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PRELIMINARY HAZARD ANALYSIS FOR AUTOMATIC LIFE RAFT SYSTEM AND --ETC(U)
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This document covers the preliminary hazard analysis (PHA) for the externally mounted, automatically expelled/inflated multiplace life raft system for helicopters (Automatic Life Raft System - ALRS), and the sink rate delay/improved in-water stability system for helicopters (Helicopter Flotation System - HFS). The analysis was prepared in accordance with the requirements of NAVAIRDEVCEN Contract N62269-76-C-0341, Data Item A009.

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ABSTRACT

This document covers the Preliminary Hazard Analysis (PHA) for the "Externally Mounted, Automatically Expelled/Inflated Multiplace Life Raft for Helicopters" (Automatic Life Raft System - ALRS) and the "Sink Rate Delay/Improved Water Stability System for Helicopters" (Helicopter Flotation System - HFS). The analysis was prepared in accordance with the requirements of NADC Contract N62269-76-C-0341, Data Item A009.

KEY WORDS

Preliminary Hazard Analysis

Fault Tree

Hazard

Safety Considerations

Safety Assessment

Risk

TABLE OF CONTENTS

List of Illustrations

List of Tables

1.0 INTRODUCTION

A Preliminary Hazard Analysis (PHA) was performed for the Automatic Life Raft System (ALRS) and the Helicopter Flotation System (HFS). A Preliminary Hazard Analysis (PHA) is a qualitative study and is the initial formal system safety analysis task. It is used to assess risk areas of the system and identify safety critical subsystem or components. It identifies gross-hazardous conditions and provides guidance for the performance of subsequent indepth safety analyses such as Subsystem Hazard Analyses (SSHA) and Operating Hazard Analyses (OHA).

2.0 BACKGROUND

2.1 When a helicopter enters water due to an emergency or impacts water inadvertently, two major causes of casualties to the occupants arise. First, helicopters enter the water and sink-often in less than one minute. Second, because helicopters are not built as boats, they are unstable in water. This instability frequently causes instant rollover, making egress difficult or impossible.

Numerous problems confront would-be survivors in their efforts to egress successfully from sinking, capsizing helicopters. They must contend with shifting displaced cargo and equipment inside the cabin. They must cope with disorientation, confusion, and panic as the helicopter impacts, fills with water, capsizes and sinks. They must release restraining straps and locate, release and display internally stowed life rafts. Through it all they must contend with inrushing water. After getting out of the helicopter and reaching the surface, both major undertakings, helicopter borne personnel must contend with the ultimate challenge, survival on the water surface.

2.2 Two concepts for increasing survivability under the above conditions have been proposed:

- o Automatic Life Raft System (ALRS)
- o Helicopter Flotation System (HFS)

The proposed systems have been configured for the H-46 helicopter.

2.3 For further background on helicopter water entry problems, the reader is referred to Document D210-11003-1 "Sink Rate Delay/Improved In-Water Stability System for Helicopters". For a comparison of the effectiveness of the two systems, Document D210-11101-1 "Comparative System Analysis of Helicopter Flotation System vs. Life Raft Study" should be referred to.

3.0 SYSTEM DESCRIPTIONS

The physical and operating characteristics are described below for each system. It should be noted that the activation systems for deploying either the life rafts or the flotation bags are basically the same. Deployment may be initiated by the aircrew or automatically, and similar system safeguards are provided in order to preclude inadvertent system operation.

3.1 AUTOMATED LIFE RAFT SYSTEM (ALRS)

3.1.1 Physical Characteristics

Basic elements of the system are:

- Two 15 man GFE life rafts
- Two reinforced fiberglass life raft containers and attachment points
- Two inflators
- Electrical activation system

The conceptual design configuration for the Automated Life Raft System is shown in Figure 1. It consists of two 15 man life rafts located in externally mounted fiberglass containers attached to either side of the H-46 helicopter. The rafts can be deployed and inflated in approximately 10-15 seconds. Pilot or automatically fired squibs cause gas to be released from the inflators and into the rafts. Types of inflators under consideration include compressed gas bottles, cool gas generators coupled with air aspirators, and solid propellant generators coupled with air aspirators.

The life raft containers are attached, via mounting brackets and bolts, to established hard points on either side of the fuselage between stations 220 and 254. The container door is secured in place by a hinge and over-center type latches. For deployment of the raft, the door is opened by the pressure from the inflating raft. (Note: Velcro is being considered as an alternate means of providing the fastening and opening functions for the door). Once deployed, the rafts remain connected to the helicopter by umbilical lines. Should the helicopter sink, the lines pull free from the helicopter due to raft buoyancy and the rafts remain on the surface.

3.1.2 System Operation

Two methods of deployment are provided. The primary methods of deployment require actuation of the system by the pilot or a cabin crewmember after the aircraft is in the water. The other method is automatic deployment of the life rafts after water

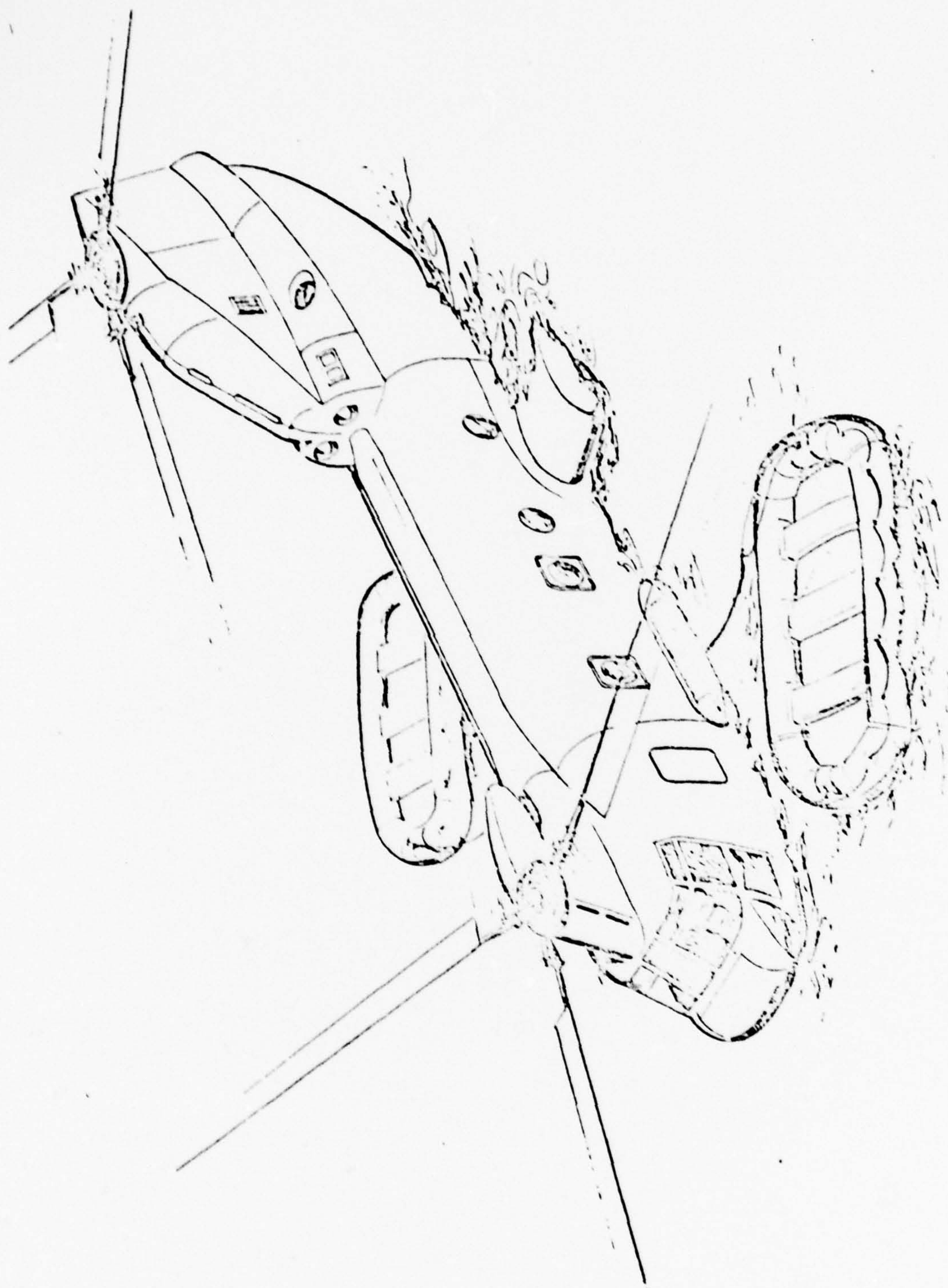


Figure 1. H-46 Helicopter with Two 15-Man Life Rafts (Deployed from External Fuselage Containers)

