# PROTECTIVE EYE SHIELD AGAINST SMALL FRAGMENTS

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NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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ABSTRACT: Casualty reports from Southeast Asia indicate that eye injuries due to small fragments are a common occurrence. A need therefore exists for a shield to protect the eyes without deleterious effects on vision, sound transmission, comfort, and ability to fire weapons. This report presents the results of an evaluation of commercially available eye goggles which are in accordance with Federal Specification FSN 4240-052-3776. Ballistic data are presented on polycarbonate and cellulose acetate lens materials. It was concluded that these goggles do not provide sufficient ballistic protection. A new eye shield utilizing a polycarbonate lens was therefore designed which can be easily attached to the M-1 steel protective helmet. The shield was evaluated in Vietnam by U. S. Navy personnel and was found to meet all the requirements of protection, comfort, vision, etc. Ballistic data on the shield and construction details are given in this report.

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This is the final report of the work conducted by the Ballistics Department on the protective eye devices (NRDU-V Project 67-68). The work was performed as part of the Vietnam Laboratory Assistance Program.

The authors wish to acknowledge the cooperation and advice of Captain Jesse Adams and Mr. J. Quinlan of the Naval Medical Field Research Laboratory.

GEORGE G. BALL
Captain, USN
Commander

A. E. Seigel

A. E. SEIGEL
By direction

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## REFERENCES

1. "Final Report of Protective Eye Devices; NRDU-V Project 67-68," letter from the Commander, U. S. Naval Forces, Vietnam to Commander in Chief, U. S. Pacific Fleet, No. 3900 Ser 1496 of 9 Apr 1970
2. "Protective Eye Devices (NRDU-V Project 67-68)," letter from the Commander, River Patrol Flotilla FIVE to Chief, Naval Research and Development Unit, Vietnam, No. 3900 Ser 444 of 14 Feb 1970
3. "Assembly of Helmet Mounted Protective Masks; instructions for," letter from Stuart L. Hanlein to Chief, Naval Research and Development Unit, Vietnam, 22 May 1969

## INTRODUCTION

There has been considerable progress in the development of protective apparel for combat personnel. The steel helmet and flak jacket have contributed appreciably toward lessening the vulnerability of the human body in the combat environment. Throughout the history of modern warfare, however, there has been a need for facial protective gear for combatants. Medical-combat experience in the Delta operations of Vietnam has shown that fragmentation wounds of the face are a common occurrence. In particular, eye injuries have been on the increase, not only to Army personnel but to Naval personnel. As a result, this Laboratory was requested by the Naval Research and Development Unit-Vietnam (NRDU-V) to survey protective eye devices to determine if a suitable eye shield is commercially available. In particular, the evaluation of protective goggles identified by government Federal Stock Number FSN 4240-052-3776 was requested. Also, it was suggested that research be initiated in developing a shield for use with the present M-1 protective helmets. It was felt that a properly designed shield would reduce eye injuries by as much as 50 percent. In addition to the fragmentation protection, the shield must meet the following requirements:

a. No reduction in field of view

b. No discomfort in high temperature and humidity

c. Usable over prescription glasses or capable of being ground

d. Tinted for day, clear for night

e. No interference with firing of a rifle from the shoulder

f. No impedance of sound transmission to the wearer.

## EVALUATION OF COMMERCIAL GOGGLES

The Naval Ordnance Laboratory established contact with other laboratories and agencies that have been investigating protective equipment. In cooperation with the Naval Medical Field Research Laboratory (NMFRL) impact tests were conducted on various commercially available protective eye devices. Specific attention was given to the safety goggles FSN 4240-052-3776 as requested by

NRDU-V. These goggles were impacted by small spheres weighing from .25 to 2.0 grains to simulate fragments. These projectiles were fired at velocities ranging from 200 to 1100 feet per second. It was found that the lens material, cellulose acetate, which is currently acceptable under the federal specification mentioned, shatters and produces spallation upon impact as shown in Figure 1. Identical tests with polycarbonate lenses, which are also acceptable under the federal specifications, do not produce shattering or fragments upon impact as shown in Figure 2. Based on these comparative tests, it was strongly recommended to NRDU-V that polycarbonate lenses be used in the safety goggles in place of the cellulose acetate. There is no direct optical method to differentiate between the two materials. Therefore, NOL devised a simple test which can be used in the field to distinguish between the two materials. Of 44 physical, chemical and electrical characteristics of these two plastics, the density difference offers the easiest method of nondestructive separation. The handbook specific gravity of polycarbonate is 1.20 and cellulose acetate is 1.28 to 1.32. A sugar-water solution formed by dissolving a 5-pound bag of sugar in 2 quarts of water has a specific gravity of about 1.23. Thus, if a lens is placed at the bottom of a container filled with this solution, it will rise and float on the surface if it is polycarbonate, while a cellulose acetate lens placed in the same solution will stay at the bottom of the container. It is felt that this type of test could be conducted in the field to evaluate large quantities of suspected lenses.

Tests were conducted on goggles wi polycarbonate lenses manufactured by American Optical Company (FSN-4240-052-3776) to determine the ballistic limit against various size fragments. The eyepiece is approximately .055 inch thick. The ballistic limit for the various size fragments is given in the following table.

