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HIGH-SPEED, ELECTROMECHANICAL GOGGLE

WAYNE-GEORGE CORPORATION
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FOREWORD

This report covers work performed by the Wayne-George Corporation, Boston, Massachusetts, under Contract No. AF 33(616)-5287, Project No. 6332, "Visual Aids and Protection," Task No. 77653, "Nuclear Flash Protection." The work was administered by the Vision Section, Physiology Branch, Aero Medical Laboratory, Wright Air Development Center, with Captain Robert D. Metcalf, USAF (MSC), and Captain Wayne E. Gulley, USAF (MSC), serving as contract monitors.

ABSTRACT

High-speed, electromechanical goggles, which were developed and constructed to protect the eyes of the wearer from burns or flashblindness caused by exposure to high-intensity flashes, are described. A signal is generated by a photodetector at the onset of the flash. This signal is amplified by an electronic amplifier and actuates the shutters of the goggles to shut out all light. The goggles are closed in less than 500 microseconds after the flash.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

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SECTION I

INTRODUCTION

The high-speed goggle is to be used to protect the eyes of the wearer from burns or flashblindness caused by a high-intensity flash. A pair of glass plates is held in front of each eye. Each plate is covered with alternate opaque vertical bars and transparent strips. Normally the plates are positioned so that the bars on each plate are superimposed on those of the other plate and the wearer has vision through the transparent slots. When a high-intensity flash is detected by a photodetector, the amplified signal triggers a device to move one of each pair of plates into such a position that the bars of each plate cover the slots of the other. In this position the goggles prevent light transmission and protect the wearer's eyes from the flash.

In the open position, the effect to the wearer is that of a low-density neutral filter since the opaque lines are very fine and are close to the eyes. The light transmission in this position is 30%.

The shutters are closed in less than 500 microseconds after onset of the flash and have a light transmission in this position of less than 0.01%. This speed is more than 20 times faster than a human can blink.

When the wearer wishes to reopen the goggles he moves a tab on the goggles to his left. This indexes a mechanism 90°, reopening and rearming the goggles for another operation. The electronic circuit is sensitive only to an increase in light so that there is no danger of the goggles reclosing due to residual light after the initial flash.

Between the goggles and the wearer's face a flexible light seal serves to prevent light from getting to the eyes by any path other than through the shutter plates. The light seal also serves to correctly position the rigid aluminum frames in front of the wearer's eyes. The goggles are held against the wearer's face by a simple, adjustable, elastic strap.

The goggles are compatible and integrate with APH-5 or P-4A helmets and A-13 or MS 20001 oxygen masks. The oxygen mask may be removed and replaced without disturbing the goggles.

When not in use, the goggles may be placed on top of the helmet. The elastic strap is fastened to the helmet's sun visor mounting bracket so it will hold the goggles down on top of the helmet when not in use.

The goggles weigh 0.51 pound with less than 0.1 pound supported by the wearer's nose. The field of vision exceeds 50° in the vertical and 120° in the horizontal plane.

Photodetectors which sense the flash are mounted on the frame and are connected by a flexible cable to the electronics package. The output signals from the electronics package are connected back to the goggles by wires in the same cable.

The entire electronic circuit associated with the goggles is contained in an aluminum housing approximately the size of a package of cigarettes. This package may be clipped to the wearer's suit or mounted near the wearer. The electronic circuit is powered by self-contained batteries. The batteries are disconnected by unplugging the cable to the goggles. There are no switches or adjustments in the electronic circuit.

SECTION II

DESIGN SUMMARY

A high-speed shutter goggle (Figure 1) that is actuated by disposable, explosive dimple motors, has been designed. These dimple motors are controlled by a transistorized electronics package which, including its batteries, is small enough to be conveniently carried by the pilot.

