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NAVAL AIR DEVELOPMENT CENTER

Johnsville, Warminster, Pennsylvania

REPORT NO. NADC-AC-6811 4 JUNE 1968

INVESTIGATION OF THE SAFETY ASPECTS OF UTILIZATION OF EXPLOSIVE LIGHT FILTER (ELF) FLASHBLINDNESS PROTECTION SYSTEM

PHASE REPORT
AIRTASK A34531001/2021/F012-10-02
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Aerospace Crew Equipment Department

REPORT NO. NADC-AC-6811 4 JUNE 1968

INVESTIGATION OF THE SAFETY ASPECTS OF UTILIZATION OF EXPLOSIVE LIGHT FILTER (ELF) FLASHBLINDNESS PROTECTION SYSTEM.

PHASE REPORT.

~~AIRTASK~~ A34531001/2021/F012110-02
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The results of a laboratory program to investigate the safety parameters involved in the operational utilization of the ELF helmet system are presented. Included in the test protocol are dummy and live subject test phases related to the accelerative stresses encountered during flight maneuvers and escape.

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SUMMARY

The results of a laboratory program to investigate the safety parameters involved in the operational utilization of the ELF helmet system are presented. Included in the test protocol are dummy and live subject test phases related to the accelerative stresses encountered during flight maneuvers and escape. It is concluded that, with minor reservations, the ELF helmet does not present a hazard to flight and escape conditions which may be encountered in U. S. Navy flight operations.

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INTRODUCTION

As part of the U. S. Navy's program to provide protection for aircrewmen who may be exposed to the effects of a nuclear detonation, a system for visual protection against flashblindness has been developed. The explosively actuated light filter system, ELF, is comprised of a specially adapted APH helmet with an appropriate sensor, a visor frame housing for the ELF lens, and an associated battery powered trigger. Briefly, the system is designed so that an appropriate signal will be sensed and amplified through the trigger unit to activate the detonator fuse which will rupture two reservoirs of opaquing material at the top of the lens. The carbon colloidal solution in the reservoirs will thereby be driven between the clear walls of the lens to achieve a terminal optical density of 3.0 or greater in less than 200 microseconds, sufficient opacity for protection against flashblindness. Visual capacity can be restored by raising the visor assembly or removing the expended lens, either of which can be accomplished with one hand.

As the only system which has been sufficiently developed and which can presently provide adequate protection for use during night missions or those flown during conditions of low visibility, it is mandatory that all efforts be expended to introduce the system into fleet operations as expeditiously as possible.

The results of preliminary flight tests of the system in a crash effort evaluation program at the Naval Weapons Evaluation Facility (NAVWEPEVALFAC), Albuquerque, and at the Naval Air Test Center (NAVAIRTESTCEN), Patuxent River, were used as the basis for structuring a laboratory test series to investigate those parameters which serve to define the operational safety aspects of utilizing the ELF helmet in a flight test program and in the fleet.

An experimental protocol consisting of parachute jump, ejection seat tower, and inertial reel retraction tests with both dummy and live subjects and dynamic crash and windblast tests with dummy subjects was established. Included in the protocol was a human factors study to determine the effects of this flashblindness protection system on the accommodation of the Navy pilot population in the aircraft designated for these special missions.

The test program, described in detail in reference (a), includes specific phases which are related to problem areas of safety and escape in U. S. Navy flight operations. An extensive program of ejection seat tower tests encompassing a range of acceleration loads was conducted. Tests utilizing the face-curtain primary actuation method and the D-ring secondary firing mechanism were scheduled. Simulated parachute drops to determine the effect of opening shock on the ELF helmet-visor-lens system were performed. Live subject parachute jumps were scheduled to be performed if it was adjudicated by the cognizant technical personnel at the Naval Aerospace Recovery Facility, El Centro, that the data obtained from such live subject jumps would add useful information to the determination of the safety aspects of the ELF helmet system utilization. Dynamic crash studies and windblast studies utilizing dummy subjects were conducted; simulated powered inertial reel retraction studies with live subjects completed the investigative program. An analysis of the effect of the ELF helmet system on aircraft accommodation and pilot assignability codes was performed.