Table 1. Ballistic Limit of Polycarbonate Goggles (FSN 4240-052-3776)

| Fragment diameter (in.) | Fragment weight (grains) | $V_{50}$ Ballistic limit (fps) |
|---|---|---|
| .0625 | .259 | 1200 |
| .093 | .86 | 850 |
| .125 | 2.0 | 700 |
| T-37 simulator (.22 caliber) | 17 | 410 |

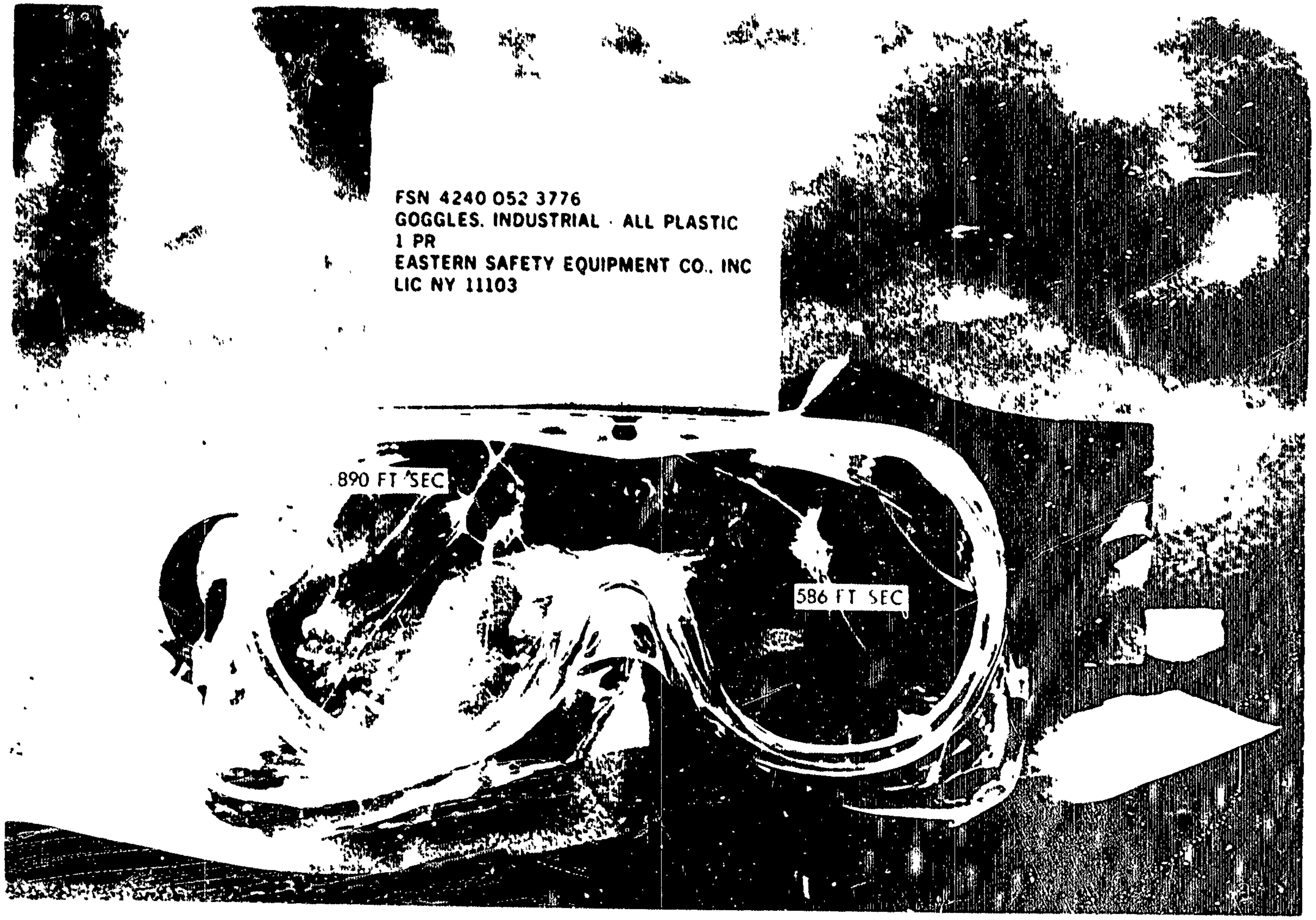


FIG. 1 TEST RESULTS FROM FIRING 1/8" DIAMETER STEEL SPHERES (2.02 GRAINS) AT GOGGLES WITH CELLULOSE ACETATE LENSES

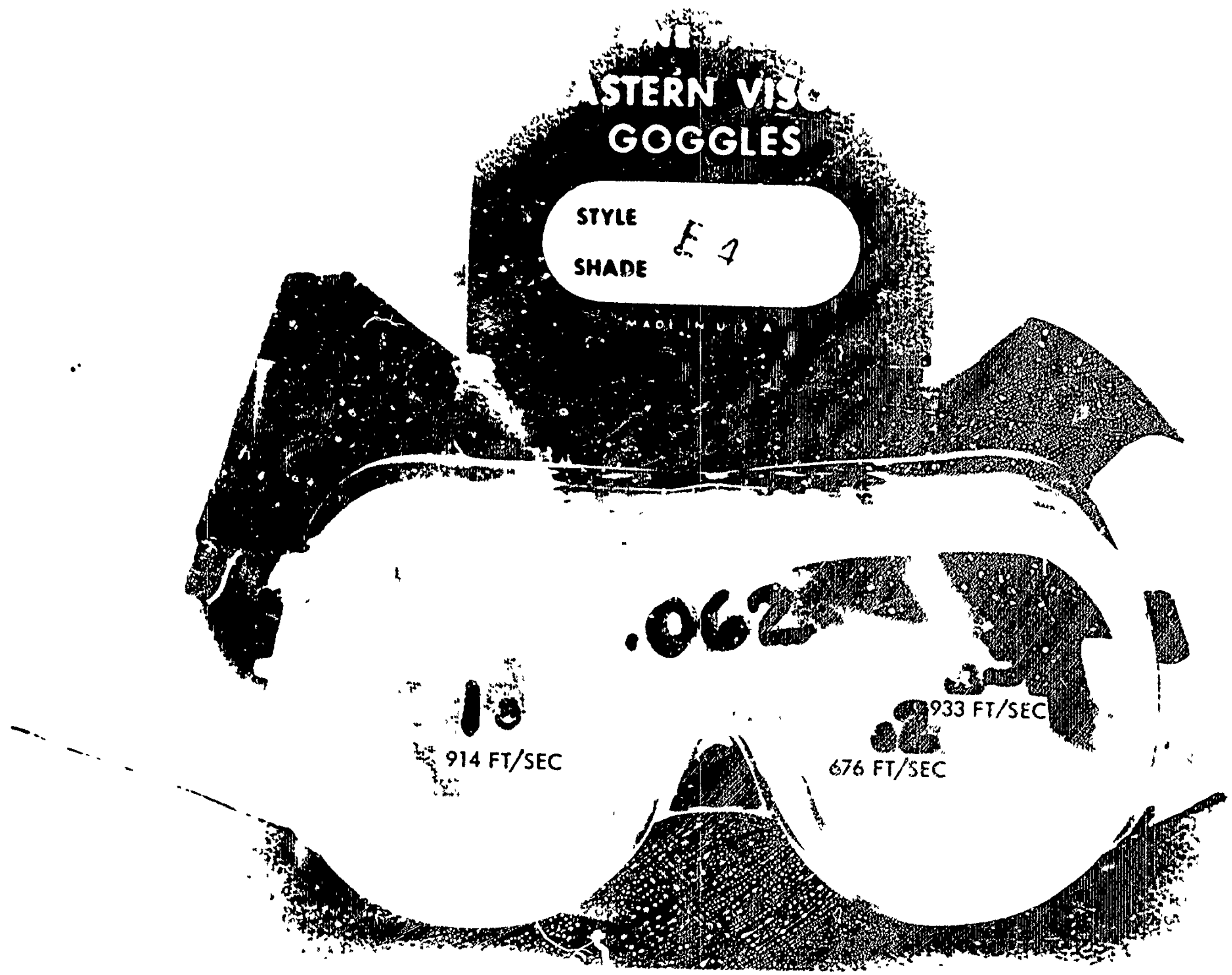


FIG. 2 TEST RESULTS FROM FIRING 1/8" DIAMETER STEEL SPHERES (2.02 GRAINS) AT GOGGLES WITH POLYCARBONATE LENSES

In none of the tests with polycarbonate was spallation off the back surface obtained. Failure was either petaling or by a shear plug.

Based on the results of the tests performed, it was concluded that polycarbonate lenses should be specified whenever ordering goggles according to Federal Specification FSN 4240-052-3776. Disadvantages of these goggles are:

a. Tend to block field of view; particularly in the lateral direction.

b. Discomfort in high temperature and high humidity because of lack of adequate ventilation.

c. Protection over a small percentage of the facial area.

d. Do not provide sufficient protection against the small fragmentation particles that cause the majority of eye injuries received in combat (see ref. 1).

e. The variety of manufacturers and materials used makes it difficult to identify acetate or polycarbonate lenses installed in the same Federal Stock Number goggles (ref. 1).

As a result, it was concluded that a new eye shield should be designed to offset these disadvantages. This was done by NOL as described in the following.

## NOL EYE SHIELD DESIGN AND EVALUATION

### A. Design

Based on the results of the preceding tests, a program was initiated to develop a new shield. Polycarbonate was considered to be the best transparent lens material. The first task was to determine the ballistic limit of the polycarbonate as a function of thickness. The results of these tests are presented in Appendix A. The amount of protection, determined by the $V_{50}$ ballistic limit, does not increase as greatly above .125 inch of thickness as the material thickness is increased. Considering this factor and the increasing weight as the thickness is increased, an optimum thickness was determined to be about .080 inch.

After consulting with various other governmental agencies, it was found that the Naval Medical Field Research Laboratory had proposed a protective eye device which would incorporate the use of a polycarbonate visor presently being used in helicopter pilots' helmets. The visors are available as federal stock items produced by the U. S. Army Natick Laboratories. The basic visor design was modified slightly and a clamping device was designed to secure the visor to the M-1 steel helmet. Two models were designed and fabricated as shown in Figures 3 and 4.

FIG. 3 HELMET MOUNTED PROTECTIVE MASK, MODEL 1

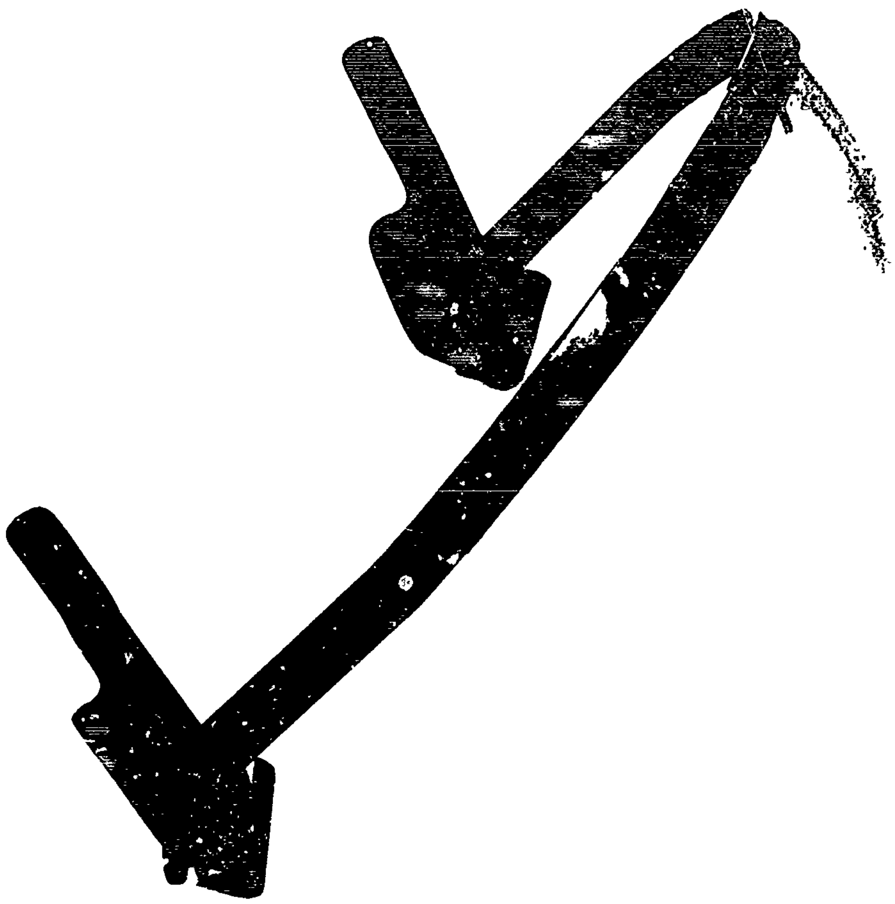

FIG. 4 HELMET MOUNTED PROTECTIVE MASK, MODEL 2

The components of Model 1 are shown in Figure 5 and the components of Model 2 are shown in Figure 6. Basically, both shields consist of a clear plastic visor and an aluminum frame for raising and lowering the visor and also for securing the entire assembly to the M-1 field helmet. The visor is fabricated from polycarbonate, which is a transparent thermoplastic material with excellent impact properties. The pivoting frame assembly is fabricated from 5052-H32 aluminum and then anodized dull black. The panhead screws and thumbscrews are made of brass and then blackened by an Ebanol-C treatment.

The assembled shields are shown in Figures 3 and 4. The crimped portion of the pivoting assembly is slipped over the head around the edge of the M-1 field helmet. This assembly is held in place by two thumbscrews on the outer edge of the fixed support on both sides of the helmet. The total weight of Model 1 is 7.9 ounces and Model 2 is 4.7 ounces.

The major difference between these two models is the protective cover shield provided with Model 1. This shield is fabricated from polycarbonate and then painted olive drab. This shield protects the clear visor from accidental scratching when the visor is in the "up" position. The clear visor is held in the "up" position by an interference fit between the fixed and the pivoting members of the pivoting assembly. This interference fit acts as a simple locking mechanism. To lower the clear visor, slight outward pressure is applied to the fixed support and the pivoting support is pushed downward. From Figure 7 it can be seen that the visor does not interfere with the wearer's eyeglasses, nor does it interfere with firing of a rifle from the shoulder or prone position.

Ballistic tests were conducted on the complete eye shield mounted to a helmet which in turn was placed on a simulated head. The ballistic limit $V_{50}$ for a 17-grain T-37 simulator fired from a .22-caliber gun is 630 feet per second. The ballistic limit for a 2-grain steel sphere is 1050 feet per second. Note the corresponding ballistic limits for the best available commerical goggle are 410 feet per second and 700 feet per second, respectively. Thus, the ballistic protection has been increased by about 50 percent.

Various commercially available protective eye devices, such as safety glasses and visors of riot control helmets and motorcycle helmets, have been investigated by NOL and compared to the polycarbonate visor. To date, no better commercially available product or mask has been found.

Complete instructions for installation of the eye shield to the M-1 helmet are given in reference 1.

