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AIR BAG PROTECTION OF THE GUNNER IN THE U. S. ARMY COBRA AH-1Q

Thomas M. Loushine

Army Materiel Command
Texarkana, Texas

April 1975

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AIR BAG PROTECTION OF THE GUNNER IN THE U.S. ARMY COBRA AH-1Q

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April 1975

Final Report

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USAMC Intern Training Center - USALMC
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FOREWORD

The research discussed in this report was accomplished as part of the Safety Engineering Graduate Program conducted jointly by the USAMC Intern Training Center and Texas A&M University. As such, the ideas, concepts, and results herein presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

This report has been reviewed and is approved for release. For further information on this project contact Dr. George D.C. Chiang, Intern Training Center, Red River Army Depot, Texarkana, Texas 75501.

Approved:

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Safety Engineering Program

For the Commander

James L. Arnett, Director, ITC

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The new version of the U.S. Army Cobra attack helicopter, the AH-1Q, makes use of a new rigid column sighting device. This rigid column introduces a serious hazard to the gunner who may come in contact with it during a crash. This report looks at the possibility of using an inflatable air bag to protect the gunner from sight inflicted injury. An overall description of the mechanics and reliability of the air bag, as found in present day automobiles, is include to give the reader a basic understanding of how air bags work. With this understanding, various considerations are made as to how an air bag system, similar

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) to an automobile air bag system, could be designed into the gunner position of the AH-1Q.

ABSTRACT

Research Performed by Thomas M. Loushine

Under the Supervision of Dr. Robert L. Street

The latest version of the U.S. Army attack helicopter, the AH-1Q, makes use of a rigid column sighting device. The rigid column introduces a serious crash hazard to the gunner who during impact may contact it with his head or thorax. Serious injury can be reduced by using an inflatable air bag. The report discusses the mechanics and reliability of air bag systems as found in present day automobiles, to show its applicability of air bag use in the helicopter. Design considerations for implementation of the air bag system for the gunner of the AH-1Q include: type of crash sensors necessary to detect crash impact, the type of energy source for inflation purpose, type of air bag material, and placement of these subsystems. Two bag locations and sizes are recommended based on the ultimate inflated position and the degree of protection offered. The optimal locations for bag placement would be on the sight itself; the other would be on the gunner's seat. The two sizes offer head and neck protection only or whole upper body and head protection.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. R.S. Morris and Dr. W.L. Johnston for serving on his committee and special thanks goes to Dr. R.L. Street for his help and suggestions regarding the preparation of this paper. Appreciation is also extended to Jim Elliott and Larry Crawford, Aviation Safety Office at AVSCOM, St. Louis, Missouri; and Major Logan and Major Garner, USAAAVS at Fort Rucker, Alabama. These men spent several hours helping the author gain information necessary to the preparation of this paper.

During the course of this work, the author was employed by the U.S. Army as a career intern in the AMC Safety Engineering Graduate Program. He is grateful for this opportunity to participate in the program.

The ideas, concepts, and results presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

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CHAPTER I

INTRODUCTION

Air bags are a relatively new concept in the area of safety. In recent years they have been researched and improved to a point of high reliability for automobiles; they have scarcely been considered for any Army vehicles or aircraft.* Crashes are inevitable in any type of man-operated vehicle; therefore, a main concern in designing such vehicles should be protection of the occupants. Presently seat belts and shoulder harnesses are the only type of restraint system found in Army vehicles or aircraft. If seat belts and/or shoulder harnesses are employed jointly with air bags, impact injuries could possibly be reduced. Also, in case the occupant forgets to buckle up, the automatically activated air bag will possibly alleviate some injuries.

Air bags have been used in a small percent of late model cars; they are employed by impact activation. An impact sensing device is located near the front of the automobile. On impact the sensor signals the gas forming or containing unit to release gas to the bag located inside the passenger compartment. The inflated bag fills the volume between the front seat passengers and the dashboard or windshield. This whole process takes less than one-tenth of a second; the bag deflates in the same instant. (Louches, Slefka, Dunford, Powell,

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* Air bag refers to an inflatable bag generally inflated with nitrogen or other inert gas.

May, 1972) More detail on the mechanics, advantages, disadvantages, reliability, etc of air bags will be given later in this paper.

This paper will be concerned with air bags and the United States Army Cobra AH-1Q. This is the soon to be employed attack helicopter, being a modification of the Cobra AH-1G used in Vietnam (see Figure 1). Two men operate the AH-1Q, the pilot being seated behind the co-pilot or gunner. Both men have the capability to maneuver the ship as well as aim and fire the armaments. Generally the pilot controls the flying while the gunner sights in on targets and fires the desired armament. In the new AH-1Q, the sighting device will be mounted on a rigid column that positions the sight directly in front of the gunner's face (see Figure 2). A crushable telescopic sight is not presently included in AH-1Q requirements. (Rutledge, D.E., April, 1974) There is a high probability that on impact, as in an accident, the gunner may be seriously injured by forcefully hitting his face or body on the sight. Since Cobra crashes are not uncommon occurrences in a war zone or in peace time operations, it is hoped that some type of safety steps can be taken to reduce impact injuries. Possibly the air bag could be one way to accomplish this. It will be the purpose of this paper to study the feasibility of designing an air bag to prevent the AH-1Q gunner from contacting the sight during an impact crash, while not interfering with normal operation of the aircraft.

Chapter II is an evaluation of the various references used in preparing this paper. The third chapter is a basic overall description of the present day automobile air bag. This will give the reader

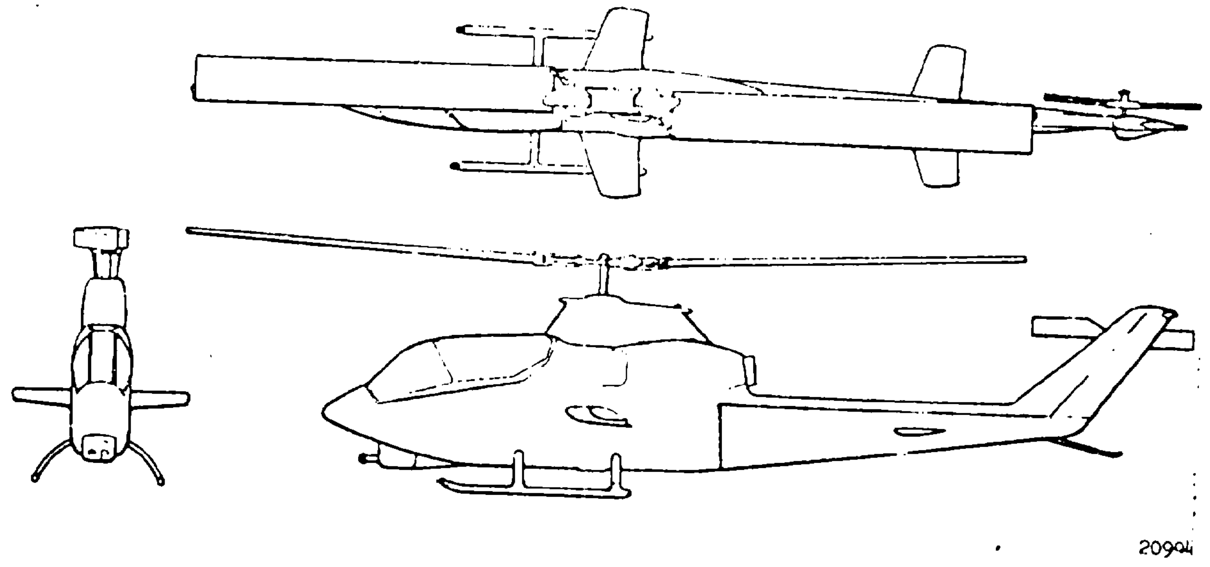

Figure 1. Front, Top, and Side Views of the U.S. Army Cobra Attack Helicopter. (Department Of Army, June 1971)

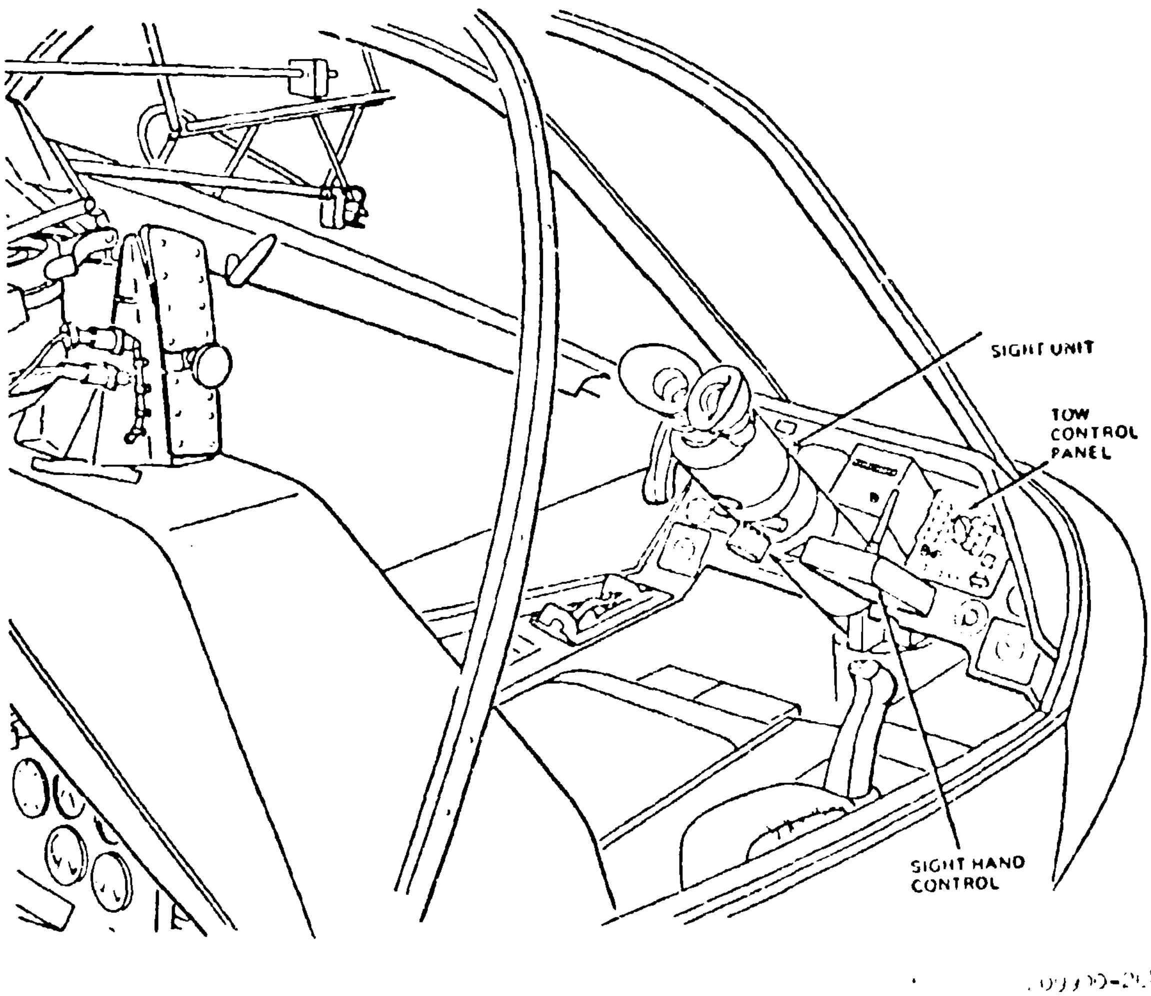

Figure 2. Gunner Position and Sighting Device in the Cobra AH-1Q.
(Department Of Army, 1974)

an understanding of the mechanics and design of the system. Chapter IV relates the automobile air bag system to its use in the AH-1Q, pointing out the different considerations and alterations necessary if the system is to be incorporated into the design of the AH-1Q. The final chapter is the author's evaluation of air bags for the AH-1Q and recommendations as to their possible employment in Army aviation safety.

