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U. S. NAVAL SCHOOL OF AVIATION MEDICINE

Special Report

TEST AND EVALUATION OF U.S. AIR  
FORCE EXPERIMENTAL CUTAWAY TYPE  
ANTI-BLACKOUT SUITS  
DESIGNATED MA-1

SPECIAL REPORT NO. 59-4

Report by

CDR J. J. Zarriello, MC USN  
Mary E. Norsworthy

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PENSACOLA, FLORIDA

SPECIAL REPORT # 59-4

TEST AND EVALUATION OF U. S. AIR FORCE EXPERIMENTAL CUTAWAY  
TYPE ANTI-BLACKOUT SUITS -- DESIGNATED MA-1

Report by

Commander J. J. Zarriello, MC USN  
Mary E. Norsworthy

Approved by

Captain Ashton Graybiel, MC USN  
Director of Research

Released by

Captain Langdon C. Newman, MC USN  
Commanding Officer

30 April 1959

## SUMMARY PAGE

### THE PROBLEM

The purpose of this study was to test and evaluate the U. S. Air Force experimental cutaway type anti-blackout suit designated MA-1

### THE FINDINGS

The MA-1 anti-blackout suit was tested and evaluated for anti-blackout protection at various positive G levels to the points of greyout and blackout. The results of the anti-blackout protection afforded by the anti-blackout suit has been presented in table form. The suit is comfortable, provides adequate anti-blackout protection, and would probably be well accepted by fleet pilots. No major differences were noted between the protection afforded by the MA-1 anti-blackout suit between experienced and inexperienced subjects.

## INTRODUCTION

In accordance with a request from the Bureau of Aeronautics, the Air Force MA-1 anti-blackout suit was tested and evaluated to the point of greyout and blackout in both experienced and inexperienced subjects as well as in naval aviators.

## PROCEDURE

### SUBJECTS

A total of twenty-seven human subjects were used for this experiment: four experienced subjects--naval personnel attached to the Acceleration Unit of the U.S. Naval School of Aviation Medicine; five naval aviators; and eighteen inexperienced subjects including four subjects generally used in research. They were all young males in the Navy and were in good physical condition.

### METHOD

The subjects were centrifuged and subjected to positive radial acceleratory force on a free-swinging platform mounted 20 feet from the center of rotation. They were in a seated position and were fastened in place by a lap belt and shoulder harness. While being centrifuged the subjects were presented a red central light and two green-blue peripheral lights. These peripheral lights were presented simultaneously and were 80 degrees to the right and left of the central light. When these lights were lost, the next centrifugation was performed using 23 degree lights to the right and left of the central light. The central light was 21.75 inches from the subject's eyes; the 80 degree peripheral lights were 19.5 inches from the subject's eyes; and the 23 degree lights were 23 inches from the subject's eyes. The mean light intensity was 5.0 millilamberts with a range from 2.8 to 8.4 millilamberts. The subjects responded to the stimuli by pressing a trigger located on pistol grip handles which were grasped in each hand. The order of presentation of the central and peripheral lights followed no particular pattern. Instructions were given to all subjects to maintain continuous fixation on the center light during each run and to make no effort to resist the effect of the acceleration other than that necessary to maintain their head erect. All centrifugation runs were commenced at 3 G x 10 seconds unless the subject experienced visual symptoms in which case the next run was decreased until a clear point was obtained. All subsequent centrifuge runs, while the subject was in a relaxed state, were increased by approximately 0.3 G increments until greyout and blackout were obtained, subjectively as well as objectively recorded. All runs were maintained for 10 seconds at peak G.

Greyout was defined as failure to respond to peripheral light stimuli (either the 80 degree light or the 23 degree light) for a period of two seconds or longer during centrifugation. Blackout was defined as a failure to respond to the central light as well as to the peripheral lights for a period of two seconds or longer during centrifugation. The data were compiled and graphs were made using G units as ordinates and objective visual findings as abscissae: clear, 80 degree peripheral light loss x number of seconds up to twenty seconds, 23 degree peripheral light loss x number of seconds up to twenty seconds, and center light loss x number of seconds up to twenty seconds.