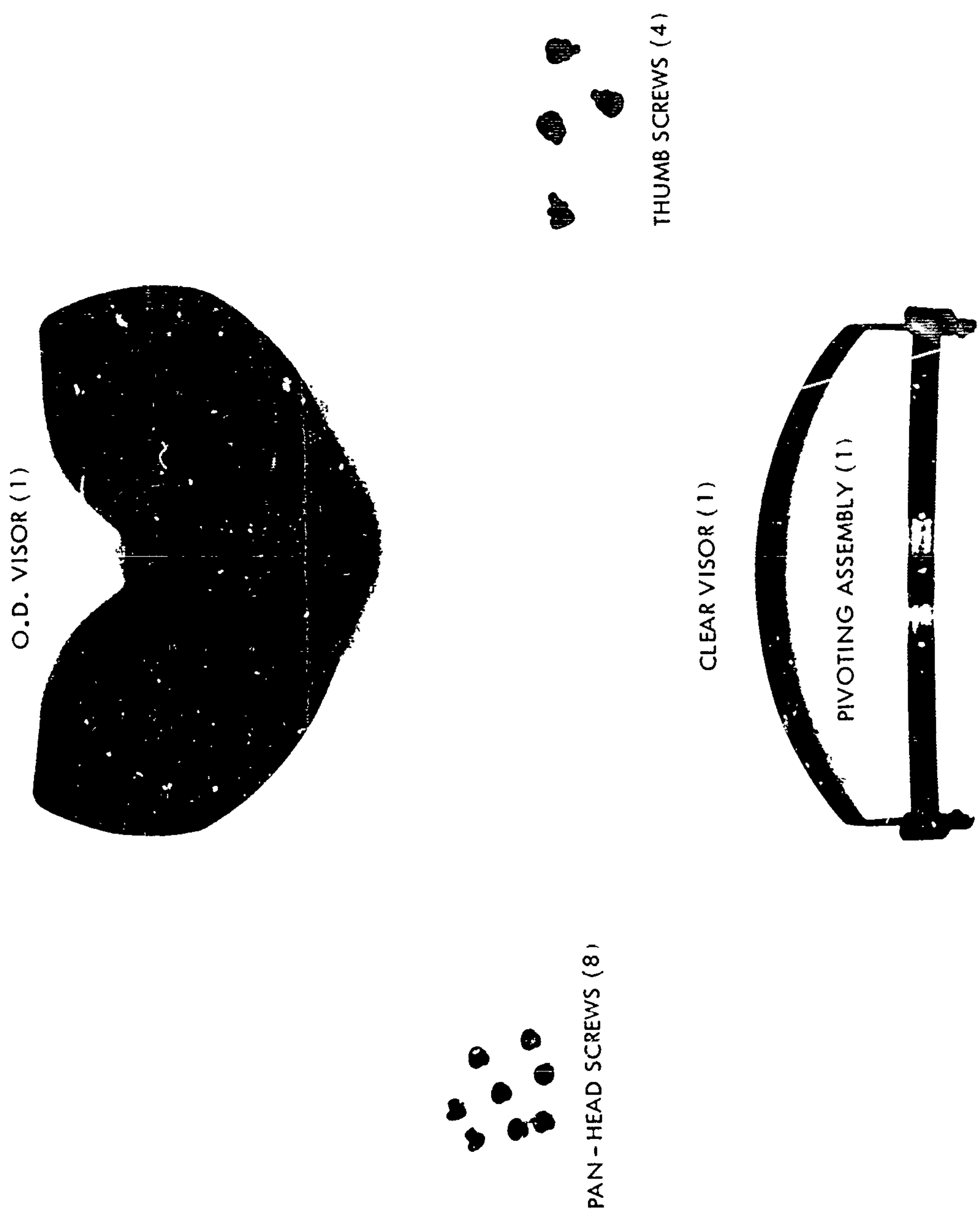


FIG. 5 COMPONENTS OF HELMET MOUNTED PROTECTIVE MASK MODEL 1

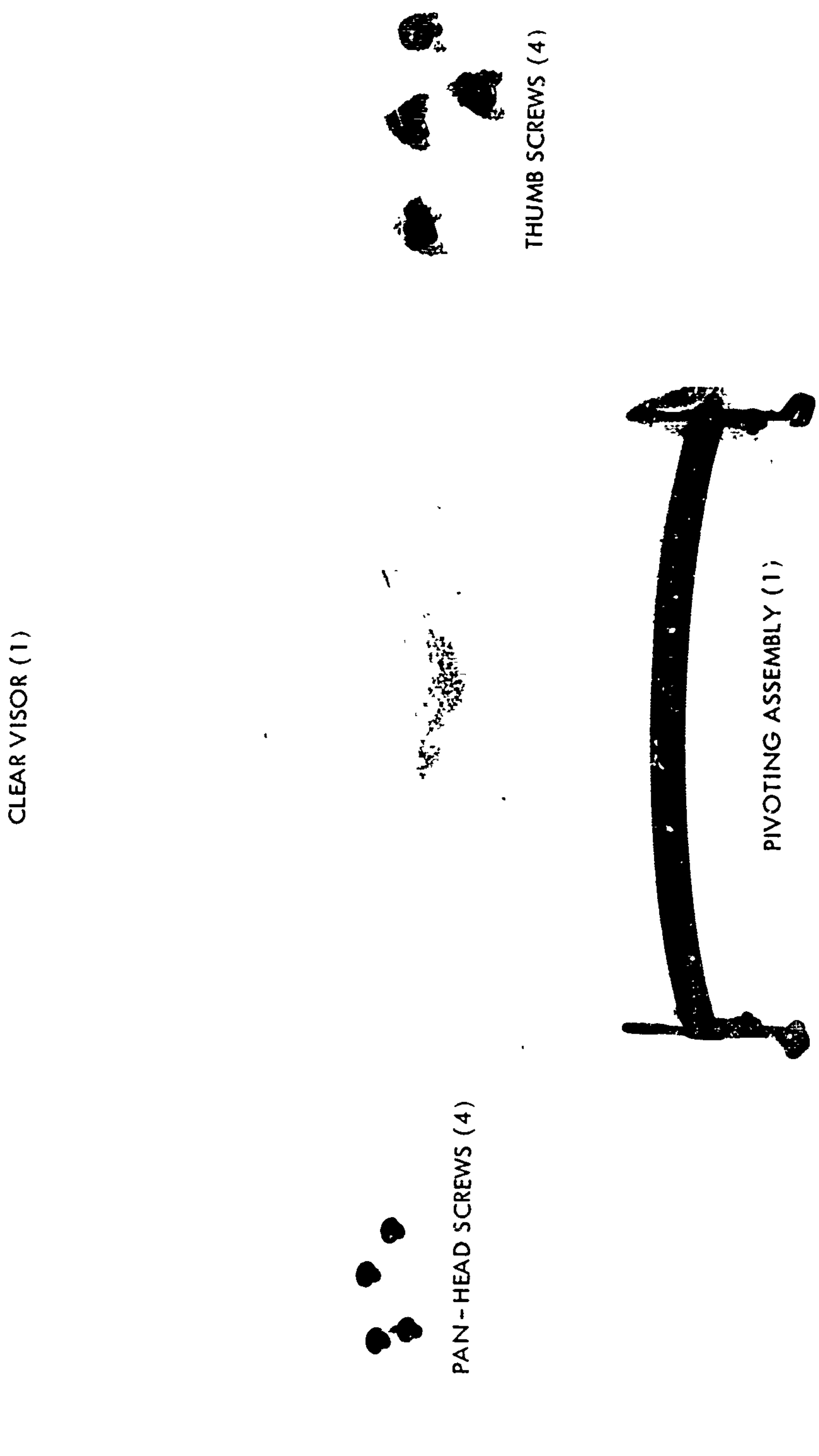


FIG. 6 COMPONENTS OF HELMET MOUNTED PROTECTIVE MASK MODEL 2

MODEL 2, VISOR DOWN

MODEL 1, VISOR UP

MODEL 2, FIRING POSITION

MODEL 1, FIRING POSITION

FIG. 7 ILLUSTRATIONS OF THE USE OF THE MODELS 1 & 2 IN VARIOUS POSITIONS

B. Evaluation of NOL Face Shield in Vietnam

In order to evaluate the eye shield under combat environment, NOL Models No. 1 and No. 2 were sent to Vietnam. It was desired to have a direct comparison made between the two types of shields. To accomplish this, it was specified that the same personnel should use both of the shields for the same specified period of time. A minimum evaluation period of two weeks per shield was specified. After using the helmet-mounted shield for the specified time period, the wearer was requested to complete a questionnaire similar to the sample shown in Appendix B.

The results of the evaluation from the field are given in references 2 and 3. Twenty sets of eye shields were evaluated, ten with protective shield visor (Model No. 1) and ten without (Model No. 2). These were issued to Commander, River Division 572, with instructions to evaluate on regular patrols for a period of 30 days. The combination of visor and guard shield received good crew acceptance when mounted on the steel protective helmet M-1. Neither model reduces the field of vision, nor interferes with firing of weapons. Both were found to be comfortable and usable over prescription glasses.

The eye shield with protective visor (Model No. 1) is considered the better of the two models because the visor protects the eye shield from scratches or damage and eliminates glare and reflection from the eye shield when in the raised position. The slight additional weight of the protective visor is not objectionable. After approximately four months of continual use and constant exposure to salt air, the eye shields, while slightly yellowed, are in excellent condition and the support frame and joints continue to function effectively.

It was concluded (ref. 2) that the steel helmet-mounted visor provides the required protection to significantly reduce the number of eye injuries from small fragments. The currently available safety goggles FSN 4240-052-3776 do not provide the same degree of protection afforded by the NOL eye shield.