CHAPTER II

REFERENCES EVALUATION

Present Day Air Bags

Much information concerning air bags has been published in recent years. General Motors Corporation has been a leader in this field doing extensive research and development on this particular restraint system. Klove and Oglesby of General Motors body division and engineering staff prepared a report in 1972 entitled "Special Problems and Considerations in the Development of Air Cushion Restraint Systems." Presented in their paper is a discussion of the air bag restraint system developed by General Motors along with problems encountered during its development. Included is a description of the components of the system, crash sensing devices, and means of inflation. Specific technical problems discussed include performance considerations such as occupant rebound, toxicity potential, noise risk, sensors, reliability, and service needs. (Klove, E.H. and Oglesby, Robert N., May, 1972)

A paper was prepared by Klove for General Motors' 1973 Report on Progress in Areas of Public Concern. (Klove, E.H., 1973) The report, entitled "Air Cushion Restraint System," covers topics such as location of air bags, components of the system, and speed of inflation. Also included are answers to problems such as accidental discharge, repairing air bags, what to use as an inflator, and the added expenses of the system.

Oldsmobile, a subdivision of General Motors, has been involved in coordinating safety improvements for several years. A paper entitled "General Motors Driver Air Cushion System" was written to describe how the system is designed to function and give a detailed description of the components. (Louches, Slefka, Dunford, Powell, May, 1972) This paper contains a description of the overall system operation by the Oldsmobile Division. Several drawings show the position of the air bag in relation to time during a crash. Each point during the crash is explained in relation to what is happening with the air cushion restraint system.

A discussion by Inland Manufacturing Division of General Motors is also a part of the paper by Oldsmobile. The steering wheel and air cushion module components are described. Included is mention of a chemical gas generator as an inflation element. Use of such a device was found necessary in order to optimize the size of the air cushion module package. This particular module was chosen after many alternatives were examined for visibility, optimum bag storage and deployment. The size and shape of the inflated bag was also an important decision. The bag was to be kept to a minimal size while providing restraint to the driver on all frontal impacts. All this was accomplished without jeopardizing the safe operation of the steering wheel.

The bumper impact detecting switch was studied for the Oldsmobile system by Delco Electronics, Division of General Motors. Problems considered included type and number of impact sensors, location of the sensor to avoid being damaged before sending a signal, and routing of the cable to avoid being cut during a crash.

Other areas in Oldsmobile's paper on development of an air bag restraint include system performance, battery back-up, crash monitoring and failure recording, mounting of the system, structural revisions required, and inflators utilized. This paper is a very good concise description of many facets of an air bag restraint system. It, along with the other mentioned publications, illustrate the leadership General Motors is exhibiting in the area of air bag restraint systems. Possibly some of their innovations can be applied to the Cobra AH-1Q.

A paper entitled "Air Cushion Systems for Full-Sized Cars" was written by an employee of Ford Motor Company. (Pflug, J.A., May, 1972) Although Ford Motors is not doing as much research on air bags as General Motors, they are working in the area. Presented in Pflug's paper are technical approaches to cars in packaging, kinematics, sensing, and deployment of the air bag system. Part of the Ford program included the effects of aging, vibrations, and temperature changes on the air bag system. Other areas encountered in this study were out-of-position occupants, possible hearing damage due to excessive noise upon deployment, life expectancy of the system, and multiple impacts.

Robert J. Hayosh and A.L. Gutherie of Ford Motor Company wrote a paper entitled "Requirements for Air Bag Restraint Energy Sources." (Hayosh, Robert J. and Gutherie, A.L., 1972) The energy source provides, releases, and controls a volume of gas at a rapid rate to inflate an air bag. Three types of energy sources are described:

stored gas, generated gas, and hybrid sources. Requirements for applications of the energy sources are discussed in terms of performance. Requirements include minimum package size and weight, ability to perform in various environments, high reliability, and controlled toxicity and heat. Some systems are to provide either secondary inflation or multiple deployment speeds depending on the design. It is obvious that all areas studied in this paper could and would have to be applied to designing an air bag system for the Cobra AH-1Q.

A very informative paper entitled "Air [illegible] Belts - Next Month You Can Choose" was written for Popular Science magazine. (Shuldinear, Herbert, November, 1972) This paper includes discussion and excellent illustrations of sensors and test crash results.

E. Pujdowski of Eaton Corporation Safety Systems Division published a paper entitled "Crash Sensors for Inflatable Occupant Restraint Systems". (Pujdowski, E., May, 1972) Particular emphasis is given to sensor type, location, and performance. Examples of possibilities for each is given along with a table showing the advantages and disadvantages of various sensors. Even though Eaton Corporation is not the leader of air bag research, they definitely have some excellent ideas in the field.

The Cobra AH-1Q

Military Standard 1290, "Light Fixed and Rotary-Wing Aircraft Crashworthiness" prepared in January 1974 covers various situations during crashes (Department Of Army, January, 1974). Areas mentioned include different angles of impact crashes, buckling deformation in severe crashes, strike envelope for lap belt only and full restraint employment, and head impact protection. It is essential that all of these areas are considered in air bag designs; however, this standard does not mention anything about the possibilities of air bags for restraint.

TM 55-1520-221-10, "Operator's Manual, Army Model AH-1G Helicopter" (Department Of Army, June, 1971) provides valuable drawings, pictures and dimensions of the cockpit area. In addition excellent drawings and pictures obtained from TM 55-1520-221-10, "Operator's Manual, Army Model AH-1Q Helicopter" (Department Of Army, 1974) served as detailed input data to the study reported herein.

The USAAMRDL Technical Report 71-22, "Crash Survival Design Guide," (Department Of Army, October, 1971) provided information on what happens inside the cockpit during an aircraft crash. This information was valuable in evaluating the possible effectiveness of an air bag restraint system in the AH-1Q.

Bell Helicopter Company prepared a technical data report entitled "Improved Cobra Armament Program". (Rutledge, April, 1974) From it, material is gained on hazards and possible corrective action during a crash of the AH-1Q. Also given are human face impact tolerances on a padded deformable surface.

The next chapter will give an overall description of the air bag system as it is presently used in automobiles. An understanding of the design and reliability of the system should be gained from it.

CHAPTER III

AIR BAG SYSTEMS EMPLOYED IN AUTOMOBILE DESIGNS

Air bags have been researched and developed for several years, but are a relatively new concept in automobile safety. During the years of study on air bags, many improvements have made them more effective and reliable. Countless tests have illustrated again and again that air bags are a definite asset in the prevention of injury during certain crashes. (Hayosh, Robert J. and Gutherie, A.L., 1972) The overall system operation of automobile air bags will be presented in the following pages. The system will be described by subsystems which will include: the crash sensor, the gas source, and the inflatable bag. Special problems in the development of the air bag restraint system will also be considered.

The paper "Driver Air Cushion Restraint System" (Louches, Slefka, Dunford, Powell, May, 1972) states that in order to understand an air bag system, one must fully appreciate the time available to accurately detect an accident and inflate an air bag. In a 30 mile-per-hour (mph) barrier collision, the air bag system accomplishes this task in less than 50 milliseconds. The initial events that occur during this time interval are contact and deceleration. Ten milliseconds later, an impact sensor has detected a deceleration of 14 mph. Within 10 milliseconds, the signal has reached the gas energy source which initiates the inflation of the bag. Before a total of 45 milliseconds has elapsed, the air bag is fully inflated and prepared to absorb passenger impact. For a period of approximately 80 milliseconds the bag absorbs approximately 85% of the impact energy. The passenger then starts to rebound backward with less than 15% impact energy at a velocity of about 10 mph.

The Crash Sensor

The crash sensor is the device that detects an accident and signals the gas source to fill the inflatable air bag. Several types of sensors have been designed and tested. Among them are radar sensors, extended probes, and electro-mechanical sensors. The radar sensor was found to have poor crash discrimination along with relatively high cost. The extended probe idea was dropped because no significant advantages were apparent. The electro-mechanical sensor was found to be a good crash discriminator, able to eliminate inadvertent activation, insensitive to the environment, simple, small, and low in cost. The main disadvantage is that contact between the vehicle and obstacle are necessary for activation. The advantages of the electro-mechanical sensor far out-weigh the disadvantages, so this is the sensor most widely used. It will also be the only one referred to in this chapter. Much of the information presented in this section has been obtained from the Eaton Corporation paper. (Pujdowski, E., May, 1972) Other material has been extracted from a paper on General Motors research and development of air bags. (Shuldinear, Herbert, 1973)

The electro-mechanical sensor is also referred to as an inertial or impulse sensor. Two types are used, one for on-board sensors, the other for bumper-mounted sensors. The on-board sensor is located under the dashboard. It has a weight, hung on a pendulum wire, held to one side by a magnet (see Figure 3). The magnet holds the weight until it feels the sudden deceleration of an accident; it then releases the weight. The pendulum swings forward and makes connection with a contact that activates the gas source of the system. The bumper sensor is comprised of a contact point held back by a leaf spring. This spring can be accurately designed to make contact only if an accident exists. Upon sudden deceleration, the sensor swings forward into a contact that initiates the firing of the gas source. (Pujdowski, E., 1972)

There are two levels of collisions considered in designing crash sensors. A low level collision is one equivalent to crashing into a solid barrier at 12 mph. A high level collision is a solid barrier crash equivalent of 18 mph. (Shuldinear, Herbert, 1973) The bumper-mounted sensor is a low level detector. It was found that a sensor mounted on the bumper responds markedly earlier in frontal impact crashes, than one located at any other location on the vehicle. This allows the system more time to deploy the air bags and produces a slower and softer inflation of the air bag. A longer inflation cycle has the advantages of reduced noise, less force applied to the system parts, and is gentler to the passengers. The sensor under the dashboard is both a high level and a low level sensor. The low level sensor acts as a backup to the bumper sensor in case of open failure.