SUBJECT SELECTION CRITERIA

In order to obtain an assessment of the flight and escape safety characteristics of the ELF system and to establish operational restrictions, if any, a series of tests was performed using ninety-fifth percentile dummies and live subjects with differing head-neck structures, the anthropomorphic feature which is considered contributory to possible hazards. In all tests, representative "long slim-necked" and "short-necked" men were selected as subjects to explore the potential for neck and/or other injury which can be attributed to the dynamic response of the head-helmet mass and the neck coupling. As a safety measure, preliminary tests with a ninety-fifth percentile dummy were performed in all series. Test series which utilized live subjects were performed in gradually increasing force loads; complete instrumentation, high-speed motion picture coverage, and intensive surveillance by a medical officer were utilized at each incremental test level. Prior to continuing the test series, instrumentation results and motion pictures were reviewed and approval for proceeding was obtained from the medical officer-in-charge.

Since the anthropomorphic characteristics which were established as criteria of prime concern in this evaluation have not been determined throughout the measured population, the pertinent anthropometric details, along with other commonly used measures, for the two men who served as subjects in the ejection seat tower tests, the most extensive within the series, are given in Table 1. Figures 1 and 2 depict the subjects in the test tower seat prior to an ejection test. Because of the non-availability of an extensive number of subjects who could satisfy the physical anthropomorphic criteria described above, the tests in this program were performed with a limited number of subjects.

EJECTION SEAT TOWER TESTS

A program of ejection seat tower tests encompassing a range of gradually increasing accelerative loads was performed with dummy and live subjects. Both the face-curtain primary actuation method and the D-ring secondary firing mode were investigated. The initial tests were performed at maximum G loading with dummy subjects to obtain at least an indication of safety for live subjects.

In order to ascertain the safety of the ELF helmet system for ejection, the series was designed to investigate, in incremental steps until the design catapult force was reached, the subjective effect of wearing the helmet system. A tabulation of the instrumentation analyses is given in Tables 2 and 3.

The entire regimen of face curtain actuated tests was performed without exhibiting objective evidence of injury or obtaining any expression of complaints. The only concession made to the weight of the ejected mass was the removal of some portions of the seat kit, an effective reduction of twenty-two pounds. It is pointed out that this weight reduction was not related to subject safety, but was intended as a weight reduction in order to maintain efficiency and effectiveness of the ejection catapult. From an ejection force of 3G, the catapult force was incrementally increased to a nominal 12G without incident.

In order to investigate fully any possible hazardous effect of the ELF helmet on ejection, a test series using the D-ring firing actuation method was conducted. The "standard operating procedure" of placing the left hand on the right wrist and actuating the firing ring with the right hand introduced sufficient turning motion to induce an asymmetrical body position during the ejection motion even at levels as low as 2G and 3G. To eliminate this twisting motion, the D-handle was released from its socket and placed in the subject's hand while properly positioning his shoulders in relation to the seat back. With the subject's posture being pre-set, the twisting and/or turning motion was eliminated. This procedure was followed throughout this portion of the test series.

A summary of the test results obtained when the D-ring actuation method was used on the ejection seat test tower is given in Table 3. At levels in excess of 5G, test number 10 of Table 3, considerable head motion accompanied by residual pain was experienced by the subject who had the "short neck." On the "slim-necked" subject, head motion was obvious at a slightly higher acceleration level; however, there was no evidence of pain. Because of possible injury, the medical officer-in-charge discontinued further testing with these subjects. The non-availability within the Department of subjects, who could satisfy the established anthropomorphic criteria and who could meaningfully add to the available information by experiencing the test procedure, caused this phase of the program to be terminated before completion. Details of the physiological aspects and implications of these results are discussed in reference (b).

PARACHUTE DROP TESTS - SIMULATED

In order to obtain an assessment of any effects which the ELF helmet may induce during the parachute drop phase of escape and to obtain the possible test parameters for further live tests, a series of simulated drops were performed with a ninety-fifth percentile dummy wearing the helmet system. All the tests were performed with a lens inserted in the visor frame; the position of the visor frame, either down or up, was varied randomly.

A data summary of these drop tests is given in Table 4. Generally, there was no apparent effect on the dummy which could be attributable to the helmet system.

At resultant accelerations of 24G and higher, considered to be in excess of any realistic loads encountered in an operational escape, there were incidents of the lens snapping out of the frame and the visor hinge at the helmet being partially sheared. These incidents, because of the conditions under which they occurred, are not considered to be a realistic hazard or detriment to the operational use of the system.