SCHEMATIC - AUTOMATED LIFE RAFT

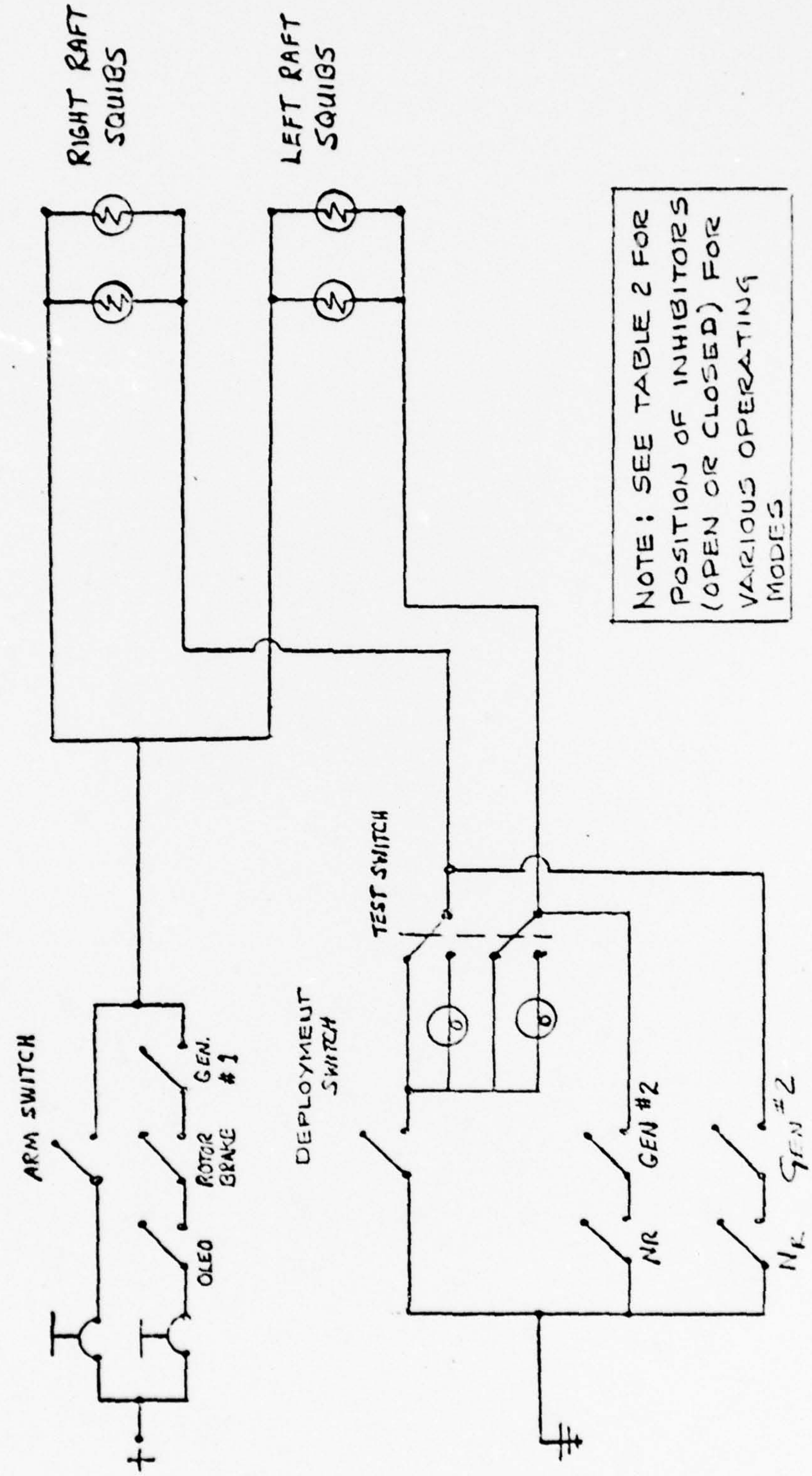


FIGURE 2

impact and rotor stoppage. Figure 2 shows a general schematic of the system.

3.1.2.1 Sequence for Pilot or Crewmember Operation

a. The pilot (or the crewmember) arms the system via the guarded arming switch. The helicopter enters the water with power, and stabilizes with rotors turning. The aircraft is under pilot control.

b. Engine condition levers are retarded; rotor brake arming lever is armed; rotor brake is applied. Aircraft is secured.

c. The deployment switch is put to the "on" position by the pilot (or crewmember) activating the inflation sequence for the two rafts.

d. The container doors open as the rafts inflate out of their containers.

e. Aircrew egress to life rafts.

3.1.2.2 Sequence for Automatic Operation

a. Rotor brake arming handle switch is closed if rotor brake is not armed. (Note: Rotor brake can not be armed if throttles are in fly position).

b. Main landing gear also is fully extended. Oleo switch is closed. (In flight, the landing gear is always extended).

c. Both generators drop off the line as rotor RPM is lost. The two generator switches are closed.

d. Zero speed sensor switch closes when rotor speed is less then 1 RPM.

e. When contacts are all closed, squibs fire, rafts inflate out of containers, popping doors open.

f. Aircrew egress to life rafts.

3.2 HELICOPTER FLOTATION SYSTEM (HFS)

3.2.1 Physical Characteristics

Basic elements of the system are:

- Four flotation bags
- Four inflators
- Four flotation bag encapsulations

- Harness and retention cable
- Electrical activation system

The conceptual design configuration for the Helicopter Flotation System is shown in Figure 3. It consists of four spherical flotation bags, externally encapsulated to the fuselage, to provide additional buoyancy and stability to the helicopter upon making a water entry. The bags are contained in two nose blisters and two stub wing pods. Established hardpoints at the base of the nose landing gear and on each stub wing serve as anchor points for the bags. The bags can be deployed and inflated in approximately 10-15 seconds. Pilot or automatically fired squibs cause gas to be released from the inflators and into the bags. Types of inflators under consideration include compressed gas bottles, cool gas generators coupled with air aspirators, and solid propellant generators coupled with air aspirators.

The bag material is a protective coated nylon construction with dual compartments in each sphere to prevent total loss of buoyancy in the event of a puncture, rupture, or leak. Each deflated bag is approximately 1.5 cubic feet in volume. The inflated bag is 6 feet in diameter. The encapsulations are of fiberglass/metal construction.

Figure 4 shows the method for retaining the inflated bags. A retention cable connects each bag harness to a hardpoint on the airframe. The bag harness consists of five harness ropes bonded to the bag at ten points around the equator of the bag. The ropes pass through a retention ring which is attached to the retention cable.

The encapsulation or container door is secured in place by a hinge and over-center type latches. For deployment of the bag, the door is opened by the pressure from the inflating bag. (Note: Velcro is being considered as an alternate means of providing the fastening and opening functions for the door).

3.2.2 System Operation

The flotation bags may be inflated by pilot command or automatically. Automatic deployment is provided in the event the helciopter is inadvertently flown into the water and the pilot is incapacitated. A general schematic of the system is shown in Figure 5.

3.2.2.1 Sequence for Pilot Operation

a. The pilot arms the system via the guarded arming switch. The helicopter enters the water with power, and stabilizes with rotors turning. The aircraft is under pilot control.

b. The flotation deployment switch is put to the "on" position activating the inflation sequence for all four bags.

c. The encapsulation doors open as the bags inflate out of their containers.

d. Engine condition levers are retarded; rotor brake arming lever is armed; rotor brake is applied. Aircraft is secured.

e. Aircraft floats upright.

3.2.2.2 Sequence for Automatic Operation

a. Rotor brake arming handle switch is closed if rotor brake is not armed. (Note: Rotor brake can not be armed if throttles are in "FLY" position).

b. Main landing gear also is fully extended. Oleo switch is closed. (In flight, the landing gear is always extended).

c. Both generators drop off the line as rotor RPM is lost. (The two generator switches are closed).

d. Zero speed sensor switch closes when rotor speed is less than 1 RPM.

e. When all of the above switches are closed, squibs fire, bags inflate out of containers, popping doors off, bags inflate into position.

f. Helicopter floats upright.