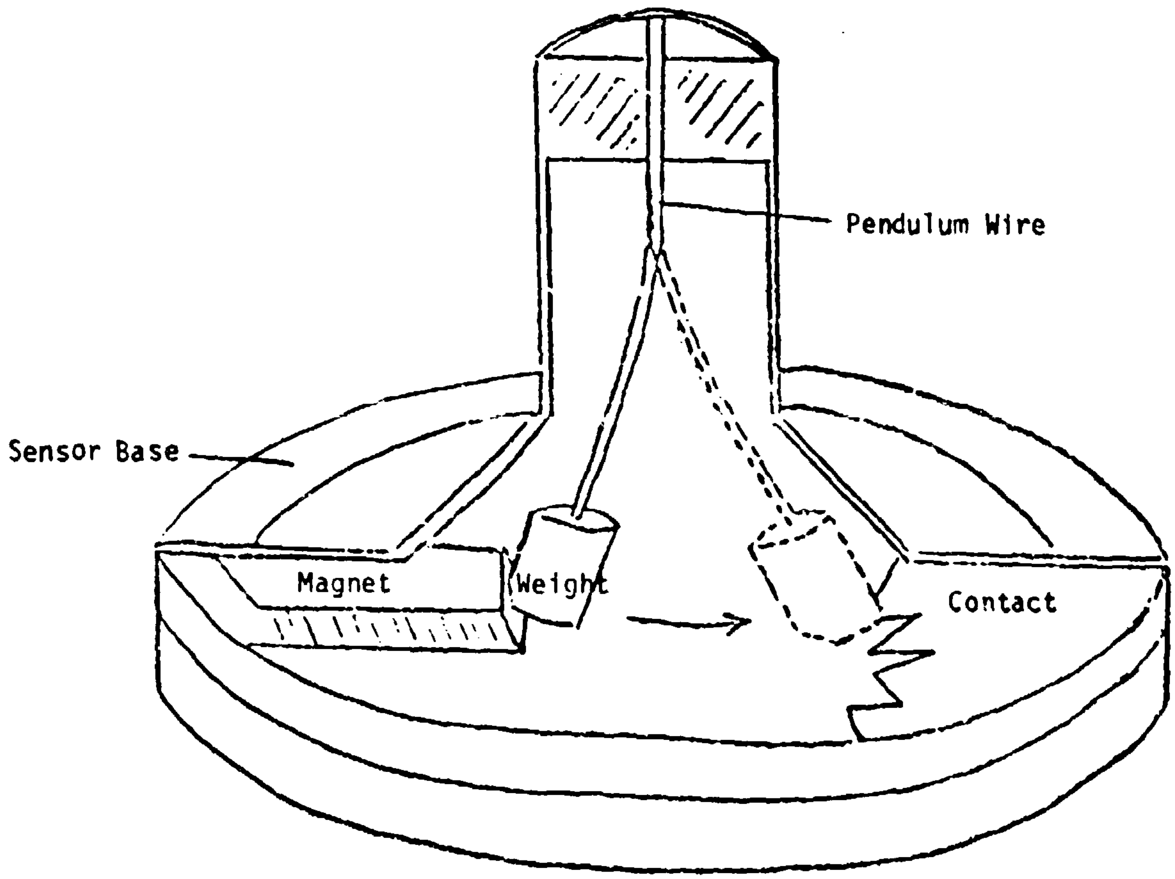

Figure 3. The Electro-Mechanical Sensor.
(Shuldinear, Herbert, November 1973)

The high level sensor responds to more severe crashes and initiates a much faster deployment of the gas source. Upon response to the high level sensor, the gas source fills the bag in approximately 20 milliseconds. This response is harder on the passenger and system, but is necessary to protect the passenger in a higher speed crash.

Figure 4 shows a simple schematic drawing of the sensor system used by General Motors. It can be seen that the on-board sensor is comprised of two low level sensors in series. This helps prevent inadvertent activation of low level inflation of the air bags. A low level sensor is in series with a high level sensor to help protect against inadvertent firing of the fast inflation system. The bumper sensor will fire only the passenger's side air bag according to General Motors' design. It is also designed with two lo mode components in series for added reliability. Delco Laboratories developed and tested this sensor under the following conditions: vibration, temperature change, humidity, dust and acceleration. The sensor performed extremely well and is being used in present day automobile air bag systems.

The Gas Source

The gas source is the second subsystem to be covered. Many of the ideas and figures presented in this section were obtained from a paper prepared for the Society of Automotive Engineers. (Hayosh, Robert J. and Gutherie, A.L., 1972) The gas source provides, releases, and controls the volume of gas necessary to inflate the air bag. Three basic gas sources will be covered: stored gas, generated gas,

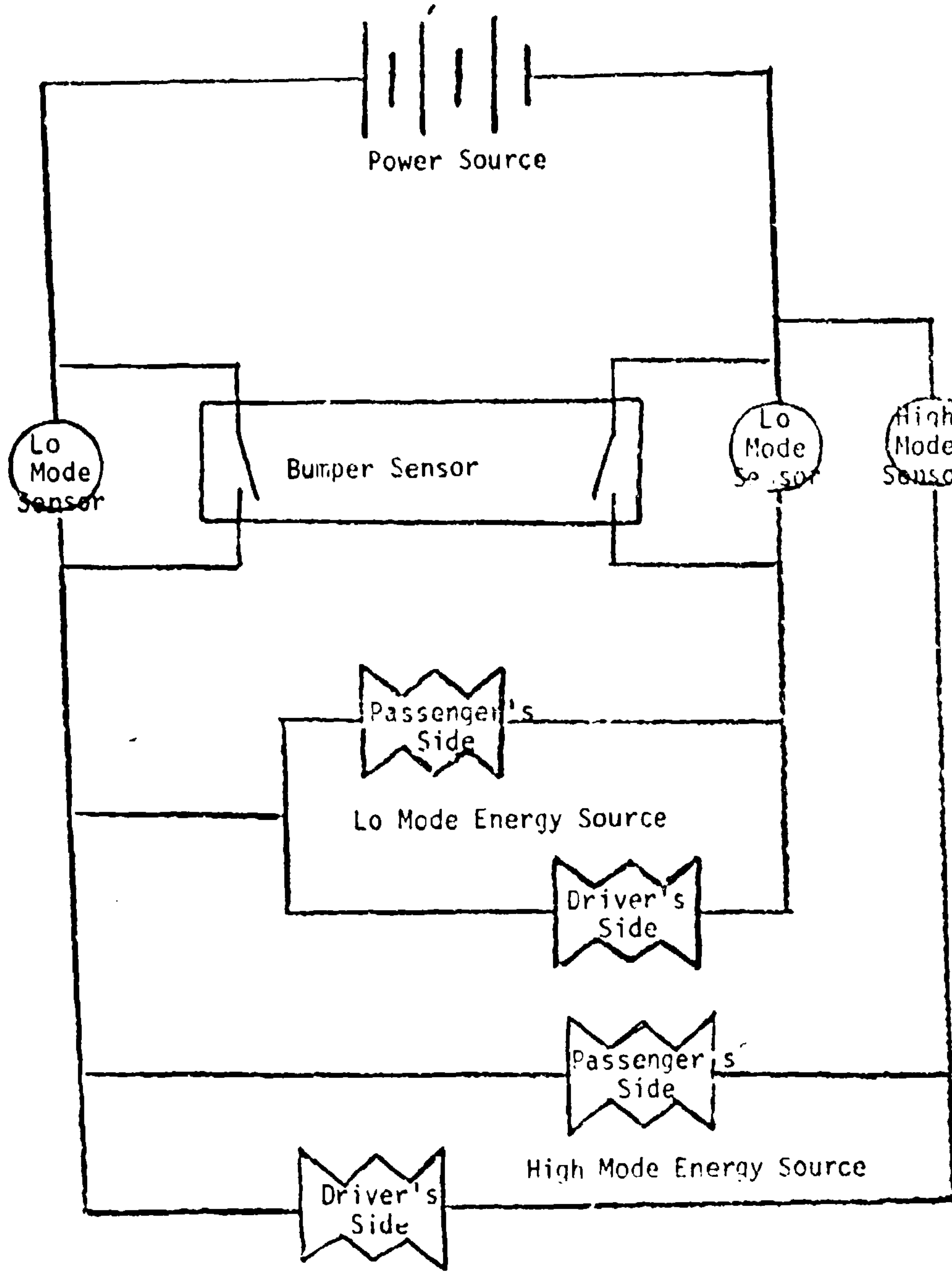

Figure 4. Electronic Circuit of General Motors Corporation Sensor System.
(Klove, E.H. and Oglesby, Robert N., May 1972)

and hybrid sources. Points of concern in choosing a gas source are size, weight, ability to operate in varying temperature, high reliability, and controlled heat and toxicity. Whatever type of source is used, it must provide rapid flow from a high pressure storage tank or a gas generator, and control it.

The stored gas source is generally used in application to front seat passenger protection. This source is set up parallel to the inflatable bag to achieve handling and assembling advantages. (Hayosh, Robert J. and Gutherie, A.L., 1972) This configuration includes a high pressure storage vessel, a release valve, a manifold, and a diffuser (Figure 5). The high pressure vessel contains an inert gas, generally nitrogen, at a pressure of approximately 3500 psi. The release valve maintains storage by use of a rupture disk or diaphragm. Upon detection of a crash, the detonator explodes the valve open and allows the gas to flow. The gas travels through the valve into a manifold that guides it to the diffuser. The diffuser then leads the gas into the inflatable bag.