For purposes of additional applicable subjective information, these helmet systems will be tested in a series of live jumps. However, since the results of an examination of the existing data by technical personnel of the Naval Aerospace Recovery Facility indicated that minimal meaningful information will be derived from these live tests, this series is being held in abeyance until it can be coupled with another experimental program.

ACCOMMODATION STUDIES

As part of the human factors investigation of the ELF helmet system, the range of pilot accommodation in the more commonly used fighter and attack aircraft were determined. The results of this determination and suppression of accommodation ranges are shown in Table 5. Details of the study are given in reference (c) which also stresses the need for modification of assignability codes for those pilots designated for nuclear weapon missions. The need for possible additional training in using the alternate ejection means is borne out by examination of the data. It is recognized that this added training may be preferable in lieu of restricting upper percentile sitting height aviators from these assignments by enforcement of a modified assignability coding.

A limited number of static tests in pulling the face curtain were performed with an eightieth percentile and tenth percentile (in sitting height) man wearing the ELF helmet. The taller man, in each of four trials, pulled the face curtain well over the helmet with the visor in the up position without making contact until the end of the stroke. The shorter man made contact of the curtain with the visor before the end of the stroke; completion of the face curtain motion caused a slight forward rotation of the helmet.

In analyzing these limited results, the apparent discrepancy is attributed to technique in the pulling motion. It is also pointed out that there was no apparent discomfort with the rotation noted in the tenth percentile subject's motion. It is concluded that the ELF helmet, even in its most limiting configuration of the visor in the raised position, will not interfere with the actuation of the face curtain during ejection.

POWERED INERTIAL REEL RETRACTION AND DYNAMIC CRASH LOADING TESTS

A limited number of tests were performed with live subjects in a simulated powered inertial reel retraction condition. Peak accelerations at the chest ranging from 3.2G to 6.2G, along a horizontal axis, with retraction times from .180 second to .240 second were recorded. The maximum acceleration with which the subject struck the seat back was as high as 8.7G. During all tests, no discomfort was experienced or expressed by any of the subjects; the ELF helmet did not sustain any damage during the tests.

Simulated dynamic crash loading tests were performed at nominal levels of 20G, 25G, and 30G. Even at 20G, the lens fell out of the visor frame, but the ELF helmet sustained no damage throughout any of the tests. "Neck failure" on the dummy was noted at 30G, but lack of meaningful analogies between the dummy neck structure and human neck musculature prohibits identifying such failure with possible injury hazard.

WINDBLAST TESTS

In order to obtain a realistic assessment of the integrity of the ELF helmet in the ejection windstream, a full-clothed dummy equipped with the helmet, trigger, and associated apparel were subjected to three-second duration head-on windblasts at nominal 350 mph, 550 mph, 650 mph, and 750 mph in tests which included the evaluation of other pilot equipment accessories. At the completion of each exposure, the entire system was examined to detect failures and discrepancies of the equipment; high speed motion picture coverage of the tests was provided.

The ELF helmet sustained no apparent damage during the first two tests. A slight momentary separation between the visor, in the lowered position, and the oxygen mask was considered insignificant. At 650 mph, however, a screw which provides retention of the visor frame to the basic helmet was sheared. The last test, an air blast in excess of 800 mph, damage to the entire seat structure and lens retention fixture was noted. The nature of the damage precluded a meaningful post-test examination of the equipment. Separation of the visor frame from the helmet structure was detected from the motion picture records.

On the basis of a realistic evaluation of these windblast test results, it is considered that the structural integrity of the helmet will be maintained under windblast conditions encountered in escape conditions.

CONCLUSIONS

As a result of the evaluation program and on the basis of an analysis of the test results, the following conclusions are presented:

1. It is concluded that the ELF helmet system is structurally sufficient to withstand the anticipated accelerative stresses of flight maneuvers and escape. It is stressed that each condition was investigated separately and that any conclusions involving the inter-relationship and/or combination of stresses must be extrapolated.

2. On the basis of results obtained in these tests, it is concluded that the middle 90% (i.e., 5% to 95%) of the pilot population can safely use ejection escape with the primary face curtain firing mechanism if they can be accommodated in the operational aircraft.