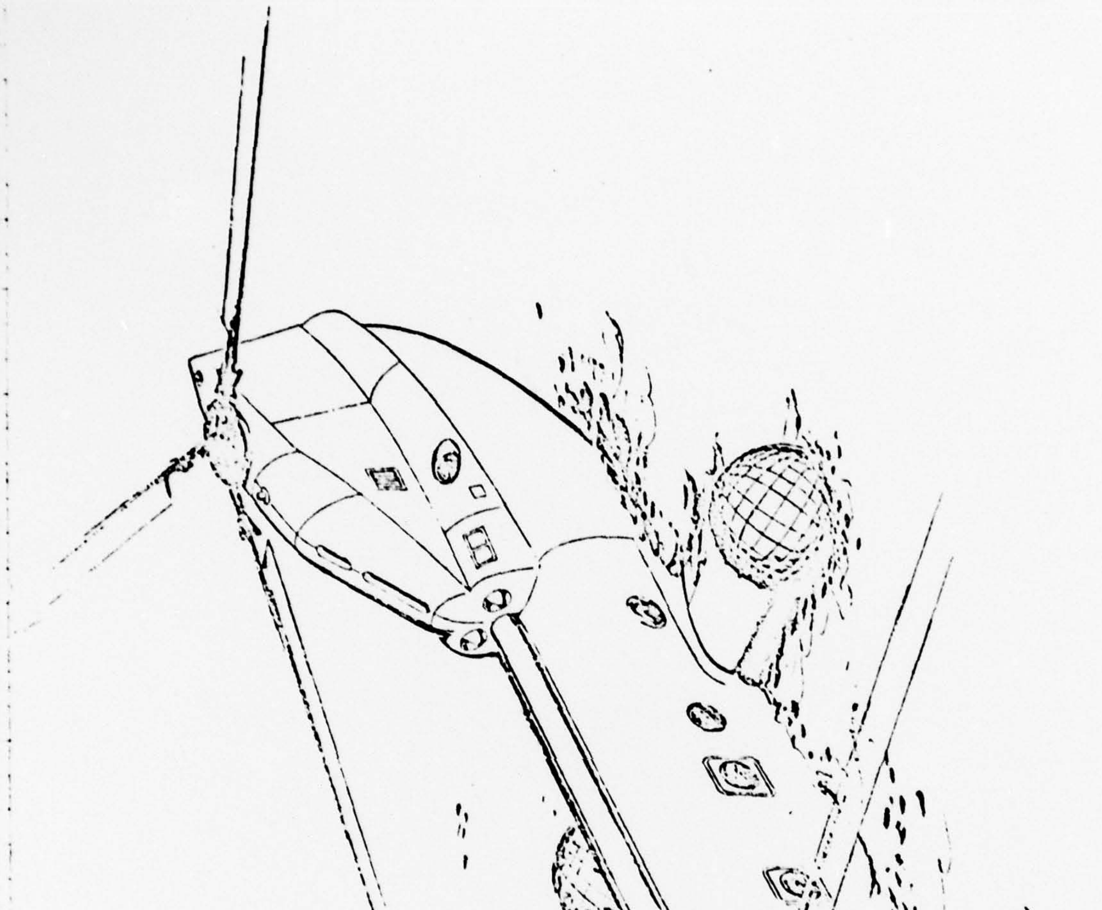


Figure 3 H-46 Helicopter Flotation-Stability System

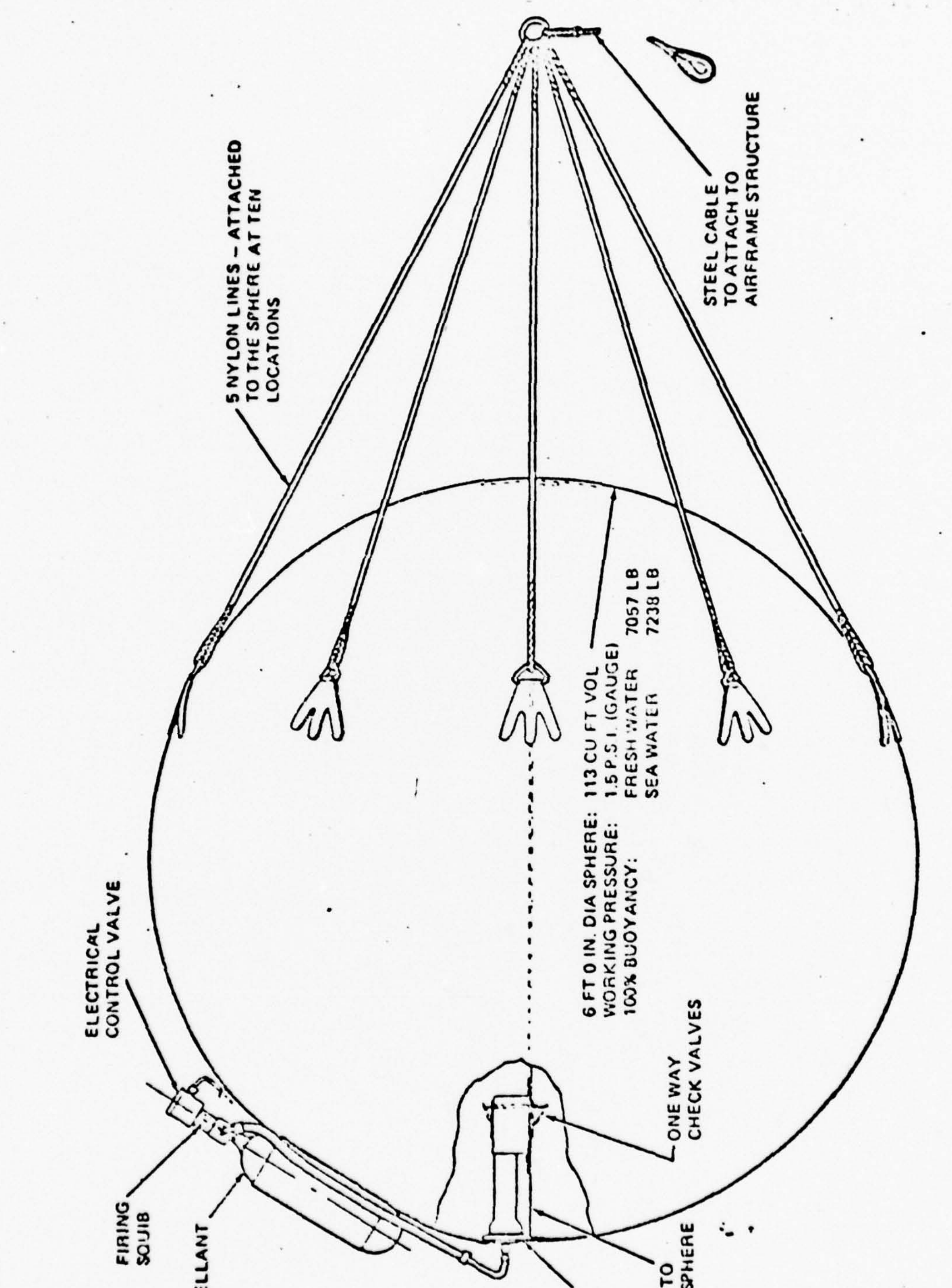


Figure 4 Spherical Buoyancy Float

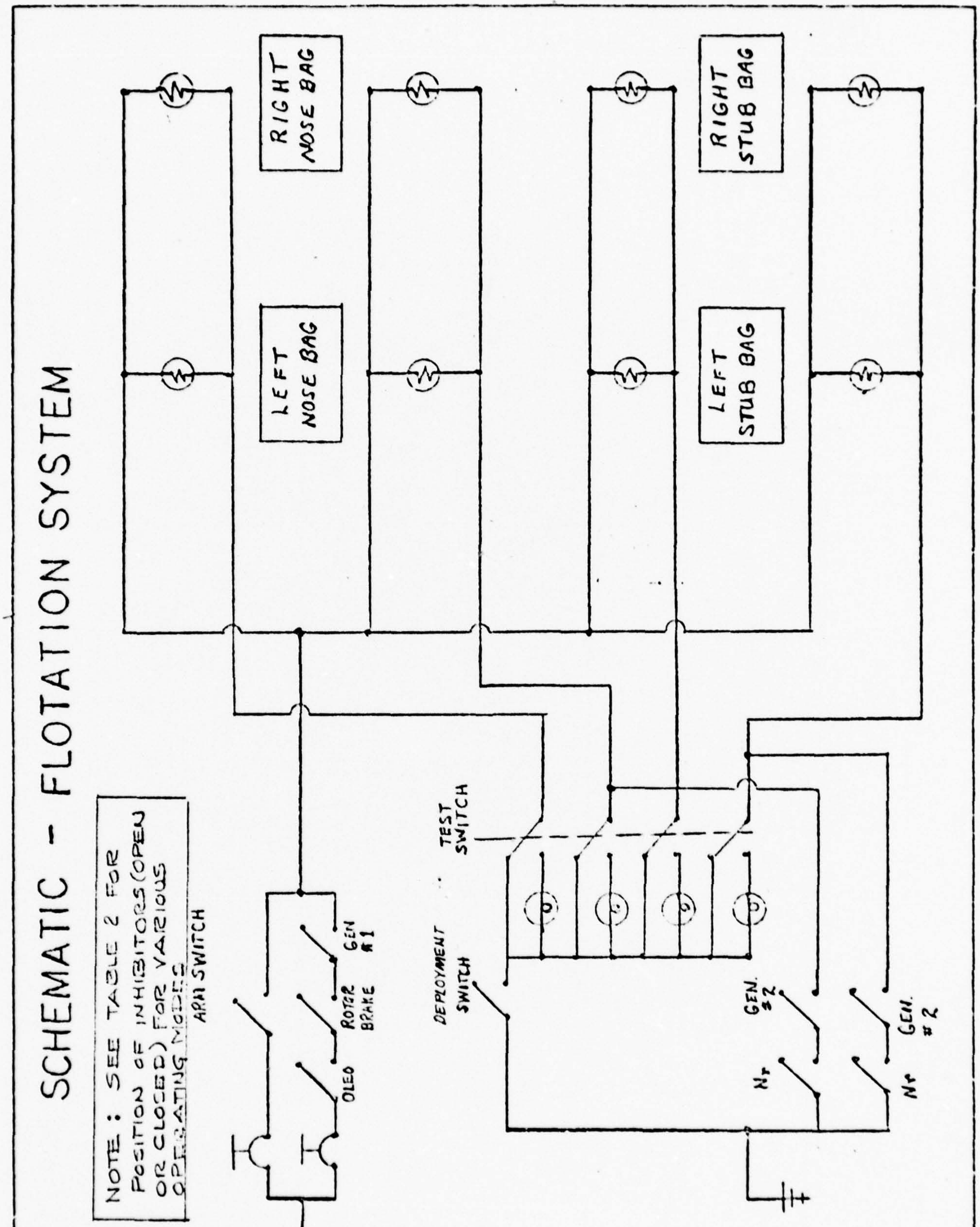

SCHEMATIC - FLOTATION SYSTEM
NOTE : SEE TABLE 2 FOR POSITION OF INHIBITORS (OPEN OR CLOSED) FOR VARIOUS OPERATING MODES
ARM SWITCH
RIGHT NOSE BAG
LEFT NOSE BAG
RIGHT STUB BAG
LEFT STUB BAG
TEST SWITCH
DEPLOYMENT SWITCH
GEN #1
ROTOR BRAKE
OLEO
GEN. #2
GEN. #2
Nr
Nr
B+

FIGURE 5

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 The hazardous conditions of primary concern relative to the HFS and ALRS[(1)] may be stated as follows:

- o Inadvertent system actuation or malfunction of system components causes a ground accident, flight accident, or injury/death to personnel.
- o Failure of the system to function as intended results in the system not being available for personnel survival.

4.2 The Preliminary Hazard Analysis (PHA) for the HFS and ALRS has not identified any items associated with the above hazardous conditions which can be classified as a high (HI) risk, as defined in Table 1. The PHA has identified a number of low (LO) risk items which will require detail attention prior to and during the design and test phases in order to assure that adequate hazard controls are incorporated.

4.3 Recommendations which resulted from the review of the concept configurations and which should be considered during follow-on design and test phases are:

a. Incorporate a "Flotation System (or Raft System) Armed" light in the cockpit.

b. Design for water impact conditions to preclude system material failures, jamming, and activation circuit failures. Select component locations which protect or shield against water impact:

- Container and container mounts
- Container door and door latches
- Activation circuit (wires and inhibitors such as oleo switch)

c. Eliminate activation circuit deficiencies noted in Appendix A.

d. Provide means for quick release of bags/rafts.

e. Assure that the selected inflator configuration

- will not permit water entry into the bags or rafts (gas generator/aspirator type)

---

(1) Because of the similarity of the HFS and ALRS, the conclusion and recommendations presented here apply, unless otherwise noted, to either system.

- will have gas temperatures compatible with bag or raft material (solid propellant type generators)

- uses a gas that has acceptable toxicity/flammability properties.

f. Review and assure that the N_R inhibitor constraints do not preclude timely system actuation. (The N_R inhibitor precludes automatic system deployment until the rotors are essentially stopped - $N_R < 1$ RPM. Under certain impact conditions such a time delay could be critical to personnel survival.)