The gas generating source has been used for steering wheel air bags. It is designed with a flat round shape to lie in the hub of the steering wheel (Figure 6). This type of design allows the manifolding and diffusing of the gas to be done by the gas source. The gas generator has a small squib buried in the solid propellant in the center of the disk. When the squib is energized by the impact sensor, it ignites the propellant. Once the reaction is initiated, it is supported by the oxidizing agent contained in the propellant. The

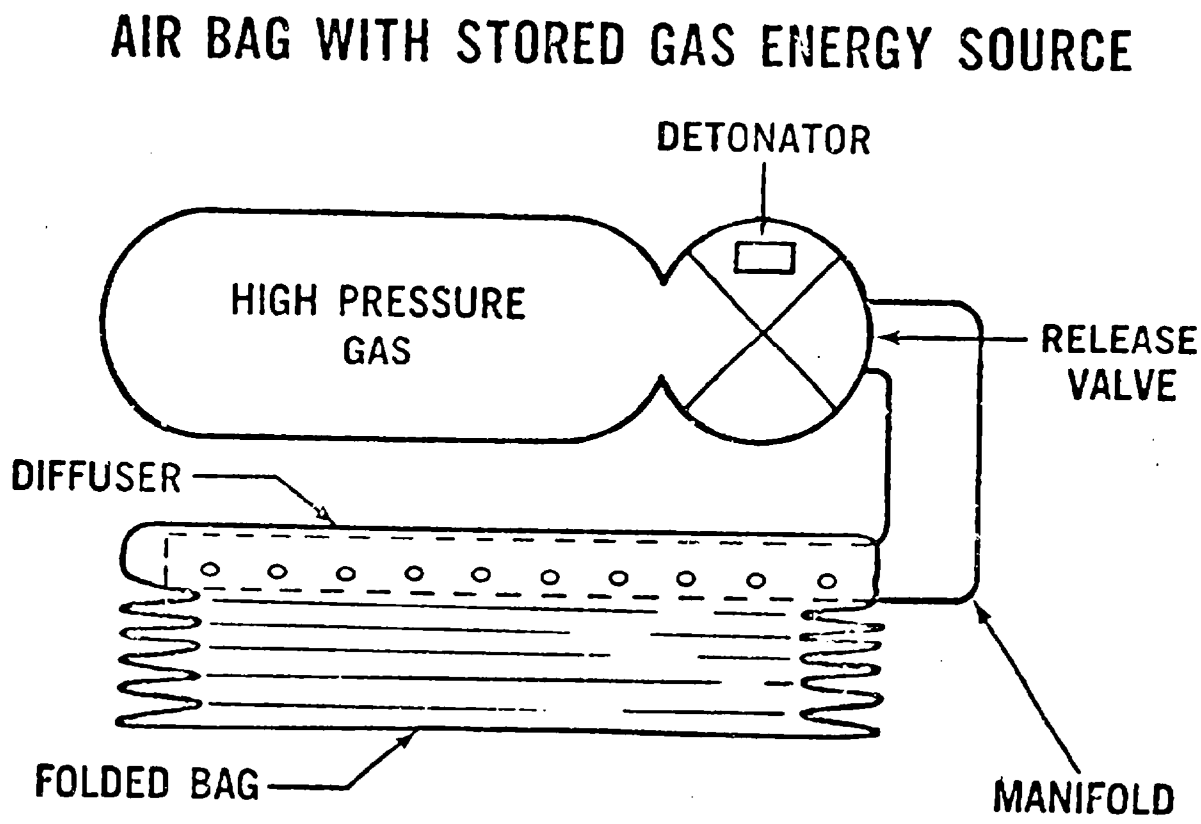

Figure 5. Air Bag With Stored Gas Energy Source.
(Hayosh, Robert J. and Gutherie, A.L., 1972)

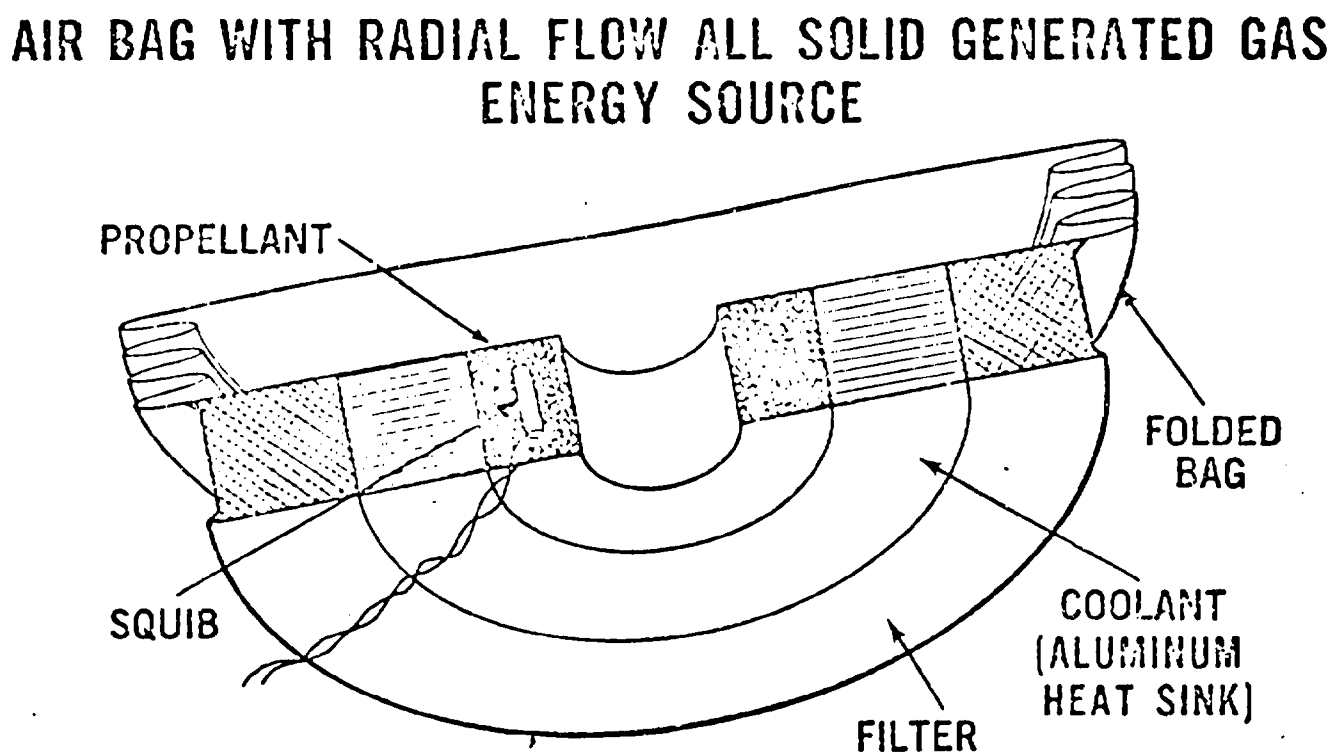

Figure 6. Air Bag With Radial Flow All Solid Generated Gas Energy Source. (Hayosh, Robert J. and Gutherie, A.L., 1972)

propellant burns almost instantaneously and produces a hot gas which is cooled as it travels through the heat sink designed around the propellant. Following cooling, the gas is filtered through the outer section of the generator and passes directly into the inflatable air bag. This system is very compact because of its integral design. A source and distributor, capable of filling a 1.5 cubic foot bag, weighs 2.7 pounds and occupies less than 40 cubic inches of volume while not in use. A similar unit can be designed to fill an 8 cubic foot bag. This system weighs 14.4 pounds and occupies less than 200 cubic inches.

The hybrid source supplies gas from two sources. The source unit is a gas generator built inside a high pressure storage vessel (Figure 7). The hybrid generator is obviously similar to the storage gas source. The main differences are the propellant cylinder and the ignitor squib. The generator produces a hot gas by the combustion of a squib ignited chemical propellant. The hot generated gas vaporizes the liquid or gas coolant in the storage vessel. A commonly used liquid coolant is Freon C-318. The freon vapor and hot generated gas mix and enter the manifold at a reduced heat of 300^{o}F, much lower than the temperature of the initially generated gas.

A chemical propellant that is capable of producing a volume of 2.4 cubic feet occupies a space of less than 25 cubic inches. The pressure vessel contains 60 cubic inches of an inert gas at a pressure of approximately 2350 pounds per square inch (psi) and a temperature

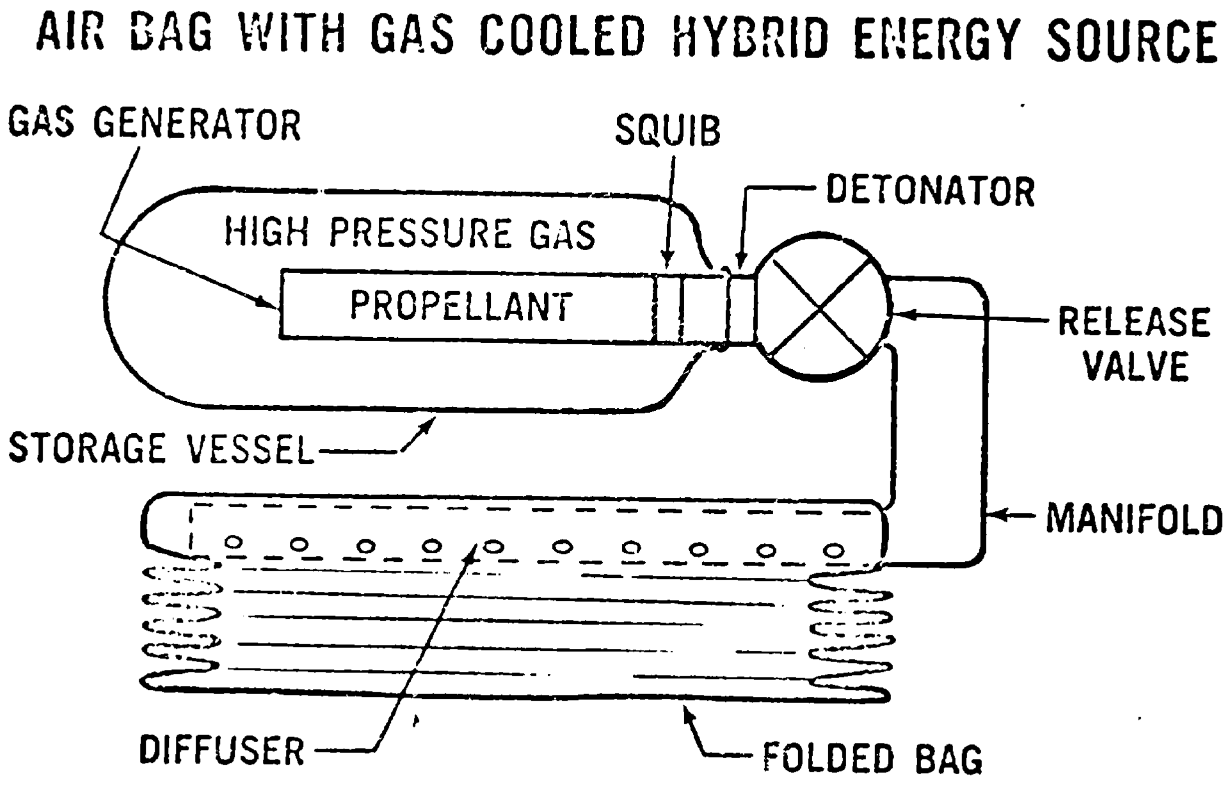

Figure 7. Air Bag With Gas Cooled Hybrid Energy Source.
(Hayosh, Robert J. and Gutherie, A.L., 1972)

of 70°F. The propellant contains a perchlorate oxidizer in a polyvinyl chloride base. The squib, after receiving a signal from the sensor, starts the gas generating process by igniting the propellant. The detonator ruptures the release diaphragm to allow the generated gas to flow into the manifold. It is possible to slightly increase the output of gas by increasing the amount of chemical propellant, and not increasing the package unit size. However, this would allow a higher temperature gas to escape to the manifold. (Hayosh, Robert J. and Gutherie, A.L., 1972)

The volume of an air bag gas producing unit is an important consideration. With all the other instruments, wiring, and bracketry, there is very little space left for additional equipment. Fortunately, the gas source container volume size is the chief variable of the system. This will allow using the space available without interrupting other system functions. This applies to automobiles, but more so to the AH-1Q since volume is a more crucial consideration in this aircraft.

