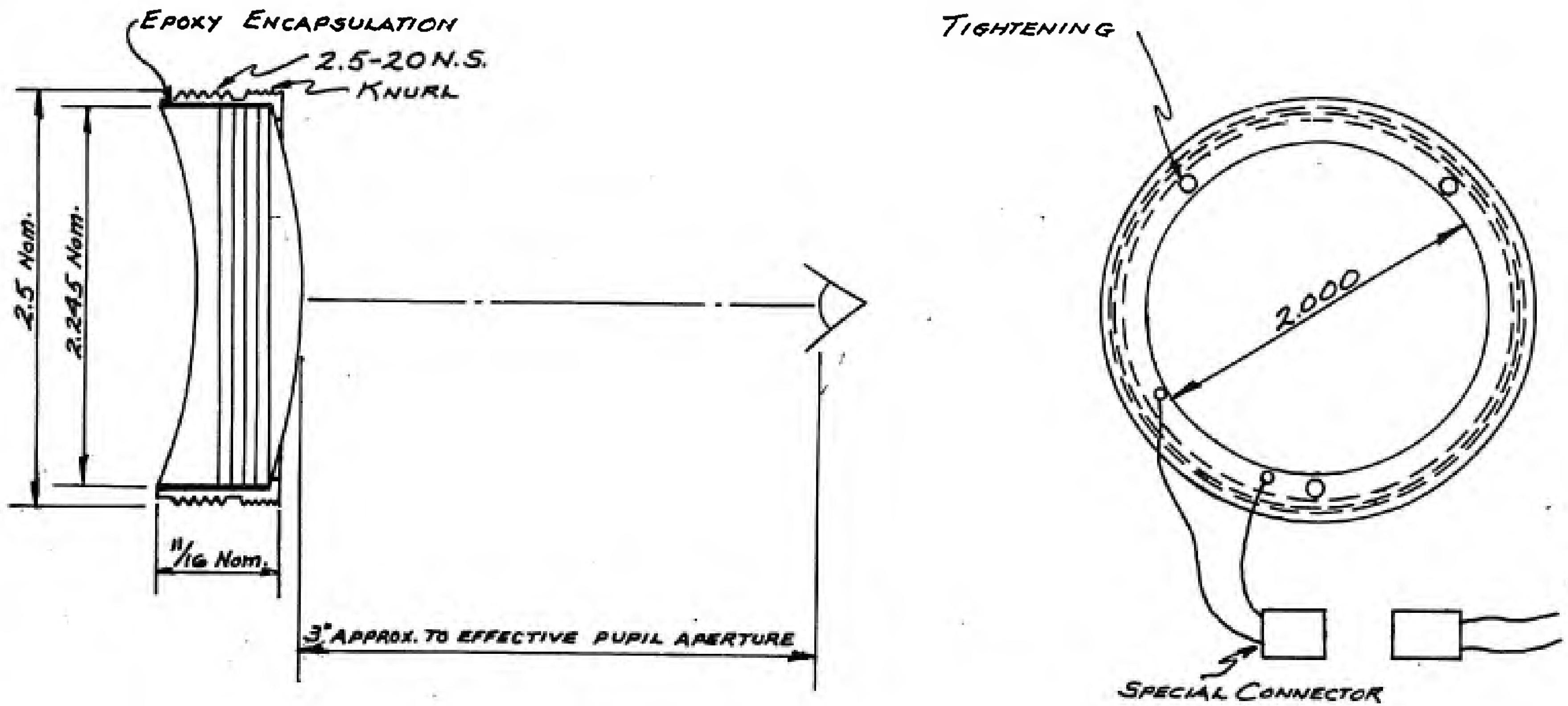
Assembly Sketch of Visor with Mark Electro-Optic Shutter Lenses-Side View

Enclosure #4



Assembly Sketch of Visor with Marks Electro-Optic Shutter Lenses-Front View

Enclosure #5



PRELIMINARY

Electro-Optic Shutter

MARKS POLARIZED CORPORATION
153-16 Tenth Ave.
Whitestone 57, N.Y.

Enclosure #6

TASK REPORT

TEST AND EVALUATION
OF
MARKS POLARIZED CORP. OF ELECTRO-OPTIC SHUTTER

CONTRACT NO. Nonr - 3177 (00)

CONTRACTOR:

Omnitech, Incorporated
561 South Main Street
Webster, Massachusetts

AGENCY:

Office of Naval Research

REQUESTED BY:

Mr. Alan Merkin
Bureau of Naval Weapons
Department of the Navy
Code RAAE-232

DATE:

5 January 1961

OMNITECH, INCORPORATED

James E. Johnston
Project Engineer

Enclosure #7

PURPOSE AND SCOPE

This report covers a task assigned to Omnitech, Incorporated under Contract Nonr-3177(00) by Mr. Alan Merkin, Bureau of Naval Weapons, Department of the Navy, Code RAAE-232.

The task assigned to Omnitech, Incorporated was:

1. To determine the spectral and visual transmissions of the Marks Polarized Corp. electro-optic shutter in the open state.
2. To determine the spectral and visual transmissions of the shutter in the closed state as a function of the applied voltage.
3. To generally evaluate the feasibility of the electro-optic shutter system.

Enclosure #7

TEST PROCEDURE AND APPARATUS

Fig. I shows a schematic of the test set up used for determining the spectral transmission of the electro-optic shutter.

A ribbon filament, tungsten lamp provides the light source for a Bausch and Lomb, 500 millimeter grating monochromator. The light emerging from the exit slit of the monochromator was modulated at 360 cycles per second by a synchronous motor driven chopper disc. An achromatic, collimating lens system followed and provided a parallel beam of light in the testing path. An iris diaphragm, located immediately after the collimator, provided a variable diameter field stop for the system. An achromatic collecting lens system then directed the light to the photo-cathode of a 1P22 multiplier phototube. The electrical signal out of the 1P22 was passed through a 360 cycle selective amplifier to enhance the signal to noise figure of the system. The output of this amplifier was measured by a Model 300 Ballantine vacuum tube voltmeter.

The collimator was set up by looking from the test position back toward the exit slit through a telescope focussed at infinity. The collimating lens system was then adjusted so that the image of the exit slit observed through the telescope was in sharp focus. The collecting lens system was adjusted to give maximum electrical signal as indicated by the vacuum tube voltmeter. The voltmeter and amplifier combination had a dynamic range of 3 density units. Additional dynamic range was obtained by fixed taps on the 1P22 multiplier phototube high voltage supply. These taps were transformed to voltmeter scale multipliers.

The actual testing consisted of measuring the light, at a given wavelength, through the system with and without the shutter in the optical path. The ratio of the two voltages yields the transmittance, and expressed as a percentage, gives the percent transmission.

All the tests reported on herein were run with the monochromator entrance and exit slits set at 50 millimicrons.

Fig. II shows the spectral characteristic of the overall system with nothing in the test zone.

VISUAL APPEARANCE OF ELECTRO-OPTIC SHUTTERS

Two electro-optic shutters were made available to Omnitech, Inc. for this test. One shutter was housed in a brown, shaped, bakelite housing while the other was mounted on a black bakelite disc. This latter shutter was found to have an internal arc-over at voltages above 2500 volts. This arc, of course, is a light source "seen" by the photoelectric measuring system and thus invalidates any measurements on this shutter. All of the test data, results, and comments which are hereafter reported will apply only to the shutter with the brown housing or mounting.

A visual inspection of the laminated sandwich showed considerable unevenness in the laminate. Bubbles and other defects were readily apparent. In particular, there was considerable unevenness in the axial area of the device.

Enclosure #7

TEST DATA AND RESULTS

The experimental data from the spectral transmission tests are tabulated in Table I. This data is shown in graph form in Fig. III.

In the open state, the shutter is quite neutral and has an average spectral transmission of about 14%. Data from tests run by the Marks Polarized Corporation show an average spectral transmission of about 27% or approximately twice the value obtained in this test. This difference in open transmission is probably due to the difference in the shutters tested. As stated in previous sections of this report, the shutter and the particular shutter tested had its main laminate defects in this area. Further testing was planned which would explore the entire clear aperture of the shutter and determine the maximum transmission of a clear area of the device. The shutter developed an internal short circuit, however, before this could be accomplished.

This data yields a visual transmission of 14.6% in the open state.

Spectral transmission for three values of voltage applied to the shutter are also given in Fig. III. The minimum transmission was obtained at 4000 volts applied and at a wavelength of 600 millimicrons. The minimum transmission was 0.06%. This corresponds to a density of 3.22, and a visual transmittance of 0.176%. The data shows also that within the applied voltage range of from 3500 to 4600 volts, the wavelength at which the minimum transmission occurs stays constant at approximately 600 millimicrons.

The transmission remains at or below 0.1% (or density 3.0) only between 550 and 650 millimicrons. It climbs rapidly below and above this band of wavelengths.

APPLICATION OF TEST DATA TO A PRACTICAL SHUTTER SYSTEM

It was noted in the previous section that the transmission of the closed electro-optic shutter rose rapidly below 550 millimicrons and above 650 millimicrons. If we arbitrarily set density 3.0 as the desirable degree of light restriction throughout the visible wavelength spectrum, a band pass filter becomes necessary.

A single colored glass filter which would provide the proper band pass does not exist, thus one glass must be selected to attenuate the light occuring below 550 millimicrons and second glass selected to attenuate those wavelengths above 650 millimicrons.

Fig. IV shows the spectral transmission of the two selected glasses and of the combination. The glasses selected are:

Corning type 3486 H.R. yellow shade yellow
1 stock thickness - 3.0mm ± 1.6mm

American Optical Company HSP-98A
Thickness - 5mm

The spectral response of the electro-optic shutter in conjunction with the band pass filter is shown in Fig. V. With the shutter closed the density does not fall below 3.0 at any wavelength within the visible range of the spectrum. The open shutter, however, has a density greater than 1.0 throughout the visible spectrum.

When the vision curve is applied to these curves of Fig. V the resultant visual transmittance is 7.3% in the open state and 0.05% in the closed state.

Enclosure #7

CONCLUSIONS AND COMMENTS

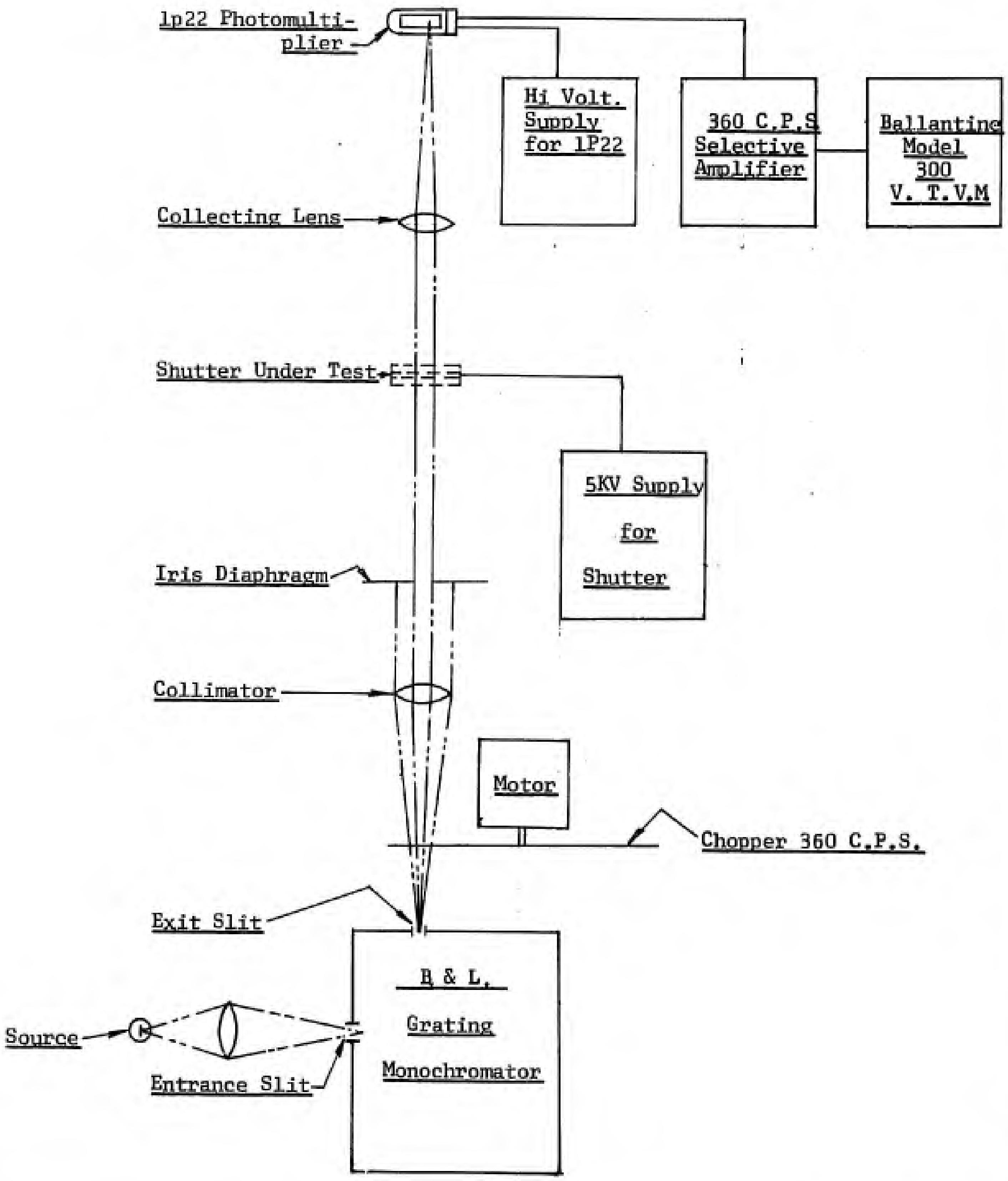
A closed shutter density of 3.0 or better is attainable throughout the visible spectrum with the appropriate band pass filter. The band pass filter, however, allows vision in the open state in that part of the visible spectrum above 525 millimicrons. This results in the system having a strong yellow-green hue. The visual transmittance of the open shutter is 7.33% while in the closed case it falls to 0.05%.

The electrical breakdown of both shutters at voltages not in excess of 5000 volts terminated any further testing or evaluation of the device.

The test results are certainly biased by the poor optical quality of the laminate. Bubbles and other defects result in a lower open shutter transmittance, and also cause a degrading of the resolution.

It should be noted at this point that the high index lenses for expanding the field of view were not included in the measurement nor taken into consideration in the practical shutter-filter combination previously described. Consequently, the open shutter transmittance will be further reduced by surface reflection losses. In the case of high index glasses these losses become quite significant. For glasses with an index of 1.8, for instance, the reflection loss can be as high as 8% per surface.