g. Review and assure the reliability of the "oleo" or "squat switch" inhibitor. (Failure of "squat switch" precludes automatic system deployment. Continuous exposure of the switch/switch sensor mechanization to the environment during normal aircraft operation and the requirement that the switch not malfunction when submerged in water requires special attention during the design phase.

h. Perform EMI tests to assure that the system is not subject to deployment by EMI sources.

i. Perform wind tunnel tests to determine controllability of aircraft if system is inadvertently deployed in flight.

j. Perform environmental testing of selected components: water immersion, humidity, salt spray, sand and dust, temperature, vibration.

4.4 Based upon the above findings from the PHA, the following safety design criteria are proposed for the HFS and ALRS:

a. No single failure or human error in the HFS or ALRS shall cause a flight safety loss.

b. No single failure or human error shall result in loss of function of the HFS or ALRS so as to preclude personnel survival.

c. No single failure or human error shall cause the HFS or ALRS to deploy when making normal ground or water landings (deployment is not wanted).

d. The above "single" failure constraints are subject to the following conditions:

o A failure following an undetected failure and causes the above events shall be counted as a single failure.

- o The pilot activated system and automatically activated system shall be considered as mutual back-up systems (e.g., a single failure in the pilot activated system which does not permit commanded deployment shall be considered to satisfy the above conditions if the automatic system causes deployment).

e. The HFS and ALRS components shall be designed for water impact conditions.

f. Provisions shall be made for pre-flight checks for activation circuit continuity and inhibitor status.

g. Provisions shall be made for rapid release of bags or rafts.

If deviations from the above criteria are required because of cost, weight, reliability, etc. issues, the supporting rationale shall be documented.

5.0 PRELIMINARY HAZARD ANALYSIS (PHA)

5.1 METHODOLOGY

5.1.1 The technique for conducting the PHA consists of two basic steps:

a. A top level fault tree to provide the visibility of the hazardous conditions to be considered.

b. A columnar format to translate the hazardous conditions identified on the fault tree to a cause and evaluation presentation on the columnar format. The columnar format describes the hazard, how the hazard can occur, safety considerations, safety assessment, relative risk, and requirements for additonal analysis.

Relative risk, as used in the PHA, is a measure of confidence of eliminating and controlling potentially hazardous conditions. Risk is defined as HIGH (HI) or LOW (LO) by assessing the likelihood of hazard occurrence. The defintions are listed in Table 1. The Detail Analysis Level column pinpoints additional types of hazard analyses which should be performed during the detail design phase.