Size of the gas source is influenced by the size of the volume that the gas filled bag must occupy. An approximate volume can be determined by a set of interior measurements. Figure 8 shows the vertical measurement, mean height from top of thigh to top of head, and longitudinal measurement, mean depth from the surface of the instrument panel to the passenger's mid-chest area. The lateral dimension is the width from the left side panel to the right side panel of the craft under consideration. The volume of these three dimensions will give an idea of how much gas volume will be necessary to inflate

VOLUMETRIC ENVIRONMENT FOR INFLATED AIR BAG

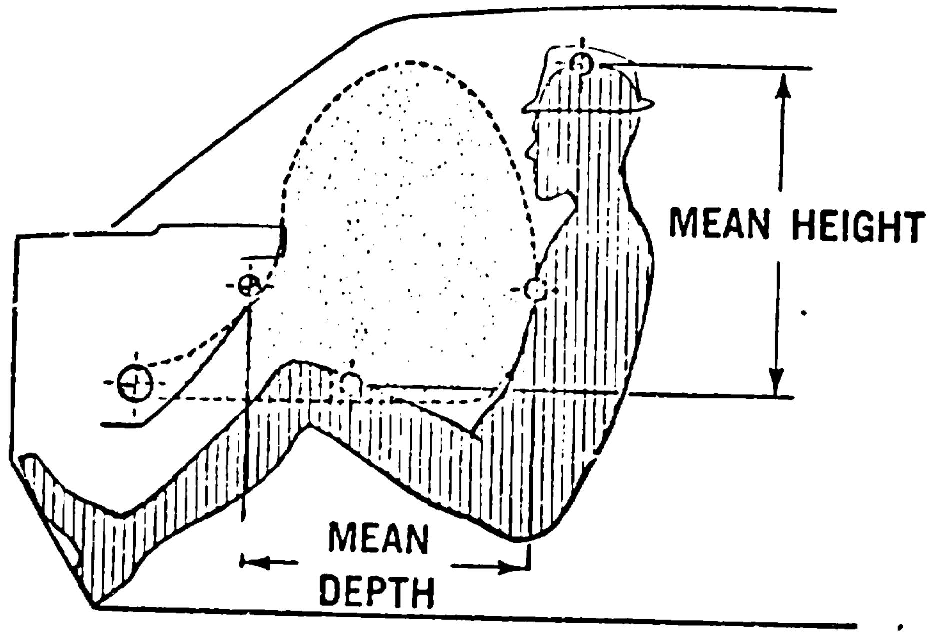

Figure 8. Volumetric Environment for Inflated Air Bag.
(Hayosh, RoLert J. and Gutherie, A.L., 1972)

a protective air bag. In some cases a larger gas volume would require a larger package volume, but this is not always true. Greater gas pressures in the same volume package would produce more volume in an air bag. The hybrid source can produce greater volumes of gas by a change in the type of amount of propellant. However, this change may create an added problem of increased temperature. Table 1 gives an idea of the various sized sources necessary to produce a certain amount of gas volume.

It may be desirable for the gas producing source to be minimal in weight, as would be the case for the AH-1Q. A typical energy source weighs 20 pounds for a 190 cubic inch stored gas source. (Hayosh, Robert J. and Gutherie, A.L., 1972) An equal volume of gas can be produced by a gas-cooled hybrid energy source weighing 10.7 pounds. An all solid propellant gas generator weighs 14.4 pounds for an 8 cubic foot air bag.

The Inflatable Bag

The inflatable bag is the ultimate container of the gas released from the energy source. The gas filled inflatable bag provides the cushion between the passenger and the instrument panel in front of him. It is important that the bag is able to fill quickly and hold the amount of gas supplied under the pressure created. For these reasons it is required that the bag be packaged correctly and be constructed of a suitably strong material. In the General Motors' paper on air bags (Louches, Slefka, Dunford, Powell, May, 1972), neoprene-

	STORED GAS SYSTEM		HYBRID SYSTEM
AIR BAG ENVIRONMENT	GAS @ 3500 PSI	VESSEL PKG.	VESSEL PKG.
VOLUME CU.FT.	VOLUME CU.IN.	VOLUME CU.IN.	VOLUME CU.IN.
6.58	150	215	145
8.00	180	254	145
8.54	190	267	145
8.74	190	267	145
8.79	190	267	145

TABLE 1. ENERGY SOURCE PACKAGE VOLUME
(Hayosh, Robert J. and Gutherie, A.L., 1972)

coated nylon is cited as a material that meets these requirements and is also light weight. According to another paper, (Klove, E.H., and Oglesby, Robert N., May, 1972), the inflatable bag material utilizes a rip or tear-stop construction. This inhibits small tears from propagating to large openings. Also, various porosities of the material can be attained by tightening or loosening the weave construction of the material; another way is to increase, decrease or eliminate the coating. Loose weave or no coating provides greater porosity which prevents the bag from becoming as hard as it does with a tight weave and coated construction. A softer inflated bag results in less rebound action on the passenger.

The folded inflatable air bag is encased by a cover that must withstand abuse and aging, yet be ready to fully open quickly on a split second's notice. The present covering used is .5 inch of polyurethane between two layers of vinyl, each a thickness of approximately 0.1 inch. (Klove, E.H. and Oglesby, Robert N., May, 1972) Predetermined split lines are provided at the sides of the cushion deployment opening. The upper section of the cover is forced open by the inflation of the bag and pivots clear. The sides and bottom of the opening in the cover are reinforced by a steel insert that provides stability and adds insurance to the proper opening of the cover. As the cushion inflates, the cover opens rapidly 180 degrees about its hinge line in 20 milliseconds.

Special Problems

Air bags were developed with the intent to reduce impact injuries during automobile crashes. However, there are some possible undesirable effects caused by air bag deployment. Some of these effects are related to the system's failure to perform as planned. These include: inadvertent activation, out-of-position occupants, and child-sized occupants. Other undesirable effects are related to inherent characteristic hazards of the air bag system. These include toxicity and noise.

A system failure that is a primary concern is the inadvertent activation of the air bag. The effect on the driver of being startled by inadvertent deployment in unknown. (Pflug, J.A., May, 1972) Tests by General Motors have shown that inadvertent activation is virtually non-existent, although one did occur in one of their test fleets. It is very rare for deceleration to exceed 0.7 g, even in a panic stop. Perhaps the highest possible is 1.25 g with cars licensed for road use. (Shuldinear, Herbert, November, 1973) Sensors are set to activate the inflation system at a higher deceleration force than 1.25 g, so braking should not cause air bag activation. Delco Electronics have tested their sensors in cabs around the country, accumulating over two and one-half million miles with no inadvertent activations. (Klove, E.H. and Oglesby, Robert N., May, 1972) There were several accidents, all below the actuation threshold, but no activations occurred. To further emphasize reliability of their sensors, Delco ran air bag equipped cars through a sensor road shock test program consisting of six roads, often with drained shock absorbers. The roads provided a good cross sectional representation of severe rough roads including various weather conditions. (Klove, E.H., and Oglesby, Robert N., May, 1972) Under these conditions, again, there were no inadvertent activations of the air bags. The inadvertent activation of an air bag during operation of a vehicle could pose some serious problems, but reliability of the system obviously makes the probability of it occurring very small.

An air bag may fail to accomplish its purpose during a crash if a passenger is out-of-normal sitting position. After riding in a car, especially for any distance, a passenger may tend to slouch or otherwise be out of the ideal upright position. Also, statistics show that panic braking before a crash, which tends to throw the unsuspecting passenger forward, occurs in 36% of all injury producing collisions. (Pflug, J.A., May, 1972) These abnormal positions may decrease the amount of time that an air bag has to come between the passenger and dashboard. It also could allow a person to slide under the air bag in the case of slouching. Out of position passengers could prevent air bags from doing their intended job. However, the problem is far from impossible to alleviate. The passenger must simply take time to buckle his seat belt.

Child-size occupants could be a reason for the system failing to perform as planned. Small children are often out of normal seating position, frequently standing to see out the windows. (Klove, E.H. and Oglesby, Robert N., May, 1972) There are some redesign changes in the air bag which improve its chance of successfully protecting a child-sized occupant. First is variable inflation, which lessens the initial deployment surge to ease the action of the cushion on the occupant. Second, the cushion is deployed from the lower instrument panel to produce a less direct impact on the head and upper torso of a standing child. The third change is deployment by the bag "unrolling" against the occupant to reduce shock, and finally greater porosity of the fabric reduces the thrust of the total system on the occupant. These changes were instigated by the need for increased small sized occupant protection. They are also good improvements to the system for increased protection to occupants of all sizes.

The possibility that the gas generators will produce toxic products is a main concern in the area of inherent system hazards. Table 2 shows tentative specifications on maximum toxic concentrations inside the air bag. (Hayosh, E.H. and Gutherie, A.L., 1971) These values have been obtained from the threshold limit values (TLV's) set by the American Conference of Governmental Industrial Hygienists and apply to present experimental systems only. The limitations may change over time depending on the interior volume and number of systems deployed. Strict TLV limits of 15 Mg/M^3, of air inside the vehicle, will be followed until other limits can be established.

Another inherent hazard of air bag deployment is the attendant noise. Many people feel the risk of impact injury potential in a high speed accident can be weighed against hearing injury from sound of deployment. Although significant research has been devoted to decreasing the noise level, the possible effect on hearing loss to

• CARBON MONOXIDE	750 PPM
• OXIDES OF NITROGEN (EXCEPT N_2O) NO_2+1/6 NO)	5 PPM
• HYDROGEN CYANIDE	20 PPM
• PHOSGENE	0.5 PPM
• CHLORINE	3.5 PPM
• OXIDES OF SULFUR	5.0 PPM
• HYDROGEN SULFIDE	20 PPM
• AMMONIA	100 PPM
• HYDROCARBONS	1700 PPM
• HYDROGEN CHLORIDE	10 PPM
• HYDROGEN FLOURIDE	20 PPM

These limits are for an eight hour period and forty hour week. It can be assumed that in the case of the AH-1Q, neither the gunner nor pilot would have an exposure anywhere near this long if either is conscious after the crash. Their exposure would very likely be less than one minute and these limits could be somewhat higher.

TABLE 2. PROPOSED TOXICITY LIMITATIONS
(Hayosh, A.H. and Gutherie, A.L., 1972)

persons with head colds or to the aged, etc., is not known. A significant reduction in noise level was found by the application of a variable inflation rate air bag. Most collision accidents are in the lower speed range and would benefit from the slower speed inflation which is inherently less noisy. (Hayosh, Robert J. and Gutherie, A.L., 1972)

This chapter has included a description of the present day air bag system, its subsystems and how they operate. Mention was also made of the special problems encountered with an automobile air bag system. Chapter IV will be concerned with how an air bag system might be designed into the Cobra AH-1Q to protect the gunner from contacting the sighting device during a crash. Relations between the special problems of the present day automobile air bag and those of the AH-1Q will be discussed.

CHAPTER IV

AIR BAGS AND THE COBRA AH-1Q

The Cobra AH-1Q is the newest version of the Army's attack helicopters, being a modification of the Cobra AH-1G used in Vietnam. The main differences between the two are that the AH-1Q employs track on wire (TOW) missiles, a helmet sub-sight, and a stabilized sighting device. Other than these differences, the two aircraft are essentially identical. It is the new stabilized sighting device that, while modifying sighting ability, introduces a safety hazard to the gunner. Upon impact of a crash, the gunner will very possibly be thrown forward enough to strike his face, neck, or chest on the rigid sight. Very serious injury or even death could be a direct result; therefore, the feasibility of an air bag(s) as a protective device from such injuries is being studied in this paper.

Figure 9 illustrates the location of a rigid or telescopic sighting device in relation to the gunner. The sight is mounted on the lower mid area of the control panel and extends out between the gunner's legs and up toward his head.

The inertia reel belt restraint system is used in the gunner's seat. The "give" in the reel as well as the stretch in the belt could allow the gunner to move as much as one foot horizontally past his initial position at the time of impact. If he is all the way back in his seat, he would possible not make contact with the sight, if the sight stays in position. If he is anywhere between the sitting

Figure 9. The Gunner in Seated Position.
(Bell Helicopter Company, June 1972)

position (Figure 9, page 33), to a point of sighting, (Figure 10), he is very susceptible to striking the sight during a crash. If his face is against the eye piece at impact, the high g loads experienced by the airframe and sighting device would be transferred to his face. It must also be kept in mind that even when the gunner is all the way back in his seat, it is still very possible that he will be struck by the sight or control panel as they are pushed toward him by the crash force. This reaction may be predictable but could vary from crash to crash.

Human face impact tolerances on a padded deformable surface (Figure 11) show that 30 to 40 g level face impacts are tolerable without serious injury. (Rutledge, D.E., April, 1974) This level would be attained for a 15 pound head/helmet weight for a 30 foot/second impact along the sighting tube axis. However, a rigid, nondeformable sight is being used in the AH-1Q. It is assumed that for a rigid device, these tolerances would be less, although the force of impact with the sight would not necessarily differ.

A crash sensor for the AH-1Q could be very similar to the type used in automobiles described in Chapter III. An electro-mechanical inertial type of sensor set to detect only high level crashes, assuming all crashes of the AH-1Q are in this category, would be ideal. This sensor is insensitive to environment, simple, small, low in cost, and relatively light. The main disadvantage of this sensor, as when used in automobiles, is that contact between the ground and helicopter is necessary before activation occurs. For this reason, the

Figure 10. Gunner in an Aiming and Firing Position.
(Bell Helicopter Company, June 1972)

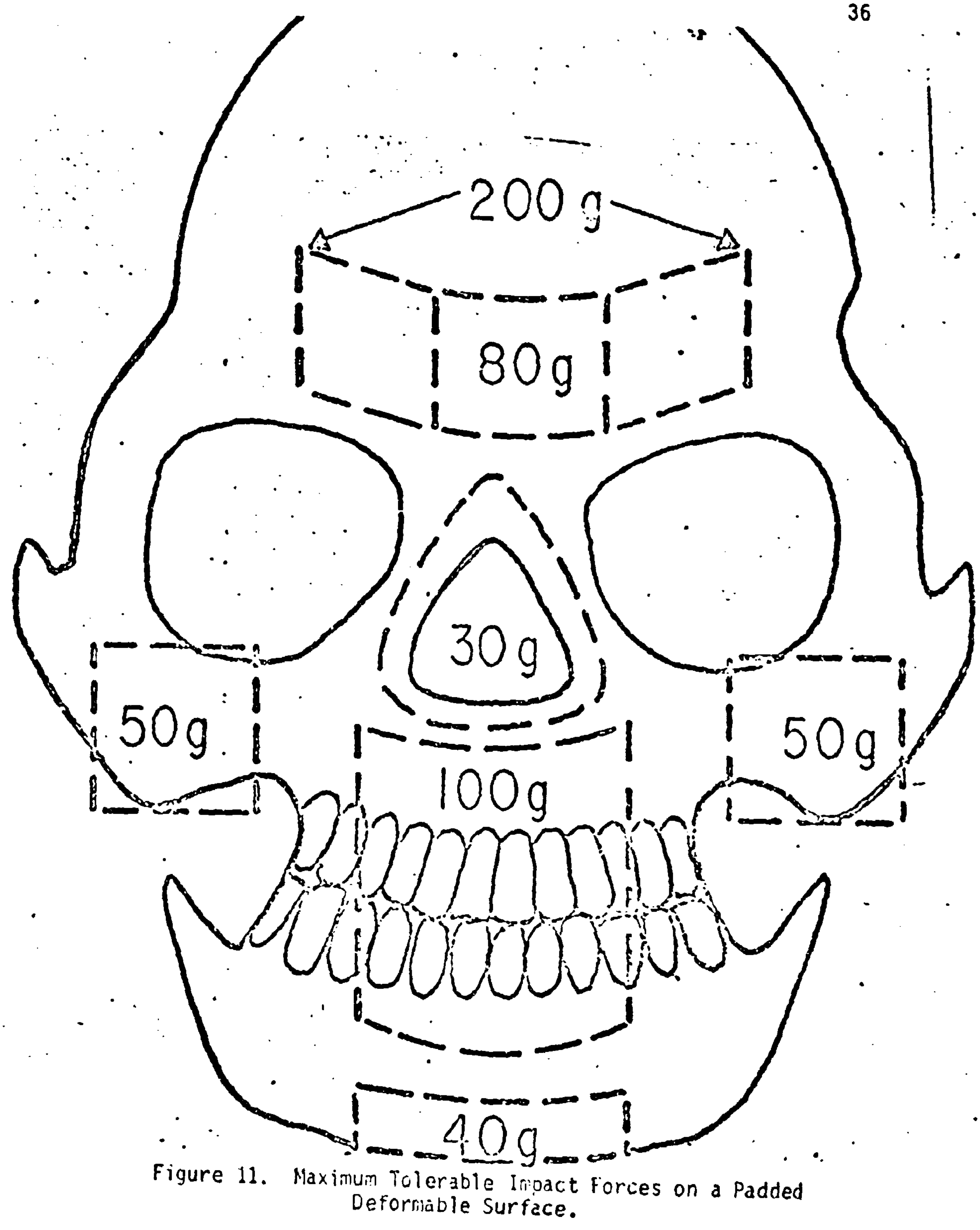

Figure 11. Maximum Tolerable Impact Forces on a Padded Deformable Surface.

(Rutledge, D.E., April 1974)

possibility of using an extended probe or radar sensor could be further investigated. These sensors lack the simplicity, low cost, and crash discrimination ability of the inertial sensor.

The sensor should be mounted in a position that is earliest to feel the impact of a crash. The first contact with the ground would most likely be with the landing skids or the nose of the aircraft. In order for the nose to hit first, the Cobra AH-1Q would have to strike the ground at an angle of 27^{0} up from the horizontal. This could mean the aircraft is tilted forward at least 27^{0} or the ground is rising at 27^{0} from the 180^{0} horizontal (Department Of Army, 1971). (Figure 12)

As in the General Motors sensor system, two sensors wired in series would help preven nadvertent activation. This is a very important aspect to include in the AH-1Q. Another consideration related to sensors is that they should be located at a point that leaves little chance of the signal carrying wires being severed, by crash impact, before they transmit their complete signal. This point may present enough reason to avoid placing the sensor on the landing skids. The nose of the ship would be the most appropriate location for the sensor. It would provide more protection as well as be early to impact.

The gas source is the next subsystem of the air bag system to be considered. Choosing between a stored gas and a generator gas source will be difficult. Since this system is being designed for an aircraft that often operates in a war zone, considerations beyond those of the automobile air bag system must be made. One of these is: how likely is it that enemy fire would penetrate and burst a high pressure

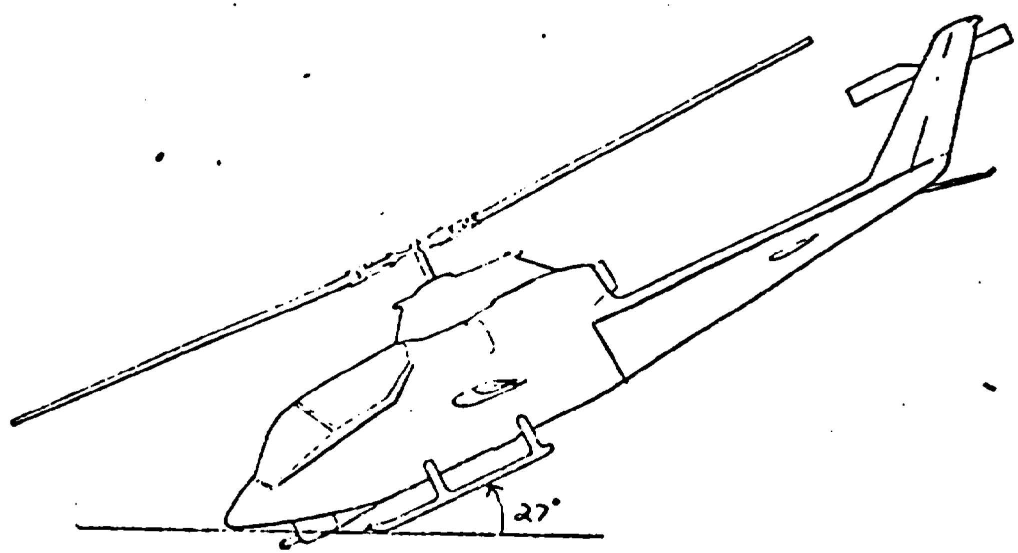

Figure 12. Minimum Angle of Impact in Order for Nose to Impact First.
(Department Of Army, 1971)

gas storage vessel? This could cause the existence of an uncontrolled missile flying around inside the aircraft cockpit, besides the hazard of uncontained heat and inflation gas. The tank could also instantaneously explode in such a given case, possibly causing extensive damage, injury, or even death. The exact probabilities of these events occurring is unknown, but certain measures should be taken to decrease them. The same precautions would be taken in the case of the gas generator and these will be discussed further in Chapter V.