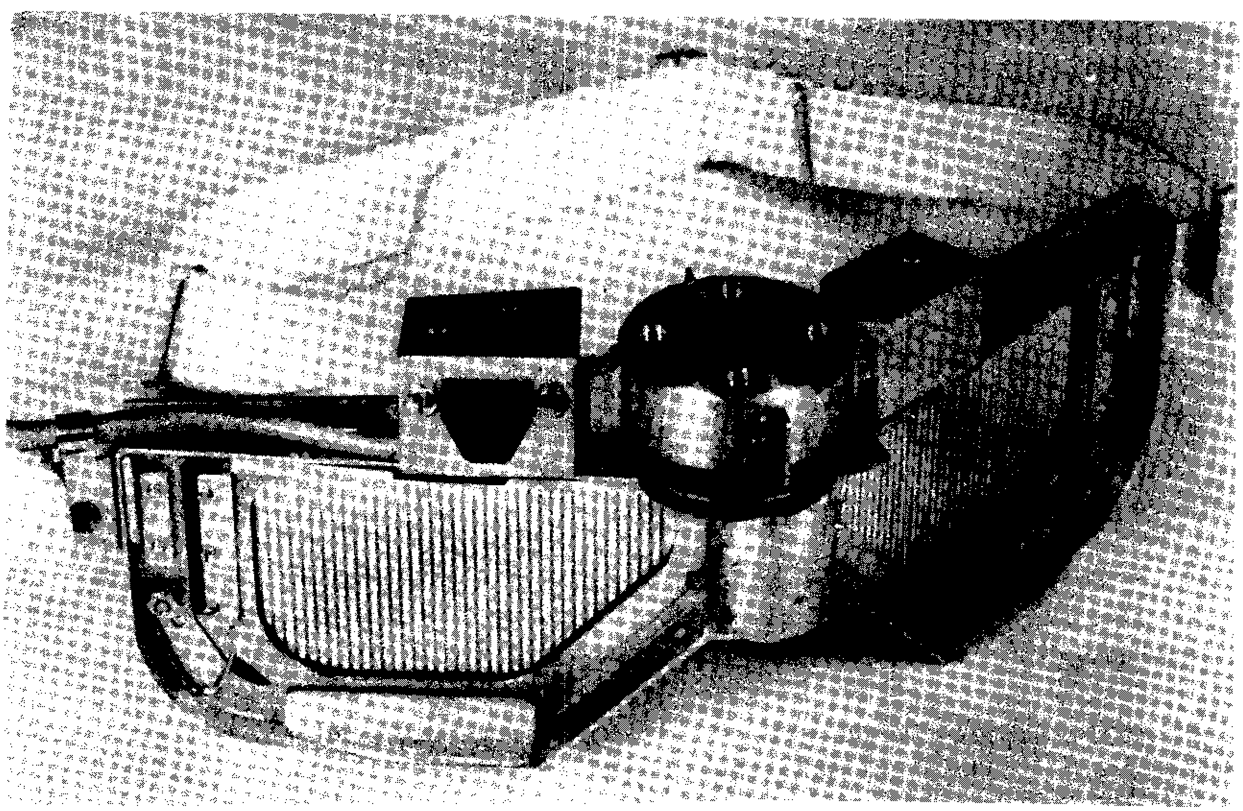

Figure 1. Electromechanical Shutter Goggle

Four goggle operations are available without reloading. A tab is moved after each operation to open and rearm the goggle. After 4 operations, 4 screws are removed and the unit containing the 4 expended motors is replaced.

The goggle is integrated with the other gear worn by the pilot and meets the required specifications.

It has been found that silicon solar batteries provide ideal characteristics for use as flash detectors for the goggle.

A method for fabricating high-quality shutter plates has been devised. A variation of this technique may be used to produce shutter patterns having different densities over different areas of the plates.

A flexible mounting for the undriven shutter has been devised that greatly alleviates shutter impact, bounce, and alignment problems.

A neoprene light seal (between the goggle and the wearer's face) has been designed that will conform to most head shapes and will permit removal and replacement of the oxygen mask without disturbing the goggle.

An elastic strap mounting has been found most suitable for mounting the goggle to the helmet.

An assembly technique has been devised utilizing silicon rubber which is vulcanized in place during assembly and prevents the shutters from getting out of adjustment afterwards.

SECTION III

PHYSICAL DESCRIPTION OF EQUIPMENT

A. Lenses

The lenses used in the goggle have a slot and opaque bar pattern etched from copper evaporated on the lens surface.

The driven lens is in an aluminum frame. A projection on the end of the frame near the nose is ground at an angle to match the wedge. A light spring at the outer edge of the lens frame holds the frame in contact with the wedge.

The fixed lens is enclosed by an aluminum frame which also has the stops for the driven lens. There is some play between the lens and the lens frame which is used during assembly to position the lens relative to the lens frame. The lens is then glued in position.

B. Goggle Frame

The main frame is a light but rigid structural aluminum outline member which contains the lens closure mechanism, the lenses themselves, and the photodetectors. A rubber face seal is cemented around the periphery of the frame.

C. Sandwich Construction

The shuttered lenses are so devised that the driven or occluding lenses are within the plane of the frame web and the fixed lenses and their frames are inside (toward the eyes) and immediately adjacent to the driven lenses. A fine gap is maintained between the driven and fixed lenses by means of thin, low-friction spacers. The total "sandwich" is formed by means of interior pressure against the fixed lenses which press against the driven lenses. These in turn find a base against aluminum guides fixed to the main frame web.

D. Dimple Motor Mechanism

The dimple motor mechanism shown in Figure 2 is the motive power assembly capable of four separate actuations without reloading. This is accomplished by having each dimple motor encased in a barrel which contains a firing pin maintained in a retracted position until fired. The four barrels are rigidly mounted in a cap which in turn is firmly fastened to the rotary base by means of four screws. The cap also serves the purpose of indexing the system for a new firing.

When an unfired dimple motor is in the firing position (i.e., over the wedge) the firing pin is in physical contact with the top extension of the wedge. This contact is maintained by means of the wedge return spring pushing upwards.

Each of the dimple motors is wired to the printed circuit commutator board which is attached to the barrels and rotates with them. The firing signal is transmitted from the source through two spring wipers in contact with the printed circuit commutator.

The entire cap, barrel, pins, motors, and commutator board assembly may be considered expendable after four rounds have been fired.

E. Wedge

The wedge receives the impact of the firing pin during firing of the dimple motor. It is a double-sided (conical) wedge, each side having an angle of approximately 18.5°. Since the wedge is widest at the top and the driven lens frames have surfaces in contact with mating angles, the net effect of the downward thrust is to deliver a side motion to each driven lens simultaneously equivalent to 1/3 the motion of the wedge.

F. Photocells

Three silicon solar cells are cemented to a clear plastic base and mounted adjacent to the dimple drive mechanism. Leads from these cells and leads that are connected through the printed circuit commutator to the dimple motors are connected at a terminal board to the cable from the electronics package.

Cell sensitivity may be reduced by inserting thin film-type neutral density filters between the plastic cell base and the cell cover.