The rate of acceleration on the runs is depicted on Table I

Table I

Rate of Acceleration G/Seconds

G Level	G/Seconds
2.0	0.50
3.0	0.67
4.0	0.79
5.0	0.91
6.0	1.03
7.0	1.09
8.0	1.15
9.0	1.19

Each succeeding run on the same subject was separated by approximately three minutes. After unprotected greyout and blackout endpoints were obtained, the subject was instructed to continue to relax and the suit was inflated during the run. The anti-G protection afforded by the MA-1 suits was checked with the valve on the low setting as well as on the high setting.

## RESULTS

The results demonstrating the protection afforded by the MA-1 suit are summarized on Table II and analyzed in detail in groups in Table III. It can be seen from Table II that the unprotected G level for the experienced groups was slightly lower than that of the inexperienced group. However, the amount of protection afforded by the MA-1 suit between the inexperienced and experienced groups with the valve set on low setting and high setting was comparable. The amount of protection afforded by the MA-1 suit can be considered superior to the Navy Z-3, and comparable to the Navy Z-2 suit. Tests on relaxed subjects have shown that a pilot is enabled to tolerate about  $1\frac{1}{2}$  G more with the coverall suit, and  $\frac{3}{4}$  G with the skeleton or Cutaway type suit than he can without the protection of this type of pressurized equipment (1). However, in a comparison of the Z-3 and the MA-1 suit the Johnsville group found in six subjects that the MA-1 suit afforded no more protection than the Navy Z-3 suit (2). Our laboratory is evaluating the Navy Z-3 anti G suit, and finds that in 29 subjects that the mean G protection in relaxed subjects to the blackout endpoint to be 1.2 G with a standard deviation of 0.5 G.

Table II

## Protection Afforded by the MA-1 Suit

Subjects	Mean Values With Standard Deviation		
	Unprotected G Level	Protection MA-1 Suit Valve Setting Low	Protection MA-1 Suit Valve Setting High
Experienced Subjects (N = 4)	80° LL 3.9 G ± 0.7	1.6 G ± 0.4	1.7 G ± 0.3
	23° LL 4.1 G ± 0.7	1.0 G ± 0.6	1.5 G ± 0.5
	BO 4.5 G ± 0.8	0.9 G ± 0.4	1.5 G ± 0.6
Aviators (N = 5)	80° LL 3.9 G ± 0.6	1.8 G ± 0.4	2.2 G ± 0.6
	23° LL 4.3 G ± 0.6	1.5 G ± 0.4	1.7 G ± 0.7
	BO 4.8 G ± 0.7	1.2 G ± 0.7	1.4 G ± 0.7
Research Subjects Numerous Repeated Runs on Same Individual (N = 4)	80° LL 3.8 G ± 0.5	1.0 G ± 0.5	1.7 G ± 0.6
	23° LL 4.1 G ± 0.6	1.2 G ± 0.6	1.7 G ± 0.8
	BO 4.5 G ± 0.7	1.4 G ± 0.7	1.5 G ± 0.7
Inexperienced Subjects Usually only one Run (N = 14)	80° LL 4.2 G ± 0.6	1.6 G ± 0.3	1.8 G ± 0.5
	23° LL 4.7 G ± 0.6	1.3 G ± 0.3	1.7 G ± 0.3
	BO 5.3 G ± 0.6	1.2 G ± 0.4	1.7 G ± 0.3