The eye shield with protective visor is considered suitable for use by Navy combatants. Based on experience of the evaluator, it should be readily accepted and regularly used. An initial outfit of five per PBR is recommended. It was recommended that consideration be given to make the NOL eye shield (Model No. 1) standard equipment on helmets issued to all U. S. Navy combatants in-country.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following conclusions are made:

a. Lenses made of cellulose acetate and polycarbonate meet the requirements of Federal Specification FSN 4240-052-3776 for eye protection goggles. Polycarbonate has excellent impact properties against small fragments at low velocities while cellulose acetate shatters and throws off back surface spall under identical impact conditions. Cellulose acetate is therefore considered an unacceptable material for goggles and should be removed from goggles in the field and replaced with polycarbonate. A simple test based on specific gravity has been devised by NOL to distinguish between the two materials. The ballistic limit of the polycarbonate lens in these goggles is 410 feet per second for a .22-caliber T-37 simulator (17 grains), and 700 feet per second for a 2-grain steel sphere.

b. An eye shield has been developed by NOL which provides many improvements over currently available commercial eye goggles. Polycarbonate appears to be the best available transparent material for the lens. Based on ballistic tests, .080 inch appears to be a near optimum thickness. The ballistic limit of the shield is 630 feet per second for .22-caliber T-37 fragment simulator, and 1050 feet per second for a 2-grain steel sphere. The shield designated as Model No. 1 meets all the requirements for ballistic protection, comfort, transmission of sound, vision, ruggedness, and compatibility with firing of weapons from the shoulder. This has been confirmed by field evaluation in Vietnam.

It is suggested that the following recommendations received from the Vietnam field evaluation be implemented:

(1) That an initial outfitting of clear visor and guard shield kits (Model No. 1) be provided to outfit those boats operating on inland waterways.

(2) That the evaluation report (refs. No. 2 and 3) be taken as a study to assist in the redesign of the steel protective helmet M-1 so that future issues of this helmet incorporate this additional safety feature.

(3) That the U. S. Naval Safety Center publish pertinent information and pictures of the installation kit so that other potential users can be informed of its existence.

(4) That Naval Material Command provide sufficient kits to retrofit steel protective helmets M-1 to meet planned stock demands.

(5) That the Military Specifications under which FSN 4240-052-3776 All Plastic Goggles are accepted be reviewed for adequacy.