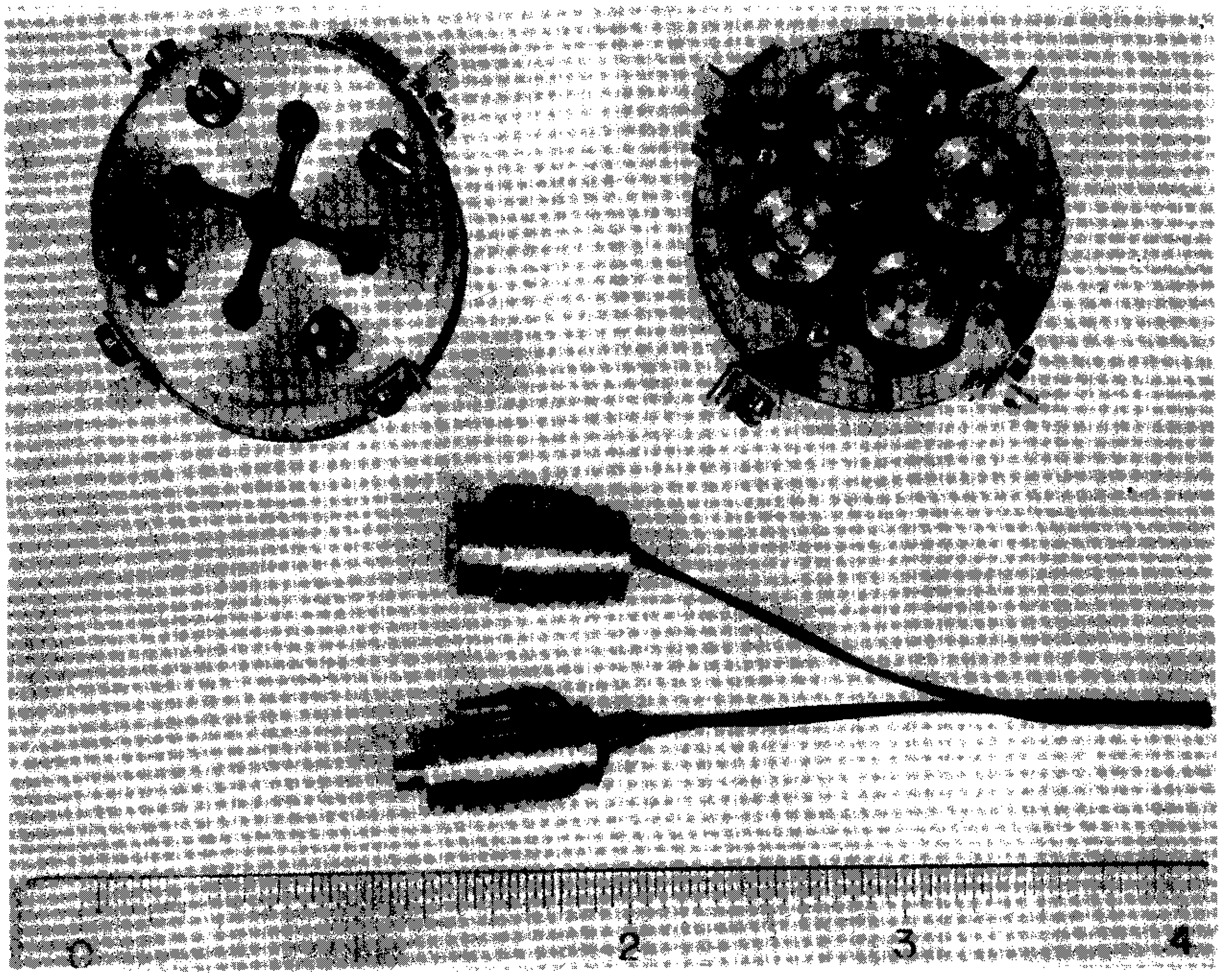

Figure 2. Dimple Motors

G. Face Seal

A neoprene rubber face seal attaches all around the goggle frame and contacts the wearer's forehead and temples and the oxygen mask to prevent any light from reaching the wearer's eyes except through the shutter grids. This face seal also positions the goggle on the head. An adjustable elastic strap holds the face seal in contact with the face and mask.

H. Electronics Package

The entire electronic circuit and batteries to power it are contained in an aluminum case small enough to be conveniently carried by the user (Figure 3).

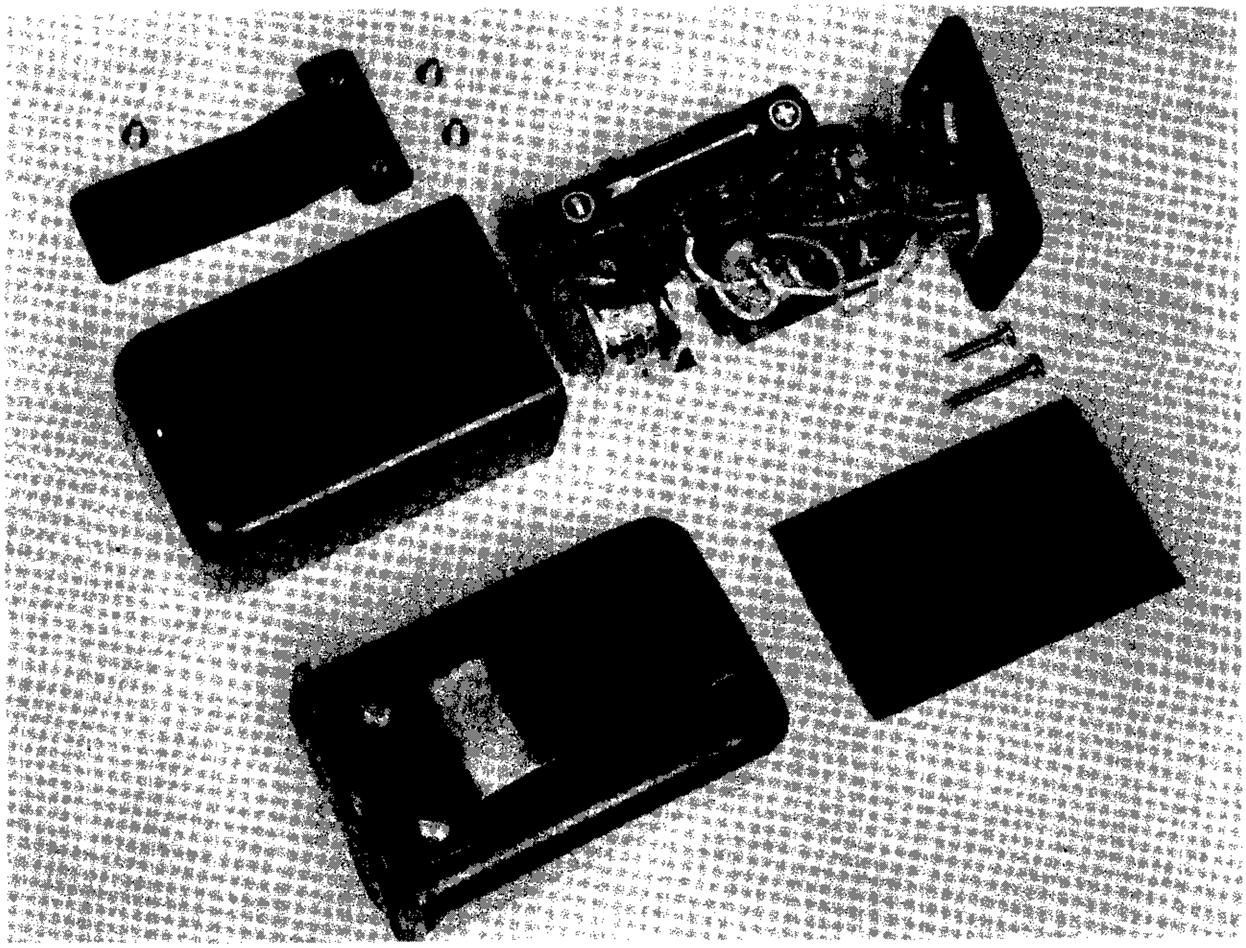

Figure 3. Electronics Package

I. Hinging

A central, limited hinge point on the goggle frame assembly was carefully investigated before a negative conclusion was reached. A design incorporating such a device would introduce unavoidable weakness at the critical center area. Any attempt to reproduce the strength of a rigid frame would result in an intolerable increase in over-all weight.