TABLE 1 - RELATIVE RISK DEFINITIONS

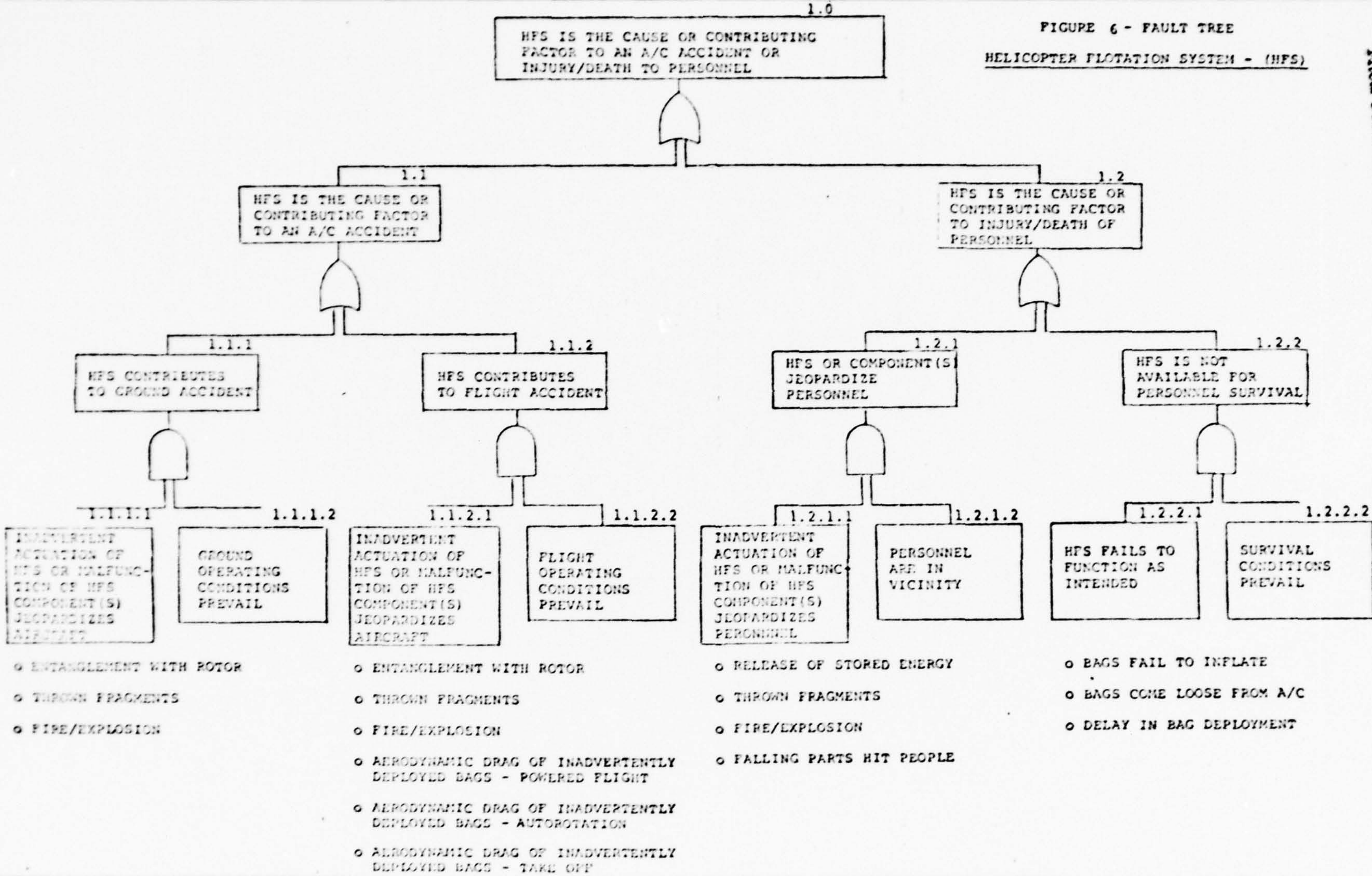
Relative Risk	Symbol	Definition
LO	X	Hazard controls are adequate, have been used in the past, and require little or no development
	(X)	Hazard controls are identified and considered adequate, but may need development. Will require monitoring during design and test.
HI	X	Hazard controls are inadequate. Method(s) have not been established.
	(X)	Hazard Controls are inadequate or are beyond the Contractor's control.

5.1.2 A brief introduction to the analysis sheets that follow is provided. The analysis for the Helicopter Flotation System (HFS) was performed first. The fault tree for the HFS is presented followed by the columnar sheets. Next, the fault tree for the Automatic Life Raft System (ALRS) is presented. Because the HFS and ALRS fault trees are, in fact, almost identical and because the HFS and ALRS are very similar in mechanization concept, the HFS analysis sheets are applicable to the ALRS.

It was found necessary to review only one additional hazardous condition (which applied only to the ALRS), "Life rafts are not accessible for survival." Finally, a cursory review was conducted of the basic HFS activation schematic for possible undesirable or hazardous conditions that could result from single point failures or human errors. This review is presented in Appendix A.

FIGURE 6 - FAULT TREE

HELICOPTER FLOTATION SYSTEM - (HFS)



HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
1.1.1.1 INADVERTENT FBS ACTUATION OR MALFUNCTION CAUSES GROUND ACCIDENT	a. FLOTATION BAGS ENTANGLE WITH ROTOR BLADES	a.1 AIRCREW OR MAINTENANCE PERSONNEL INADVERTENTLY ACTUATE SYSTEM AND DEPLOY BAGS	• PERSONNEL MUST INADVERTENTLY ACTUATE TWO SWITCHES: ARMING SWITCH AND DEPLOYMENT SWITCH. • ARMING SWITCH IS GUARDED. • LENGTH OF BAG RESTRAINING CABLES RESTRICT BAG MOVEMENT INTO BLADES	• ADEQUATE HAZARD CONTROLS. • RECOMMEND CONSIDERATION BE GIVEN TO INSTALLATION OF A "FLOTATION SYSTEM ARMED" WARNING LIGHT.	X		SSHA OHA
		a.2 ELECTRICAL FAULT(S) (SHORTS TO GROUND OR POWER) INADVERTENTLY ACTUATE SYSTEM AND DEPLOYS BAGS	• NO SINGLE ELECTRICAL FAULT IN EITHER THE PILOT OR AUTOMATIC ACTUATION SYSTEM WILL CAUSE SYSTEM ACTUATION • TEST SWITCH/ADVISORY LIGHTS PROVIDED TO CHECK CIRCUITS • LENGTH OF BAG RESTRAINING CABLES RESTRICT BAG MOVEMENT INTO BLADES	• ADEQUATE HAZARD CONTROLS	X		SSHA OHA
		a.3 INHIBITORS IN THE AUTOMATIC CIRCUIT FAIL OR ARE MISRIGGED TO THE CLOSED POSITION CAUSING INADVERTENT ACTUATION OF THE SYSTEM AND DEPLOYMENT OF THE BAGS	• REQUIRES FAILURE OF 4 INHIBITORS: – OLEO INHIBITOR (OPEN WHEN M.L.G. STRUT IS COMPRESSED – GEN #1 INHIBITOR (OPEN WHEN ROTOR RPM IS ABOVE 80% NR) – GEN #2 INHIBITOR (OPEN WHEN ROTOR RPM IS ABOVE 80% NR) – NR INHIBITOR (OPEN WHEN NR IS ABOVE 1 RPM) • LENGTH OF BAG RESTRAINING CABLES RESTRICT BAG MOVEMENT INTO BLADES	• ADEQUATE HAZARD CONTROLS	X		SSHA

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
		2.4 Auto-ignition of squibs causes bags to inflate and deploy	• Switch disconnection and circuit inhibitors at both power and ground connections protects against shorts to power and shorts to ground • EMI test requirements • Length of bag restraining cables restrict bag movement into blades	• Adequate hazard controls	X		SSHA

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
	b. THROWN FRAGMENTS CONTACT ROTOR BLADES	b.1. CONTAINER DOOR COMES OFF AND STRIKES ROTOR BLADES	• DOOR LATCHES ARE OF THE OVER CENTER LOCKING TYPE. LATCHES ARE OPENED BY THE PRESSURE FROM THE INFLATING BAGS. SEE SAFETY CONSIDERATIONS FOR ITEMS 1.1.1.1.a1 THRU 1.1.1.1.a.4 THAT CONTROL INADVERTENT ACTUATION	• DESIGN SHOULD INCLUDE PROVISIONS FOR VISUAL VERIFICATION BY M PERSONNEL THAT LATCHES ARE IN THE LOCKED POSITION.	(X)		SSHA
				• VELCRO IS BEING CONSIDERED AS AN ALTERNATE TO MECHANICAL HINGES BECAUSE OF WEIGHT, COST AND SIMPLICITY ADVANTAGES. FULL SCALE TESTING, INCLUDING FLIGHT TESTING, SHOULD BE ACCOMPLISHED TO VERIFY ITS RELIABILITY	(X)		
	C. FIRE - HFS MALFUNCTION	C.1 ELECTRICAL SHORT	• PILOT OPERATED AND AUTOMATIC CIRCUITS ARE PROTECTED BY CIRCUIT BREAKERS • PRIMARY HFS CIRCUITS ARE NORMALLY NOT ENERGIZED, ONLY IN TIME OF AN EMERGENCY	• ADEQUATE HAZARD CONTROL	X		SSHA
		C.2 SQUIB EXPLOSION	• CHARGE IS VERY SMALL • QUAL TESTED TO CONTAIN EXPLOSION. • SUBJECT TO CONTROLLED IGNITION DURING EMERGENCY CONDITIONS ONLY • CONTROLS FOR INADVERTENT IGNITION COVERED BY ITEMS 1.1.1.1.a.1 THRU 1.1.1.1.a.4.	• ADEQUATE HAZARD CONTROLS	X		