# APPENDIX A

## TERMINAL BALLISTICS TESTS OF POLYCARBONATE MATERIAL

This appendix contains the results of tests conducted to determine the ballistic limit of polycarbonate material as a function of thickness. The ballistic limit $V_{50}$ is defined as that velocity necessary to just perforate the thickness 50 percent of the time. The residual velocity is essentially zero. Fragments were simulated by .0625-, .093-, and .125-inch diameter steel spheres, and by a .22-caliber T-37 fragment simulator. The spheres were fired from a gas gun and the T-37 simulators were fired from a .22-caliber smoothbore rifle. Velocity of the projectiles was measured just prior to impact by light screens spaced approximately 2 feet apart. The first series of tests was conducted on thin polycarbonate plates of 5-inch diameter and square plates 5 inches on a side. The plates were rigidly mounted in a fixture. Figure A-1 shows the results of those tests for polycarbonate with a thickness ranging from .010 inch to .0625 inch and sphere size ranging from .0625-inch diameter to .125-inch diameter. Figure A-2 shows the results for a .22-caliber T-37 simulator against polycarbonate thicknesses ranging from .020 inch to .1875 inch. The areal density (thickness times the density of target) is also shown. Note that the ballistic limit appears to flatten out as the thickness is increased. This means that the increase in weight by increasing the thickness results in a small payoff as far as ballistic limit for thicknesses greater than about .080 inch.