However, as a design approach toward the possible future demand for a hinged device, the wedge is fabricated as a cone allowing for hinging without affecting the relative positions of the lenses at any time. Also, the lower portions of the frame have been designed broader than otherwise necessary to permit attachment of stiffening pieces that would bridge over the oxygen mask.

SECTION IV

DESCRIPTION OF OPERATION

A. Flash Detection and Electrical Circuits

A flash is detected by 3 silicon cells wired in series and the signal voltage is connected to a 3-transistor control circuit (Figure 4). The output transistor is used as a switch and, when turned on by the amplified signal voltage, connects a charged capacitor across the dimple motor bridge (ignition heater). The capacitor discharges through the bridge, delivering about 5 amperes, which fires the dimple motor and closes the goggle.

The circuit is a.c. coupled and the cells remain saturated until the flash subsides. Therefore, the goggle cannot reoperate on the same flash if manually opened before the flash has completely subsided.

B. Power Supplies

The internal battery and bias cell are rated to provide a life of more than 100 operating hours. This life is virtually unaffected by the number of operations. Shelf life ratings on these batteries show a 7% deterioration in capacity after one year.

When not in use, the connector on the electronics package is removed, automatically disconnecting the batteries.

C. Dimple Motor Operation

Dimple motors are about the size of a .22 caliber cartridge but contain only a small charge. The motors are manufactured with one end pushed inward to form a dimple. Heat from an internal, resistance-wire "bridge" ignites the explosive when a current is passed through the wire. When fired the gas pressure forces this dimple outward providing the desired mechanical motion. The drive mechanism encloses the motor and prevents the case from rupturing so all combustion products are retained in the dimple motor case.

Each dimple motor is mounted on a vertical axis so that when fired it drives a firing pin downwards.

D. Wedge

The wedge is spring loaded upwards and its flat, front face is retained in a single plane by means of a cross pin. It is driven downward by means of the dimple motor firing pin which contacts and drives it during the actuation period. The wedge is loaded only by the drive acceleration due to the inertial reaction to acceleration of the driven shutters. Subsequent to operation only very light spring pressure loads the wedge.