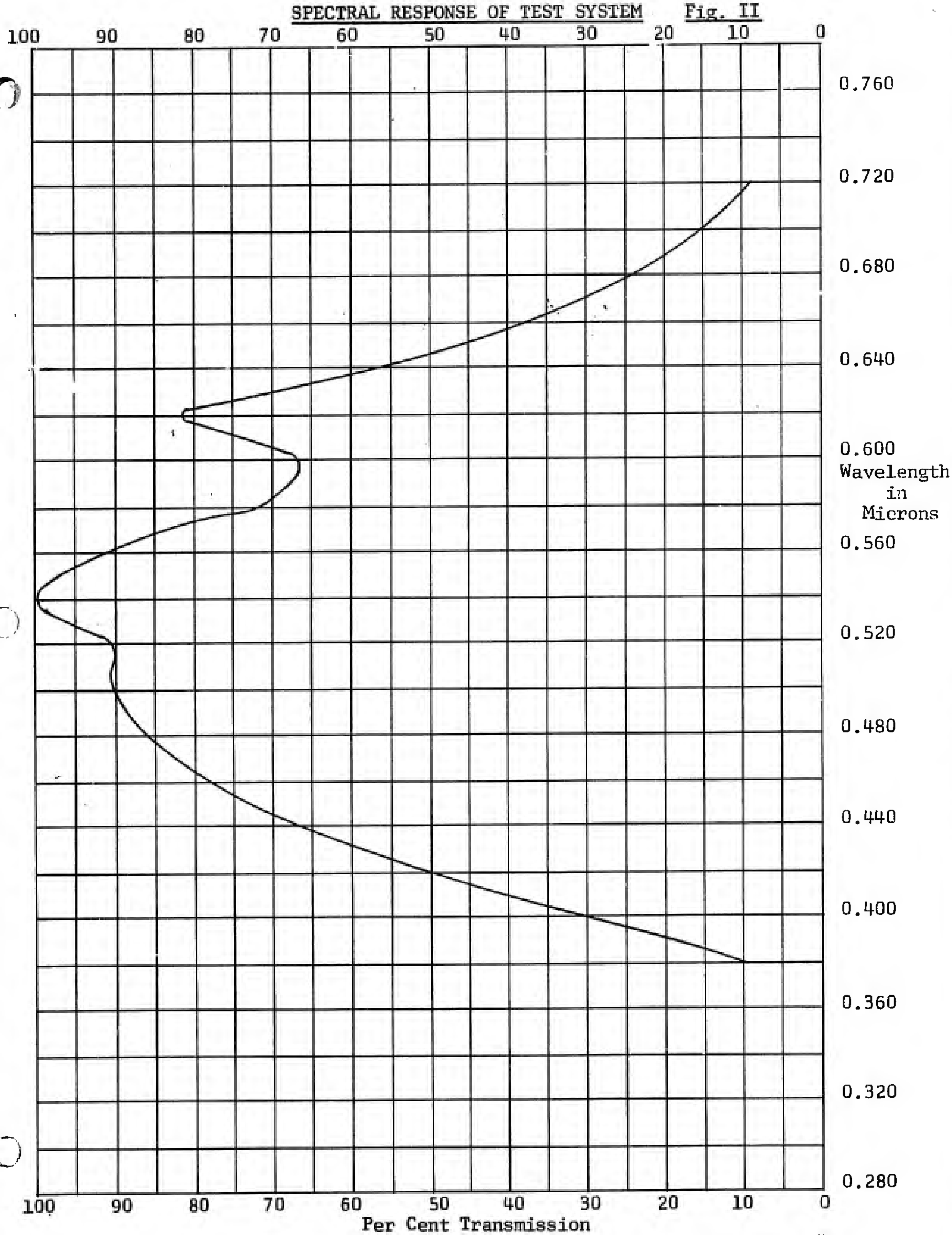
Enclosure #7



Monochromator - B. & L. Cat. #33-86 - 45-59, 500 MM Model, 1200 Groove S/MM Grating,
Source - Tungsten, Ribbon Filament,
Optics - Collimating & Collecting Lenses Are Color Corrected,
Entrance & Exit Slits At 50 Millimicrons,

Figure I

Enclosure #7


SPECTRAL RESPONSE OF TEST SYSTEM
Fig. II
100 90 80 70 60 50 40 30 20 10 0
0.760
0.720
0.680
0.640
0.600
Wavelength in Microns
0.560
0.520
0.480
0.440
0.400
0.360
0.320
0.280
100 90 80 70 60 50 40 30 20 10 0
Per Cent Transmission

Enclosure #7

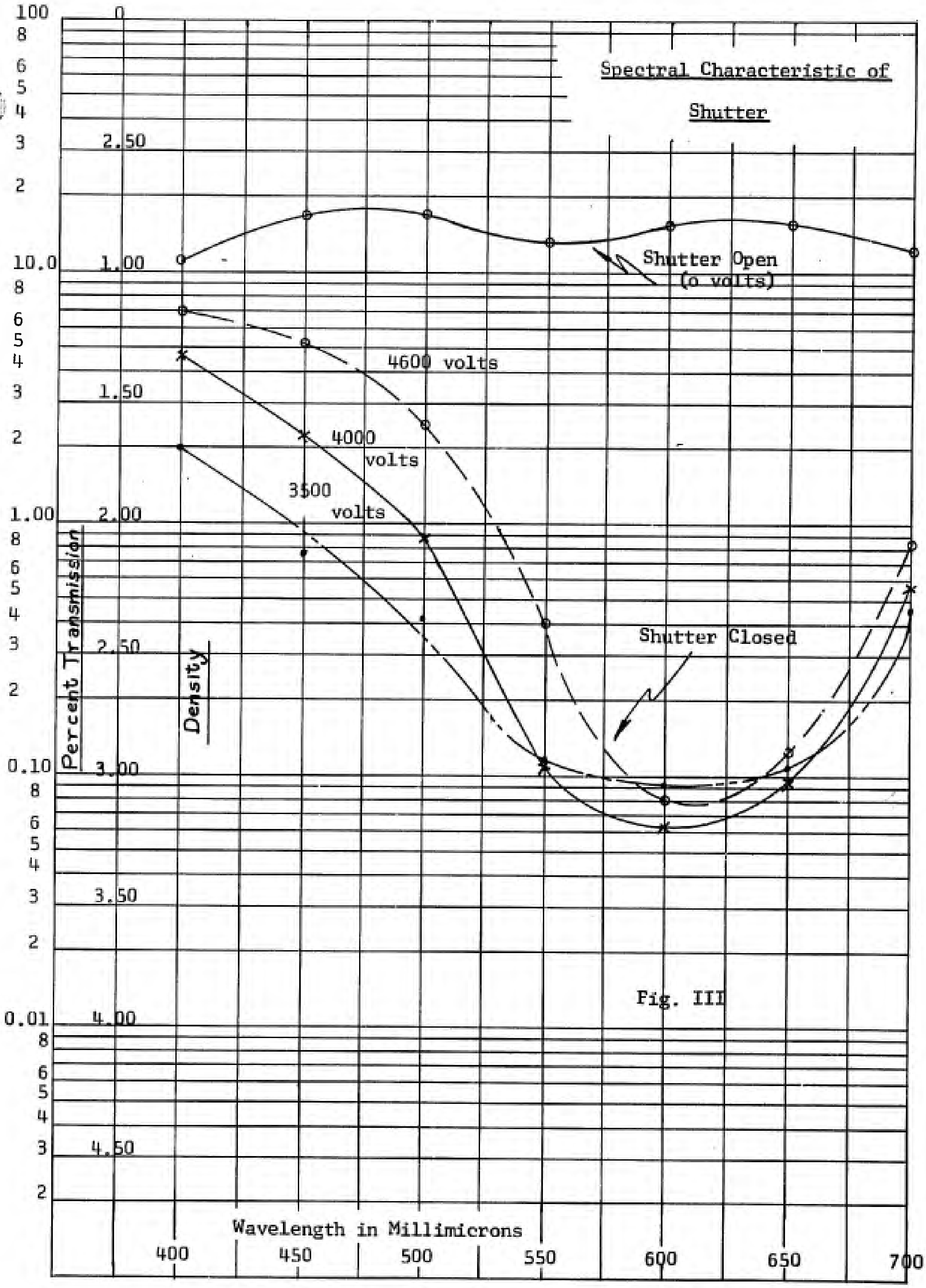
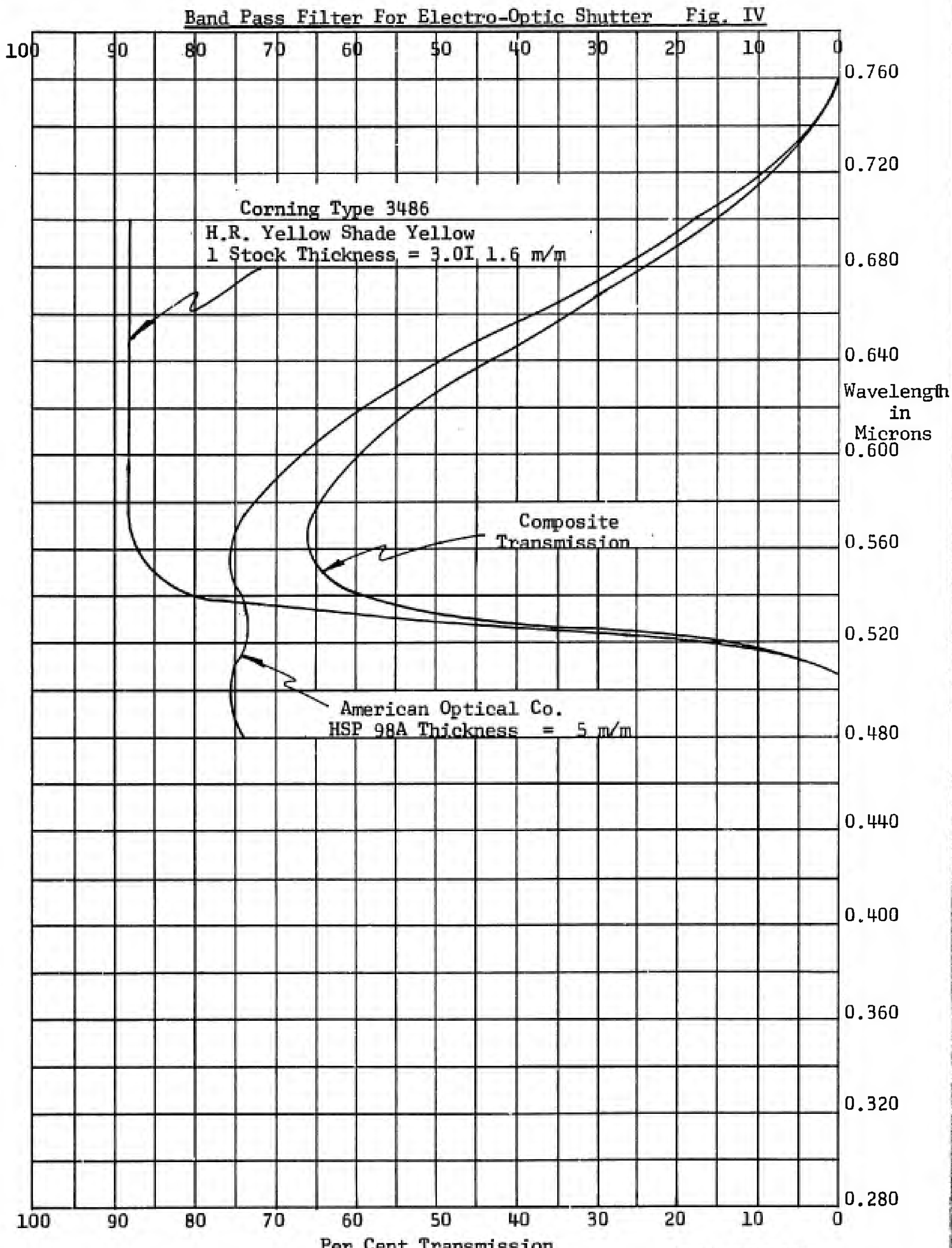


Fig. III

Enclosure #7



Band Pass Filter For Electro-Optic Shutter Fig. IV
100 90 80 70 60 50 40 30 20 10 0
0.760
0.720
0.680
0.640
Wavelength in Microns
0.600
0.560
0.520
0.480
0.440
0.400
0.360
0.320
0.280
Corning Type 3486
H.R. Yellow Shade Yellow
1 Stock Thickness = 3.0I 1.6 m/m
Composite Transmission
American Optical Co.
HSP 98A Thickness = 5 m/m
100 90 80 70 60 50 40 30 20 10 0
Per Cent Transmission

Enclosure #7

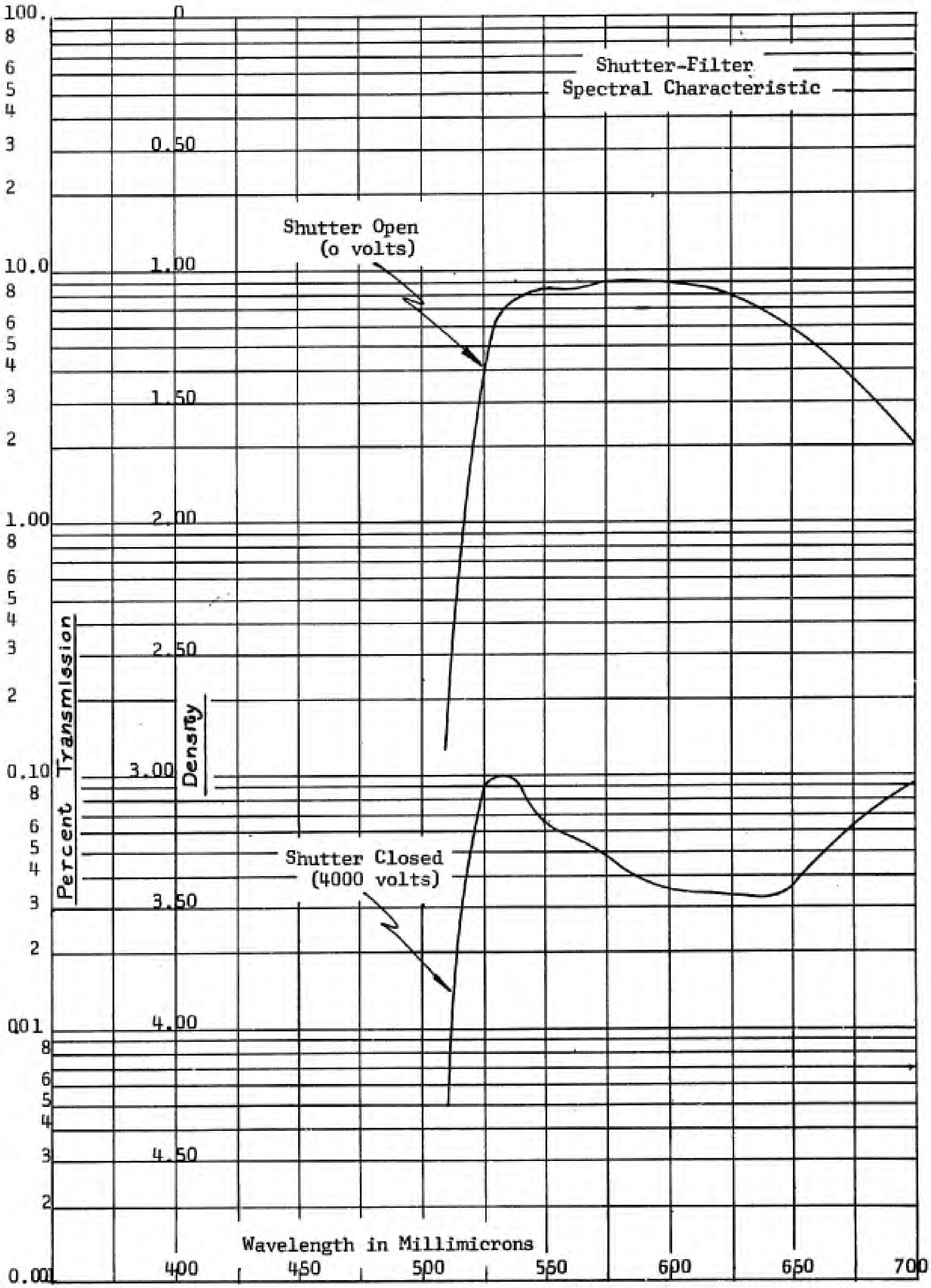


Fig. V

Enclosure #7

TABLE I - TEST DATA

(mu)	No Shutter		SHUTTER IN							
			0 Volts		3.5 K Volts		4.0 K Volts		4.6 K Volts	
	E a c	%T	E a c	% T	E a c	% T	E a c	% T	E a c	% T
400	0.84	100	0.0905	10.8	0.0170	2.02	0.0401	4.78	0.0584	6.96
450	2.05	100	0.330	16.1	0.0154	0.751	0.0451	2.2	0.1090	5.32
500	2.70	100	0.460	17.0	0.0114	0.423	0.0244	0.905	0.0685	2.54
550	2.95	100	0.391	13.3	0.00307	0.104	0.00321	0.109	0.0124	0.421
600	1.95	100	0.299	15.3	0.00184	0.094	0.00117	0.060	0.00157	0.0805
650	1.35	100	0.207	15.35	0.00144	0.107	0.0013	0.096	0.00164	0.1215
700	0.48	100	0.0582	12.1	0.00230	0.480	0.00268	0.558	0.00401	0.835

Enclosure #7

TO: Distribution DATE 20 September 1960

FROM: F. E. Barstow

SUBJECT: The ADP Crystal Goggle As An Electrical Load

From the start, it was recognized that the subject crystal configuration was not a straight forward capacity or resistance capacity load. Mr. Felix Elleren of Marks, in fact, had made some calculations which were dated 3 December 1959.