It was pointed out in Chapter III that the gas generator is generally used in application to a steering wheel hub mounted air bag. The storage gas source is generally used to fill the larger under-the-dashboard mounted air bags. It would be logical to first decide how large a volume is to be filled with air bag and then decide which type of source would be best to accomplish that task. The overall volume of the gunner cockpit is not very large, about 20 cubic feet. To completely engulf it with air bag would be possible; although not feasible for the particular problem studied in this paper. The concern in this study is to protect the gunner from the sighting device only. It seems logical that a relatively small air bag could perform this task.

As mentioned in Chapter III, a chemical propellant gas generator and air bag unit capable of filling a 1.5 cubic foot inflatable bag weighs 2.7 pounds and occupies a space of less than 40 cubic inches. (Hayosh, Robert J. and Gutherie, A.L., 1972) Along with a small sensor, wiring, and bracketry, the whole system could very possibly be kept to less than 5 pounds in weight. Both the storage and the hybrid sources occupy more space and weigh more. They will be discussed more in Chapter V.

The inflatable bag will be the ultimate container of the gas and must be as reliable as any other component in the system. Possibly a bag made of the same material used for automobile air bags could be used, but that would depend on the desired deflation time of the bag. The AH-1Q is very likely to have multiple impacts during a crash before it finally comes to a halt. For this reason, it may be best that the bag does not deflate as fast as it does in an automobile. There is not much of a chance of a helicopter pilot pulling the aircraft out of a serious crash once initial impact has been made, as may be the case in an automobile. An automobile driver could glance off a rail, have his air bag inflate to protect him and deflate, and still drive his car to a safe stop. In a helicopter, once the primary air bag activating impact is made, control of the aircraft is assuredly left to fate. Therefore, an air bag that stays inflated for an extended period of time could only increase protection. This can be accomplished by tightening the weave construction of the bag to prevent fast permeation of the gas through it. Also, various material coatings decrease the porosity of the bag material.

Chapter III made note that the bag covering used in cars is generally constructed of a .5 inch polyurethane between two layers of vinyl. (Klove, E.H., and Oglesby, Robert N., May, 1972) This protects the lighter bag material held inside. It is important that the bag covering for the AH-1Q be tough and temperature resistant. Limited space makes entering and exiting more of a task than it is from a car, so bumping and rubbing against the bag unit is to be expected. The temperature inside the cockpit can reach an excess of 200°F when the aircraft is resting on a pad on a hot day with the canopy down. This is a main reason that the covering must be able to resist high heat conditions; this applies to the inflatable bag and gas source also.

Two special problems, already mentioned, are the chance of inadvertent activation and an uncontrolled missile which is caused by an exploded gas source. Other problems also exist and will be discussed next. The two main problems are inherent to the system's operation and involve toxicity of the inflation gas and noise caused by air bag deployment. Two problems found in automobiles that the AH-1Q would not have to be concerned with are out-of-position passengers and child-sized occupants.

Table 2, page 30, shows some of the specifications on maximum toxic concentrations inside automobile air bags. (Hayosh, Robert J. and Gutherie, A.L., 1972) These limits could be used as guidelines for aircraft air bags unless more stringent ones are set. In most cases after a crash, the gunner, if conscious, would be attempting to get out and away from the wreck. Or possibly the canopy will have been cracked in places. Both cases will allow the gunner fresh air and not allow him to be affected by the gas unless it was of a very fast reacting toxic type.

The noise caused by the rapid inflation of the air bag would be more of a problem in cars than in the AH-1Q. The gunner wears a helmet with built-in head phones. The noise created by the air bag deployment would not be likely to harm his ears. In relation to the air bag, the noise from firing armaments is at least as noisy and harder on the gunner's ears since they are extended over longer periods of time. The gunner may receive a solid bump in the face or chest from the inflated air bag depending on the size of the bag. This force would not be strong enough to seriously hurt the gunner and would surely be less than the impact that the bag is designed to prevent.

The best air bag system for the AH-1Q would most likely be very similar, in basic components, to the present day automobile air bag system. There may be some slight alterations to it, but it would be comprised of a sensor, a gas source, and an inflatable bag. The next chapter will contain recommendations as to where these components should be located to accomplish the desired protection. Also, Chapter V will contain the author's evaluation of the feasibility of having such a system on the Cobra AH-1Q.

CHAPTER V

EVALUATION AND RECOMMENDATIONS

An air bag restraint system for the Cobra AH-1Q would work, in principle, much as the present automobile system, but there would be several differences. Among these differences are: locations, sizes, and weights of the various components; and, as mentioned earlier, possibly the time the bag stays inflated. These topics will be discussed in this final chapter.

Various Army and civilian personnel were interviewed to gain opinions of the idea of having an air bag restraint system in the AH-1Q. All of these people work with or fly this particular aircraft, so their ideas and feelings were taken with much respect. Many of these ideas will be reflected in the following paragraphs. In general it was found that safety related personnel showed a positive attitude toward the idea, where the men who actually fly these machines were more hesitant about accepting it. One instructor pilot noted that when a helicopter pilot is trained, he is taught to attempt to safely land the aircraft in a panic situation, with little thought given to what may occur to him if it crashes. Another Army pilot who had flown both fixed and rotary-wing aircraft was the only pilot who thought the idea of air bags had merit. He first learned to fly fixed-wing aircraft in which the pilot and crew bail-out when the aircraft is going down. He noted that he gets a wary feeling when flying a helicopter, knowing he has no way to eject when going down and only seat belts, harnesses, and a helmet to protect him in a crash.

The sensor will have to be located in the front of the ship, in the nose area of the body. The reason for this is that it is a more protected area than the skids which would be the other logical point of location. The skids, hanging down, may be damaged and ripped away from the aircraft, as it crashes, before the signal of impact has reached the gas source. Also, the skids are more in the open to enemy fire which could either destroy or activate the sensor. Inside the nose, the sensor could be so placed as to provide it protection from enemy fire. Added weight is to be avoided, but possibly some protective shielding would help protect it. The sensor itself could be of the electro-mechanical type with two sensors in series to help prevent inadvertent activation; although this should not occur with high reliability. Even when the AH-1Q lands under heavy load or in auto-rotation, the impact would not be nearly severe enough for the sensors to detect if they are properly designed. The idea of pilot activation of the air bag, instead of sensor activation, was discussed in several interviews. Most personnel disagreed with this idea on the grounds that the helicopter pilot's mind is totally engulfed with safely landing the craft when it is going down and in most cases he would never think to activate the air bag. There is no positive data on this claim.

The gas generator as an energy source appears to be the most advantageous for the AH-1Q. It is small, light, and unable to introduce an uncontrolled missile to the cockpit area. The storage tank is worse than the generator in each of these areas and there is no difference in the reliability of the two sources (Table 3). Added insurance could be provided by protective shielding being placed around the source. Perhaps this shielding could be of the same type used to protect the pilot and gunner. Since the generator type of source is built integrally with the air bag, its location will be decided by where the bag is located. The amount of propellant will be governed by how large a bag is to be filled; this will be discussed next.

The air bag study in this paper is done with the idea of protecting the gunner from contacting the rigid sighting device in case of a crash. For this reason, the inflated bag would not have to be very large; perhaps 2 cubic feet would be sufficient. In this case the integral unit of source and bag would weigh about 3 pounds and occupy less than 50 cubic inches. Its location is the most difficult decision to make.

The air bag could be located in one of several places: on the sighting unit, on the floor, on the gunner's seat, on the canopy, on the belt and harness system, or on the gunner. The canopy and floor can be excluded first on the assumption that the bag would have to be bigger than 2 cubic feet to be attached to either of these points and still come between the sight and gunner. Most likely the same would apply to the seat location, but this location (on the seat, between the gunner's legs) would be excellent if a bigger bag was to be used for more complete protection. This would protect the gunner's whole body from waist to top of head. This protection could be very

COMPONENT	STORED GAS W/O FLOW CONTROL	STORED GAS W/ FLOW CONTROL	GENERATED GAS - ALL SOLID	HYBRID GAS COOLED	HYBRID LIQUID COOLED
Storage Vessel	.9999	.9999	--	.9999	.9999
Coolant/Fluid	.9999	.9999	.9999	.9999	.9999
Generator Housing	--	--	.9999	.9999	.9999
Propellant	--	--	.9999	.9999	.9999
Squib	--	--	.9999	.9999	.9999
Detonator	.9999	.9999	--	.9999	.9999
Rupture Valve	.9999	.9999	--	.9999	.9999
Flow Control Valve	--	.999	--	--	--
ENERGY SOURCE	.9996	.9986	.9996	.9993	.9993

TABLE 3. RELIABILITY OBJECTIVES OF ENERGY SOURCES AT 90% CONFIDENCE LEVEL
(Hayosh, Robert J. and Gutherie, A.L., 1972)

effective in keeping the panel, canopy, and front end of the aircraft from crushing the gunner as it is pushed toward him by the impact force. However, this would add more weight and will not be considered at this time. Locating the source and bag unit on the gunner would be undesirable for the reason of unnecessarily adding supporting strain on him. However, if the unit were to be designed on the front top edge of the gunner's helmet or on the upper chest area of his nomex uniform, the bag would be sure to come between the gunner's head and the sight, but this idea will be excluded to avoid the added strain. Designing the source and bag unit on the belt harness or on the sight are the only two points left. The on-the-belt design may be undesirable since the bag would originate from the shoulder area, which is to the side of a mid line through the pilot, and may be easily deflected to the side as the gunner's head strikes it. The sighting device is the last point to be considered, and probably the best for the 2 cubic feet size air bag. Located on the underside of the sight at the end nearest the gunner, the bag could be designed to inflate and come up and back toward the gunner to occupy the space between his head and the sight (Figure 13).