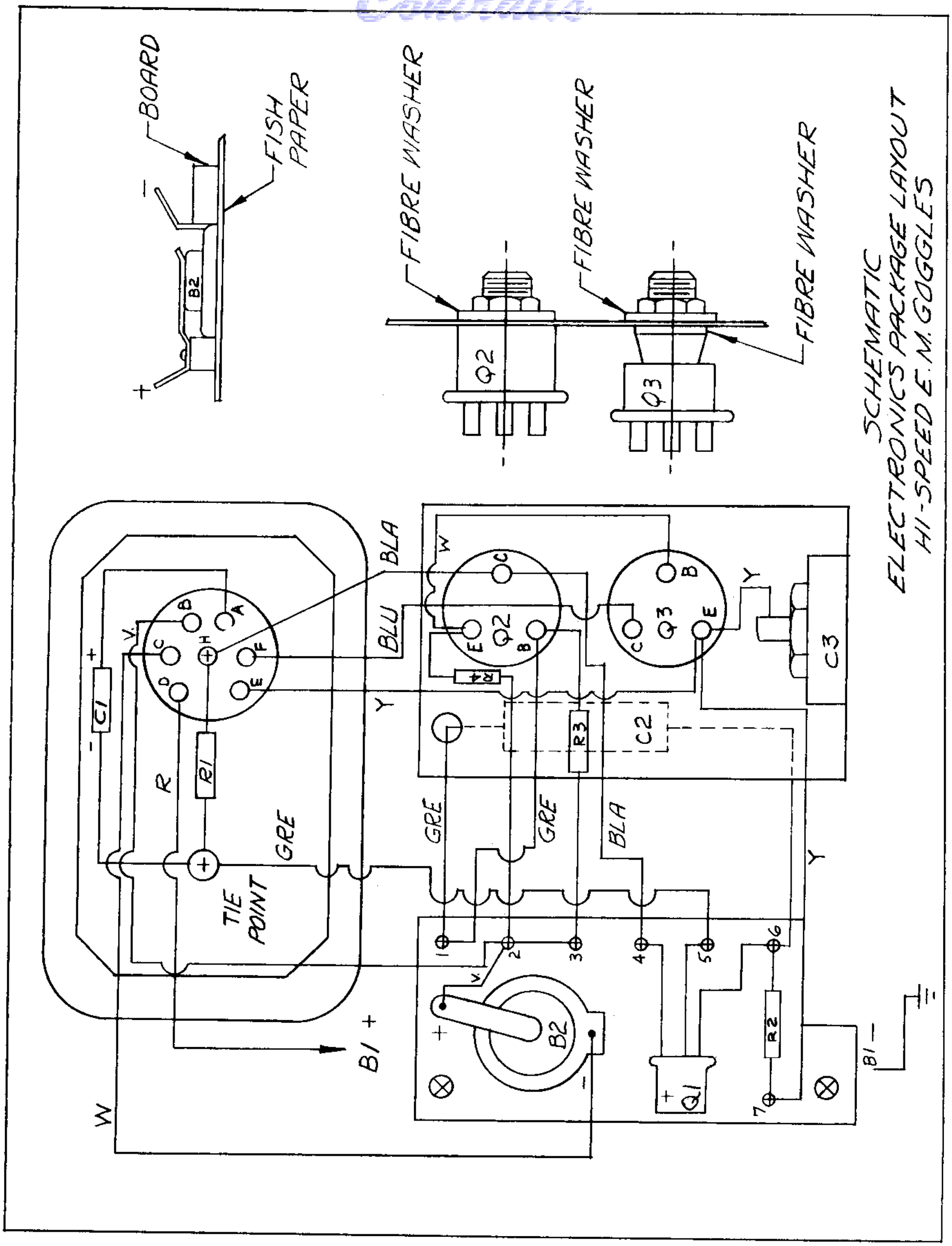

Figure 4. Circuit Schematic

E. Shutter Operation

The opaque bars on the driver lens are normally superimposed over the bars of the fixed lens. In this position the wearer has vision through the transparent slots. The driven shutter is spring loaded against stops to maintain this position. When the dimple motor drives the wedge down, it forces the driven lenses outward--i.e., away from the nose. The driven lens hits stops on the fixed lens frame when the bars of the driven lens cover the slots of the fixed lens and vice versa. A deceleration takes place and the wedge holds the lenses in this closed position until a new dimple motor is manually indexed into position.

F. Indexing

After each operation the dimple motor mechanism is indexed into a new drive position by moving the rotary cap from right to left. This operation moves the old motor out of place and places another motor into firing position. A spring-loaded pawl, as well as the upper wedge pin entering the new barrel aperture, center and lock the firing pin and motor over the wedge.

SECTION V

INSTALLATION

The shutter goggle is to be used with an APH-5 or P-4A helmet.

The goggle is held in place by an adjustable strap passing around the outside of the helmet. The rubber face seal positions the goggle on the wearer's face. The strap is held in place by a retainer on each side of the helmet that is fastened to the sun visor mounting piece. When not in use the goggle is placed on top of the helmet and the elastic strap holds it down in this position.

The 3-wire cable to the goggle is dressed along the top of the goggle and along the elastic strap until it is clamped to the strap retainer. The cable is then free to the electronics package.

The electronics package is provided with a clip to attach a pocket or strap on the wearer's outfit or the helmet. Or it may be permanently mounted within 5 feet of the goggle. Heavier cable would permit a further displacement.

SECTION VI

COMPONENT INVESTIGATIONS

A. Shutter Plates

Two shutter grid plates are used in each eyepiece. Experiments have shown the best shutter pattern to be 0.034-inch vertical bars alternated with 0.0285-inch transparent strips (see Figure 5).

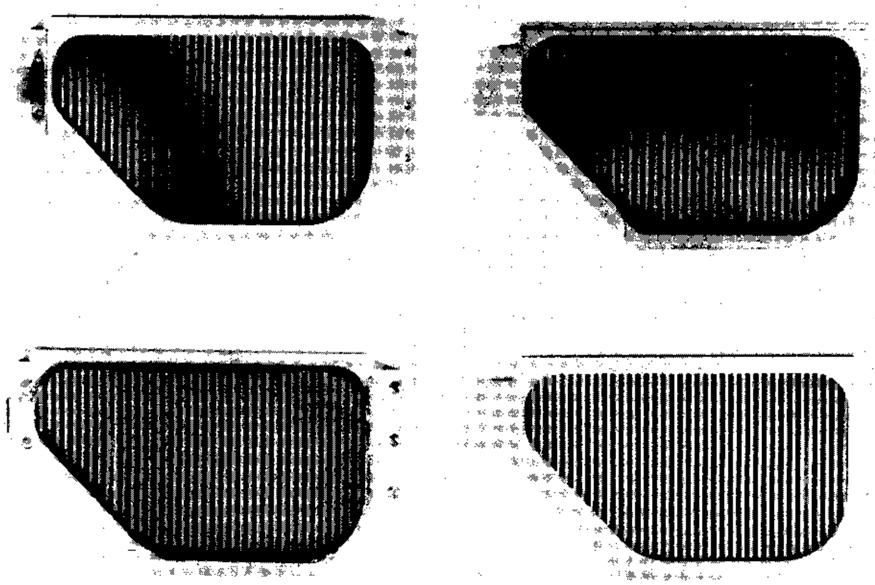

Figure 5. Shutter Plates

The specifications call for the transmission of the closed goggle to correspond to a density four at a minimum. Consequently, effort has been aimed at achieving the highest density possible.

1. Glue - Silver Shutters

Shutters developed previously used a photographic technique and, after several processes, resulted in silver deposited in fish glue. Imperfect patterns, pinholes, poor density, and pattern fragility are the objections to this process.

2. Evaporated Metal on Glass

Copper is evaporated over the entire surface of the glass plate which is then coated by a thin layer of wax. The wax is removed by machine from the areas to be transparent and the plate is placed in an etching solution which removes all metal not protected by wax. Since each transparent slot must be individually engraved in the wax with high accuracy requirements, the method is expensive. However, the results are excellent.

The cost was subsequently reduced without loss of accuracy by photographically transferring the pattern from a master to the "resist" covering the copper. The copper is then etched as before. This method produced excellent results.

3. Dual-Density Shutters

A shutter with dual density became of interest to the Air Force during the course of this development. In this type of shutter, a small area at the bottom of each lens plate would provide a density two in the closed position. This would allow some vision in the cockpit with the shutters closed, while still providing the necessary glare protection from without, through the top portion of the shutter. The etched metal technique is the only one suitable for this type of shutter.

To make these shutters, metal is evaporated over the entire surface to a density of two and then completely removed from the low-density areas. Metal is again evaporated over the entire surface to a density of two in the low-density areas. The other areas will be covered by metal from two evaporation cycles and will be density four.

The pattern is made using both photographic and etching processes.

4. Silk-Screening

The shutter pattern is silk-screened on glass providing a durable surface. The thickness of the pattern is a problem here and accuracies and densities are not sufficient.

5. Etched and Filled Glass

The pattern is photographically transferred to the glass plate and then etched to a depth of several thousandths of an inch. The etched areas are filled with an opaque pigment. Sufficient pattern accuracy was not obtained and the small transmission through the opaque areas was diffused and consequently not useful for vision.

6. Etched Metal Attached to Glass or Plastic

A number of samples were obtained of thin metal sheets with slots etched out between vertical bars. The sheets were necessarily thin to avoid side vision restriction due to the tunnel effect of slots through a thick plate.