3. In those aircraft where population accommodation is depressed, Table 5, and where the use of the D-ring secondary firing means may become necessary, potential hazards of neck and other injuries exist, especially for anthropomorphic types who are not able to assume proper pre-positioning.

4. Results of the tests performed in this evaluation program indicate that the ELF helmet configuration will not induce subjective discomfort in take-off and landing maneuvers which impose accelerative stresses greater than those encountered in normal flight. In order to preclude accidents caused by the inadvertent release of the lens, take-off and landing operations should be performed with the lens removed from the visor frame in the lowered position.

RECOMMENDATIONS

In order that the ELF helmet system be fully evaluated prior to issuance to the fleet operational forces, it is recommended that the complete system be submitted to a pilot carrier evaluation. Complete personal and support/maintenance equipment with required documentation should be delivered to a designated carrier operation for subjective evaluation pertinent to the utilization of the entire system with its separate components. Specific information on the practical utilization of the support/maintenance equipment and documentation should be elicited.

It is further recommended that pilot personnel be selected for participation in the carrier evaluation of the ELF helmet who can be accommodated in the operational aircraft to the extent that face-curtain ejection seat actuation is functionally possible.

It is also recommended that a re-design of the D-ring secondary ejection seat firing means be accomplished. The D-ring should be so structured and located that at least 90% of the pilot population can reach and actuate the mechanism while maintaining proper pre-ejection posture. With such a re-design, the potential hazard in the use of the secondary firing means for ejection would be reduced. The results of the test program described in this report show that the head-neck configuration, the established anthropomorphic criteria, had no apparent effect on the subjective test results except in the tests utilizing the D-ring as the ejection seat firing mechanism. The recommended re-design of the D-ring will reduce injury hazards whenever this mode of ejection is utilized.