Table III Continued

EXPERIMENTAL SUBJECTS  
NAVAL AVIATORS

SUBJECT NUMBER	SUITS TRIED	PROPORTION				PROPORTION				SUITS SIZE	SUITS FIT									
		NO. 1 SUIT, VALUE POSITION LOW	NO. 1 SUIT, VALUE POSITION HIGH	NO. 2 SUIT, VALUE POSITION LOW	NO. 2 SUIT, VALUE POSITION HIGH	NO. 1 SUIT, VALUE POSITION LOW	NO. 1 SUIT, VALUE POSITION HIGH	NO. 2 SUIT, VALUE POSITION LOW	NO. 2 SUIT, VALUE POSITION HIGH											
2113	4	3.0	3.3	3.7	4.0	4.8	4.9	5.0	5.1	2.0	2.1	2.8	2.9	2.1	2.1	Medium regular	No comment.			
2117	4	2.9	3.4	3.9	4.3	4.9	5.5	5.7	6.2	2.0	2.1	2.8	2.9	2.1	2.1	Medium regular	1 inch shorter; 1/2 inch too large in elbows; 1 inch too large in waist; 1/2 inch too large in collar.			
2171	4	3.1	3.5	4.0	4.5	4.7	4.8	4.9	5.0	1.6	1.3	0.9	0.5	1.5	0.8	Medium regular	1 inch shorter; 1/2 inch too large in waist; 1/2 inch too large in collar.			
2190	3	4.0	4.4	4.6	5.1	5.7	7.1	7.2	7.3	2.2	2.0	1.7	1.3	3.1	2.8	2.7	2.3	1.8	Medium long	1 inch too large in collar.
2199	4	4.3	4.7	5.3	6.0	6.5	6.7	7.0	7.2	2.2	2.0	1.7	1.3	3.1	2.8	2.7	2.3	1.8	Medium long	1 inch too large in collar.
Mean Standard deviation		3.5	3.9	4.3	4.8	4.9	5.0	5.1	5.1	1.9	1.8	1.3	1.2	2.5	2.2	2.7	2.4	1.6		

Reference (2)

MEASURED SUBJECTS  
STAFF MEMBERS

Table III

SUBJECT NUMBER	SEX	HEIGHT	WEIGHT	DIAPHRAGM C LEVEL				MAMMARY SUIT, VALVE POSITION LOW				MAMMARY SUIT, VALVE POSITION HIGH				PROTECTION C LEVEL	PROTECTION LOW	PROTECTION HIGH	SUIT SIZE	SUIT FIT						
				CL	BL	CL	BL	CL	BL	CL	BL	CL	BL	CL	BL						CL	BL				
18	1	171	420	4.6	4.8	4.7	4.7	3.5	3.9	4.2	4.4	6.6	6.9	7.3	7.9	1.7	1.9	1.9	1.7	2.6	2.3	2.5	2.8	Medium regular	Good fit; some large in elbows.	
	2	171	340	4.0	4.0	4.3	4.7	6.2	6.6	6.9	7.1	4.0	4.2	4.3	4.5	1.7	1.8	1.7	1.4	1.5	1.4	1.3	1.1	Medium regular	fit; some shorts; 1 inch too large in elbows.	
	3	171	285	2.8	2.9	3.4	3.4	3.6	3.4	3.6	4.0	0.9	0.8	0.6	0.6	1.8	1.9	1.7	1.6	1.7	1.4	1.2	1.2	Medium regular	fit; some shorts; 1 inch too large in elbows.	
	4	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
2218	5	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
	6	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
	7	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
2219	8	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
	9	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
	10	171	345	3.9	4.6	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.9	1.7	1.6	1.6	Medium long	1 inch too large in elbows.
Mean				3.9	4.1	4.1	4.1	3.6	3.4	3.8	4.1	3.3	3.8	4.4	4.7	1.4	1.0	0.7	0.4	1.8	1.7	1.7	1.5	1.5		
				0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	

00111: 80 degree peripheral Light Jacket  
00112: 23 degree peripheral Light Jacket  
00113: 23 degree peripheral Light Jacket  
00114: 23 degree peripheral Light Jacket

Reference (11)

Table III Continued

DETERMINED RESPONSE  
RESEARCH SUBJECTS (cont'd)