Since long, thin bars are not rigid enough to withstand the accelerations and decelerations required, attempts were made to attach the etched sheets to glass or plastic. Molding plastic on the etched sheets caused warpage due to the differential of heat expansion between the plastic and the metal. A good bond was not obtained between the metal and glass by any of the companies attempting the problem.

Heavier metal would not solve the rigidity problem since the mass increases in the same ratio as the strength.

7. Other Methods

Corning Glass Works looked into three of their techniques called photoglass, photostain and photoetch with negative results.

8. Conclusions

Of the various techniques investigated, evaporated metal on glass offers the greatest advantages. The photographic technique described in VI. A. 3 is well suited to quantity production of either dual- or single-density lenses.

B. Frames

1. Fabricated

An initial trial was made to create a goggle frame by fastening together individual members. It was intended that an extra-high tensile-strength aluminum sheet be used and precision inert gas welding be introduced for a superior bonding of individual parts. The aluminum sheet specified was found to be of longterm delivery and lower-strength available sheet was substituted. The frame was not satisfactory due to tolerance, welding, and strength problems.

2. Machined from Solid

Frames were "hogged out" of a solid hi-tensile aluminum bar because it offered the shortest term delivery. This method turned out a satisfactory item.

3. Investment Cast

Paralleled with the fabrication from solid stock, a precision investment casting was made. The investment cast results were very satisfactory and established a method for possible future production at low cost.

C. Drive Mechanisms

The specifications call for the goggle to be completely closed 500 microseconds after the onset of the flash. Twenty microseconds are required for detection and amplification and, if 80 microseconds are reserved for a safety factor, then 400 microseconds are available in which to move the goggle to the closed position. A number of techniques were examined to provide such high-speed operation.

1. Direct Hot Wire

The method of actuation used in earlier goggles was reviewed and found undesirable in many respects. In these goggles a spring force is constantly applied to each of the shutter plates. Normally the springs are restrained by a chromel wire which holds the shutters in the open position. When the photodetector is illuminated by a flash, the signal causes a very large current to be passed through the chromel wire. This current heats the wire and extends it permitting the springs to drive the shutter to the closed position. After the flash the current ceases and the wire cools, pulling the shutter open again. However, the wire does not contract exactly back to its original position so the goggle remains partially closed. Another disadvantage of this scheme is the large electronic components and heavy wire needed to handle the currents involved. Finally this drive method permits the lenses to bounce when the stops are reached, sometimes reopening the goggle momentarily.

2. Explosive Dimple Motor

Dimple motors were chosen as the prime mover for goggle operation. They consist of a small charge of explosive powder contained in a brass cartridge, 0.30 inch in diameter and less than 1/2 inch long. The powder is packed around a resistance wire "bridge" at one end of the case. Two wires pass through this end to connect the bridge to external circuits. The brass at the other end of the case is pushed inward toward the bridge end to form the dimple.

When a current is passed through the bridge, the wire heats, igniting the explosive. The gas pressure then forces the dimple axially outward at a high speed and with considerable force. The case does not rupture, however, so combustion products are not released. Consequently the operation is accompanied by a barely audible click.

Dimple motors have been used extensively in military equipment and the wire bridge type used in the goggle does not create handling problems. These wire bridge motors will not ignite due to mechanical shock, vibration, low temperature, high temperature to 225° F., or static charge.

The standard motors operate in 2 milliseconds. Therefore, a special motor was developed that would operate in 400 microseconds under the loads imposed by the goggle shutters.

3. Double Dimple Motor

In the early part of the goggle program, approval was received to design the goggle to use a single, replaceable dimple motor. That is, after each goggle operation the dimple motor is extracted and a new one inserted.

A double dimple motor was designed and tested for this purpose. This type had dimples on opposite sides of the motor. When fired, the dimples move radially outward from both sides, each driving one shutter. In this way one shutter of each eyepiece is driven while the other remains fixed. The expanded dimple motor prevents the shutter from rebounding to a partially open position when they hit the stops at the closed position. The goggles are reopened by extracting the dimple motor and are rearmed by inserting a new one.

Reconsideration of the problems of replacing dimple motors resulted in the conclusion that at least three operations should be possible without reloading. This led to the final design described below using more conventional dimple motors having a single dimple in one end.

4. Mechanism for Single Dimple-Type Motors

Various schemes for utilizing the single dimple motor were considered. The attitude of the wedge indicated the positioning and attitude of the dimple motor. The requirement for a minimum of three operations per loading pointed to either a linear or a rotary device for indexing after each shot. It was decided that a rotary device was most economical in weight as well as superior in terms of mechanical simplicity (see Figure 2).

The simple manual index device with a single spring pawl was chosen for its basic simplicity and freedom from breakdown. Since the manual actuation is designed with a "finger" stop, the indexing mechanism cannot be pushed beyond the correct position for rearming.

Due to high-pressure buildup in the dimple motor, a barrel-contained dimple motor with a limited-travel firing pin was found necessary. This permits the motor pressure to be safely contained without rupturing the motor and exerts no more load upon the wedge in its "down" position than was required to accomplish shutter movement.

5. Spring-Driven Wedge

Another drive mechanism that was found practical for the goggle has a wedge at the bridge of the nose which is driven downwards by a spring when released. The ends of the driven shutters are cut at the same angle as the wedge so that they contact the wedge along their entire length. When the wedge is driven downwards it forces the movable shutters apart closing the goggle. When the shutters hit the stops in the closed position the wedge prevents them from bouncing open again.

The wedge is normally restrained from driving downwards by a latch and trigger mechanism. A small spring is normally constrained by a chromel wire from pushing the latch hook out of a detent. When a flash is detected, the electronics package dumps a large current into the chromel wire. Heat generated in this way extends the wire and permits the spring to release the latch so that the drive spring may move the wedge downward and close the goggles.

The trigger spring and wire are designed for a total travel considerably more than necessary to release the latch so that repeated operations do not require adjustment to compensate for changes in length of the wire when cold.

The goggle is reopened and rearmed by manually lifting the wedge up until the latch snaps into the detent again.