FIGURE 1.
SUBJECT A IN THE TEST TOWER EJECTION SEAT

PHOTO NO: CAN-386112(L)-1-68

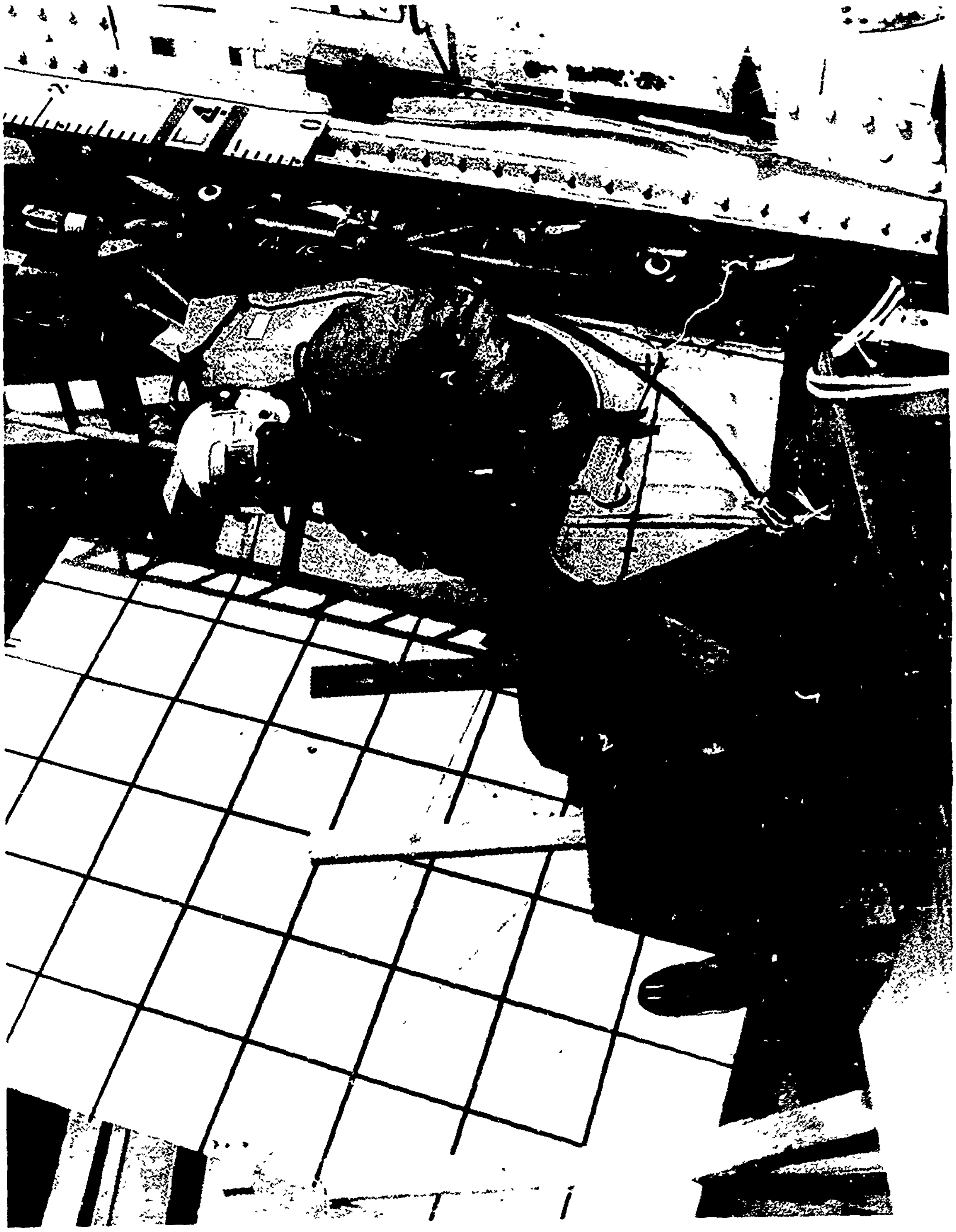

FIGURE 2.
SUBJECT B IN THE TEST TOWER EJECTION SEAT

PHOTO NO: CAN-385906(L)-1-68

TABLE 1

ANTHROPOMETRIC DATA ON SUBJECTS USED IN EJECTION TOWER TESTS OF ELF HELMET SYSTEM

SUBJECT †	WEIGHT*		HEIGHT*		FUNCTIONAL REACH*		SITTING HEIGHT*		SHOULDER BREADTH*		TRUNK HEIGHT*	
	Pounds	%ile	Inches	%ile	Inches	%ile	Inches	%ile	Inches	%ile	Inches	%ile
A	145	9	71.0	67	30.0	15	37.0	72	17.2	4	24.2	65
B	185	77	70.3	57	32.7	80	36.7	64	20.7	98	25.6	95

SUBJECT †	BUTTOCK-KNEE LENGTH*		POSTERIOR NECK LENGTH**		NECK CIRCUM.*		HEAD BREADTH*		HEAD LENGTH*		MENTON-VERTEX DIST.***	
	Inches	%ile	Inches	%ile	Inches	%ile	Inches	%ile	Inches	%ile	Inches	%ile
A	23.5	28	4.1	79	14.2	10	6.1	55	7.8	42	9.7	--
B	25.0	82	4.1	79	14.7	27	5.8	5	7.7	35	9.7	--

NOTES:

*Percentiles per USN 1964 Anthro. Survey on Naval Aviators - NAEC-ACEL-533.
**Percentiles per USAF 1950 Anthro. Survey - WADC Technical Report 52-321.
***No percentile data available.
†Subject A is representative of the "long slim-necked" man;
Subject B is representative of the "short-necked" man.

TABLE 2

EJECTION SEAT TEST TOWER DATA - FACE CURTAIN ACTUATION

TEST NO.	SUBJECT	EJECTED WT.	TEMPERATURE (°F)		PRESSURE	RATE OF APPLICATION	TOWER HT.	PEAK CAT. G
		pounds	ambient	cartridge	psi, peak	G/sec.	feet	
1	Dummy	498	36	72	--	--	--	--
2	Dummy	498	36	72	--	--	--	--
3	Dummy	498	36	72	--	--	--	--
4	"B"	501	41	70	493	18.4	12	3.6
5	"A"	458	41	70	382	10.4	10.5	3.0
6	"B"	479	53	70	800	47.6	20	6.5
7	"A"	436	53	70	705	45.6	21	6.6
8	"B"	479	53	70	955	66.3	26	8.1
9	"A"	436	53	70	810	63.6	25	7.9
10	"B"	479	38	68	1062	83.0	28	8.7
11	"A"	436	38	68	1062	86.3	30	9.5
12	"B"	479	54	70	1370	unavailable	37	12.3
13	"A"	436	54	70	1260	116.1	37	12.3