STUDY ID	SUIT NO.	SUIT NO.	IMPROVED G LEVEL		M-1 SUIT, VALVE POSITION LOW		M-1 SUIT, VALVE POSITION HIGH		PRODUCTION G LEVEL		PRODUCTION G LEVEL		SUIT SIZE	SUIT FIT			
			Clear	80% 23% CL. M.	Clear	80% 23% CL. M.	Clear	80% 23% CL. M.	Clear	80% 23% CL. M.	Clear	80% 23% CL. M.					
244	A	15	4.9	5.1	6.1	6.5	7.2	7.5	7.8	0.9	1.2	1.1	0.7	Medium regular	1 - 1/2 inches too large in elbows.		
	B	13	4.0	4.5	5.0	5.3	5.0	5.3					0.5				
	C	10	3.5	3.8	4.4	4.8			1.1	1.1	1.3	2.0					
	D	12	2.9	3.4	3.7	4.3											
	E	19	3.5	3.9	4.1	5.1	6.1										
	F	21	2.0	2.4	2.9	3.4											
	G	20	1.6	1.9	2.0	2.4					2.3	2.7	2.0	1.2	Medium long	1 inch too large in elbows.	
	H	22	1.4	1.7	1.9	2.3					2.4	2.6					
	I	23	1.4	1.6	1.9	2.3											
	J	20	1.0	1.2	1.3	1.6	6.4'				1.4	1.9	1.8	1.8			
	Mean		2.5	2.8	4.1	4.5				1.0	1.0	1.2	1.4	1.6	1.7	1.7	1.5
	Standard deviation		.7	.5	.6	.7				.5	.5	.6	.6	.8	.6	.6	.7

Energy converted - all 1100 lbs.

Endurance (1)

Table III Continued

EXTENDED-LENGTH  
RESEARCH PROGRAMS

SUBJECT	RESEARCH NUMBER	PROPOSED				PROPOSED				S OF AIR	SIC FTY				
		CLASS	NO. OF LEVELS	CELL NO.	VAL. POS. FOR	CLASS	NO. OF LEVELS	CELL NO.	VAL. POS. FOR						
219	0	40	4.1	4.0	4.0	5.5	5.8	6.0	6.3	1.5	1.6	1.9	2.3	Medium regular	1 - 24 Studies too large to estimate.
	1	38	3.8	3.8	3.8	4.0	5.0	5.4	5.4	1.0	1.5	2.0	1.6	Medium large	1 - 12 Studies too large to estimate.
	2	36	3.6	3.6	3.6	4.4	4.5	4.7	4.9	0.8	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	3	34	3.4	3.4	3.4	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	4	32	3.2	3.2	3.2	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	5	30	3.0	3.0	3.0	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	6	28	2.8	2.8	2.8	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	7	26	2.6	2.6	2.6	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	8	24	2.4	2.4	2.4	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
	9	22	2.2	2.2	2.2	4.4	4.5	4.6	4.7	1.0	1.0	1.0	1.0	Medium regular	1 - 12 Studies too large to estimate.
218	1	35	3.5	3.5	3.5	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	2	33	3.3	3.3	3.3	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	3	31	3.1	3.1	3.1	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	4	29	2.9	2.9	2.9	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	5	27	2.7	2.7	2.7	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	6	25	2.5	2.5	2.5	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	7	23	2.3	2.3	2.3	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	8	21	2.1	2.1	2.1	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	9	19	1.9	1.9	1.9	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	10	17	1.7	1.7	1.7	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
217	1	34	3.4	3.4	3.4	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	2	32	3.2	3.2	3.2	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	3	30	3.0	3.0	3.0	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	4	28	2.8	2.8	2.8	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	5	26	2.6	2.6	2.6	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	6	24	2.4	2.4	2.4	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	7	22	2.2	2.2	2.2	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	8	20	2.0	2.0	2.0	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	9	18	1.8	1.8	1.8	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.
	10	16	1.6	1.6	1.6	4.4	4.5	4.6	4.7	0.9	0.9	0.9	0.9	Medium regular	1 - 24 Studies too large to estimate.