The trigger spring and its chromel restraining wire operate only a latch so they both may be small. Sufficient energy can be supplied by a single 50-microfarad capacitor charged to 500 volts. A miniature, cold-cathode gas tube is used to control this current. A high-voltage power supply is necessary, making the electronics package about twice the size of the package for the control of dimple motors. Batteries, as an alternate to external 400 c.p.s. power, would be twice as large as the electronics package but they would have a very long life.

A spring-driven wedge goggle was built as a backup program and used for testing shutter operation. The design was not carried beyond the point of the first model.

This spring-and-hot-wire triggered wedge avoids the three major difficulties encountered in earlier goggles. These objections were: the large electronics package and cables required (due to the four heavy chromel wires used in each pair of the original goggles), the requirement of that design that the wires contract exactly to their initial length when the heating current is removed, and finally the bounce problems occurring when the moving shutters hit the stops at the closed positions.

6. Direct Spring Drive

With this drive a spring is normally prevented from pushing the movable shutter plates outward by a latch and trigger mechanism. This trigger is similar to the one described in VI. C. 5.

This drive is simple but it has inherent bounce problems when the movable shutters hit their stops upon closing. A deceleration technique discussed in D. might solve this bounce problem but it is considered more prudent to use a drive that avoids the problem altogether.

7. Spring-Driven Eccentrics, Toggles, and Rotary Cams

These three drive methods are all powered by some form of spring which is normally restrained by a chromel wire trigger mechanism similar to that described in VI. C. 5.

While all three of these have the antibounce feature of the wedge, they were abandoned due to prohibitive bearing pressures. The driving force of a wedge is distributed over an area contact with the shutter, while a cam makes only line contact. The computed pressures for a cam were too high for further consideration. The eccentric drive has area contact but the space available for driving mechanisms dictated eccentrics so small that bearing pressures again were high. With toggle arrangement the toggle pins could not take the loads that would be imposed.

8. Hydraulic and Pneumatic Drives

Hydraulic or pneumatic operation could yield a very simple, hinged goggle but no control valves were found that are fast enough. The fastest available valves utilize an explosive dimple motor which ruptures a diaphragm which is in the fluid path. These valves require 2 milliseconds to operate (before the goggle starts moving) and can be used only once. Long development periods were quoted for faster, repeatable valves.

9. Piezoelectric and Magnetic Drives

The Dynamics Analysis and Control Laboratory of the Massachusetts Institute of Technology was consulted about the possibilities of piezoelectric and magnetic drives. Both were ruled out primarily because of size and weight.

D. Mechanical Stops for the Movable Shutters

The dimensions of the opaque bars and transparent strips (dictated by physiological factors and specifications on light transmission in the open position) provide only 0.0055-inch overlap in the closed position. Overlap as used here means the amount that any bar on one plate extends over a bar of the other plate in the closed position.

When actuated the movable shutter moves toward the closed position and then must be decelerated in the distance provided by the overlap. Any bounce must also be confined to this area of overlap. Thus, the kinetic energy of the moving plate must be dissipated in the stop within only a few thousandths of an inch.

A thorough search was made to find a material capable of absorbing the kinetic energy of the moving lens, but no material was found that was consistent with the volume available for stops. Therefore, any constant force drive such as a direct spring cannot operate without bounce, if fixed stops are used. A locking type of drive such as a wedge does not permit the lens to rebound and forces the energy to dissipate in the stop and the drive; however, mechanical forces grow very large.

During the design phase a technique was evolved which considerably increases the distance available for deceleration and consequently reduces impact and reaction forces. With this technique the undriven or "fixed" shutter is mounted in rubber rather than in a rigid mounting.

Stops for the moving shutter are fastened to this floating shutter. In use the moving shutter hits these stops when its opaque bars cover the transparent strips of the floating shutter (that is, when the shutter is closed). The shutter is then closed to light but the motion is permitted to continue because the stops will drag the floating shutter along. In this way the shutter remains closed while motion continues. The rubber mounting of the floating shutter resists the motion and finally stops both shutter plates. Stops for the open position of the goggle are also fastened to the floating shutter. When opened the movable shutter moves until it contacts these stops and then carries the floating shutter along while remaining fully open, until the wedge reaches its upward extreme.

In the goggle the stop for the closed position contacts much of the outer edge of the driver lens frame so that the impact forces will be distributed over as much area as possible. The driven lens comes into contact with the open stops when the goggle is rearmed. Impact is negligible when opening the lenses, so small stop areas are satisfactory. Two open stops are used, one at the top and one at the bottom edge of the driven lens. Both are at the end of the lens near the nose.

Alignment of the pattern on the fixed lens relative to the pattern on the driven lens is also determined by the stops. The two open stops are machined in the fixed lens frame and the closed stop is bolted to the frame. Adjustment of the fixed stops is done with shims during final assembly. Consequently, the open positioning, the closed positioning, and alignment cannot get out of adjustment.

E. Rubber Face Seal

The face seal must be flexible to conform to facial contour, light in weight, and nontoxic or nonirritating. Several techniques and materials were tried for this part.

1. Dipped Neoprene

The method used for the goggle was a dipping technique. With this method a form is made in the shape of the desired piece. This form is dipped in liquid neoprene and a coating formed over the entire surface. Repeated dippings build the coating to the desired thickness. The form is then removed leaving a smooth, flexible, nonporous shell.

2. Poly-Koolfoam

This product of Dayton Rubber Company is a white, flexible, foamed plastic of very low density. It is mixed, poured, and cured at room temperature. A polished mold will provide a smooth surface for the areas of the light seal that contact the skin. Its light transmission was too high, however, and no suitable materials were found for an opaque inner covering.

3. Lockfoam

Lockfoam is a product of Nopco Chemical Company. It is chemically and physically very similar to Poly-Koolfoam discussed above.

4. Sprayed Latex

A form is made and liquid latex is sprayed on the exterior. When vulcanized, the form is removed leaving the shell. This method was tried but the contour was too complex to fill all the cavities. The resulting irregular surface was also undesirable.

5. Face Seal Shape

Many factors were considered in designing the face seal shape. Since the face seal positions the goggle on the wearer's face, the seal was designed to contact primarily on the forehead and the oxygen mask (or the nose when the mask is removed). High flexibility was desired in the area of the cheeks and the temples since there is much variation among humans in these areas.