TABLE 3
EJECTION SEAT TEST TOWER DATA - SECONDARY (D-HANDLE) ACTUATION

TEST NO.	SUBJECT	EJECTED WT.	TEMPERATURE (°F)		PRESSURE	RATE OF APPLICATION	TOWER HT.	PEAK CAT. G
		pounds	ambient	cartridge	psi, peak	G/sec.	feet	
1	"A"	436	55	70	275	13.5	9	2.0
2	"B"	479	55	70	367	10.3	8	2.5
3	"A"	436	56	70	379	20.6	11	2.9
4	"B"	479	56	70	381	12.3	11	2.9
5	"A"	436	51	70	442	23.5	12	3.5
6	"B"	479	51	70	463	21.2	13	3.7
7	"A"	436	51	70	502	24.8	15	4.6
8	"B"	479	51	70	603	26.5	16	4.8
9	"A"	436	49	68	540	26.2	16	5.0
10	"B"	479	49	68	700	40.0	18	5.6
11	"A"	*	55	70	600	38.0	18	5.5
12	"B"	*	55	70	750	51.0	19	6.2
13	"A"	436	45	68	689	47.0	21	6.2

*APH/6 helmet substituted for ELF helmet.

TABLE 4

DATA ON SIMULATED PARACHUTE DROPS (DROP WEIGHT - 190 LBS.)

TEST NO.	DROP HT.	RISER LOAD (POUNDS)		ACCELERATION FORCES (G)			VISOR POSITION	
	Feet	Single	Total	Vert.	Horiz.	Resultant	Up	Down
1	28	1340	5360	23.5	5.1	24.2		√
2	28	1170	4680	24.6	5.3	25.1	√	
3	28	1301	5204	24.8	4.5	25.3	√	
4	7	520	2080	9.9	2.2	10.1		√
5	9	796	3184	14.3	3.8	14.8	√	
6	11	850	3400	15.8	3.1	16.1		√
7	13	990	3960	18.7	3.5	19.0		√
8	16.5	1078	4312	20.9	2.4	21.1		√
9	20	1170	4680	22.4	5.0	22.9		√
10	25	1250	5000	24.0	3.2	24.2		√

TABLE 5

AIRCRAFT SITTING HEIGHT ACCOMMODATION (UPPER LIMIT) WITH ELF HELMET

AIRCRAFT TYPE	ELF VISOR POSITION				PRESENT ACCOMMODATION*	
	UP		DOWN			
	Inches	%ile	Inches	%ile	Inches	%ile
A-1**	38.6	96	39.8	99+	40.0	99+
A-3**	38.5	96	39.7	99+	39.9	99+
A-4	37.3	80	38.5	96	38.7	99+
A-5	37.7	87	38.9	98	39.1	98
A-6	42.2	99+	43.4	99+	43.6	99+
A-7	38.9	98	40.1	99+	40.3	99+
F-4	37.1	75	38.3	94	38.5	96
F-8	37.0	72	38.2	93	38.4	95
F-111**	43.8	99+	45.0	99+	45.2	99+

NOTES:

*Present accommodation allows 1.2 inches for APH-5/6 helmet and 1.0 inches for ejection seat operational clearance, Report NAEC-ACEL-533 of 8 Oct 1965.

**Non-ejection seat type aircraft.

REFERENCES

(a) Program for test and evaluation of G. E. ELF Flashblindness Protection System, NAVAIRDEVCEN ltr ACSH-2 (90184) of 31 Jan 1968.

(b) Interim phase report on test and evaluation of G. E. ELF Flashblindness Protection System, NAVAIRDEVCEN ltr ACSH-2 (90854) of 4 Apr 1968.

(c) Results of accommodation studies; Development of flashblindness protective devices, AIRTASK A34531-001-2021-F012 10 02, NAVAIRDEVCEN ltr ACSH-2 (91029) of 6 Nov 1967.

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13. ABSTRACT

THE RESULTS OF A LABORATORY PROGRAM TO INVESTIGATE THE SAFETY PARAMETERS INVOLVED IN THE OPERATIONAL UTILIZATION OF THE ELF HELMET SYSTEM ARE PRESENTED. INCLUDED IN THE TEST PROTOCOL ARE DUMMY AND LIVE SUBJECT TEST PHASES RELATED TO THE ACCELERATIVE STRESSES ENCOUNTERED DURING FLIGHT MANEUVERS AND ESCAPE.

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