The main reason for limiting the bag size was to keep the weight to a minimum of approximately 5 pounds. If this minimum is increased, more protection could be provided, as in the case explained above with the larger unit being mounted on the gunner's seat. The author feels that if any air bag restraint system were to be added to the AH-1Q, the slightly larger unit mounted on the seat would provide the best

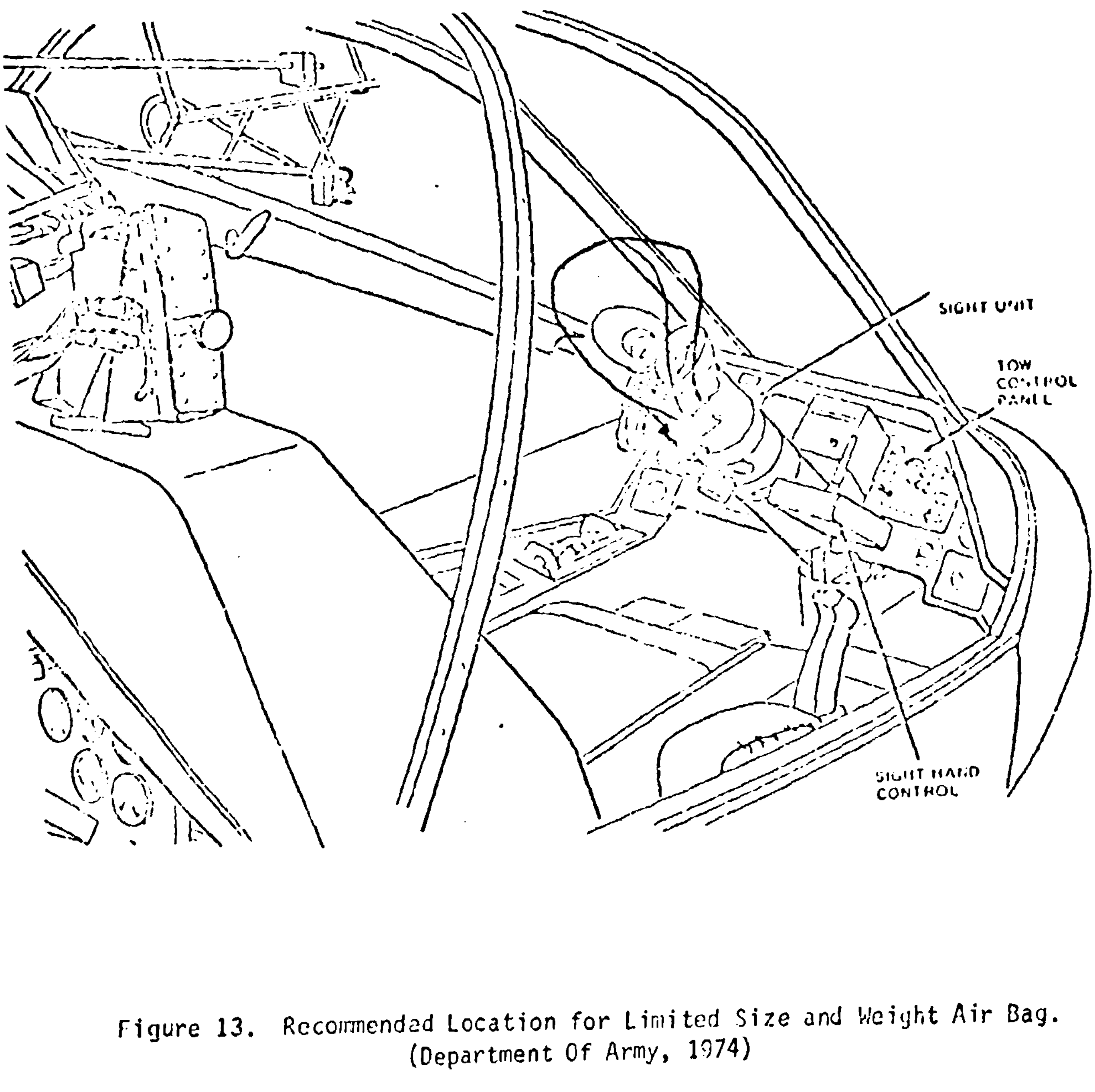

Figure 13. Recommended Location for Limited Size and Weight Air Bag. (Department Of Army, 1974)

protection pound for pound (Figure 14). This location, as with the location of the smaller unit, would not interfere with aircraft operation.

Other areas that would need further investigation and research would concern the sensor and the inflatable bag strength. The effects of turbulence as well as pulling up from a dive attack would need further study to learn whether or not these forces may be greater than the 4g load setting. Possibly the forces from these situations would make it necessary to increase the setting to a higher g load force. Another point to consider would be the possible need for a sensor to detect horizontal impact and another to detect vertical crash impact. As was considered earlier in this paper, the single horizontal detector would be reliable to detect impact if the craft crashed with a horizontal movement. But the case may exist where the helicopter may have very little forward motion and drop almost straight to the ground. In this case it may be desirable to have a sensor to detect vertical impact.

The strength of the material used for the inflatable bag may have to be increased from that used in automobile air bags. In the AH-1Q, crashes may be of much higher speeds plus the sighting unit may act as a spear to puncture the bag during crash impact. Further research may find that a different reinforcing material or stronger fabric would be necessary for an effective air bag for the Cobra.

This research paper has looked at a present day automobile air bag system: its components, mechanics, and reliability. Using this system as a guide, a similar system is being considered for the

Cobra AH-1Q gunner position to prevent crash injuries caused by impact with the rigid sighting device. Three subsystems comprise the whole air bag system and each was discussed and evaluated for the AH-1Q. It was decided that an air bag system could very possibly prevent gunner injury without adding a significant amount of weight or interfering with aircraft operation.

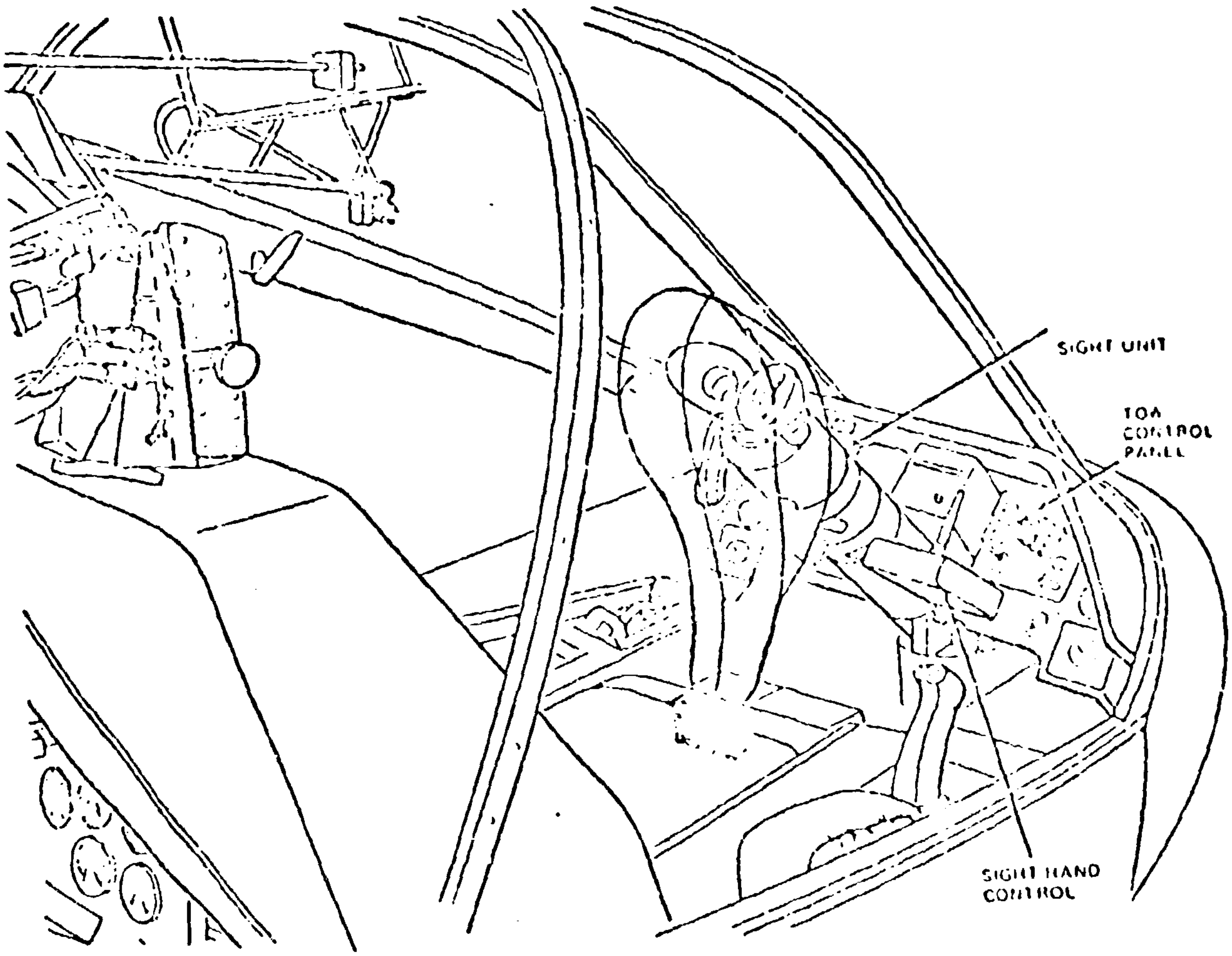

Figure 14. Recommended Location for Larger Extra Protection Air Bag. (Department Of Army, 1974)

LIST OF REFERENCES

1. Bell Helicopter Company, Bell Monthly Letter of Progress Report, (June 1972), 26-44.

2. Department Of Army, "Crash Survival Design Guide," USAAMRDL Technical Report 71-22, (October 1971), 183-188.

3. Department Of Army, Operator's Manual, Army Model AH-1G Helicopter, TM 55-1520-221-10, (June 1971), 1-2, 1-3, 2-5, 2-13.

4. Department Of Army, Operator's Manual, Army Model AH-1Q Helicopter, TM 55-1520-221-20, (1974), 2-4.

5. Hayosh, Robert J. and Gutherie, A.L., "Requirements for Air Bag Restraint Energy Sources," Society of Automotive Engineers, (1972), 1-9.

6. Klove, E.H., "Air Cushion Restraint System," General Motors Corporation 1973 Report on Progress in Areas of Public Concern, (1973), 55-56.

7. Klove, E.H. and Oglesby, Robert N., "Special Problems and Considerations in the Development of Air Cushion Restraint Systems," Society of Automotive Engineers, (May 1972), 1-9.

8. "Light Fixed and Rotary-Wing Aircraft Crashworthiness," Military Standard 1290, (January 1974), 38-43.

9. Louches, Slefka, Dunford, Powell, "General Motors Driver Air Cushion Restraint System," Society of Automotive Engineers, (May 1972), 1-16.

10. Pflug, J.A., "Air Cushion System for Full-Sized Cars," Society of Automotive Engineers, (May 1972), 1-5.

11. Pujdowski, E., "Crash Sensors for Inflatable Occupant Restraint Systems," Society of Automotive Engineers, (May 1972), 1-9.

12. Rutledge, D.E., "Improved Cobra Armament Program-Hazardous Failure Mode and Effects Analysis," (April 1974), D-9.1-D-9.4.

13. Shuldinear, Herbert, "Air Bags vs Belts - Next Month You Can Choose," Popular Science, (November 1973), 84-86.

14. Terry, S.L., Vice President Chrysler Motor Company, Speech before U.S. Senate Commerce Committee, (March 1974), 1-13.