(continued next page)

Table III Continued

UNDESIGNED STRUCTURE  
OTIAMS (cont'd)

PLOT NO.	SIZES	VOLUME	PROTECTION				PROTECTION				SUIT SIZE	SUIT FIT			
			Clear	SO'PIL	23'PIL	CLL	Clear	SO'PIL	23'PIL	CLL					
2195	4	17	4.9	5.0	3.5	5.8	5.7	7.3	7.3	1.4	2.0	1.1	1.3	Medium Long	3 inch too large 16 curves. 2 inches too large in curves; 1 inch too large - at top; 1 inch too large in waist. Good. 11 inches too large in curves, 11/2 inch and waist.
	8	16	4.0	4.2	4.8	5.8	6.2	7.1	7.1	1.8	2.0	2.0	1.8		
2197 2193	8	15	4.4	5.0	5.3	5.5	5.7	6.1	6.7	2.2	1.9	0.8	1.2	Medium Long	
	8	10	3.5	3.9	4.2	4.9	5.7	6.0	6.1	1.7	1.9	1.2	0.9		
2199	8	12	3.5	3.8	4.0	5.0	5.7	6.0	6.1	1.6	1.6	1.3	1.4	Medium Long	
	8	12	4.0	4.5	4.8	5.2	6.2	6.4	6.4	1.7	1.3	1.2	0.9		
Mean			3.9	4.2	4.7	5.3				1.6	1.6	1.3	1.4		
Standard deviation			.6	.6	.6	.6				.3	.3	.3	.4		

Continued (1)



The anti G valve was placed on high setting. This is slightly lower than the G protection afforded by the MA-1 suit (3). The amount of protection afforded by the MA-1 suit with the valve setting on high is significantly greater than when the valve setting is on low. It was not observed that there was any additional abdominal discomfort by the abdominal bladder of the MA-1 anti-G suit as compared to the Navy Z-2. However, the Johnsville group found in their series of six cases that the larger bladder of the MA-1 suit tended to produce nausea due to pressure in the "pit of the stomach(2)."

The MA-1 suit showed a definite tendency to have zipper failure. After completing 246 pressure runs on the medium regular suit, the right thigh "bellows" zipper broke. The zipper was replaced locally and 15 additional pressure runs were completed. A total of 261 pressure runs were completed on the medium regular suit. The suit material showed evidence of failure along the seams particularly the waist seams.

After completing 44 pressure runs on the medium long suit, the waist zipper parted. The zipper was repaired locally and 9 additional pressure runs were completed. A total of 53 pressure runs were thus completed on the medium long suit before the waist seams pulled on the left side and along stays in back on the medium long suit.

The suit was comfortable to wear under G forces and it was easy to don and remove. The pilots that employed the suit generally like it; also, it had high pilot and group acceptance since it could be worn over the summer flight suit. There was no tendency towards nausea due to the larger size of the abdominal bladder on the MA-1 suit. The suit does not provide any means of adjusting the lower leg bladders by a lacing procedure, and it is considered that since tissue pressure is important, a better fit at the calves should be provided.

An evaluation of the MA-1 suit was also conducted to determine to what extent the requirements of paragraph 4.6.2 and 4.6.3 of specification MIL-C-5085A (Aer) were met. The suits were exposed to the following conditions: 24 hours at 100° F and 100 per cent relative humidity; 4 hours at 15°; and 20 hours at 120° F, and dry. These conditions were repeated for a total of three cycles. The MA-1 suits were inflated to a pressure of 8 psi for a total of 100 times. The inflation tests for the MA-1 suit revealed no damage to the material. No leakage developed, however, on the 97th test a seam split about 1½ inches on the outboard side of the right thigh bladder. The MA-1 suits were inflated in three or four seconds to a pressure of 15 psi and held at that pressure for ten seconds. The test resulted in tearing of the seam of the thigh bladder of the medium regular, which was already damaged in previous tests. The medium long seams were pulled on the legs without tearing under similar conditions.

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