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
2.1 INADVERTENT HFS ACTUATION OR MALFUNCTION CAUSING FLIGHT ACCIDENT	2. FLOTATION BAGS ENTANGLE WITH ROTOR BLADES	2.1 AIRCREW INADVERTENTLY ACTUATES SYSTEM AND DEPLOYS BAGS	• AIRCREW MUST INADVERTENTLY ACTUATE TWO SWITCHES: ARMING SWITCH AND DEPLOYMENT SWITCH • ARMING SWITCH IS GUARDED • BAG HARNESS MUST FAIL IF BAGS ARE TO CONTACT BLADES	• ADEQUATE HAZARD CONTROLS • RECOMMEND CONSIDERATION BE GIVEN TO INSTALLATION OF A "FLOTATION SYSTEM ARMED" WARNING LIGHT • CONSIDER RELEASE SYSTEM TO [illegible] BAGS FROM A/C	(X)		SSHA OHA
		2.2 ELECTRICAL FAULT(S) (SHORTS TO GROUND OR POWER) INADVERTENTLY ACTUATES SYSTEM AND DEPLOYS BAGS	• NO SINGLE ELECTRICAL FAULT IN EITHER THE PILOT OR AUTOMATIC ACTUATION SYSTEM WILL CAUSE SYSTEM ACTUATION • TEST SWITCH/ADVISORY LIGHTS PROVIDED TO CHECK CIRCUITS • BAG HARNESS MUST FAIL IF BAGS ARE TO CONTACT BLADES	• IF THE PILOT SHOULD ELECT TO ARM THE SYSTEM PRIOR TO AN IMMINENT WATER LANDING, A SINGLE SHORT COULD CAUSE THE BAGS TO DEPLOY	(X)		SSHA
		2.3 INHIBITORS IN THE AUTOMATIC CIRCUIT FAIL OR ARE MISRIGGED TO THE CLOSED POSITION, CAUSING INADVERTENT ACTUATION OF THE SYSTEM AND DEPLOYMENT OF THE BAGS	• REQUIRES FAILURE OF 3 INHIBITORS – GEN. #1 INHIBITOR (OPEN WHEN ROTOR RPM IS ABOVE 80%) – GEN. #2 INHIBITOR (OPEN WHEN ROTOR RPM IS ABOVE 80%) – N_R INHIBITOR (OPEN WHEN N_R IS ABOVE 1 RPM) • BAG HARNESS MUST FAIL IF BAGS ARE TO CONTACT BLADES.	• ADEQUATE HAZARD CONTROLS	X		SSHA
		2.4 AUTO-IGNITION OF SQUIBS CAUSE BAGS TO INFLATE AND DEPLOY	• SWITCH DISCONNECTION AND CIRCUIT INHIBITORS AT BOTH POWER AND GROUND CONNECTIONS PROTECTS AGAINST SHORTS TO POWER AND SHORTS TO GROUND • TWISTED PAIR POWER/GROUND WIRING • EMI TEST REQUIREMENTS • BAG HARNESS MUST FAIL IF BAGS ARE TO CONTACT BLADES	• ADEQUATE HAZARD CONTROLS	X		SSHA

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HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
	b. THROWN FRAGMENTS CONTACT ROTOR BLADES	b.1 CONTAINER DOOR COMES OFF AND STRIKES ROTOR BLADES	• DOOR LATCHES ARE OF THE OVER CENTER LOCKING TYPE. LATCHES ARE OPENED BY THE PRESSURE FROM THE INFLATING BAGS. SEE SAFETY CONSIDERATIONS FOR ITEMS 1.1.2.1.a.1 THRU 1.1.2.1.a.4 THAT CONTROL INADVERTENT ACTUATION • HINGE RESTRAINED DOOR	• SAME AS FOR ITEM 1.1.1.1.b.1 • NOTE: UNINFLATED BAG IS THEN FREE TO DROP OUT OF CONTAINER BUT REMAINS SECURED TO A/C BY THE HARNESS	(X)		SSHA
	c. FIRE-HFS MALFUNCTION	c.1 ELECTRICAL SHORT	• SAME AS FOR ITEM 1.1.1.1.c.1	ADEQUATE HAZARD CONTROLS	X		SSHA
		c.2 SQUIB EXPLOSION	• SAME AS FOR ITEM 1.1.1.1.c.2	• ADEQUATE HAZARD CONTROLS	X		SSHA
	d. AERODYNAMIC DRAG OF INADVERTENTLY DEPLOYED BAGS DURING POWERED FLIGHT	d.1 CAUSES OF INADVERTENT ACTUATION SAME AS ITEMS 1.1.2.1.a.1 THRU 1.1.2.1.a.4	• SAME SAFETY CONSIDERATIONS FOR ITEMS 1.1.2.1.a.1 THRU 1.1.2.1.a.4 THAT CONTROL INADVERTENT ACTUATION.	• ADEQUATE HAZARD CONTROLS • CONSIDER REQUIREMENT FOR CONDUCTING WIND TUNNEL TESTS TO DETERMINE CONTROLLABILITY OF A/C WITH DEPLOYED BAGS • CONSIDER RELEASE SYSTEM TO SEPARATE BAGS FROM A/C	(X)		SSHA
	e. AERODYNAMIC DRAG OF INADVERTENTLY DEPLOYED BAGS DURING AUTOROTATION	e.1 CAUSES OF INADVERTENT ACTUATION SAME AS ITEMS 1.1.2.1.a.1 THRU 1.1.2.1.a.4	• SAME AS ABOVE EXCEPT THAT ITEM 1.1.2.1.a.3 CHANGES AS FOLLOWS: REQUIRES FAILURE OF 1 INHIBITOR: – NR INHIBITOR (OPEN WHEN NR IS ABOVE 1 RPM.) FOR WORST CASE DURING AUTOROTATION, IT IS ASSUMED THAT NR COULD DROP BELOW 80% AND	• ADEQUATE HAZARD CONTROLS	X		SSHA

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
			GENERATORS DROP OFF THE LINE, THEREBY CLOSING THE GEN #1 AN GEN #2 INHIBITORS. • FOR THIS HAZARDOUS EVENT TO OCCUR, MUST HAVE ENGINE FAILURE AND HES FAILURE. OCCURRENCE CONSIDERED REMOTE				
	F. AERODYNAMIC DRAG OF INADVERTENTLY DEPLOYED BAGS DURING TAKE-OFF	F.1 HUMAN ERROR - PILOT FORGETS TO DEACTIVATE AUTOMATIC SYSTEM UPON MAKING AN INTENTIONAL WATER LANDING. BAGS REMAIN DEPLOYED FOR SUBSEQUENT T.O.	• UPON MAKING AN INTENTIONAL WATER LANDING, THE PILOT MUST ARM THE ROTOR BRAKE PRIOR TO SHUT DOWN. THIS ACTION OPENS THE N_R INHIBITOR IN THE AUTOMATIC DEPLOYMENT CIRCUIT	• FLIGHT MANUAL MUST INCLUDE THIS OPERATING PROCEDURE • CONSIDER PROVISIONS FOR DECOUPLING BAGS. FROM A/C	(X)		SSHA