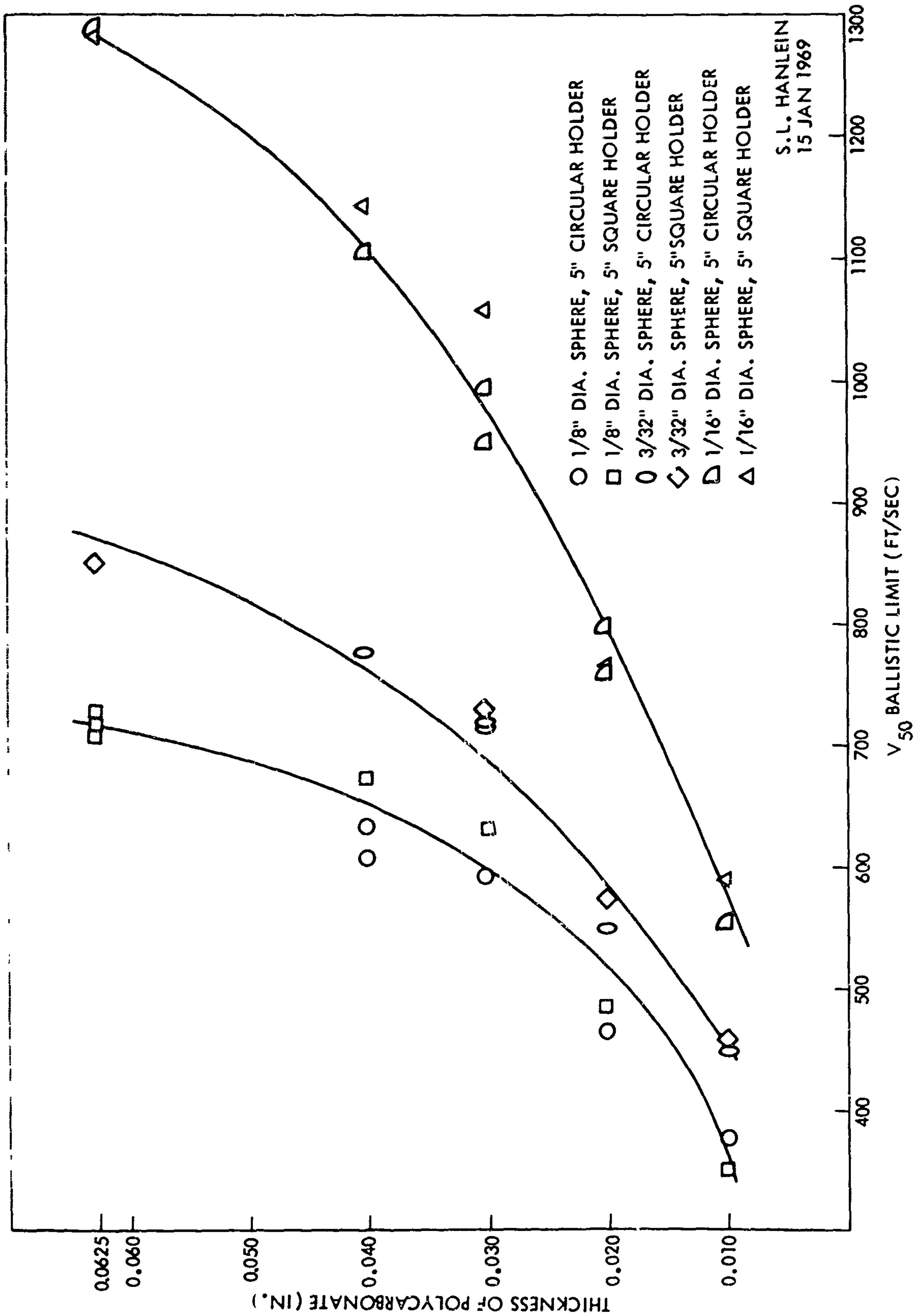


FIG. A-1 BALLISTIC LIMIT VS. THICKNESS OF POLYCARBONATE FOR VARIOUS SIMULATED FRAGMENTS

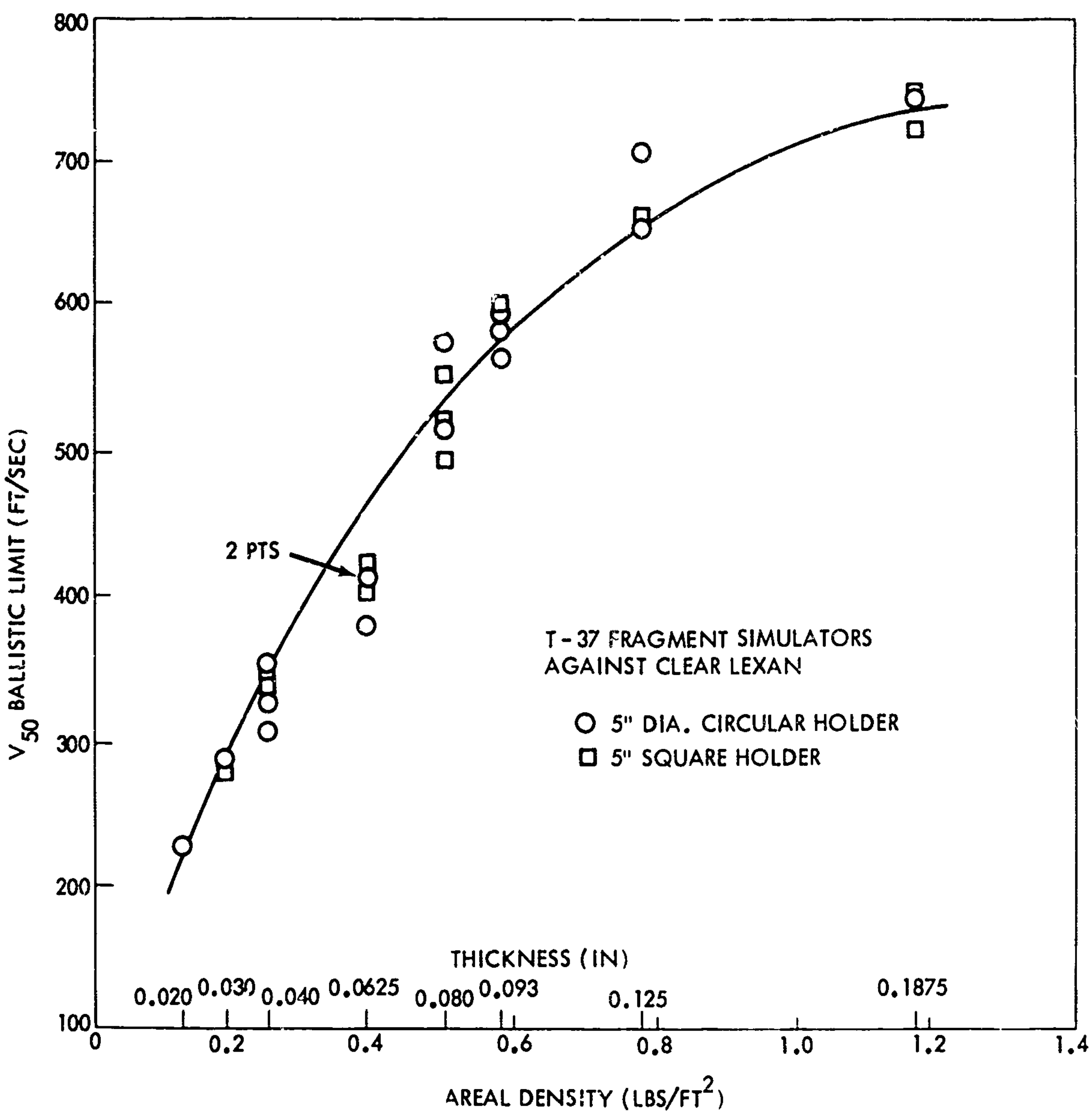


FIG. A-2 BALLISTIC LIMIT VS THICKNESS OF POLYCARBONATE FOR .22 CALIBER T-37 FRAGMENT SIMULATOR

# APPENDIX B

## SAMPLE QUESTIONNAIRE

Evaluation of Helmet Mounted Protective Mask

1. Were there any problems encountered in assembling the mask? If yes, please explain.

2. Did you read the instruction manual before assembling the mask?

3. Was the instruction manual clear enough? If not, please explain.

4. Were there any problems encountered in attaching the mask to the M-1 field helmet? If yes, please explain.

5. Did you wear both masks?

6. How long did you wear each mask?

7. Do you have a preference for either of these masks? If so, which one and why.

8. Did the mask cause you to have any difficulty accomplishing your routine assignments? If so, please explain.

9. Did you experience any discomfort caused by wearing the mask? If so, please explain.

10. Were any problems encountered in raising or lowering the clear visor? If so, please explain.

11. Were you able to see through the clear visor without any distortion?

12. Did you have any problems with the clear visor being badly scratched? If so, please explain.

13. Did you have any problems with the mask other than those mentioned in this questionnaire? If so, please explain.

14. Were there any instances where you felt that this mask saved you from being injured? If so, please explain.

15. If you have any suggestions for improving the design or operation of the mask, please comment here.

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13. ABSTRACT
Casualty reports from Southeast Asia indicate a need for a small fragment protective eye shield which will not interfere with the normal duties of the user. Commercially available eye goggles which are in accordance with Federal Specification FSN 4240-052-3776 were evaluated and found to provide inadequate ballistic protection. A polycarbonate eye shield which can be easily attached to the M-1 steel helmet was designed and found acceptable in evaluation reports from Vietnam. Ballistic data on the shield and construction details are given in this report.

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| Eye shiela<br>Polycarbonate shields<br>Ballistic data polycarbonate | | | | | | |



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