On receipt by EG&G of the contract with ONR (BuWeps) to develop the driver for the crystals, the first step was to evaluate the crystals as an electrical load. Mr. John Tredwell of EG&G did calculations and this memo primarily summarizes this work.

Because the crystal coating has a relatively high resistance, different parts of the crystal reach the required voltage at different times, and these in turn depend upon how electrical connections are made to the coatings. To describe the behavior, Tredwell has posed three questions, and has then found solutions for two methods of electrical connections.

1. If a step of voltage is applied at the connection, what will the behavior of the voltage be at the most remote point? (This determines the response time of the goggle.)

2. What will the "steady state" voltage distribution be accross the goggles? (This will affect the "Steady State" transmission.)

3. What will the current be into the crystal system? (This will affect the design of the power supply.)

Of greatest importance to us is the first question.

Two types of connections have been considered.

(a) Ring connection
(b) Tab connection

In the case of the tab connection, an approximation was made to simplify the solution. Thus, the calculations were made for a strip connection along one edge of a rectangle rather than a tab as shown in the sketch on the next page.

Enclosure # 8

(a) (b)

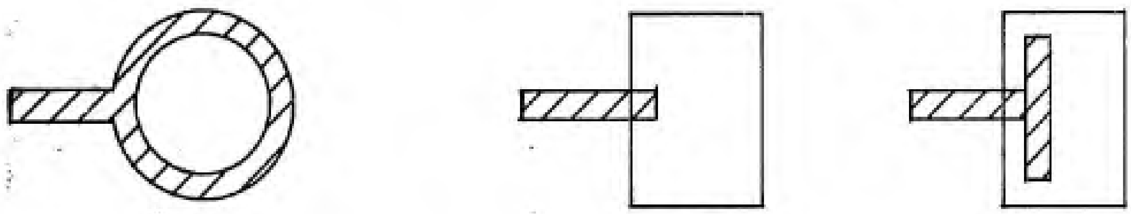


Figure 1 shows the relative response of the most remote point of the crystal for the above two cases. Also shown is the response of a 20 section load which Mr. Tredwell set up to approximate the filter. It is important to note that charging is eight (8) times faster when the ring configuration is used.

Substituting the values given by Marks Polarized Corporation in their letter of 31 August, we find:

TABLE I

Coating Resistance In Ohms Per Square	Time to Reach 90% of Voltage: Tab or strip Configuration	Time to Reach 90% of Voltage: Ring Configuration	Remarks
500,000 ohms	160 μsec.	20 μsec.	Present resistance value
10,000 ohms	3.2 μsec.	0.4 μsec.	Resistance value which Marks believes can be reached
30,000 ohms	10 μsec.	1.2 μsec.	Resistance value that must be obtained if tab construction is to be used.

Enclosure #8

Due to the distributed nature of the capacity and resistance in the load, steady state voltage will be different at different points of the crystal. However, if the charging time is of the order of 10-microseconds, this voltage variation is entirely negligible.

It is important to establish the required voltage tolerance for the goggle system. First, it can be shown that the transmission varies as the fourth power of the voltage ($T = k_1 \cos^4 k_2 v$). This is plotted in Figure 2. Table II below shows the voltage changes which produce a 25% change in transmission.

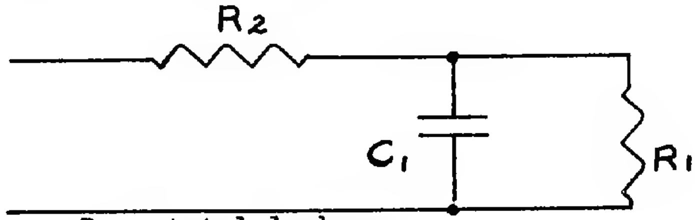
TABLE II

Closed Nominal Density	Transmission Range	Corresponding Voltage Change
ND4	0.0100% - 0.0125%	± 4.5%
ND3	0.100% - 0.125%	± 8.0%
ND2	1.00% - 1.25%	± 14.5%

Conclusions from Table II:

A ± 10% voltage variation can be tolerated.
A ± 5% voltage variation is preferred.

For experimental purposes, the simple equivalent circuit below can be substituted for the goggles.



R_1 = total leakage

C_1 = total capacity of the goggles

R_2 = 0.144 R_s for the tab configuration
= 0.0175 R_s for the ring configuration

where R_s = coating resistance per side in ohms/square

Enclosure # 8

This equivalent circuit gives a very close approximation to the true charging curbe above 75% of voltage.

FEB/jfg

Distribution:

C. Lilliott, EG&G
E. P. Sullivan, EG&G
J. R. Tredwell, MIT
A. Merkin, Bu Weps
A. Marks, Marks Polarized Company
A. Laliberte, OMNITECH, INC.
J. Hill, AMAL

Enclosure #8

TASK PROGRESS REPORT

OPTICAL SYSTEM FOR EXPLODING MIRROR, LIGHT

RESTRICTIVE DEVICE

CONTRACT NO. Nonr - 3177(00)

CONTRACTOR:

Omnitech, Incorporated
661 South Main Street
Webster, Massachusetts

AGENCY:

Office of Naval Research

REQUESTED BY:

Mr. Alan Merkin
Bureau of Naval Weapons
Department of the Navy
Code RAAE-232

DATE: 20 January 1961

OMNITECH, INCORPORATED

James E. Johnston
Project Engineer

Enclosure # 9

PURPOSE AND SCOPE

The purpose of this task is to investigate various optical systems and designs into which it is possible to incorporate the Isomet Corporation's exploding mirror type of light restriction device.

Under this task, Omnitech, Incorporated, will investigate a number of optical designs; and on the basis of simplicity, weight, overall dimensions, optical image quality, and cost, recommend a preferred system.

This task was assigned to Omnitech, Incorporated, by Mr. Alan Merkin, Bureau of Naval Weapons, Department of the Navy, Code RAAE-232.

Enclosure # 9

INTRODUCTION

The Isomet Corporation has proposed an exploding mirror device for eye protection in the presence of extremely high amfient light levels. The device consists, basically, of a highly reflecting, metallic surface deposited on a dielectric material such as glass or plastic. This mirror is positioned in an optical system so that it directs the optical path to the eye and permits normal vision. When the ambient light level reaches a predetermined intensity, a high voltage pulse is applied to the dielectric mirror backing. The amplitude of this pulse is sufficiently high to apply a stress to the dielectric in excess of its dielectric strength. Under this condition the mirror will shatter, effectively remove itself from the optical system, and reduce to near zero the light energy reaching the eye. The light energy incident on the eye after the mirror is exploded will be that light which is scattered within the device. This energy can never be reduced to zero, but by proper choice of geometry and through the use of high absorption materials it may be made to approach zero.

Enclosure # 9

INVESTIGATION OF OPTICAL DESIGN

Omnitech, Incorporated, has, to date, considered four possible optical configurations. In all of these designs, the field of view is 35°

In general, the optical requirements for systems such as this may be satisfied with either plane from surface mirrors, unit power telescopes, or various combinations of the two. Image inversion and reversion and also the displacement of the effective eye point are factors which must be considered in arriving at a preliminary design. Once the preliminary design, based on first order optics, is accomplished, it is then necessary to perform a higher order analysis and redesign to yield the optimum system.

Figure I shows a simple two mirror system. This design has certain advantages. It has the minimum number of optical surfaces, namely two reflecting plane surfaces, one of which is the exploding mirror. It also allows direct viewing through a high density dark glass during the high intensity light period. It also has some major disadvantages.

Its size is approximately seven or eight inches in heigth and the same in length. Another defect is the eye-point displacement. The effective eye point of this design is about three inches above and two inches behind the natural eye point. This displacement gives the wearer the sensation of apparently viewing from this point. We feel that this system is not acceptable, and will not proceed any further with the design.

Figure II shows an optical system consisting of a unit power telescope plus three reflecting surfaces. It is a binocular system and requires a hinge for interpupillary distance adjustment. This system suffers from the same defects as found in the first design. Its overall dimensions are large and the effective eye-point displacement is considerable. This design does not warrant any further investigation.

The design of Figure III is somewhat similar to that of Figure II. The spherical lenses are replaced by cylindrical lenses and the reflecting surfaces are placed so as to minimize the overall size of the device. The use of cylindrical lenses eliminates the need for a hinge, but does have the disadvantage of introducing some astigmatism into the system. Whether or not this astigmatism would be tolerable is best determined by subjective tests. The mirror placement is such that the effective eye point is located one inch in front of and on the optical axis of the eye. The exploded mirror is easily replaced by rotating the hexagonal element shown in the upper left of the figure.

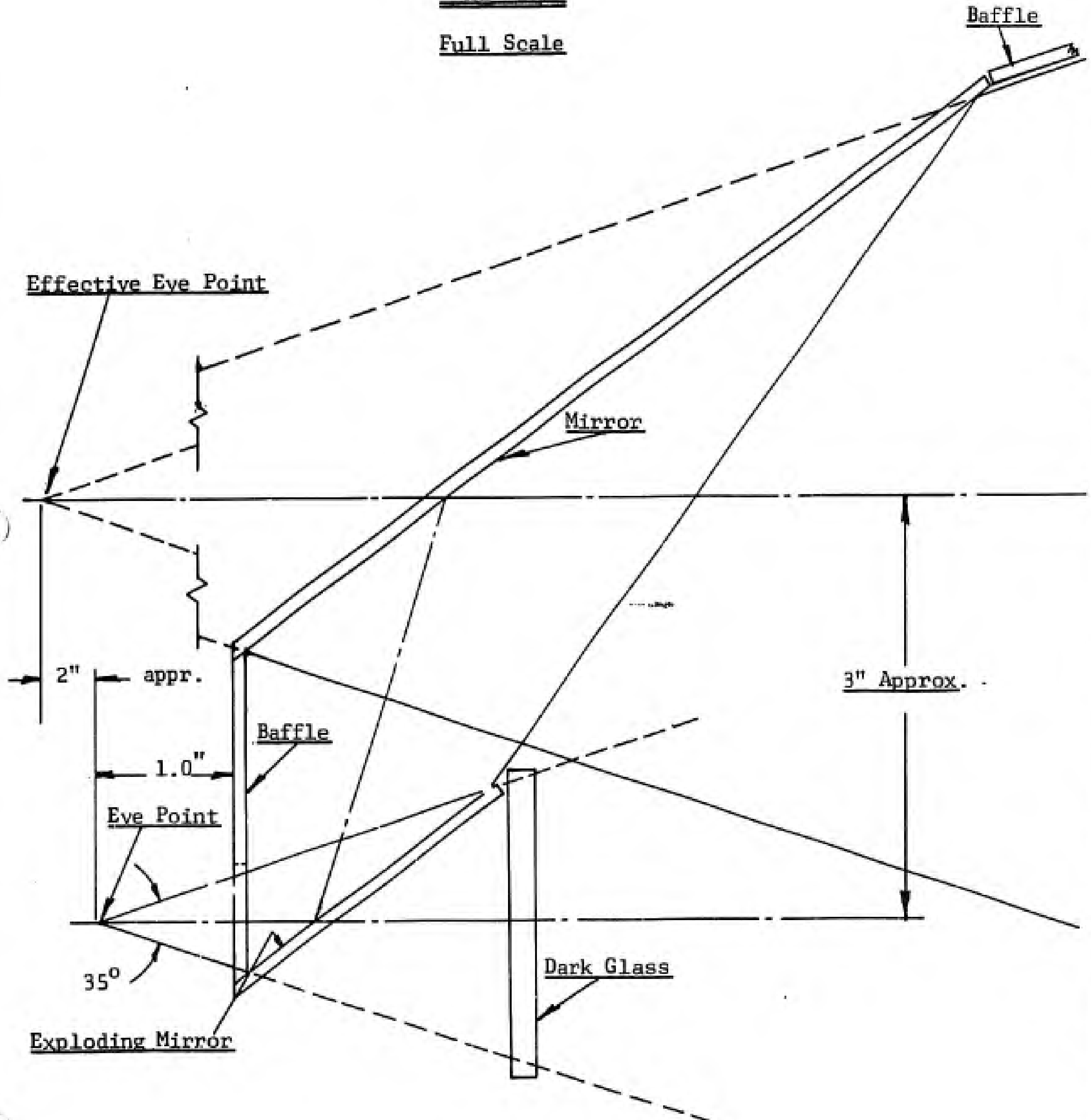
Enclosure # 9

Figure IV shows a system consisting of two unit power telescopes plus four mirrors. From an optical standpoint, this system could probably be corrected to yield almost any degree of optical quality required. Through the use of the mirrors, it is possible to make the effective eye point coincident with the real eye point.

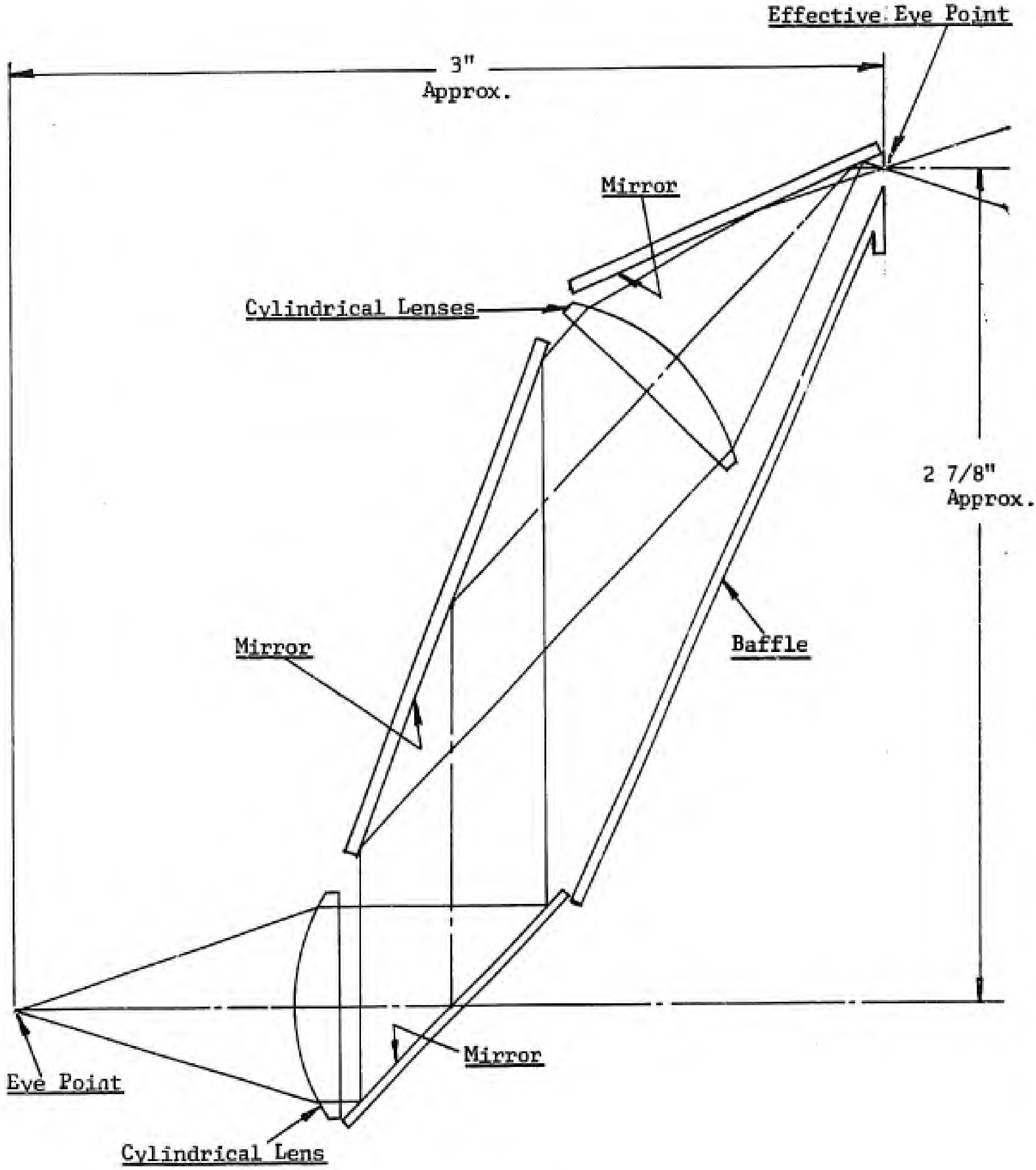
Fig. I

End View

Full Scale



Enclosure #9



End View

Scale = 2 x

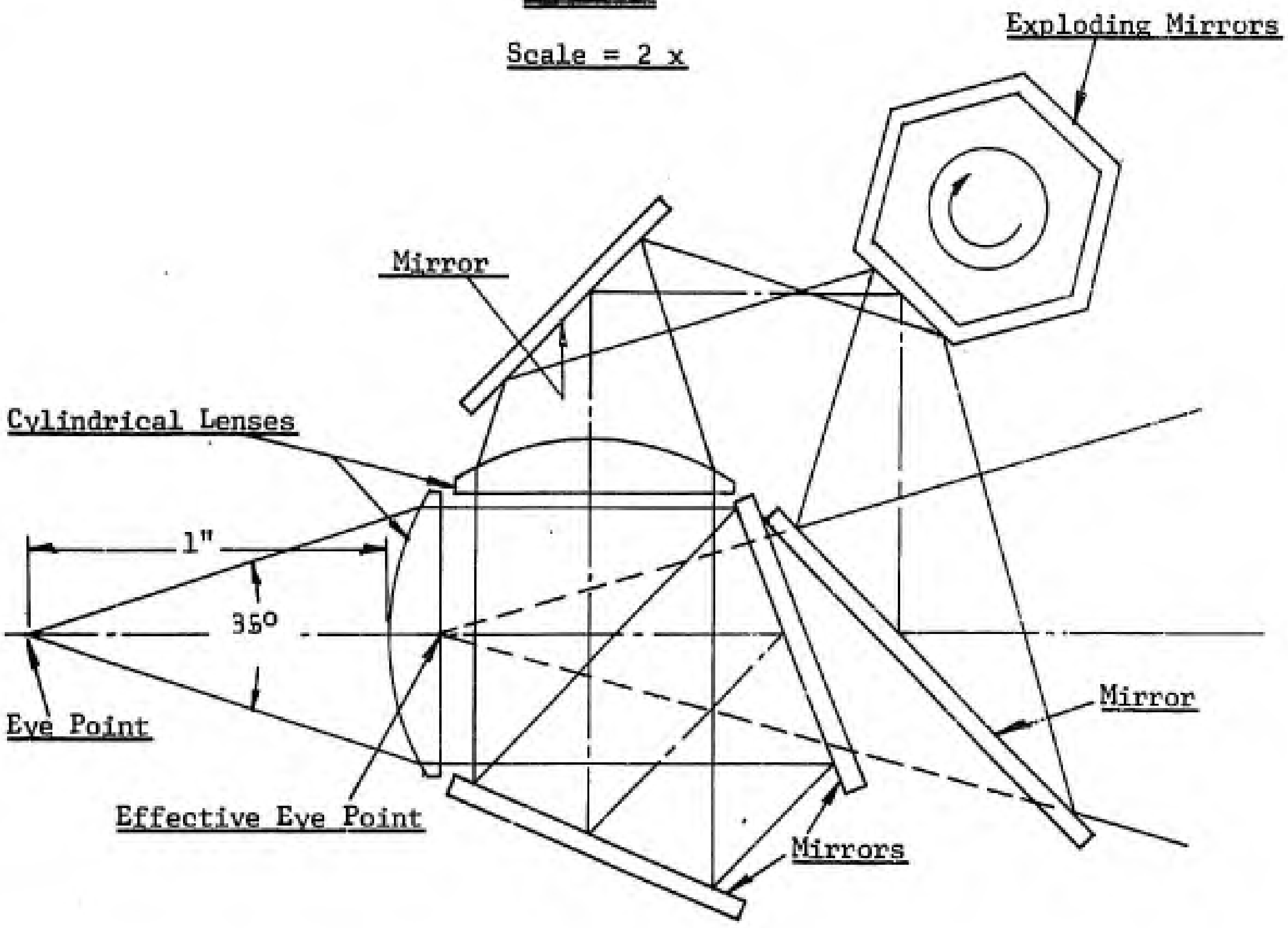
Fig. II

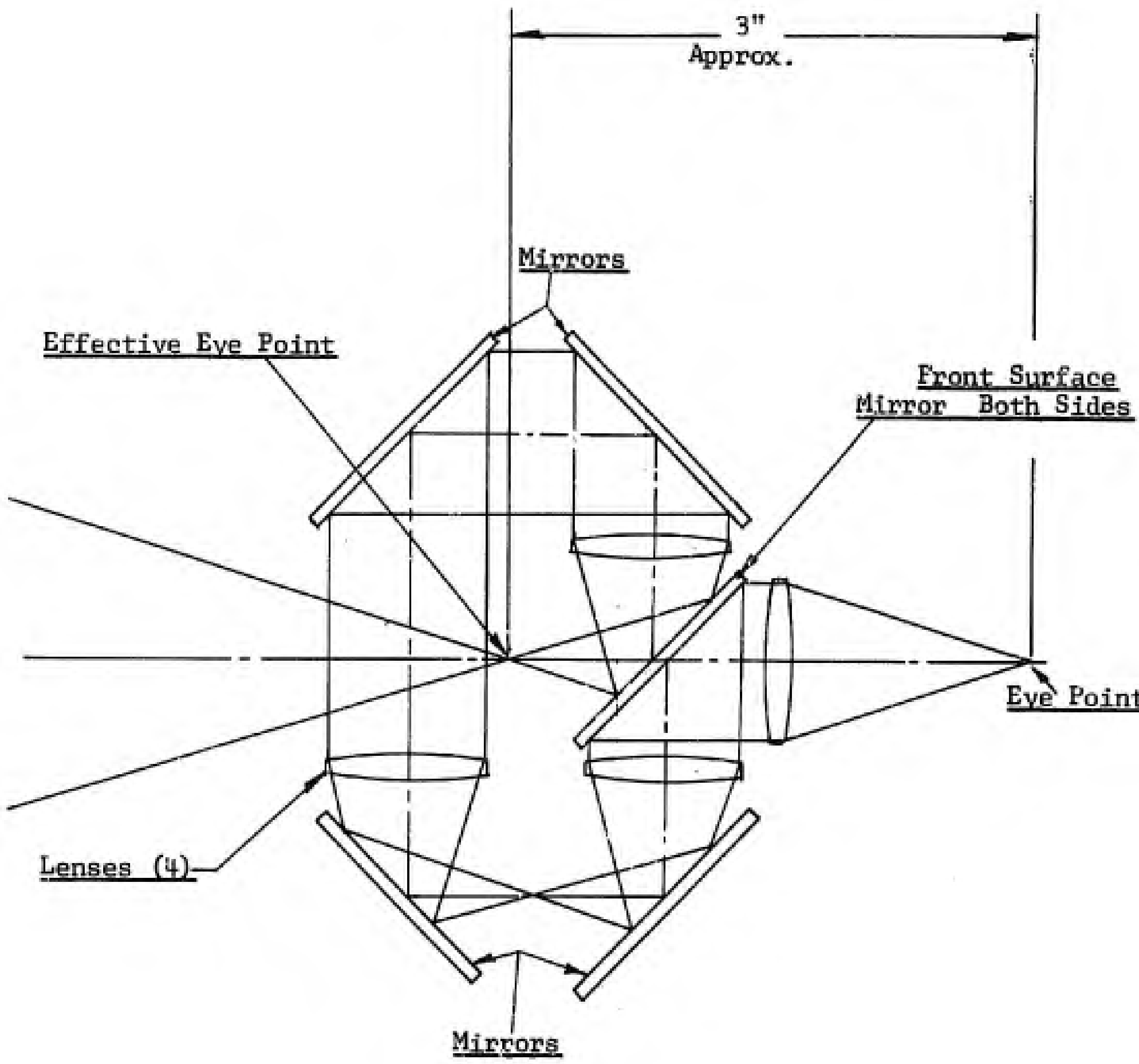
Enclosure #9

Fig. III

End View

Scale = 2 x





End View

Full Scale

Fig. IV

Enclosure #9

O M N I T E C H , I N C .
661 South Main Street
Webster, Massachusetts

M E M O R A N D U M

TO: Albert J. Laliberte DATE: 9 February 1961

FROM: James E. Johnston

SUBJECT: Optical System for Exploding Mirror, Light Restrictive Device

PURPOSE AND SCOPE

Task Progress Report, dated 20 January 1961, discussed four optical configurations adaptable to the Isomet Corp.'s exploding mirror system for flash blindness protection. It was felt that only two of these configurations warranted further study, namely Figure III and Figure IV of the Task Progress Report. This memorandum will discuss the results to date of further optical analysis and design work performed on these two systems.

DISCUSSION

The system of Figure III mentioned above will now be designated Design #1, and that of Figure IV will be designated as Design #2.

Design #1 originally consisted of a pair of cylindrical lenses, a penta-mirror, and other flat mirrors. Further analysis showed that, in order to keep the device at a reasonable size and maintain a 35° field of view, the penta-mirror could not be tolerated. The penta-mirror was replaced by a pair of cylindrical lenses and then folded with mirrors. The resulting system is shown in the accompanying drawings. This system still is only a first-order design, but the off-axis rays have been considered. The field of view in the horizontal meridians is almost full view while the vertical field is not well defined. As one goes off axis in this meridian, the amount of light reaching the pupil of the eye will diminish. There will be some vision at a 35° viewing angle, but at this point in the design the attenuation is not known.

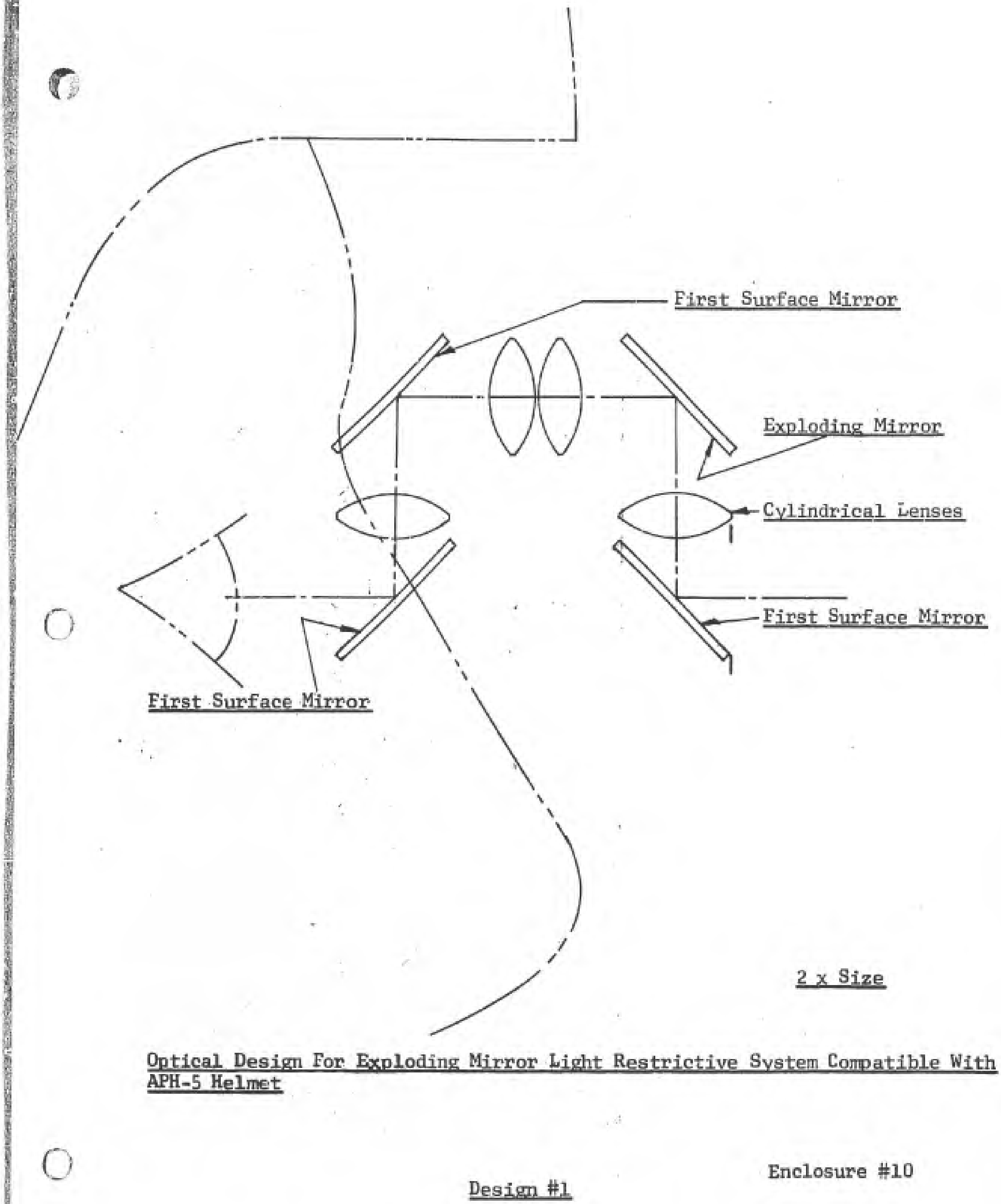
Enclosure #10

Memorandum 9 February 1961

Design #2 is very similar to Design #1. In this design the cylindrical singlets are replaced with spherical achromatic doublets. This results in a binocular system, but it would be better color corrected than Design #1.

It is interesting to note that two quite dissimilar configurations, when subjected to our design restrictions, reduce to two very similar systems. It is quite probable that after further design and analysis a single solution will result. Further work is necessary to determine whether a cylindrical or spherical system is the better, the amount of light reaching the eye at various viewing angles, and the degree to which the aberrations may be corrected. In the final analysis, the system must be set up on a lens bench and viewed through to determine whether or not the optical quality is acceptable.

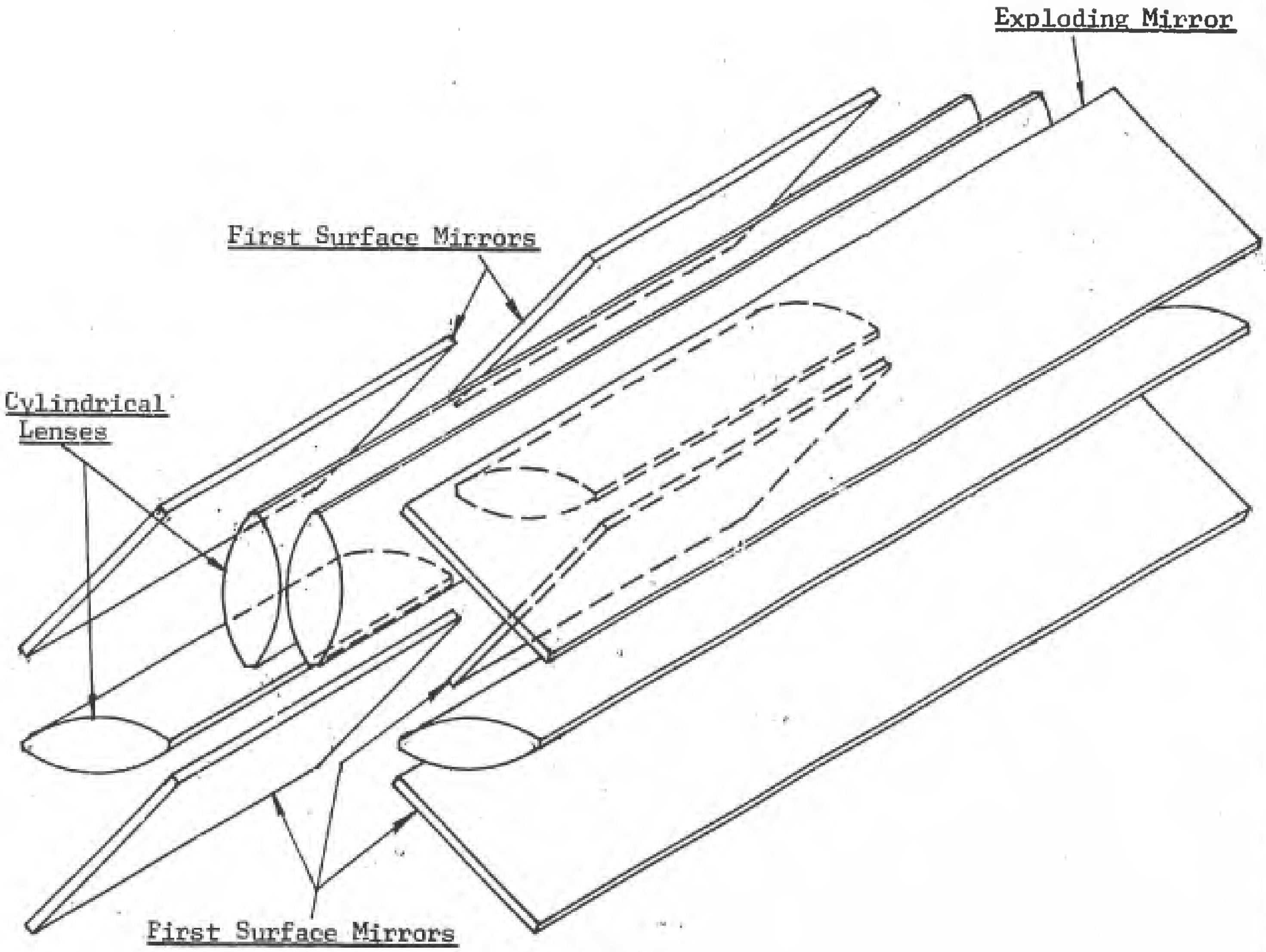
Enclosure #10



Optical Design For Exploding Mirror Light Restrictive System Compatible With APH-5 Helmet

Design #1

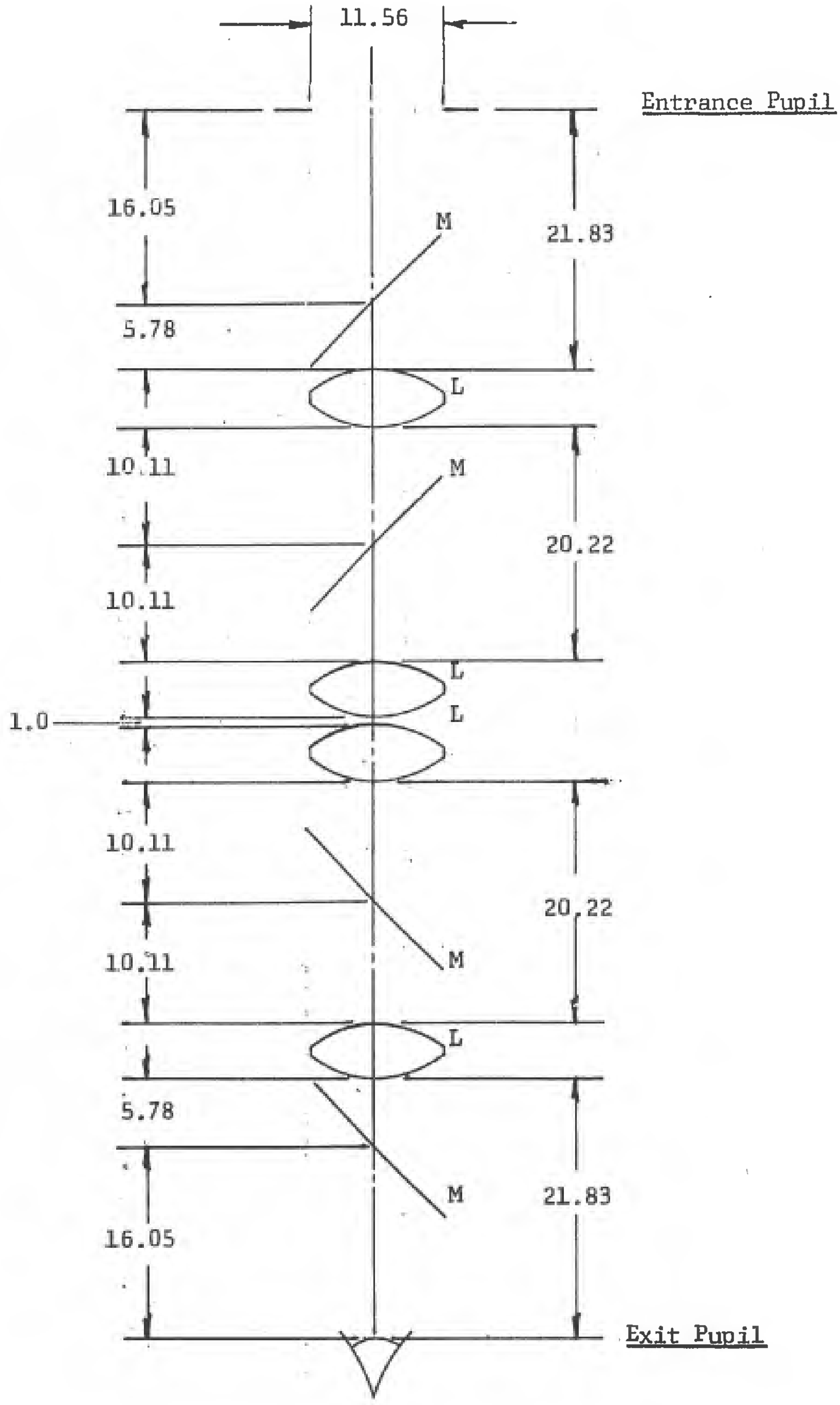
Enclosure #10



2 x Size

Isometric View of Design #1

Enclosure #10



2 x Size
Design #1

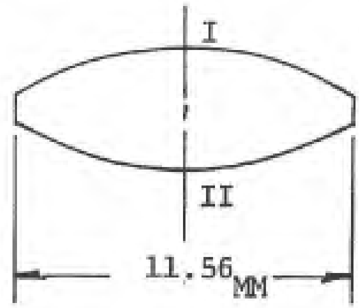
Schematic of Optical System

M = 1st Surface Mirror
L = Cylindrical Objectives

Note:
Dimensions are in M/M

Enclosure #10

Cylindrical Objective   4 x Size

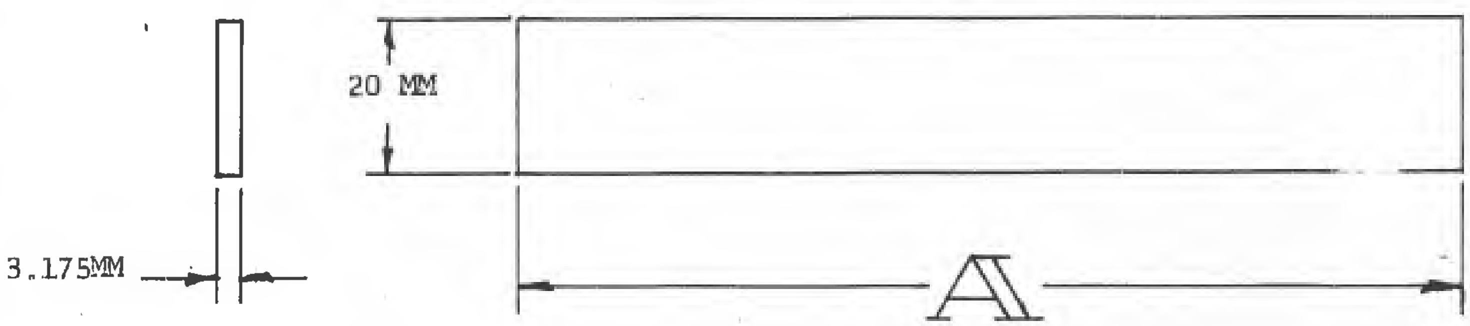


Surface I   R = 11.38 M M
II   R = 11.38 M M

Thickness = 3.969 M M
Length = See Chart
Mat'l = Spectacle Crown n_d = 1.5230 ν = 58.4

No. Req'd	Length M M
2	50.8
3	127

First Surface Mirror   Full

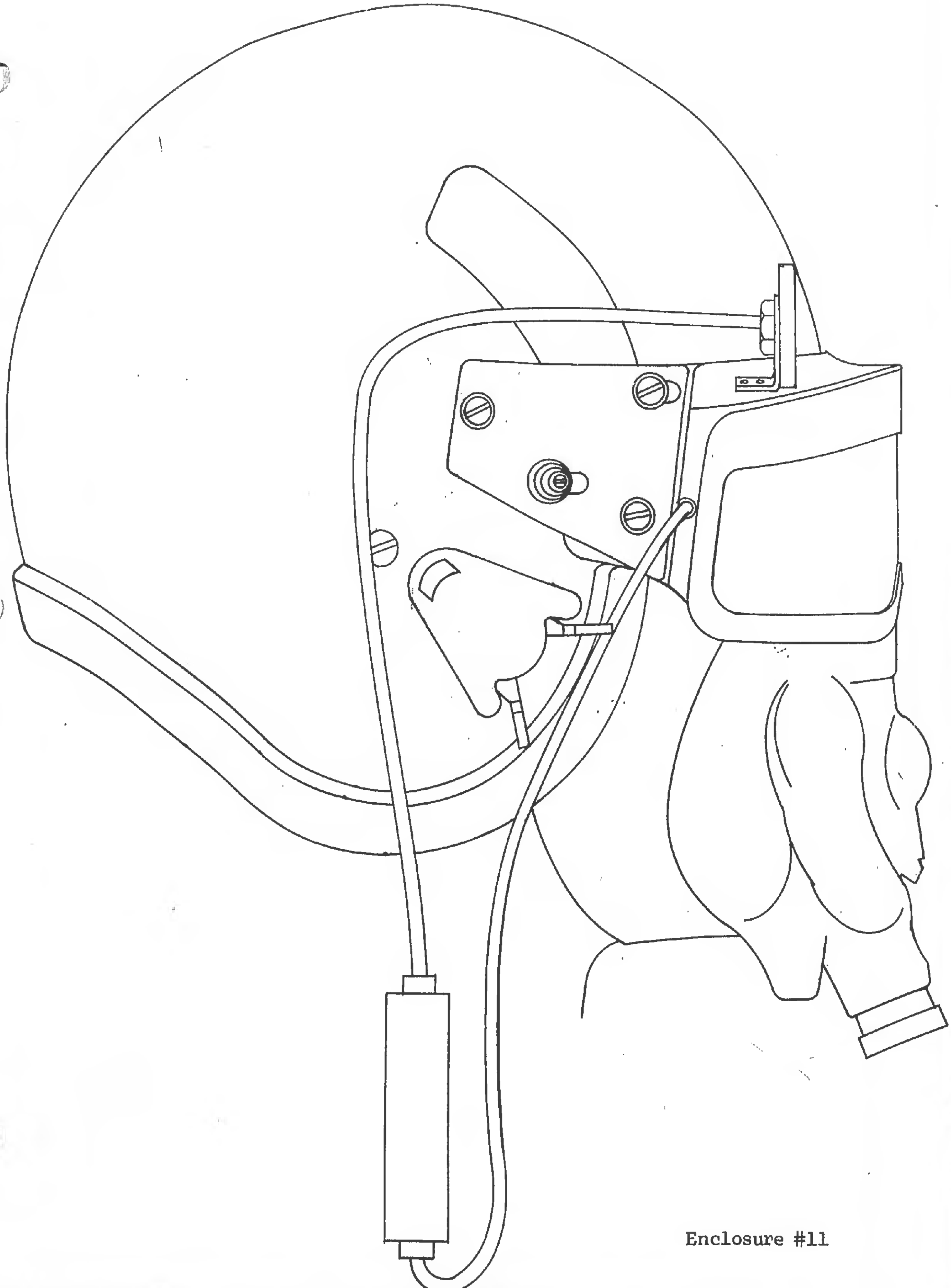


Note:
Exploding Mirror To Be 20MM Wide x 127MM Long

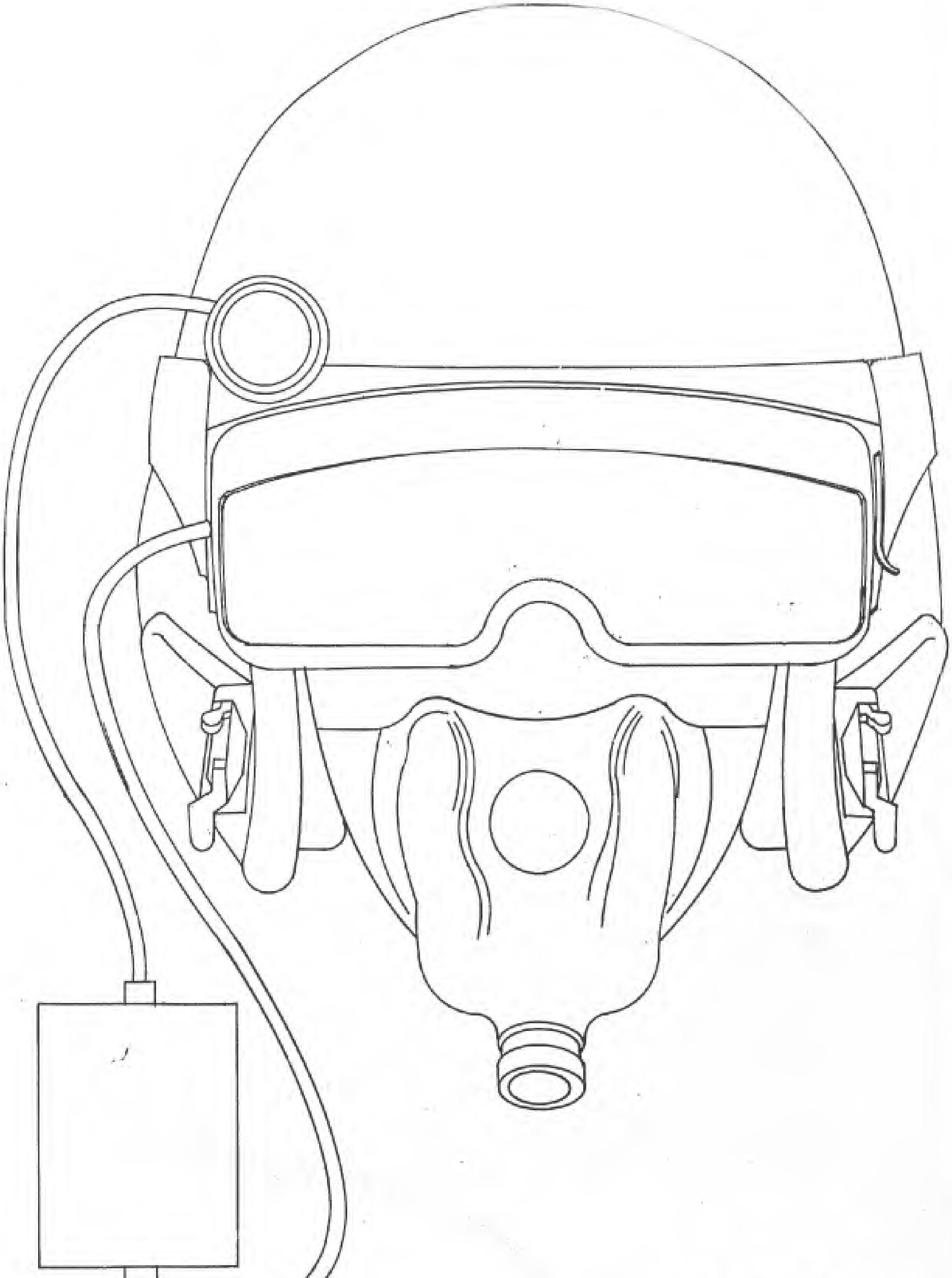
Mat'l:
Glass, Optically Flat - Aluminize One Side

No. Req'd	A
4	50.8 MM
1	127 MM

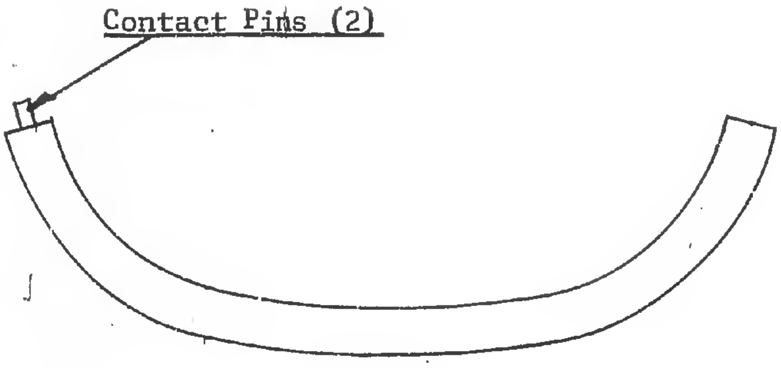
Enclosure #10

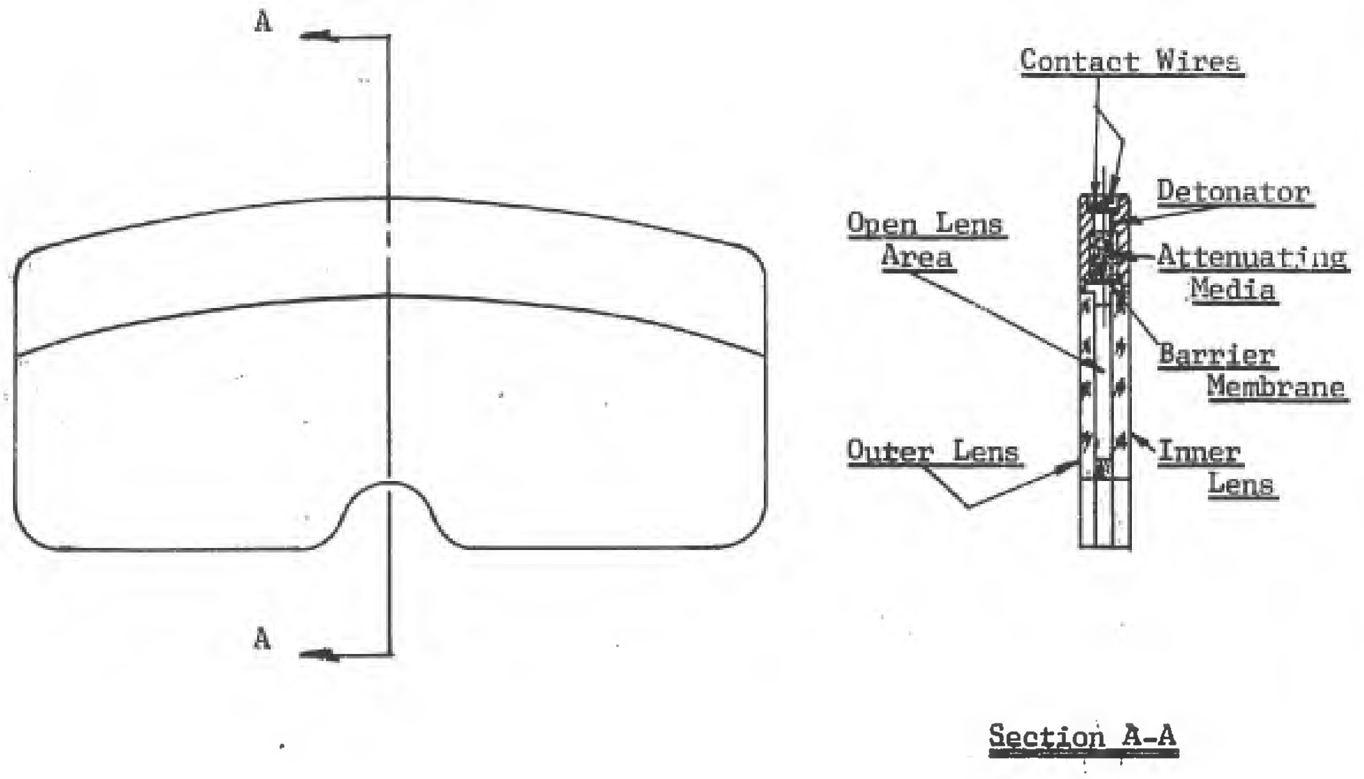


Enclosure #11

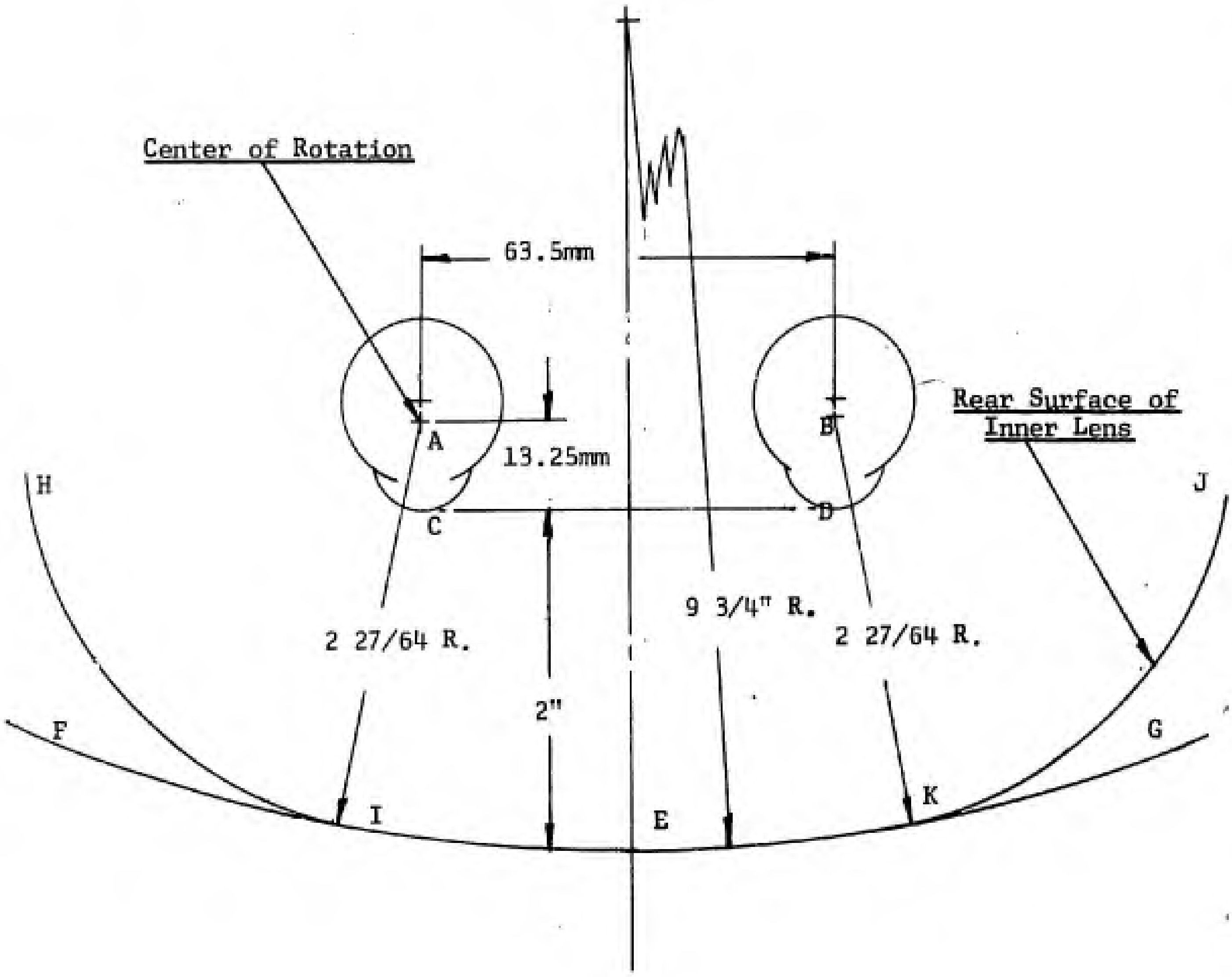


Enclosure #12





Enclosure #13



MEANS FOR DETERMINING BASE CURVE OF AN
ACYLINDRICAL LENS, BENT FROM FLAT OPTICAL GRADE PLASTIC SHEET
TO MINIMIZE PRISMATIC DEVIATION.

1) Select 2 points, A & B corresponding to the center of rotation of 2 eyes, at an interpupilary distance of 63.5 mm (2.5 in)

2) Points C & D are the front surfaces of the corneas. These points are 13.25 mm in from of the center of rotation of the eyes.

3) Assume a distance of 2" between the front surfaces of the eyes (line CD), and the rear surface of the inside lens. Establish point #E.

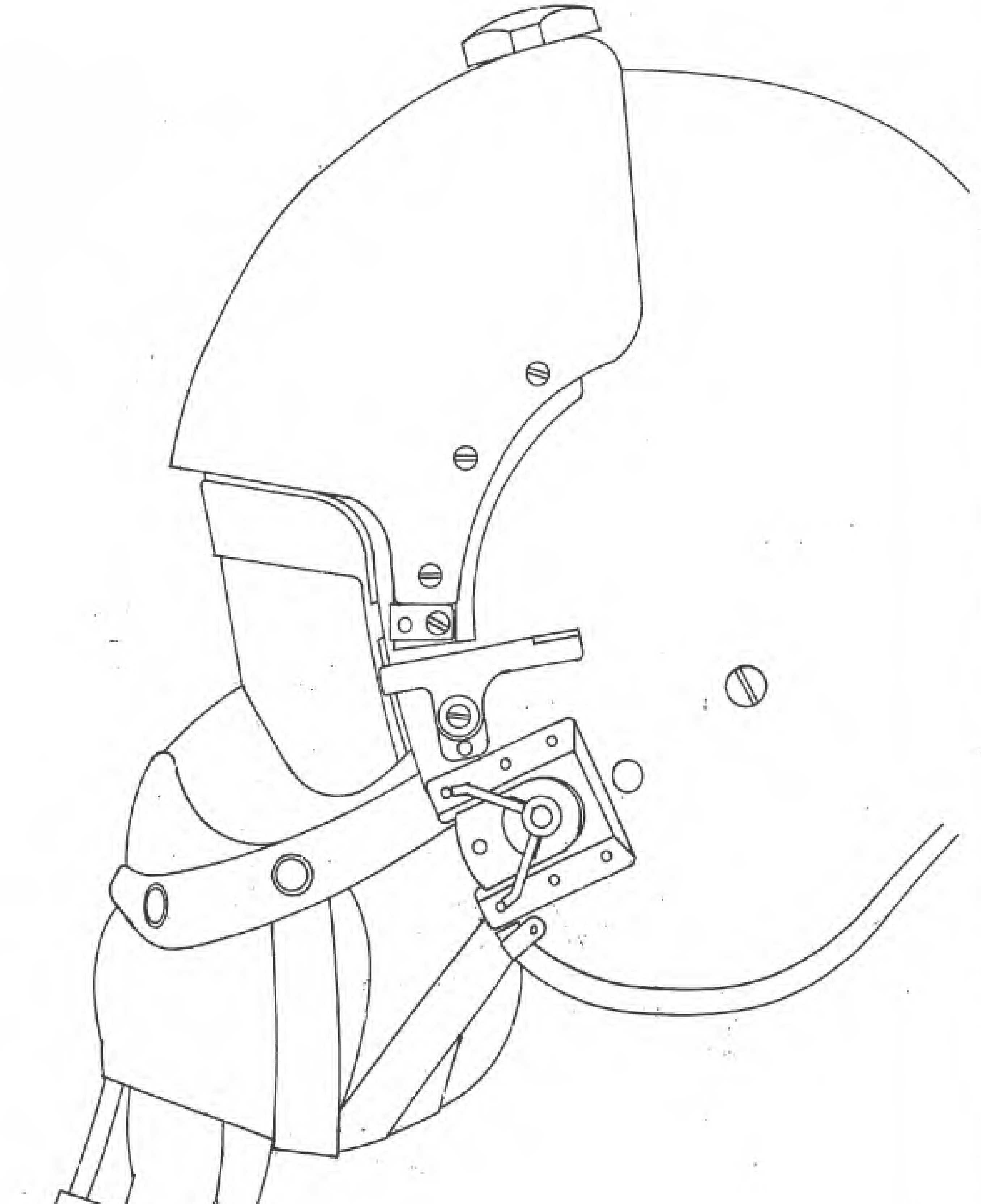
4) Through point E, draw curve FEG on center between the 2 eyes, and having a radius of 9 3/4".

5) From point A, draw curve H I tangential to FEG at point I.

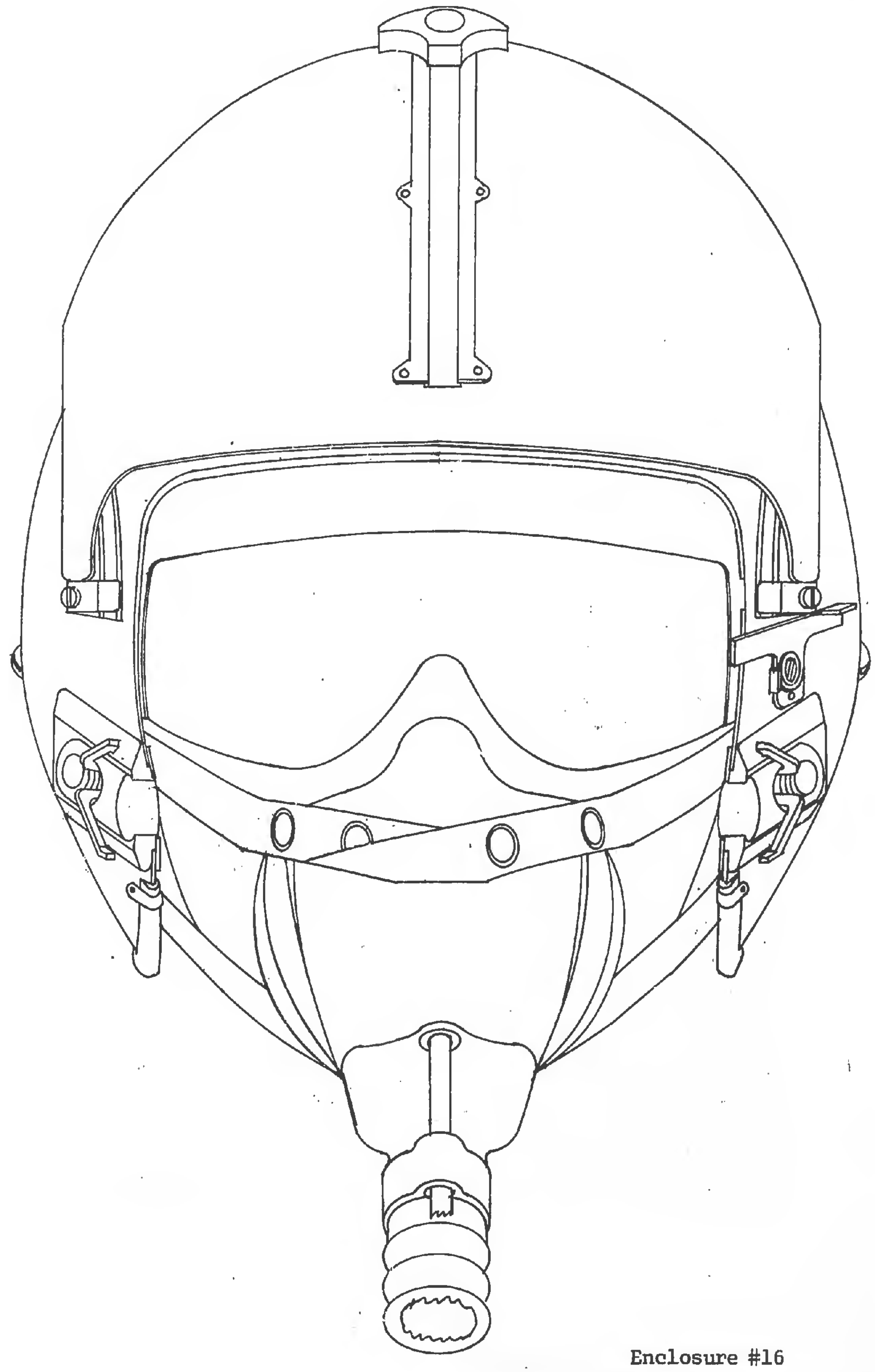
6) From point B, draw curve K J tangential to FEG at point K.

7) Curve established by J K E I H represents the top projection of the inner surface of an acylindrical lens, formed from flat optical plastic sheeting having parallel surfaces. This design provides minimum prism imbalance between the two eyes.

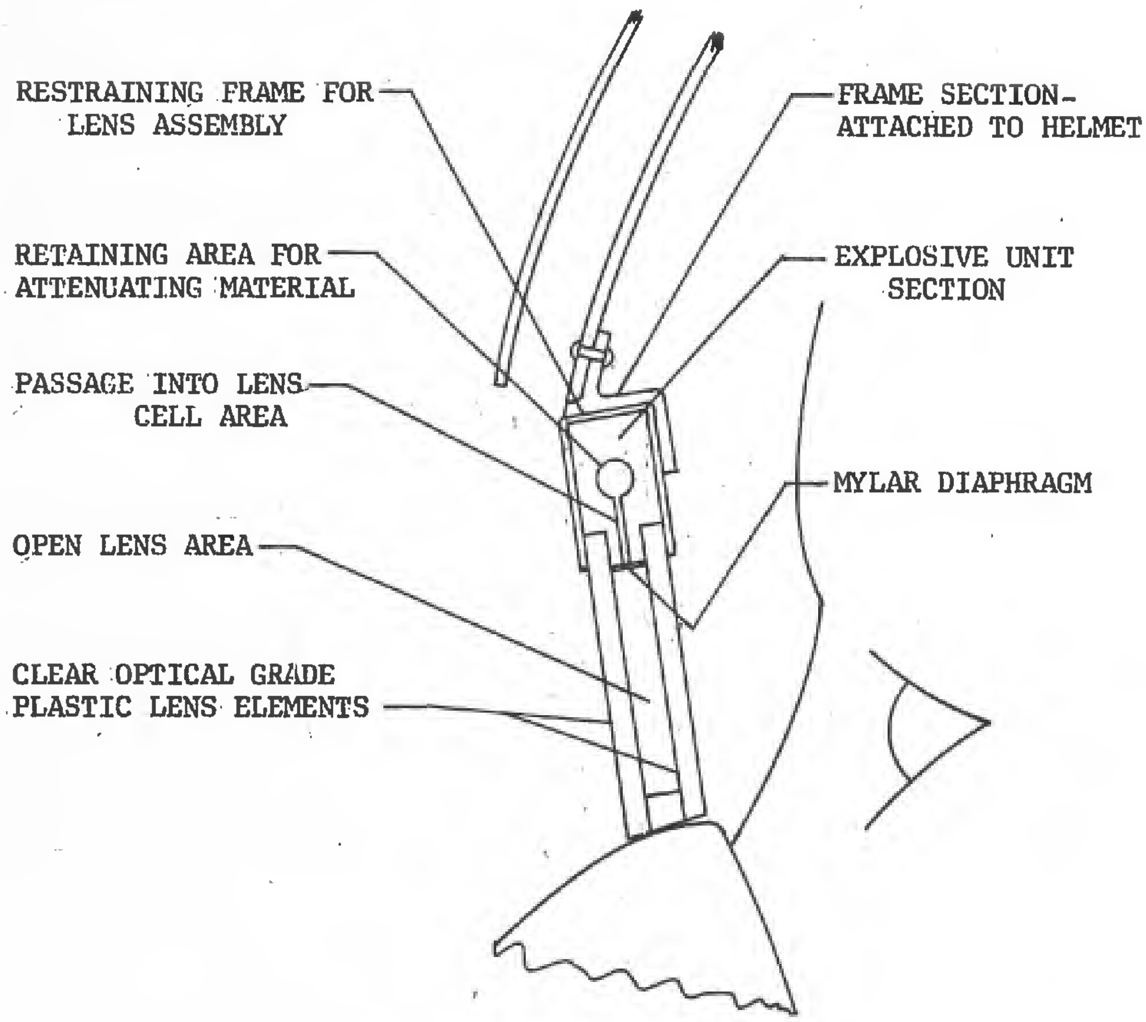
Enclosure #14



Enclosure #15



Enclosure #16



Enclosure #17

BLANK PAGE

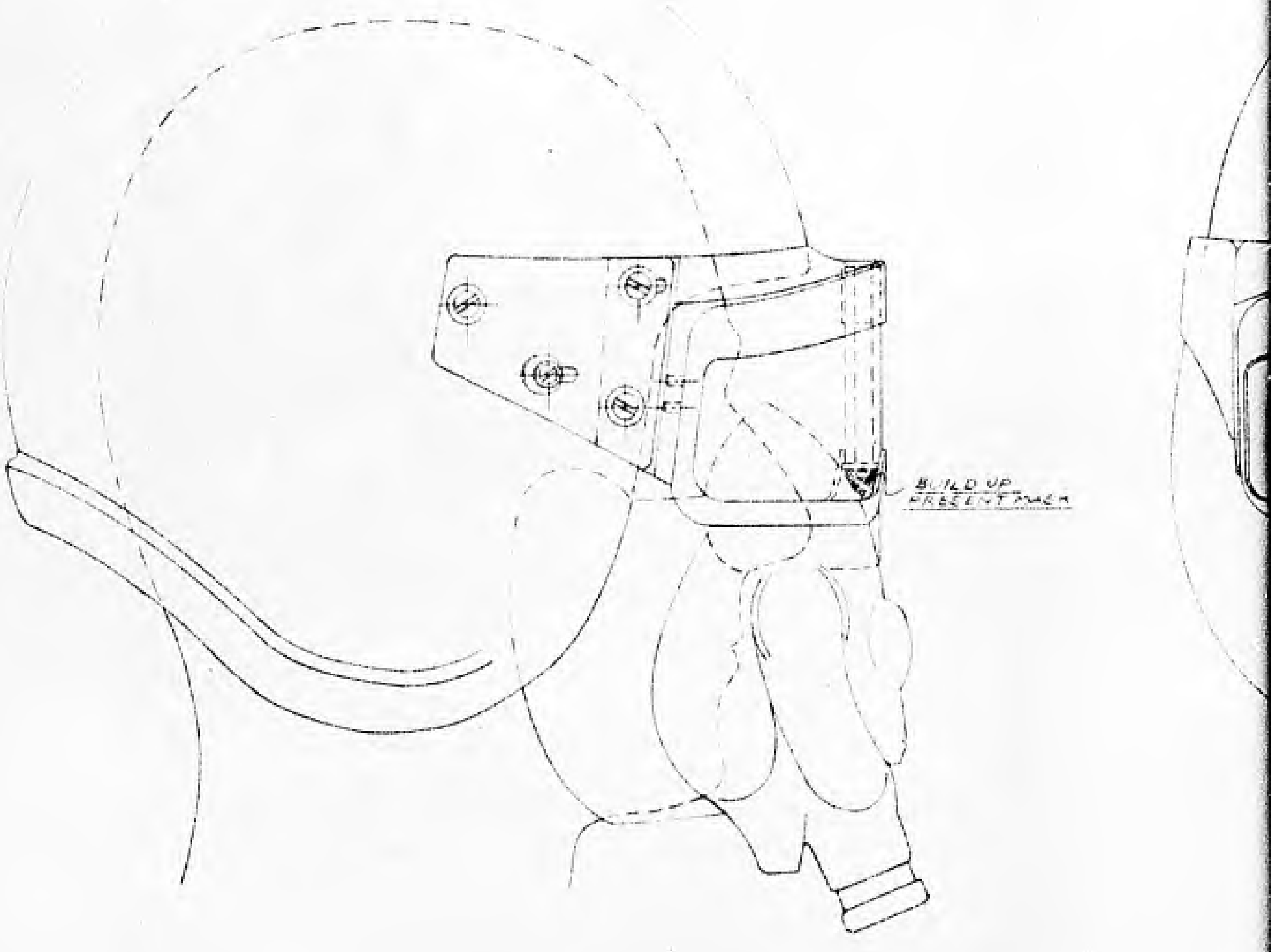
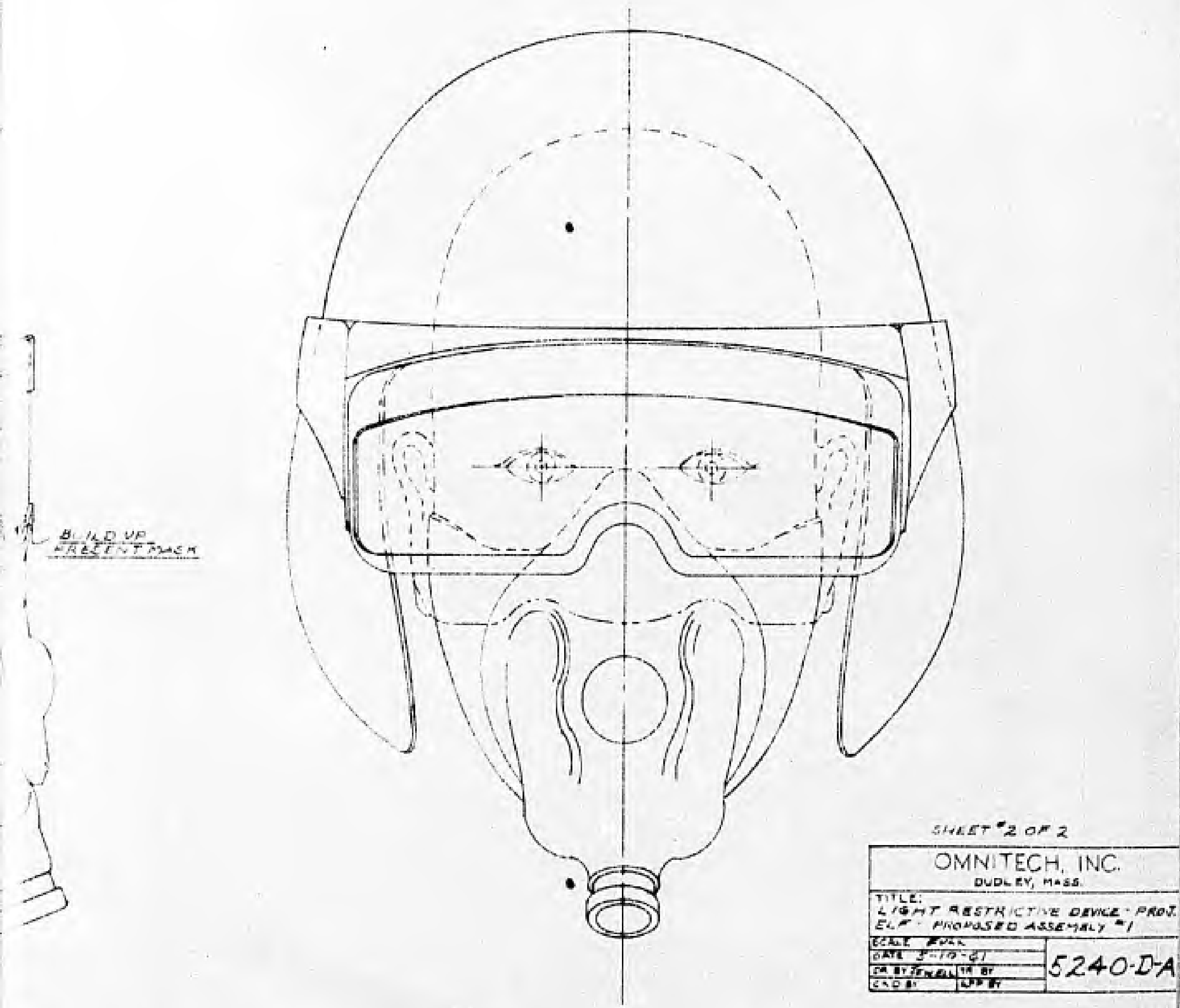


Figure 18. Front and Side View, Complete A

A



. Front and Side View, Complete Assembly

B

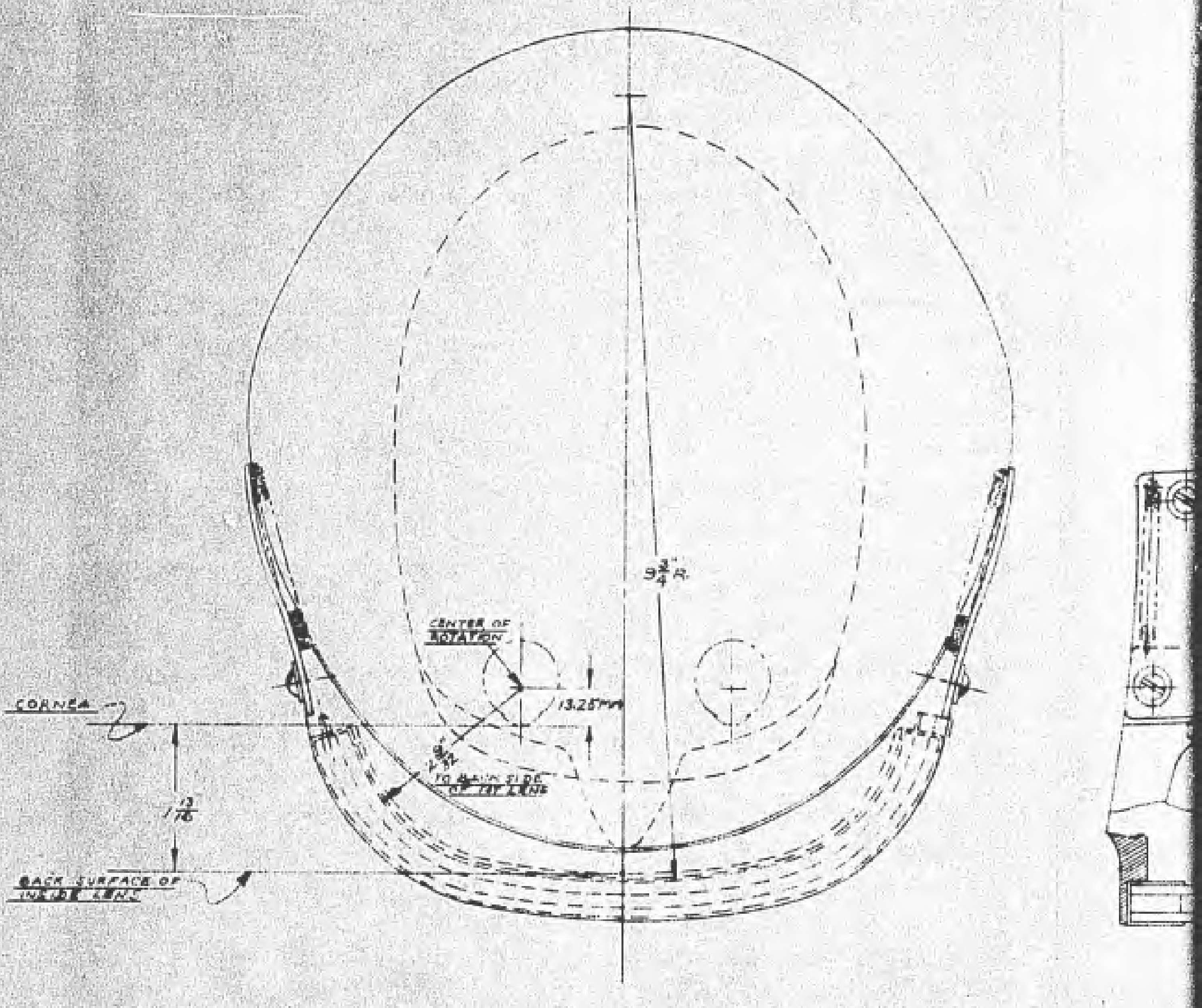
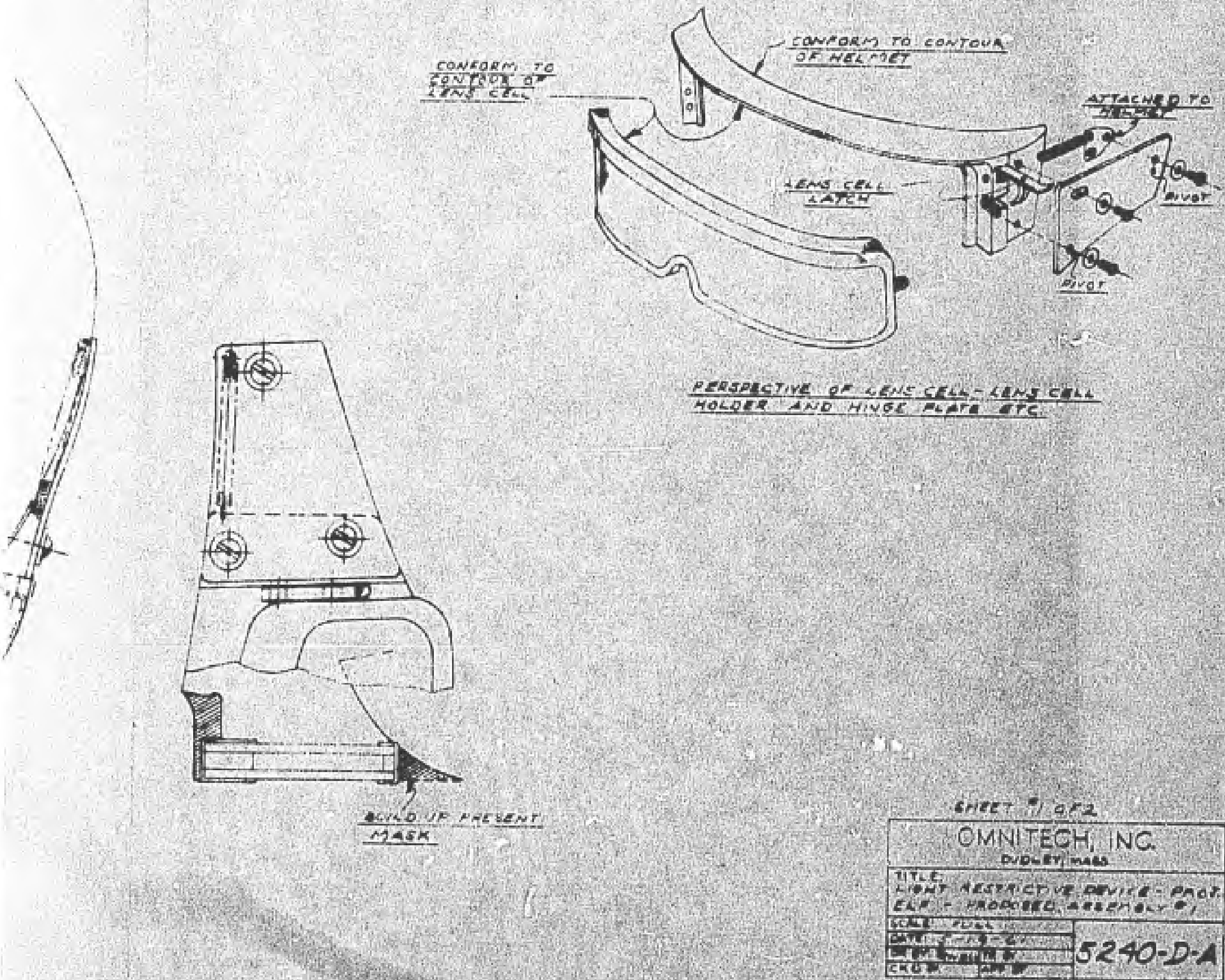


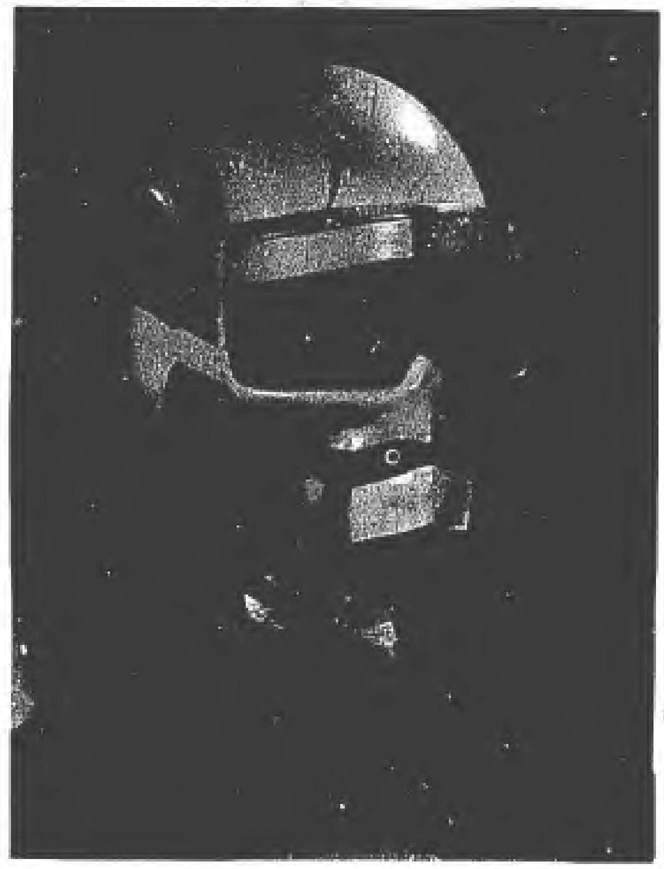
Figure 19. Top View of Complete Assembly an
Lens Cell Holder, and Hinge-R

A



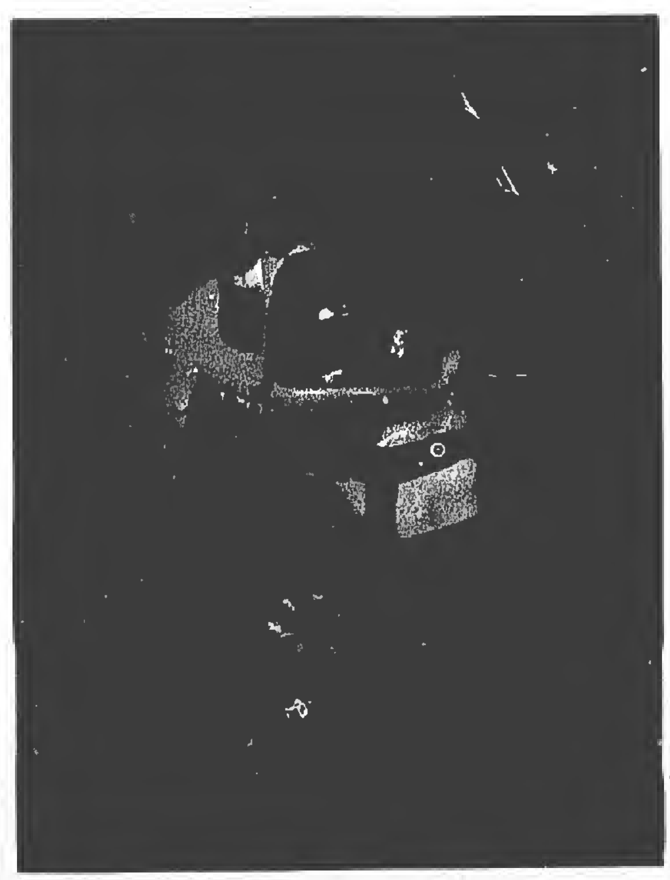
.* Complete Assembly and Exploded View of Lens Cell,
Cell Holder, and Hinge Plate Assembly

B



Light Restrictive Visor Assembly

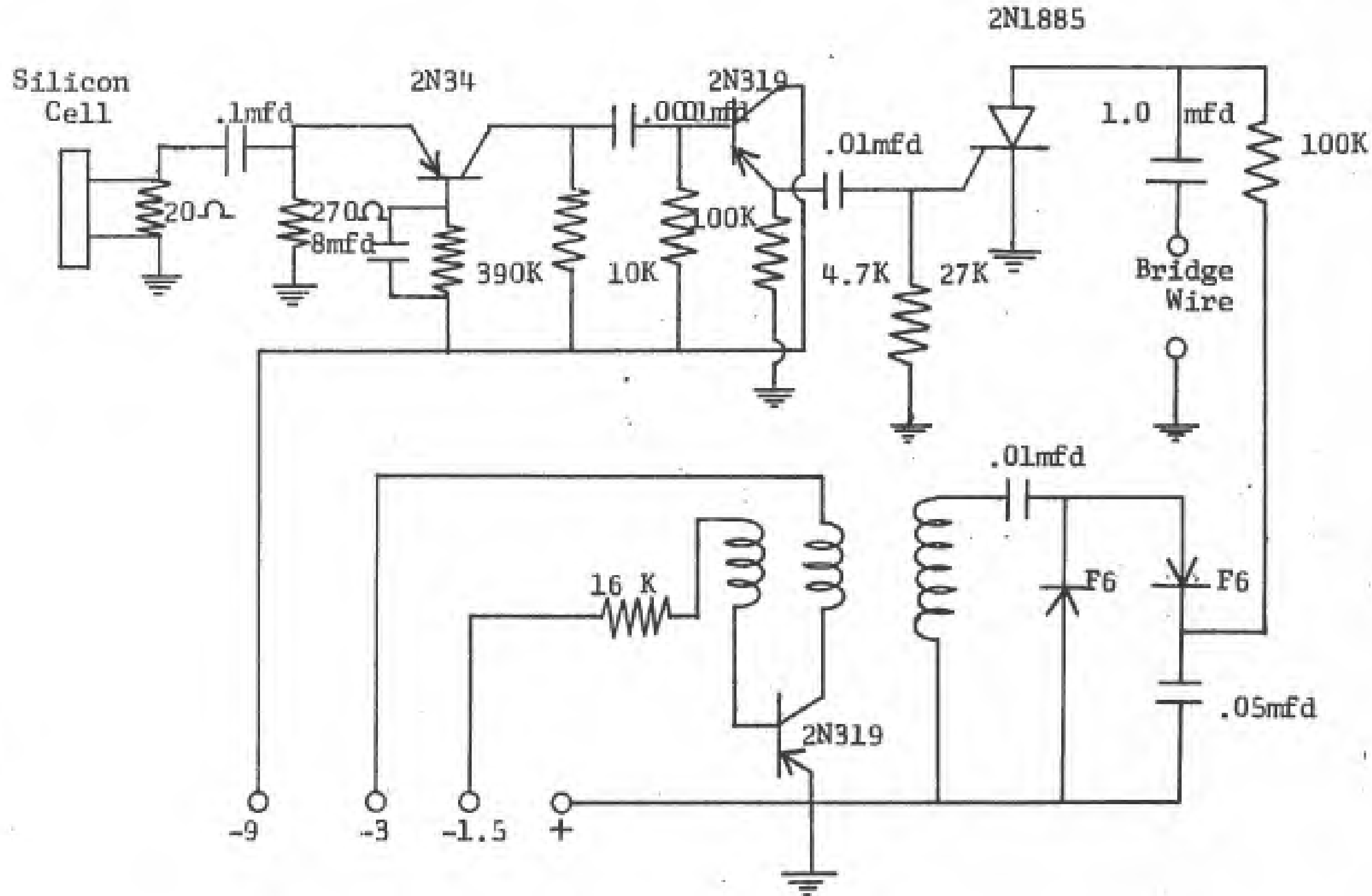
As Worn



Light Restrictive Visor Assembly

in Retracted Position

Enclosure #20

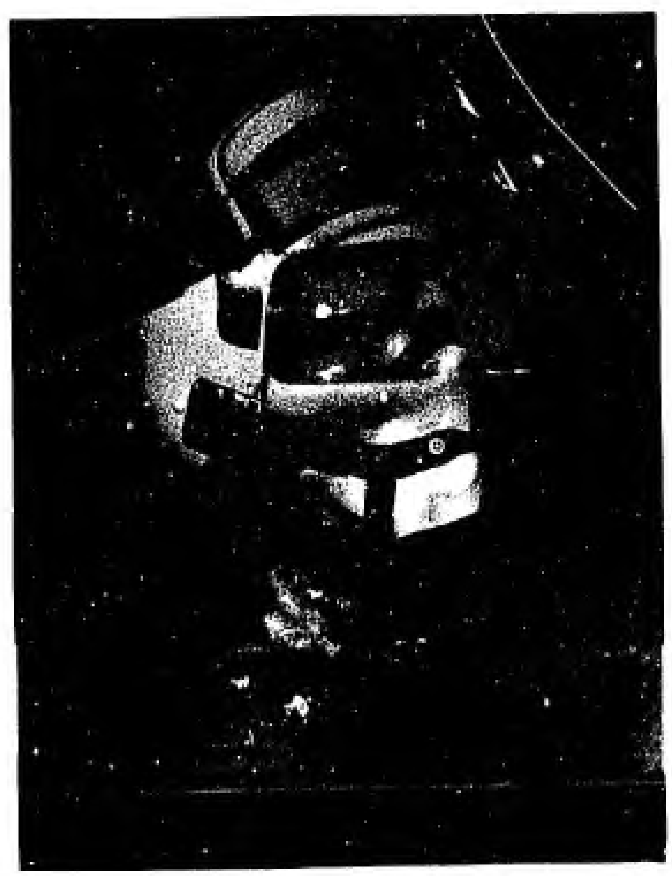


Sensor and Trigger Circuitry

Enclosure #21

Light Restrictive Visor Assembly

As Worn



Light Restrictive Visor Assembly

in Retracted Position

Enclosure #20