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HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
1.2.1.1 INADVERTENT ACTUATION OF HFS OR MALFUNCTION OF HFS COMPONENTS INJURES PERSONNEL	a. RELEASE OF STORED ENERGY / WHICH CAUSES FRAGMENTS TO STRIKE PERSONNEL.	a.1 BAG BURSTS	• BAG IS NORMALLY DEFLATED • PRESSURE IS LOW ~ 2 PSI. A TEAR OR PUNCTURE IN THE BAG SHOULD NOT BE INJURIOUS TO ANYONE THAT HAPPENED TO BE IN THE VICINITY OF AN INFLATED BAG.	• ADEQUATE HAZARD CONTROLS	X		SSHA
		a.2 GAS GENERATOR BURSTS	• VESSEL CONSERVATIVELY STRESSED FOR BURST PRESSURE • WARNING PLACARD ADVISES PRESSURE LIMITS • PRESSURE GAGE INSTALLED ON VESSEL.	• ADEQUATE HAZARD CONTROLS	X		SSHA
		a.3 MOVING "ARM" SWITCH TO ARM INFLATED BAGS		• CIRCUIT NEEDS REVISION TO PRECLUDE THIS HAZARD	(X)		
	b. FIRE - HFS MALFUNCTION	b.1 ELECTRICAL SHORT	• SAME AS FOR ITEM 1.1.1.1.C.1	• ADEQUATE HAZARD CONTROLS	X		SSHA
		b.2 SQUIB EXPLOSION	• SAME AS FOR ITEM 1.1.1.1.C.2 • SPECIAL PROCEDURES/WARNING NOTES OR PLACARDS PROVIDED FOR HANDLING AND/OR STORAGE	• ADEQUATE HAZARD CONTROLS	X		SSHA
	c. FALLEN PARTS HIT PEOPLE ON GROUND	c.1 CONTAINER DOOR COMES OFF IN FLIGHT	• DOOR LATCHES ARE THE OVER CENTER LOCKING TYPE • HINGE RESTRAINS DOOR	• DESIGN SHOULD INCLUDE PROVISIONS FOR VISUAL VERIFICATION BY M PERSONNEL THAT HINGES ARE IN LOCKED POSITION NOTE: UNINFLATED BAG IS ALSO FREE TO DROP OUT OF CONTAINER BUT REMAINS FASTENED TO A/C BY HARNESS	(X)		SSHA
		c.2 CONTAINER COMES OFF IN FLIGHT	• MULTIPLE MOUNTING POINTS ARE CONSERVATIVELY STRESSED	• ADEQUATE HAZARD CONTROLS	X		SSHA

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
1.2.2.1 AFS FAILS TO FUNCTION AS INTENDED — NOT AVAILABLE FOR PERSONNEL SURVIVAL	2. BAG(S) FAIL TO INFLATE	2.1 HOLE IN FLOTATION BAG	• ONE FLOTATION BAG FAILURE TO INFLATE DOES NOT COMPLETELY JEOPARDIZE FLOTATION/STABILITY CAPABILITY. EITHER OR BOTH FORWARD BAGS CAN FAIL OR ONLY PARTIALLY INFLATE AND STABILITY/FLOTATION WILL BE PROVIDED. • BAG(S) HAVE DIVIDED COMPARTMENTS TO PREVENT TOTAL LOSS OF BUOYANCY • SYSTEM PERIODICALLY CHECKED	• ADEQUATE HAZARD CONTROLS	X		SSHA
		2.2 INFLATOR DOES NOT PROVIDE PRESSURE	• AFFECTS ONLY ONE FLOTATION BAG • PREFLIGHT VISUAL PRESSURE CHECK	• ADEQUATE HAZARD CONTROLS	X		SSHA
				• ALTERNATE INFLATORS ARE BEING CONSIDERED: — GAS GENERATOR/ASPIRATOR, MUST ASSURE THAT ASPIRATOR WILL NOT PUMP WATER INTO BAGS. — SOLID PROPELLANT GENERATORS, MUST ASSURE BAGS ARE COMPATIBLE WITH EXHAUST GAS TEMPERATURE. ALSO, ASSURE CONTROL OF POSSIBLE TOXICITY HAZARDS. THESE HAZARDS WILL BE REVIEWED IN THE SSHA, PENDING INFLATOR SELECTION	(X)		SSHA

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
		2.3 CONTAINER DOOR FAILS TO OPEN	• AFFECTS ONLY ONE FLOTATION BAG • PERIODIC FUNCTIONAL CHECK PERFORMED	• ADEQUATE HAZARD CONTROLS	X		SSHA
				• VELCRO BEING CONSIDERED AS AN ALTERNATE MEANS OF DOOR RETENTION. TESTING REQUIRED TO ASSURE THAT DOOR IS RETAINED AND WILL PEEL OFF WHEN REQUIRED. DEGRADATION OF VELCRO WHEN SUBJECT TO ENVIRONMENTAL CONDITIONS (MOISTURE DIRT, OIL ETC) TO BE EVALUATED	(X)		
		2.4 SQUIBS FAIL TO FIRE	• DUAL SQUIBS PROVIDED FOR EACH BAG • SERVICE LIFE OF SQUIB IS CONTROLLED • OPERATIONAL TEST SWITCH (AND LIGHTS) PROVIDED	• TEST CIRCUIT NEEDS FURTHER DEVELOPMENT TO ASSURE STATUS CHECK OF SQUIBS	(X)		SSHA
		2.5 ELECTRICAL COMPONENTS FAIL (E.G. INHIBITORS SUCH AS SWITCHES AND RELAYS) IN THE PILOT ACTIVATED SYSTEM	• AUTOMATIC ACTIVATION SYSTEM PROVIDED • PRE-FLIGHT TEST SWITCH/LIGHTS PROVIDED TO VERIFY CIRCUIT CONTINUITY	• TEST CIRCUIT NEEDS FURTHER DEVELOPMENT TO ASSURE STATUS CHECK OF ALL ELEMENTS	(X)		SSHA

HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
		2.6 ELECTRICAL COMPONENTS FAIL (E.G. INHIBITORS SUCH AS SWITCHES AND RELAYS) IN THE AUTOMATICALLY ACTIVATED SYSTEM	• PILOT ACTIVATED SYSTEM PROVIDED	• TEST CIRCUIT NEEDS FURTHER DEVELOPMENT TO ASSURE STATIC CHECK OF ALL ELEMENTS OF THE AUTOMATIC CIRCUIT.	(X)		SSHA
		2.7 WATER IMPACT INCAPACITATES OCCUPANTS, UNABLE TO ACTIVATE SYSTEM	• AUTOMATIC, SYSTEM DEPLOYS BAGS	• ADEQUATE HAZARD CONTROLS	X		SSHA
		2.8 HUMAN ERROR - PILOT FORGETS TO ARM SYSTEM	• AUTOMATIC SYSTEM DEPLOYS BAGS • PILOT TRAINING, FLIGHT MANUAL OPERATING PROCEDURES	• ADEQUATE HAZARD CONTROLS • CONSIDERATION TO BE GIVEN TO A SINGLE TWO POSITION ARM/DEPLOY SWITCH	X		SSHA OHA
		2.9 LOSS OF ELECTRICAL POWER	• ALTERNATE POWER SOURCES AVAILABLE - GEN #1 PMG, GEN #2 PMG, BATTERY	• ADEQUATE HAZARD CONTROLS	X		SSHA

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HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
	b. BAG(S) COME LOOSE FROM AIRCRAFT	b.1 RETENTION HARNESS DOES NOT HOLD - HARNESS BREAKS - FASTENERS DISENGAGE - A/C HARD POINTS FAIL	• TEN HARNESS ATTACHMENT POINTS. ANY 3 CAN FAIL AND BAG REMAINS ATTACHED AND PROVIDES BUOYANCY/STABILITY • FASTENINGS, HARDPOINTS, HARNESS RING CONSERVATIVELY STRESSED.	• ADEQUATE HAZARD CONTROLS	X		SSHA
	c. DELAY IN BAG DEPLOYMENT	c.1 IF BAG DEPLOYMENT IS DEPENDENT UPON ACTIVATION OF THE AUTOMATIC CIRCUIT, BAGS WILL NOT DEPLOY UNTIL ROTOR RPM IS LESS THAN 1 RPM	• ASSUMES PILOT IS INCAPACITATED AND CANNOT ACTIVATE NORMAL SYSTEM (WHICH IS NOT DEPENDENT UPON ROTOR RPM) • LIKELIHOOD THAT IF PILOT IS INCAPACITATED (DUE TO HARD IMPACT), THE A/C WOULD NOT BE CONTROLLED, ROTOR BLADES WOULD CONTACT WATER, AND SUDDEN STOPPAGE OF ROTOR WOULD RESULT • UNDER THE ABOVE CONDITIONS, IT IS PROBABLY BETTER TO DEPLOY BAGS WHEN ROTORS HAVE STOPPED RATHER THAN HAVE THE RISK OF ROTATING FRAGMENTED BLADES PUNCTURE PREVIOUSLY DEPLOYED BAGS	• ADEQUATE HAZARD CONTROLS	X		SSHA