To insure a good light seal, contact with the skin and the oxygen mask is made over broad areas. The face seal folds back under itself and is very flexible in the area of the cheeks and around the nose to permit single-hand replacement of the oxygen mask without disturbing the goggle. This also allows a good light seal without the oxygen mask.

Light weight and simple attachment to the frame were other requirements.

F. Photodetectors, Control Circuits, and Power Supplies

1. Photodetectors

Silicon solar cells offered many advantages for flash detection. They are photovoltaic--that is, they convert light energy into electrical energy, supplying approximately 1/2 volt each at less than 100 ohms impedance at saturation. Higher light intensities reduce this impedance even further. Being photovoltaic they require no bias voltage and are very stable with temperature. Silicon cells are also very sensitive, saturating at 1000 foot-candles. The time constant is a function of illumination intensity and is in the order of several microseconds with several suns illumination. Three square cells are used, each measuring 0.5 cm. on the side and about 0.020 inch thick. They are connected in series by soldering leads directly to the cells. The cells are unaffected by humidity. The cells are mounted by cementing to a clear plastic base.

Lead sulfide cells were also considered but were found to have a number of objections. These cells are photoresistive, that is, their resistance changes with illumination. Photoresistive operation requires a bias voltage and a series resistor. The cell impedance is high and changes drastically with time, temperature, humidity, and surface conditions. Leads are delicately attached with a conductive paste when the cells are manufactured. The cells themselves are also fragile.

2. Direct Operation of Dimple Motors from Photocells

Consideration was given to firing dimple motors directly with the energy supplied by the photocells. Samples of dimple motors with very sensitive "carbon bridges" (instead of wire bridges) were obtained for experiments in this direction. A large number of cells must be used with much area exposed to convert sufficient energy. The area required for reliable operation was too much to permit attachment directly to the goggle. The top front of the helmet could be covered with cells but the weight of a mounting for this many cells would not be acceptable under the current specifications.

3. Circuits for Dimple Motor Operation

The dimple motor is fired by passing about 5 amperes of current through the wire bridge (currents down to 0.050 ampere will fire it, but the time delay becomes appreciable). This current is supplied by a 50-microfarad capacitor charged to 28 volts. The dimple motor bridge is connected across the condenser by a power-switching transistor. The signal from the photodetector is amplified by the input transistor stage which is connected to the second or "drive" transistor stage. This, in turn, supplies the control current to the output or "switching" transistor stage. All stages are normally biased to cut-off and collectively draw less than 1 milliampere from the power source. During this normal period the capacitor is charged in less than 1 second to 28 volts.

The capacitor, 3 transistor stages, bias cell, and battery are housed in a 1-3/8 x 1-7/8 x 3-inch aluminum case. The connector on top is for the cable to the goggle.

When the goggles are not in use, the cable connector is removed, disconnecting the battery and bias cell.

Three types of batteries were considered for this supply: mercury batteries, manufactured by P. R. Mallory and Company, Incorporated, are the best suited for this application. The 28-volt battery measures 2-1/4 x 1 x 5/8-inch and should last for more than 100 operation hours.

Carbon zinc batteries are considerably larger, heavier, and shorter lived.

Silver zinc wet batteries are small, have very high capacity, and are rechargeable, but their electrolyte (potassium hydroxide) is considered too dangerous to be near the wearer.

4. Circuits for Goggles with Chromel Wire Triggers

Shutters triggered by heating a chromel wire (such as a spring-driven wedge) require electronics capable of handling about 100 amperes at 300 or more volts. This current is supplied during an operation by switching a charged capacitor across the chromel wire. Between flashes the capacitor is recharged at a slow rate.

Two miniature gas tubes are available that can control these currents. Both tubes require a preamplifier.

A 2D21 thyratron has been successfully used for currents much higher than required here. The high voltage drop across this tube reduces efficiency of the circuit. A 500-microfarad capacitor charged to several hundred volts would be used. This circuit has been built and tested.

The 6873 (Sylvania) cold-cathode discharge tube has no heater and is mechanically very rugged. It will not operate with a supply voltage below 500 volts, but has a low voltage drop across the tube so that a 50-microfarad capacitor would suffice. The large trigger voltage required would be obtained from a transistor amplifier driving a pulse transformer. This circuit has been built and satisfactorily tested.

A power supply for charging the capacitor and the transistor stage would operate from 400 c.p.s. and normally deliver less than 1 milliampere current. The circuit and power supply could be housed in a case two to three times the size of the dimple motor electronics package. Battery operation is of doubtful value. Mercury batteries are not available at this time above 30 volts. Other batteries for 500 volts are heavy, bulky, expensive, and short-lived.

SECTION VII

SUMMARY OF DESIGN FEATURES

Extensive laboratory tests indicate that the high-speed, electromechanical goggle using dimple motors will give very satisfactory performance.

The goggle has been built with the following features:

1. The drive mechanism uses single-dimple, explosive dimple motors.

2. Four dimple motors are contained in the drive mechanism and are used successively, manually indexing a new motor into position after each goggle operation.

3. Indexing a new motor into position automatically reopens the goggle.

4. After using the four dimple motors, the assembly containing them is discarded and replaced by a new assembly.

5. The flash is detected by three silicon photodetectors.

6. Lenses are thin glass with the shutter pattern deposited on them using a technique of etching away metal that has been deposited on one surface.

7. A rubber face seal is used that permits simple removal and replacement of the oxygen mask.

8. The goggle is held in place with an elastic strap around the outside of the helmet.

9. When not in use the goggle is placed on top of the helmet and held there by the elastic strap which is retained under the helmet visor mounting hardware.

10. The electronics package is about the size of a cigarette package and may be clipped to the wearer or permanently mounted in the aircraft.

11. The electronics package is powered by internal 100-hour life batteries.

12. The goggle weighs 8.1 ounces and the electronics package weighs 8.2 ounces.

13. Open goggle light transmission is 30%. When closed the goggle has a light transmission of 0.01% (density 4).

14. The goggle is fully closed within 500 microseconds after the onset of a flash.

15. The goggle is compatible with types APH-5 and P-4A helmets and A-13 and MS 20001 oxygen masks.