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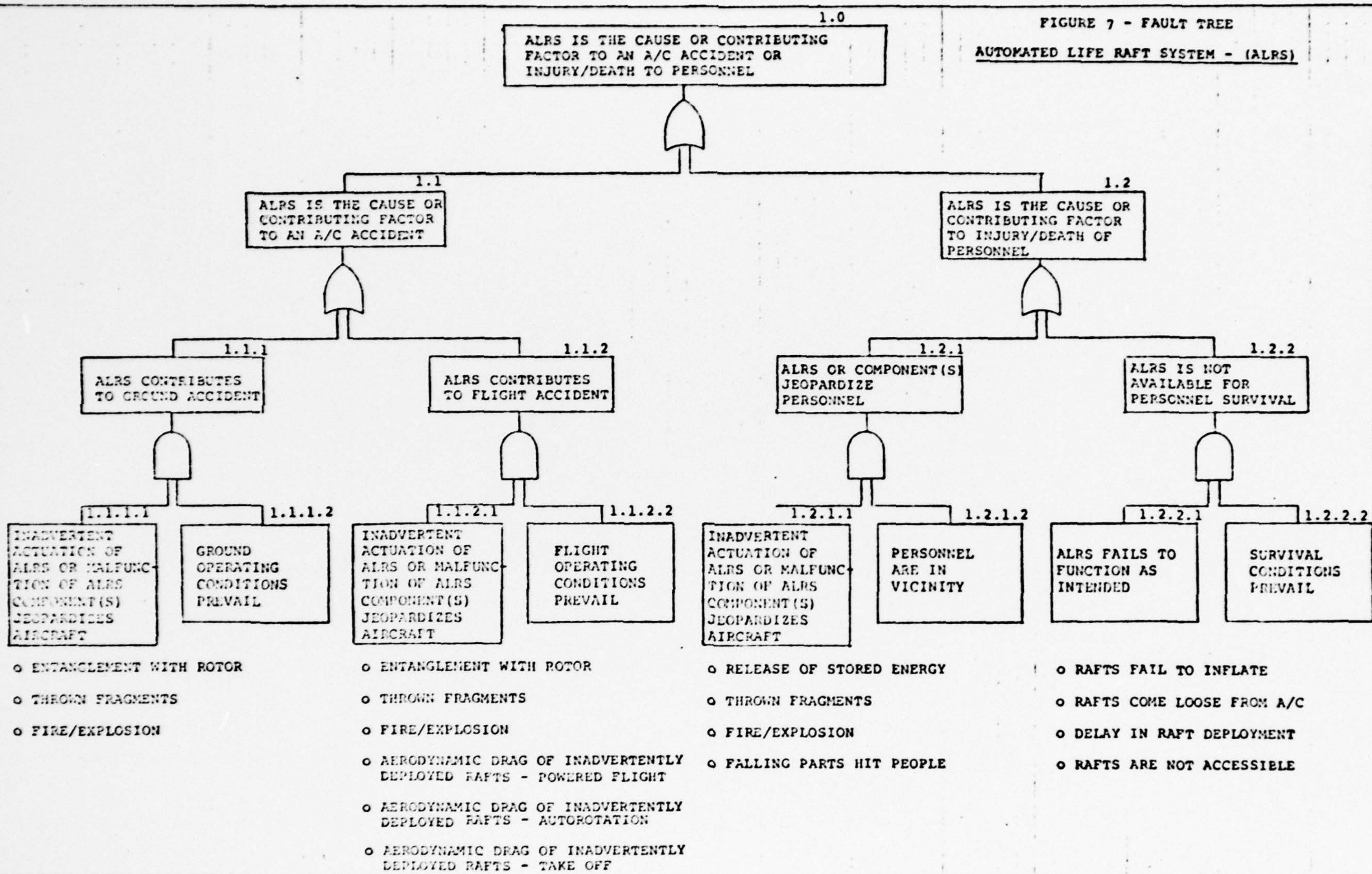
FIGURE 7 - FAULT TREE

AUTOMATED LIFE RAFT SYSTEM - (ALRS)



HAZARD	HOW HAZARD CAN OCCUR	CAUSE OF HAZARD OCCURRENCE	SAFETY CONSIDERATIONS	SAFETY ASSESSMENT	RELATIVE RISK LO	RELATIVE RISK HI	DETAIL ANALYSIS LEVEL
1.2.2.1 ACRS FAILS TO FUNCTION AS INTENDED - NOT AVAILABLE FOR PERSONNEL SURVIVAL	2. LIFE RAFTS ARE NOT ACCESSIBLE	2.1 INFLATED LIFE RAFTS REMAIN ATTACHED TO SINKING A/C	• CONSIDER WHETHER RESTRAINT SYSTEM SHOULD PROVIDE AUTOMATIC DISCONNECTION WHEN A GIVEN FORCE IS EXERTED, OR RELY ON SURVIVORS TO UNCOUPLE RAFTS.		(X)		SSHA
		2.2 INFLATED LIFE RAFTS SEPARATE AND DRIFT AWAY FROM A/C BEFORE RAFTS CAN BE OCCUPIED.	• SEE ABOVE CONSIDERATIONS		(X)		SSHA

APPENDIX "A"

Safety Comments on HFS Activation Schematic

A cursory review was conducted of the HFS activation schematic for possible undesirable or hazardous conditions that could result from single point failures or human errors. The schematic per Figure 5 was reviewed for various operating modes as shown in Table 2. The review has indicated the need for further considerations and/or revisions of the schematic before proceeding with hardware design. Conditions noted are:

1. Operation Mode: A/C Parked, Electrical Power on A/C (e.g. for maintenance check, etc.)
   - o Bags deploy if "arm switch" is intentionally closed to make the test circuit check.
   - o Test circuit verifies continuity of only one of the two squibs connected in parallel.
   - o Test circuit does not verify status of all circuit inhibitors.
   - o Sneak circuit precludes test function of two lights.
   - o Failure of Oleo inhibitor will cause bags to deploy.
2. Operation Mode: Pilot Deploys Bags after Water Landing (Rotor $N_R = 0$)
   - o Single failure (wire break or short to ground) precludes deployment by pilot.
   - o Single failure (wire break or short to ground) precludes deployment by automatic circuit.
3. Operation Mode: Water Impact - Pilot is Incapacitated
   - o Single failure (wire break or short to ground) precludes deployment by automatic system.
4. Operation Mode: Normal Water Landing and Shutdown - Bag Deployment Not Wanted
   - o If HFS "arm switch" is in the "armed" position, bags will deploy.
   - o If pilot forgets to arm rotor brake, bags will deploy.

APPENDIX "A" (Continued)

5. Operation Mode: Normal Water Landing, Rotor RPM @ Ground Idle - Bag Deployment Not Wanted

   o Failure of N_R inhibitor can cause bags to deploy.

   o Single failure (short to ground) causes bags to deploy.

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TABLE 2

POSITION OF HFS INHIBITORS (OPEN OR CLOSED) FOR VARIOUS OPERATING MODES

INHIBITOR (SWITCH AND/OR RELAY)	DESCRIPTION	1 A/C PARKED $N_R = 0$	2 START ROTOR BRAKE ON $N_R = 0$	3 GROUND RUN $N_R > 80\%$	4 NORMAL FLIGHT $N_R > 80\%$	5 PILOT DEPLOYS BAGS AFTER WATER LDG. & SHUTDOWN $N_R = 0$	6 WATER IMPACT - PILOT IS INCAPACITATED $N_R = 0$	7 NORMAL WATER LDG. & SHUTDOWN (BAG DEPLOYMENT NOT WANTED) $N_R = 0$	8 NORMAL WATER LDG. & ROTORS @ G.I. (BAG DEPLOYMENT NOT WANTED) $N_R < 80\%$	9 GROUND LANDING $N_R > 80\%$	10 GROUND LANDING $N_R < 80\%$
HFS ARM	N.O. - PILOT ACTUATES TO "CLOSE" POSITION TO ARM HFS	OPEN	OPEN	OPEN	OPEN	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN
HFS DEPLOYMENT	N.O. - PILOT ACTUATES TO "CLOSE" POSITION TO DEPLOY HFS	OPEN	OPEN	OPEN	OPEN	CLOSED	OPEN	OPEN	OPEN	OPEN	OPEN
OLEO	N.O. - CLOSES WHEN LDG. GEAR OLEO IS EXTENDED	OPEN	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN
ROTOR BRAKE	N.C. - CLOSED WHEN ROTOR BRAKE IS NOT ARMED	CLOSED	OPEN	CLOSED	CLOSED	OPEN	CLOSED	OPEN	CLOSED	CLOSED	CLOSED
GEN #1	N.C. - CLOSED WHEN GEN #1 DROPS OFF LINE ($N_R < 80\%$)	CLOSED	CLOSED	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	CLOSED
GEN #2	N.C. - CLOSED WHEN GEN #2 DROPS OFF LINE ($N_R < 80\%$)	CLOSED	CLOSED	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	CLOSED
N_R	N.C. - CLOSED WHEN ROTOR RPM IS BELOW 1 RPM	CLOSED	CLOSED	OPEN	OPEN	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN