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**SUBJECTIVE RESPONSES TO POSITIVE PRESSURE BREATHING
UNDER SUSTAINED HIGH-G USING THE COMBAT EDGE SYSTEM**

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

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FOR THE COMMANDER



JAMES W. BRINKLEY, SES
Director

BioDynamic and Bioengineering Division
Harry G. Armstrong Aerospace Medical Research Laboratory

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and chin. The majority of subjects reported an increase in breathing ease with the COMBAT EDGE system. Subjects also overwhelmingly reported an increase in their personal G-tolerance. However, subjects new to the system had a greater incidence of abnormally fast and deep breathing during initial exposures. Subjects terminating high-G exposures usually did so due to arm pain and breathing difficulty. These results have a direct bearing on training issues related to the COMBAT EDGE system during operational deployment. It is recommended that pilots be exposed to positive pressure breathing under G as part of a training regimen to reduce prevalence of body pain, breathing difficulties and to demonstrate the difference in straining maneuvers between the anti-G suit alone and the COMBAT EDGE system.

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INTRODUCTION

The current high-G protection ensemble for aircrew personnel includes an anti-G suit coupled with straining techniques to offset the hydrostatic column effects of high +Gz exposures (Burton, 1974; Gillingham, 1974; Wood, 1988). Anti-G suit pressures usually start around +2 to +3Gz, and increase as G increases to a maximum suit pressure of approximately 520 to 620 mmHg or 10 to 12 pounds per square inch (Wood, 1988). The idea behind the external increase in suit pressure is to reduce blood shunting to the extremities, to mechanically increase internal blood pressure, and to increase a pilot's physiological tolerance above the normal +5Gz. Thus, an anti-G suit gives the relaxed pilot an extra +2Gz of tolerance for a total of approximately +7Gz (Palets, Tikhonov, Popov, Arkhangel'skiy, Palets and Bonarenko, 1987). When anti-G suits are combined with a straining maneuver (M-1 or L-1), G-tolerance can increase up to +3 to +5Gz allowing the pilot to tolerate +8 to +10Gz without losing consciousness (Burton, 1974; Burton and Shaffstall, 1980).

For long duration exposures of +7Gz and above, straining maneuvers must be repeated every 3 to 5 seconds. The M-1 and L-1 maneuvers, while quite effective, are physically taxing. When straining maneuvers are performed for long periods of time (15 to 45 seconds), or repeated in close succession during numerous high-G flight maneuvers, pilots become severely fatigued. When this happens, straining maneuvers obviously lose their G protection effectiveness (Gillingham, 1974).

Positive pressure breathing with an external counterpressure vest has been suggested as a means to increase G-tolerance and endurance (time-at-G) which would give an operational flight advantage to the pilot. Pressures of 45 to 70 mmHg presented to the lungs via an oro-nasal mask have been shown to increase G-tolerance and endurance by increasing intrathoracic pressures, reducing the mechanical effects of G on respiration and reducing the effort needed to perform straining maneuvers (Burns, 1988; Chambers, Kerr, Augerson and Morway, 1962; Shaffstall and Burton, 1979; Shubrooks, 1973). Experience with positive pressure breathing in the Royal Air Force (RAF) of the United Kingdom has shown that, when coupled with full-coverage anti-G trousers, relaxed G-tolerance was increased to +8.3Gz and high-G fatigue was reduced to a minimum during flight (Prior and Cresswell, 1989). Thus, positive pressure breathing allows the pilot to maintain high-G flight profiles for longer periods of time, as well as perform more high-G profiles in succession. However, Prior and Cresswell (1989) also recorded an increase in pilots' reports of pain and petechial hemorrhaging in body parts not protected by counterpressure, namely the arms.

At the present, the U. S. Air Force is preparing to man-rate a positive pressure breathing apparatus (with vest counterpressure) for inclusion into a new G-protection ensemble known as COMBAT EDGE. This study was conducted during the oxygen regulator check-out phase of the Combined Advanced Technology Enhanced Design G Ensemble (COMBAT EDGE) system during the March-August 1990

time frame. The regulators which control air pressure to the cranial mask and counterpressure vest were tested during two different occasions under sustained high-G stress in the Dynamic Environment Simulator (DES) centrifuge at Wright-Patterson Air Force Base, Ohio. The two series of manned regulator tests presented an early opportunity to obtain subjective data from subjects concerning the use of positive pressure breathing under high-G in our laboratory. Subjective opinions of the COMBAT EDGE system so obtained may help predict the range of pilots' reactions (as well as degree of acceptability) to positive pressure breathing. Hopefully, the results presented here will eliminate any surprises concerning pilot opinion and degree of acceptance during operational deployment of the COMBAT EDGE system.

EXPERIMENT 1: SUBJECTIVE DATA COLLECTED DURING REGULATOR CHECK-OUT NUMBER ONE

Methods

The COMBAT EDGE Ensemble. A centrifuge subject fully suited with the COMBAT EDGE ensemble is shown in Figure 1a. A close-up picture of the helmet configuration is shown in Figure 1b. Figure 2 depicts the pressure hose leads and a detailed breakdown of the ensemble apparatus. The anti-G suit worn with the ensemble was the standard CSU-13B/P suit, and was worn over the bottom portion of the counterpressure vest. The pressures to the G suit were controlled independently of the mask or vest pressures.

A Litton CRU-93 regulator controlled the breathing pressure to the MBU-20P mask and chest counterpressure to the vest. The main pressure hose from the CRU-93 fed into an Integrated Terminal Block (ITB) which split off to provide the same pressures to the mask and vest. Thus, equal pressures were assured to provide approximately one-to-one external counterpressure at the chest area to those pressures being delivered to the lungs.

The helmet was a modified HGU-55P helmet with an occipital bladder which inflated simultaneously with the onset of mask pressure. A small pressure line from the main mask hose fed into the occipital bladder. This assured equal pressures at the back of the head and at the mask point-of-contact to prevent the mask from "riding away from the face".

Positive Pressure Breathing Profiles. The CRU-93 was designed to smoothly deliver pressures at a rate of 12 mmHg/+1Gz, with onset at +4Gz. The maximum pressure delivered to the mask and jerkin was 60 mmHg. Thus, the maximum pressure occurred at +9Gz. The reason for the manned regulator check-out was to evaluate the smoothness and accuracy of this profile. Overall, the regulator performed reasonably well, although some problems precipitated a re-design effort by Litton and was the reason for the second manned regulator testing session outlined later in this report. The detailed results of the engineering evaluations will be addressed in a future report.



A

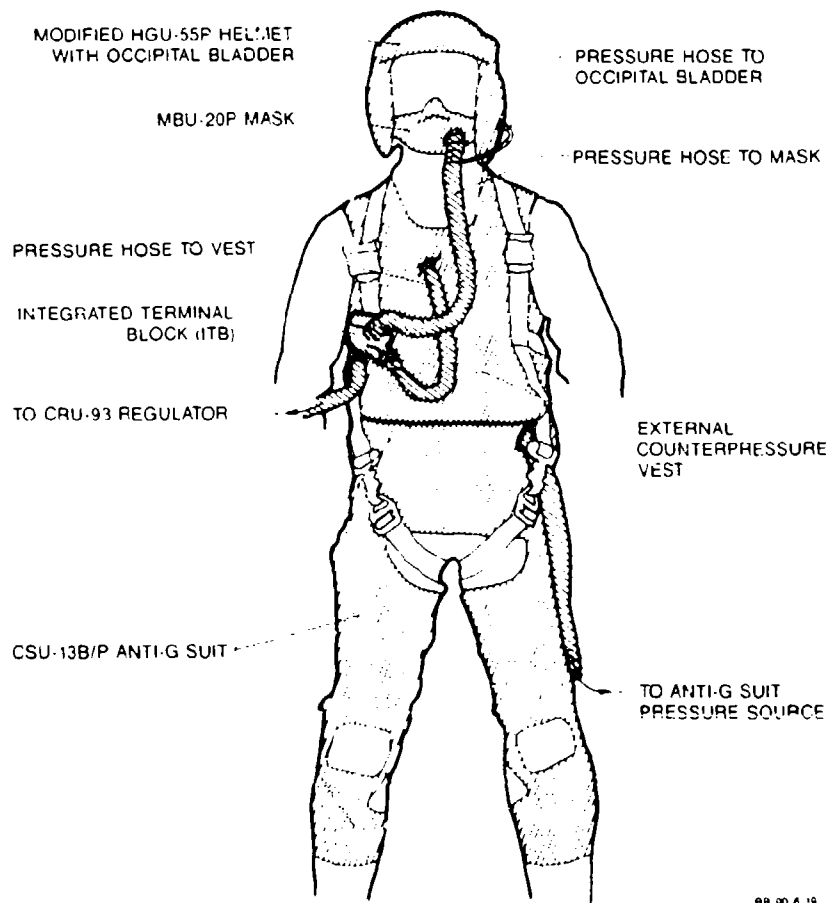
- A fully suited subject.



B

- Close-up of the helmet.

FIGURE 1.

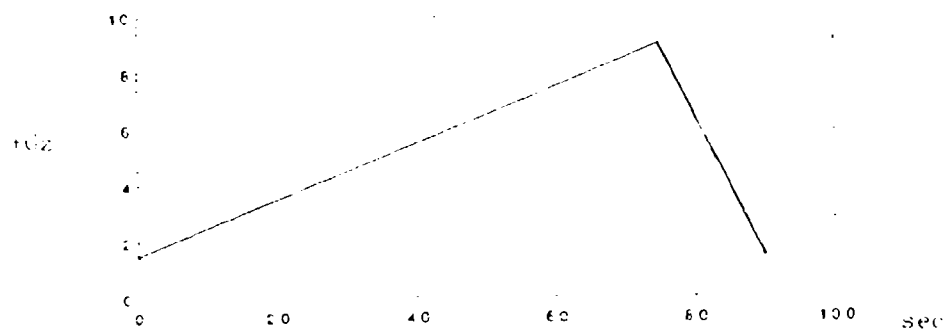


A detailed schematic of the COMBAT EDGE ensemble.

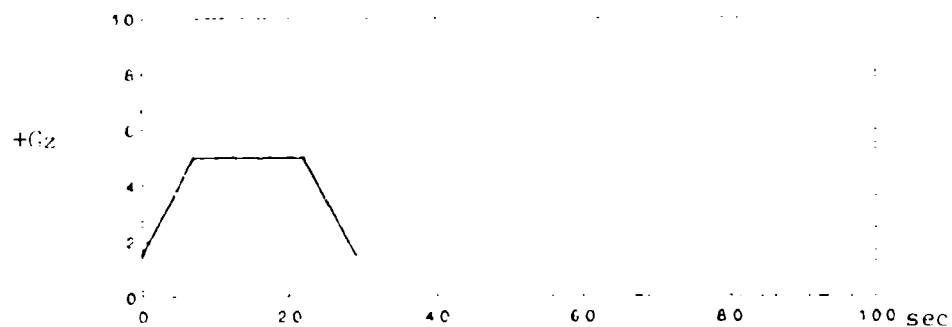
FIGURE 2.

High-G Profiles. The acceleration profiles consisted of four different runs and are depicted in Figure 3. The first run was +9Gz maximum with a gradual onset rate (GOR) of 0.1 G/sec and an offset rate of 0.5 G/sec. The second run was +5Gz maximum with a rapid onset rate (ROR) of 0.5 G/sec, a plateau of fifteen seconds in length, and an offset rate of 0.5 G/sec. The third and fourth runs were identical to the +5Gz run, except the maximum G levels were +7Gz and +9Gz, respectively.

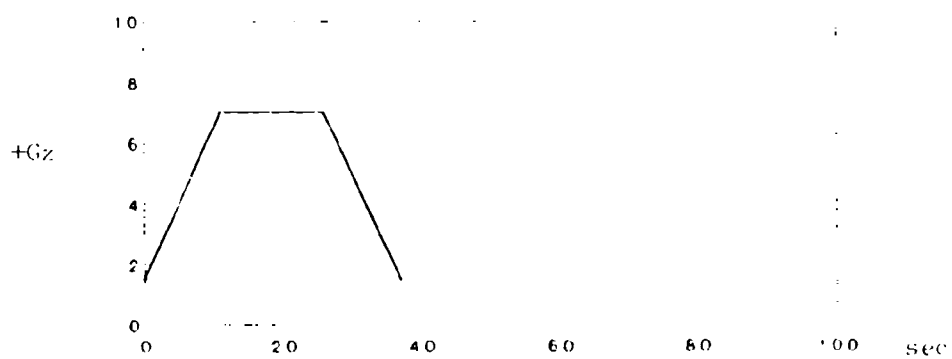
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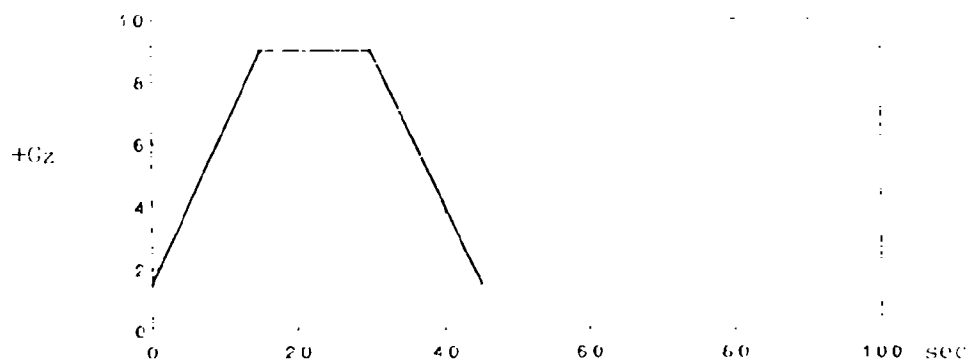
+5Gz ROR



+7Gz ROR



+9Gz ROR



High-G Profiles

FIGURE 3.

Experimental Design. The order in which centrifuge subjects experienced the high-G profiles was determined by the requirements of the regulator evaluation, as well as a need for consistency with tests previously conducted on the centrifuge at Brooks Air Force Base, Texas. Because of these requirements, the order of exposure was not counterbalanced to eliminate learning effects for the subjective evaluation. Instead, the +9Gz GOR run was always followed by the +5Gz ROR, the +7Gz ROR and the +9Gz ROR profiles.

A daily session consisted of these four run profiles for most of the subject exposures. Some of the subjects were only exposed to a few of the runs because of regulator problems, time constraints or termination of the exposures by the subject. Some of the subjects were exposed to each run more than once depending on regulator quality and/or the subject's performance. For a more detailed listing of each subject's exposure description, see Appendix A.

Elicitation of Subjective Responses. There were four major categories of COMBAT EDGE positive pressure breathing system performance. The first was the incidence of body awareness or pain. Subjects were asked after each run if they were aware of pain or discomfort in any body part. The second category was straining characteristics. Subjects were asked after each run if they were using straining maneuvers, and if so, what type of straining maneuver was used. The third category was mask quality. Subjects were asked to relate any instances of mask leakage or changes in mask pressure smoothness. The fourth category was breathing ease. Each subject was asked to give opinions as to breathing ease. In addition, the experimenters recorded any incidence of extremely rapid and deep breathing (hyperventilation).

In addition to the above four categories, data were collected concerning the subjects' reasons for terminating high-G exposure, subjects' reasons for withdrawing from the study, incidence of petechiae, the effectiveness of using arm wraps to reduce the incidence of arm pain and talking ability during positive pressure breathing. However, the nature of these data did not allow for systematic collection and serve as anecdotal evidence only.

Subjects. Eleven male subjects, ages 26 to 39 (mean=30.7, std=3.9) participated in the first testing session. Table 1 shows the total number of daily sessions in which each subject participated, flight experience, altitude chamber experience, days since last centrifuge run and total centrifuge experience on the DES. One subject had more than 5 daily sessions with the COMBAT EDGE system; two subjects had 4 sessions; two subjects had 3 sessions; three subjects had 2 sessions and three subjects had 1 session. Five subjects had flight experience. Eight subjects had altitude chamber experience with positive pressure breathing. Days since last centrifuge run ranged from 5 to 38 (mean=26.1; std=10.3).

TABLE 1.

COMBAT EDGE PBG TRAINING EVALUATION EXPERIENCE PROFILE

Subject Code	Total Number of Sessions	Flight Experience	Alt. Chamber	Days Since Last Centrifuge Run	Total Centrifuge Experience
TR	18 at USAFSAM 4 checkouts training	120 hours F-111, F-4 med. observer	1.5 hours	5	94.0 hours
BE	4 training	80 hours T-41, T-37 ex-pilot	3.0 hours	29	3.0 hours
SC	4 training	none	none	23	10.5 hours
PO	3 training	2-3 hours flight surgeon	3.0 hours	33	12.5 hours
WH	3 training	114 hours T-37, T-38 ex-pilot trainee	4.0 hours	38	6.5 hours
SH	2 training	150 hours ex-F16 pilot	5.0 hours	34	5.5 hours
CA	2 training	none	0.5 hours	23	17.5 hours
FA	2 training	none	none	31	3.5 hours
LP	1 training	none	none (licensed scuba diver)	23	4.0 hours
WA	1 training	none	0.5 hours	12	17.5 hours
HU	1 training	none	0.25 hours	36	37.0 hours

* Extreme arm pain. Subject withdrew from program after first run of the second session.

** Extreme arm pain and numbness after first session. Subject withdrew from program immediately afterwards.

Results

Each subject's detailed subjective response is presented in Appendix A. The following results were obtained by averaging responses across subjects. A total of 26 scorable runs were determined for the +9Gz GOR profile, 27 runs for the +5Gz ROR profile, 26 runs for the +7Gz profile, and 25 runs for the +9Gz ROR profile. Considering all high-G profiles, a total of 104 scorable runs were obtained.

Incidence of Pain. Table 2 shows the incidence rates of pain in various body parts. Arm pain was the most often reported, followed by leg pain, ear pain, buttock pain, facial pain and rib pain. Pain occurred most often in the +9Gz ROR run, followed by the +9Gz GOR, +7Gz ROR and +5Gz ROR runs.

TABLE 2.

Incidence of Pain

Type	+9Gz GOR (26 runs total)	+5Gz ROR (27 runs total)	+7Gz ROR (26 runs total)	+9Gz ROR (25 runs total)	TOTAL
arm pain	14 (.54)	8 (.29)	15 (.57)	17 (.68)	54 (.49)
leg pain	2 (.08)	2 (.07)	2 (.08)	2 (.08)	8 (.08)
head pain	0 (.00)	0 (.00)	0 (.00)	1 (.04)	1 (.01)
buttock pain	1 (.04)	0 (.00)	0 (.00)	1 (.04)	2 (.02)
rib pain	1 (.04)	0 (.00)	0 (.00)	0 (.00)	1 (.01)
ear pain	0 (.00)	3 (.11)	0 (.00)	0 (.00)	3 (.03)
TOTAL	18 (.69)	10 (.37)	17 (.65)	21 (.84)	

Subjects reports of pain (percentage of total runs in parentheses).

Types of Straining Maneuvers. Table 3 shows the most common types of straining maneuvers reported. Tensing of the legs was the most common, followed by the abdomen, the arms, a whole body strain, the chest, the buttocks and the M-1 or L-1 straining maneuvers. Straining was required most often in the +9Gz ROR run, followed by the +7Gz ROR, the +9Gz GOR and the +5Gz ROR runs. Two interesting subjective reports were obtained here also. There were 7 instances where subjects forgot to perform any straining maneuver at all. In addition, there were two instances where subjects lost vision during the +9Gz ROR run, yet spontaneously recovered their vision at plateau with no straining required.

TABLE 3.

Types of Straining Maneuvers

Type	+9Gz GOR (26 runs total)	+5Gz ROR (27 runs total)	+7Gz ROR (26 runs total)	+9Gz ROR (25 runs total)	TOTAL:
<u>legs</u>	7 (.27)	6 (.22)	13 (.50)	14 (.56)	40 (.38)
<u>abdomen</u>	6 (.23)	2 (.07)	4 (.15)	5 (.20)	17 (.16)
<u>arms</u>	2 (.08)	1 (.04)	4 (.15)	5 (.20)	12 (.12)
<u>whole body</u>	2 (.08)	1 (.04)	1 (.04)	4 (.16)	8 (.08)
<u>chest</u>	0 (.00)	0 (.00)	1 (.04)	2 (.08)	3 (.03)
<u>buttocks</u>	0 (.00)	0 (.00)	1 (.04)	1 (.04)	2 (.02)
<u>M-1 or L-1</u>	1 (.04)	0 (.00)	0 (.00)	1 (.04)	2 (.02)
TOTAL:	18 (.69)	10 (.37)	24 (.92)	32 (1.28) **	

** Subjects reported more than one type of straining maneuver for each run.

NOTES:

<u>Straining Forgotten:</u>	2 (.08)	1 (.04)	3 (.12)	1 (.04)	TOTAL: 7 (.07)
<u>"Spontaneous" visual recovery without straining:</u>	0 (.00)	0 (.00)	0 (.00)	2 (.08)	2 (.02)

Mask Quality. Table 4 shows the most often reported decrements in mask quality. Leakage at the nose and eyes was the most common, followed by leakage at the chin, general seal leakage, mask raised away from the face and mask "chatter". Mask quality decrements occurred most often during the +9Gz GOR run, followed by the +9Gz and +7Gz ROR runs, and the +5Gz ROR run.

TABLE 4.

Mask Quality					
Type	+9Gz GOR (26 runs total)	+5Gz ROR (27 runs total)	+7Gz ROR (26 runs total)	+9Gz ROR (25 runs total)	TOTAL:
<u>Leakage at nose and eyes</u>	6 (.23)	0 (.00)	3 (.12)	4 (.16)	13 (.125)
<u>leakage at chin</u>	2 (.08)	1 (.04)	4 (.15)	3 (.12)	10 (.10)
<u>general leakage</u>	4 (.15)	0 (.00)	1 (.04)	1 (.04)	6 (.06)
<u>mask raised away from face</u>	1 (.04)	0 (.00)	1 (.04)	0 (.00)	2 (.02)
<u>pressure "chatter" and unevenness</u>	0 (.00)	1 (.04)	0 (.00)	1 (.04)	2 (.02)
TOTAL:	13 (.50)	2 (.07)	9 (.35)	9 (.36)	

Subjects' reports of mask quality (percentage of total runs in parentheses).

Breathing Ease. Table 5 shows the subjects' ratings of breathing ease, as well as the experimenters' identification of hyperventilation occurrence. There were 9 instances where subjects were breathing extremely fast and deep, and the results of these occurrences ranged from "talking the subject down" into more normal breathing rates to where subjects stopped the centrifuge by using the emergency B-stop (B-stop is defined here as the subjects' termination of the high-G profile before the prescribed end point). Subjects reported more breathing ease than breathing difficulty, however. More difficulties were reported during the +9Gz GOR run than during the other runs. Conversely, more reports of breathing ease were obtained during the +9Gz ROR run than during the other runs.

TABLE 5.

Breathing Ease

Type	+9Gz GOR (26 runs total)	+5Gz ROR (27 runs total)	+7Gz ROR (26 runs total)	+9Gz ROR (25 runs total)	
<u>needed coaching ("talked down" from hyper- ventilation)</u>	1 (.04)	1 (.04)	2 (.08)	0 (.00)	TOTAL: 4 (.04)
<u>hyper- ventilation</u>	1 (.04)	2 (.07)	1 (.04)	1 (.04)	5 (.05)
<u>very hard</u>	6 (.23)	3 (.11)	1 (.04)	3 (.12)	13 (.125)
<u>hard</u>	6 (.23)	4 (.14)	2 (.08)	1 (.04)	13 (.125)
<u>easy</u>	6 (.23)	7 (.26)	7 (.27)	6 (.23)	26 (.25)
<u>very easy</u>	4 (.15)	9 (.33)	9 (.35)	7 (.28)	29 (.28)
<u>outstanding</u>	1 (.04)	1 (.04)	1 (.04)	5 (.20)	8 (.08)
Overall Difficulty:	14 (.54)	10 (.37)	6 (.23)	5 (.20)	35 (.34)
Overall Ease:	11 (.42)	17 (.63)	17 (.65)	18 (.72)	63 (.61)

Subjects' reports of breathing ease (percentage of total runs in parentheses).

Anecdotal Data. Table 6 shows the reasons for subjects' B-stops which ended their acceleration runs before the prescribed exposure time. Arm pain was the reason most reported, followed by breathing difficulties, straining forgotten, vertical nystagmus and fatigue. B-stops occurred most often during the +9Gz ROR run, followed by the +9Gz GOR run and the +7Gz ROR run. There were no B-stop occurrences during the +5Gz ROR run.

TABLE 6.

Reasons for Subjects' B-Stop

Type	+9Gz GOR (26 runs total)	+5Gz ROR (27 runs total)	+7Gz ROR (26 runs total)	+9Gz ROR (25 runs total)	TOTAL:
<u>arm pain</u>	3 (.12)	0 (.00)	0 (.00)	2 (.08)	5 (.05)
<u>breathing difficulty (including hyper- ventilation)</u>	2 (.08)	0 (.00)	0 (.00)	2 (.08)	4 (.04)
<u>straining forgotten</u>	0 (.00)	0 (.00)	2 (.08)	0 (.00)	2 (.02)
<u>vertical nystagmus</u>	0 (.00)	0 (.00)	0 (.00)	1 (.04)	1 (.01)
<u>fatigue</u>	0 (.00)	0 (.00)	0 (.00)	1 (.04)	1 (.01)
TOTAL:	5 (.19)	0 (.00)	2 (.08)	6 (.24)	

Subjects' reasons for B-stop (percentage of total runs in parentheses).

Two subjects withdrew from the study. Subjects SH and LP (Appendix A) dropped out due to extreme arm pain. During the first daily session, subject SH reported major degrees of discomfort due to high pressures in the G-suit, pain in the arms and buttocks and difficulties in exhaling. Subject SH stopped the runs using the B-stop three times, twice during the two +9Gz GOR runs and once during the +9Gz ROR run. During the first run of the second daily session, subject SH stopped the run and withdrew from the study due to extreme arm pain. It was determined during the debriefing period that subject SH had injured his right elbow within the last two years severely enough to require corrective surgery. However, this subject reported extreme pain in both arms and general dislike for the system as the reasons for withdrawal. It should be noted that subject SH was an ex-pilot with 150 hours of flight experience in the F-16 aircraft, as well as 5 hours of altitude chamber experience.

During the first daily session, subject LP reported pain in both arms during the +9Gz GOR run, the +7Gz ROR run and the +9Gz ROR run. Subject LP did not stop the runs through the B-stop, however, until he was well within the +9Gz ROR profile (and then because of vertical nystagmus, not arm pain). Subject LP did not report any major problems with breathing during the runs, and in fact reported that breathing was quite easy at the higher-G runs (the subject showed very mild signs of hyperventilation during the +5Gz ROR run). However, 24 to 72 hours after this first daily session the subject reported that he could not raise his left arm due to extreme shoulder/elbow pain and muscle numbness. Subject LP subsequently withdrew from the study. It should be noted that subject LP had no flight experience, no altitude chamber experience, and had only 4 hours of previous centrifuge experience before participating in this COMBAT EDGE evaluation.

All subjects exhibited marked petechiae on the arms at some time during their respective daily sessions. For example, subject TR exhibited petechiae after the first session, yet did not after the second to fourth sessions. Subject BE exhibited petechiae on the arms and buttocks after the first two sessions, yet did not after the third or fourth. In contrast, subject SC exhibited petechiae on the arms after all four sessions. All subjects with three daily sessions or less exhibited petechiae after every session.

The high incidence of pain and petechiae of the arms was most probably due to the shunting of blood into those body parts not protected by external counterpressure (buttock pain/petechiae included, see Figure 2 for the areas of the body protected by the vest and anti-G suit). As early as 1966, Ernsting stated that a full body counterpressure garment used with positive pressure breathing would eliminate pain due to blood shunting and blood pressure increases in unprotected areas. Thus, arm wraps (ACE elastic bandages or surgical support hose) were used with four subjects in an attempt to alleviate arm pain. For two of those subjects, TR and BE, arm pain was eliminated using arm wraps during a total of 12 runs of varying G levels. Petechiae were

also reduced. For subject WH, arm pain still occurred during the +9Gz GOR and +9Gz ROR runs while wearing arm wraps. Pain was eliminated during the +5Gz ROR runs. Subject FA reported no arm pain wearing the arm wraps until the +9Gz ROR run, where he could manipulate the degree of pain by squeezing and tensing his arms. The harder he tensed his arms, the less severe the pain. Subjects WH and FA still exhibited petechiae after wearing the arm wraps.

Subjects also devised their own ways in which to reduce arm pain. Subject FA repeatedly raised the left hand to the right shoulder in an attempt to elevate the elbow and alleviate pain. Subjects BE, SC, FA and WA tensed their arms and hands to reduce arm pain.

Another anecdotal result concerned talking ability during positive pressure breathing. Two subjects, TR and SH, attempted to talk during the +9Gz ROR run while at plateau. The subjects were instructed to repeatedly count from 0 to 9. Subject TR could not talk during the first two runs. During the third run, talking could be heard but not understood. Subject SH could not talk during his only run at +9Gz ROR.

Still another anecdotal finding concerned the mask seal. Subjects BE and CA reported that the quality of the mask seal could be manipulated by jaw and/or facial movements, which is a standard procedure during pressure breathing indoctrination in the altitude chamber. For example, subject CA had trouble with the mask "riding away from the face" during pressure delivery. This subject moved and re-positioned his jaw to bring the seal back into place and remove the leakage around the mask. He reported that, whenever he felt the mask begin to "ride" or leak, he simply re-positioned his jaw and/or mouth. The mask also caused noticeable imprints around the nose and mouth of each subject. These imprints seemed to disappear quickly after the mask was removed, and were rather benign according to subject opinion.

Two subjects, PO and SH, reported an intense dislike for the COMBAT EDGE system due to a loss of control of their normal straining maneuvers, as well as a loss of normal bodily feedback from the anti-G suit during high-G runs. During his first two daily sessions, subject PO reported that he was "fighting" against his G-suit, and the pressures of the suit were much greater than he remembered during other runs (although the actual pressures were the same as all standard G-suit profiles). By the third daily session, however, this subject was becoming accustomed to the system and had changed his straining maneuver techniques. Subject SH reported that the loss of feedback from the anti-G suit did not allow him to regulate his straining maneuvers, and expressed doubts as to whether or not pilots would accept and/or use the system (subject SH was the ex-F16 pilot who withdrew from the study due to arm pain).

Finally, there were two subjects who reported virtually no problems with the system (other than intermittent arm pain), and thoroughly enjoyed the extra high-G protection of the positive

pressure breathing system. The first subject, TR, had the most experience with the COMBAT EDGE system of any of the subjects. Subject TR had a total of 22 sessions with the COMBAT EDGE system before these subjective data were collected. Subject TR also had up to 120 hours of flight experience, 1.5 hours of altitude chamber experience, and 94 hours of centrifuge exposure. This subject came the closest to emulating a typical operational pilot in terms of overall high-G experience and static altitude chamber positive pressure breathing experience. Conversely, subject HU had no flight experience, 0.25 hours of altitude chamber experience, and 37 hours of centrifuge exposure. Yet, this subject reported that "I couldn't believe I was at 9 G". Subject HU "played" with his peripheral vision during the onset of the +9Gz ROR run, then relaxed at plateau with no problems.

EXPERIMENT 1: SUBJECTIVE DATA COLLECTED DURING REGULATOR CHECK-OUT NUMBER TWO

Methods

The COMBAT EDGE ensemble, the positive pressure breathing profiles, the high-G profiles and the experimental design used during the second session were identical to those used in the first session, above.

Elicitation of Subject Responses. The elicitation of subject responses differed from the verbal protocol used for session one. Two questionnaires were developed using the information obtained from the earlier high-G runs. Questionnaire 1 concerned the subjects' opinions of each of the separate high-G profiles (+9Gz GOR, +5Gz ROR, +7Gz and +9Gz ROR). Questionnaire 2 concerned overall ratings of the entire session and was completed after all profiles had been run. Questionnaires 1 and 2 are presented in Appendix B and C, respectively.

Subjects. Eight male subjects, ages 24 to 39 (mean=29.3, std=4.1) participated in the second testing session. Five of the eight subjects had participated in the first testing session, and so had obtained some experience with positive pressure breathing under high-G. Table 7 shows the total number of runs each subject participated in during the second session as well as the number of runs during the first session, flight experience, altitude chamber experience, days since last centrifuge run and total centrifuge experience on the DES.

Results

Questionnaire 1: Individual Profile Ratings. The following results were obtained by averaging responses across subjects. A total of 12 scorable runs were obtained for the +9Gz GOR profile, 11 runs for the +5Gz ROR profile, 11 runs for the +7Gz ROR profile and 11 runs for the +9Gz ROR profile.

TABLE 7.

COMBAT EDGE PBG EXPERIENCE PROFILES FOR SESSION #2

Subject Code	Number of Sessions (this evaluation)	Involved in First Evaluation	Flight Experience	Alt. Chamber	Days Since Last Centrifuge Run	Total Centrifuge Experience
TR	2	Yes, 27 runs	120 hours, F-111, F-4, med. observer	1.5 hours	3	101.5 hours
SC	2	Yes, 4 runs	none	none	5	15.0 hours
CA	2	Yes, 2 runs	none	0.5 hours	31	19.5 hours
WA	2	Yes, 1 run	none	0.5 hours	2	20.0 hours
BE	1	Yes, 4 runs	80 hours, T-41, T-37 ex-pilot	3.0 hours	35	5.5 hours
MA	1	No	none	none	7	4.5 hours
JA	1	No	none	0.25 hours	38	27.0 hours
* OL	1	No	none	none	15	4.0 hours

* Subject withdrew from study due to lack of experience at +9Gz acceleration levels.

a. Breathing Ease: Question #1. Figure 4 shows the subjects' responses concerning breathing ease. For all four profiles, most subjects reported an increase in breathing ease while using the COMBAT EDGE system. The instances of breathing difficulty occurred during the two +9Gz runs and the +7Gz run.

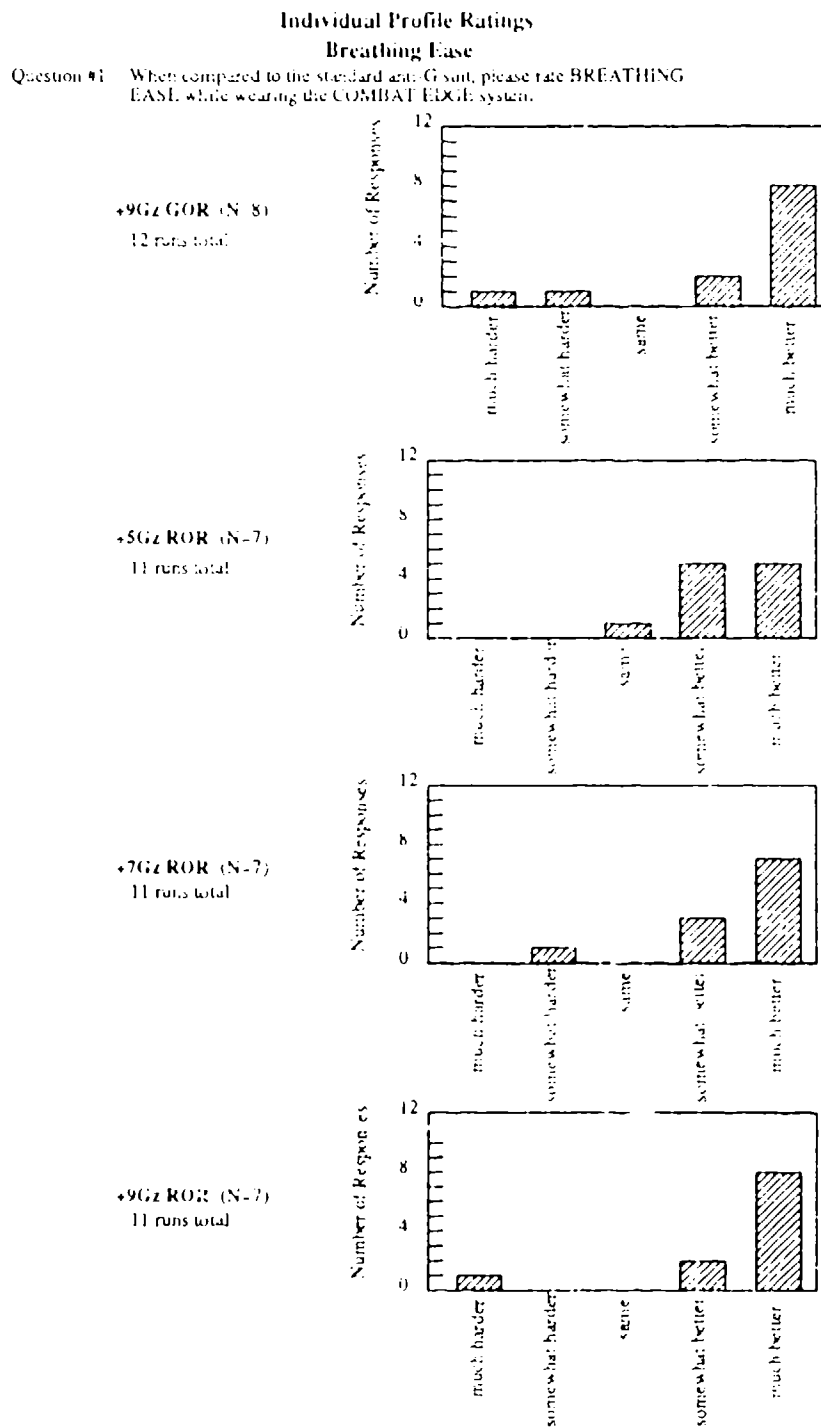


FIGURE 4.

b. Mask Seal: Question #2. Results for quality of the mask seal are shown in Figure 5. As can be seen, during the +5Gz RCR run there were no reports of mask leakage. However, during the +7Gz ROR and +9Gz ROR runs, reports ranged from slight to noticeable leakage of the mask seal. During the +9Gz GOR run, responses were more evenly distributed, suggesting that mask leakage occurred most often during this profile.

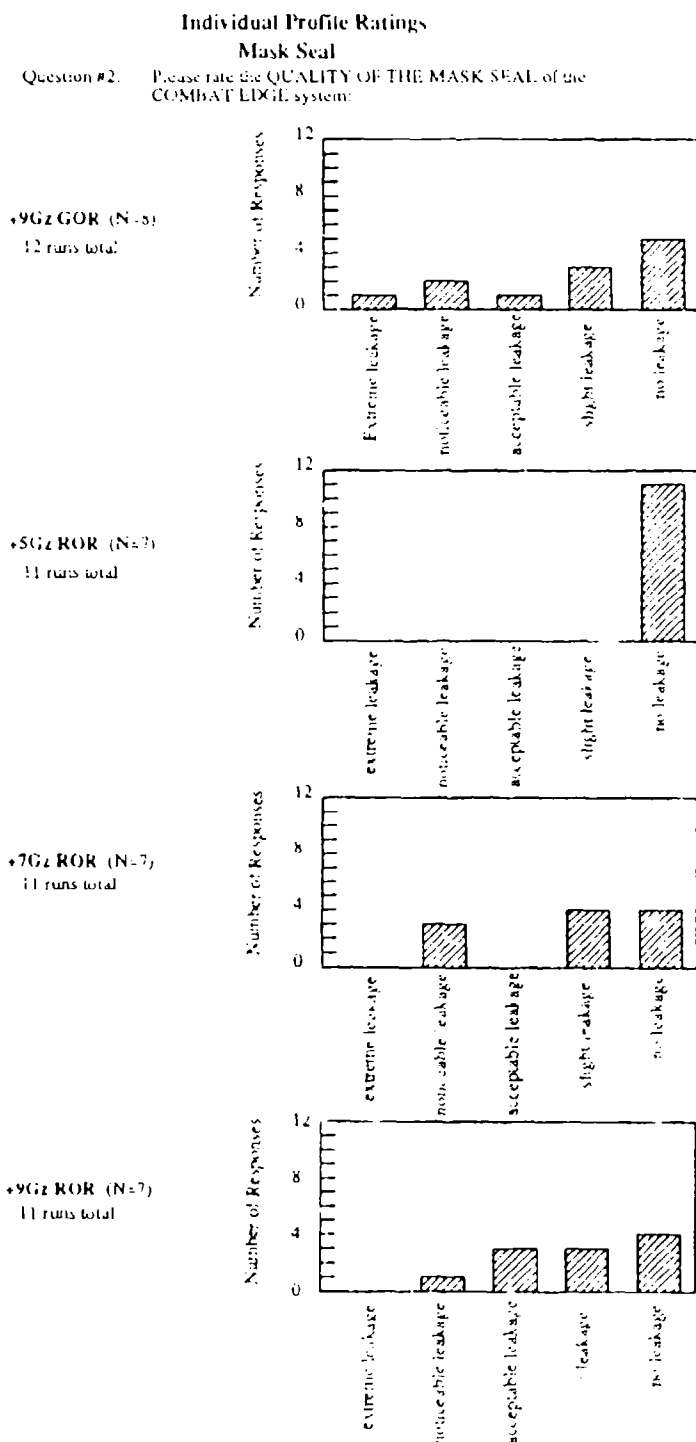


FIGURE 5.

c. Degree of Straining Required: Question #3. Figure 6 shows subjects' responses as to the degree of straining required under each of the four profiles. For the +5Gz, +7Gz and +9Gz ROR runs, straining effort was roughly equal.

Individual Profile Ratings
Straining Maneuver Effort
 Question #3: When compared to the standard anti-G suit, please rate the DEGREE OF STRAINING REQUIRED while wearing the COMBAT EDGE system.

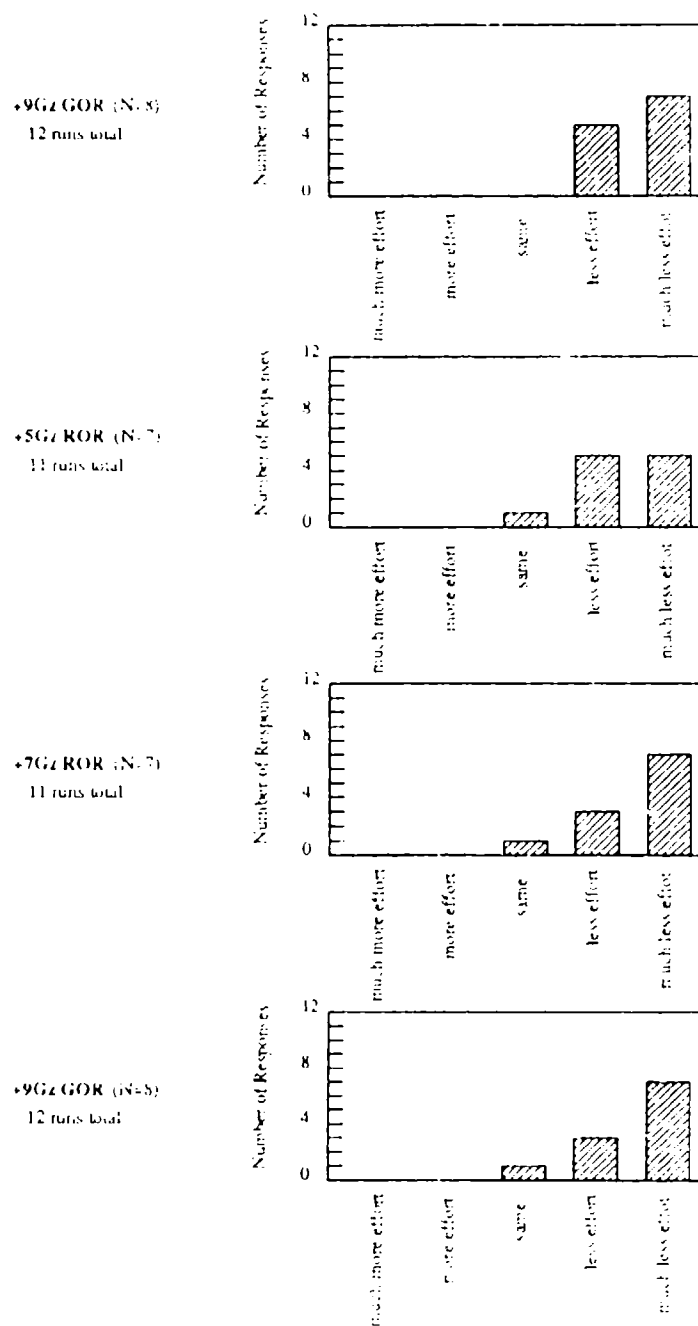


FIGURE 6.

d. Types of Straining Maneuvers: Question #4. Table 8 shows the frequency at which subjects reported using straining techniques. Tensing of the legs was used most frequently, followed by the M-1, arms and buttocks, the chest and the L-1 maneuver. Straining maneuvers were used least during the +5Gz ROR profile, followed by the +7Gz ROR, and the two +9Gz profiles.

TABLE 8.

**Individual Profile Ratings
Types of Straining Maneuvers**

Question #4: While straining, which BODY AREAS or TECHNIQUES did you use the most with the COMBAT EDGE system:

	+9Gz GOR (N=8) 12 runs total					+5Gz ROR (N=7) 11 runs total					+7Gz ROR (N=7) 11 runs total					+9Gz ROR (N=7) 11 runs total					TOTAL incidence of Straining:
	** A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
Arms	1	1	4	2	4	1	0	0	2	8	1	1	2	1	6	2	2	3	1	3	24
M-1	0	3	4	2	3	0	1	2	1	7	2	1	3	2	3	2	3	3	0	3	29
L-1	0	0	2	2	8	0	0	0	1	10	0	0	1	1	9	0	3	0	0	8	10
Chest	0	1	4	2	5	0	0	0	1	10	1	0	1	1	8	2	4	0	0	5	17
Buttocks	0	5	3	0	4	0	0	3	1	7	2	1	0	1	7	2	2	3	1	3	24
Legs	3	4	1	0	4	0	1	3	3	4	3	2	2	1	3	3	2	4	1	1	33
TOTALS:	4	14	18	8	28	1	2	8	9	46	9	5	9	7	36	11	16	13	3	23	

** A - Used all the time
B - Used most of the time
C - Used periodically
D - Used rarely
E - Didn't use at all

e. Body Pain: Question #5. Table 9 shows the areas of the body where pain occurred most often. Pain occurred most often in the area of the arms at the wrist to elbow, followed by the elbows, the area from elbow to shoulder and the wrists. The highest instances of pain occurred during the two +9Gz profiles. However, overall ratings suggested that pain occurred much less frequently during the second session (approximately 8 percent of the time) than it had in the first session with the COMBAT EDGE system (approximately 40 percent of the time).

TABLE 9.

Individual Profile Ratings
Body Pain

Question #5. While under high-G stress with the COMBAT EDGE system, in which BODY AREAS did you experience the most PAIN:

	+9Gz GOR (N=8) 12 runs total					+5Gz ROR (N=7) 11 runs total					+7Gz ROR (N=7) 11 runs total					+9Gz ROR (N=7) 11 runs total					TOTAL incidence of PAIN:
	**A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
Head	0	0	0	0	12	0	0	0	0	11	0	0	0	0	11	0	0	0	0	11	0
Ears	0	0	0	1	11	0	0	0	1	10	0	0	0	2	8	0	0	0	1	10	6
Nose/Throat	0	0	0	0	12	0	0	0	0	11	0	0	0	1	10	0	0	0	0	11	1
Face	0	1	0	0	11	0	1	0	0	10	0	1	0	0	10	0	2	0	0	9	5
Neck	0	1	1	0	10	0	0	1	0	10	2	0	0	0	9	2	0	0	0	9	7
Shoulders	0	1	0	0	11	0	1	0	0	10	0	1	0	0	10	0	1	0	0	10	4
Elbows	2	1	0	3	6	1	1	0	0	9	2	0	0	1	8	2	0	1	1	7	15
Wrists	0	1	1	1	9	1	0	0	0	10	1	0	1	0	9	1	1	0	0	9	8
Arm (wrist to elbow)	3	3	1	0	5	1	2	2	0	6	3	2	0	1	5	2	3	1	0	5	21
Arm (elbow to shoulder)	1	2	1	1	7	1	0	2	0	8	2	1	0	0	8	1	2	0	0	8	14
Hands	0	0	1	0	11	0	0	0	0	11	0	0	0	0	11	0	1	0	0	10	2
Chest	0	0	0	0	12	0	0	0	0	11	0	0	0	0	11	0	0	0	0	11	0
Back	0	0	0	1	11	0	0	0	0	11	0	0	0	0	11	0	0	0	1	10	2
Abdomen	0	0	0	1	11	0	0	0	0	11	0	0	1	0	10	0	0	1	0	10	3
Buttocks	0	0	1	0	11	0	0	0	0	11	0	0	2	0	9	0	1	1	0	9	5
Thighs	0	0	0	0	12	0	0	0	0	11	0	0	0	0	11	0	0	0	1	10	1
Knees	0	0	0	0	12	0	0	0	0	11	0	0	0	0	11	0	0	0	0	11	0
Ankles	0	1	2	0	9	0	0	0	0	11	0	0	0	1	10	0	0	1	0	10	5
Feet	0	0	1	0	11	0	0	0	0	11	0	0	0	0	11	0	0	0	0	11	1
TOTALS:	6	11	9	8	194	4	5	5	1	194	10	5	4	7	183	8	11	5	4	181	

** A - Pain all the time
B - Pain most of the time
C - Pain periodically
D - Pain Rarely
E - No pain at all

Questionnaire 2: Overall Ratings. A total of 11 questionnaires obtained from 7 subjects were used as data. Figures 7, 8, 9 and 10 show the responses to Questionnaire 2.

The overall wearing comfort of the COMBAT EDGE system was rated, on an average, somewhat better than the standard anti-G suit. The straining effort required while wearing the COMBAT EDGE system was rated overwhelmingly less than the anti-G suit. Overall severity of body pain was rated somewhat better with the COMBAT EDGE system, while the severity of petechiae was rated the same or somewhat worse.

The level of fatigue was rated much less with the COMBAT EDGE system. Loss of control of bodily feedback with the COMBAT EDGE system showed no discernible response patterns.

The COMBAT EDGE system was rated as an advancement in G-protection four times and was rated as "a great leap forward" seven times.

Subjects recommended the COMBAT EDGE system for use in the cockpit without reservation six times, and with some changes five times. Recommended changes included custom-fitting the helmet, custom-fitting the mask and a training program aimed at familiarizing pilots with the system before use in the cockpit.

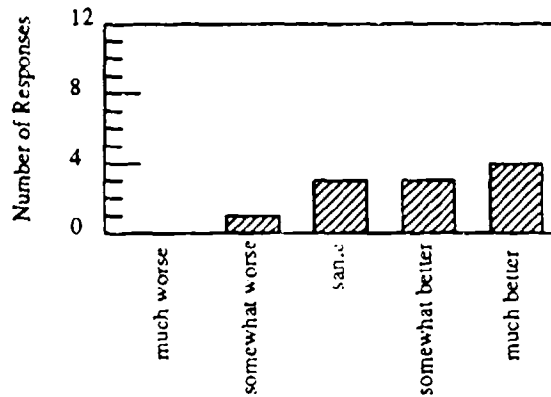
Subjects chose the COMBAT EDGE system nine out of eleven times over the standard anti-G suit. All subjects, no matter how many times they had run, stated that the COMBAT EDGE system increased their personal G-tolerance on an average of +2.2Gz. The average rated personal G-tolerance with the anti-G suit was +8.9Gz, while with the COMBAT EDGE system it was rated +10.9Gz.

Overall Ratings

(N=7) 11 runs total

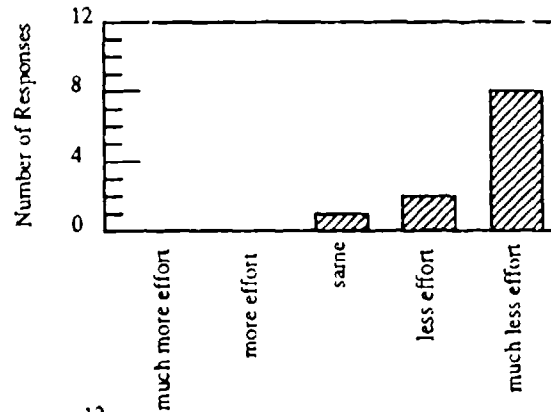
Question #1.

When compared to the standard anti-G suit, please rate the **OVERALL WEARING COMFORT** of the COMBAT EDGE system:



Question #2.

When compared to the standard anti-G suit, please rate the **OVERALL STRAINING EFFORT** required while wearing the COMBAT EDGE system:



Question #3.

When compared to the standard anti-G suit, please rate the **OVERALL SEVERITY OF BODY PAIN** while wearing the COMBAT EDGE system:

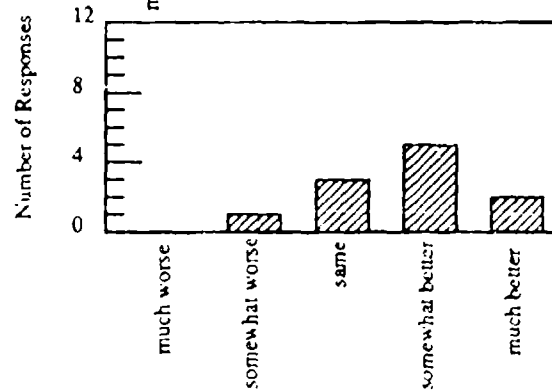


FIGURE 7.

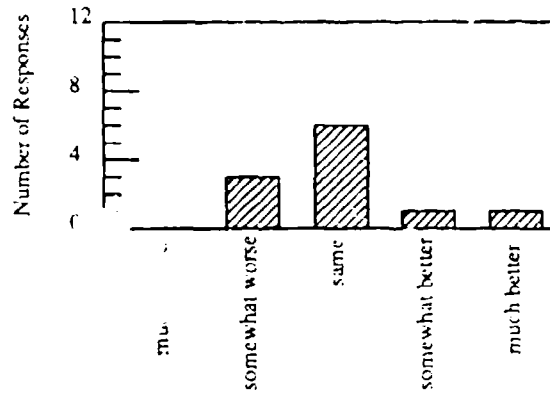
Overall Ratings

(continued)

(N=7) 11 runs total

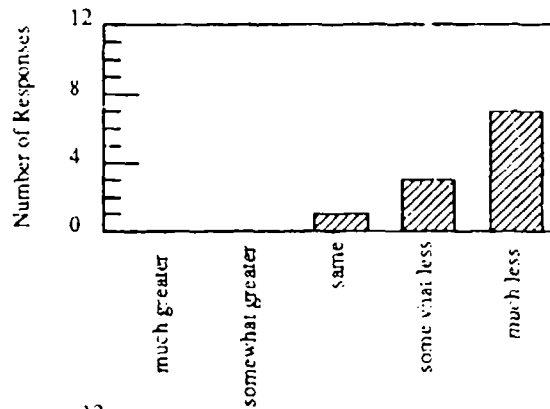
Question #4.

When compared to the standard anti-G suit, please rate the severity of the tiny red spots (PETECHIAE) that appear on your body after wearing the COMBAT EDGE system:



Question #5.

When compared to the standard anti-G suit, please rate your OVERALL LEVEL OF FATIGUE while wearing the COMBAT EDGE system:



Question #6.

When compared to the standard anti-G suit, did you experience the feeling of LOSS OF CONTROL OF BODILY FEEDBACK due to COMBAT EDGE system characteristics during high-G:

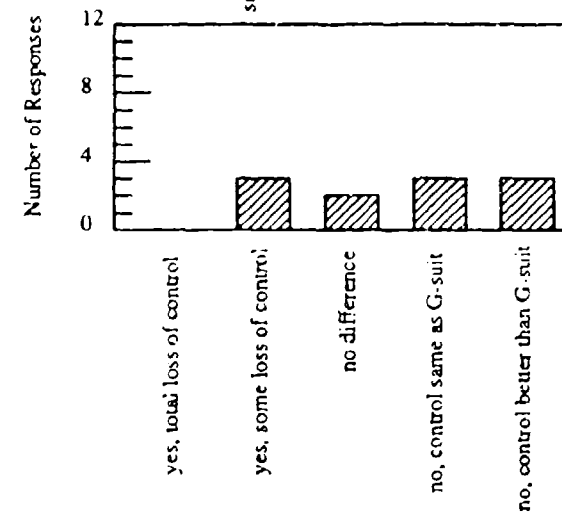


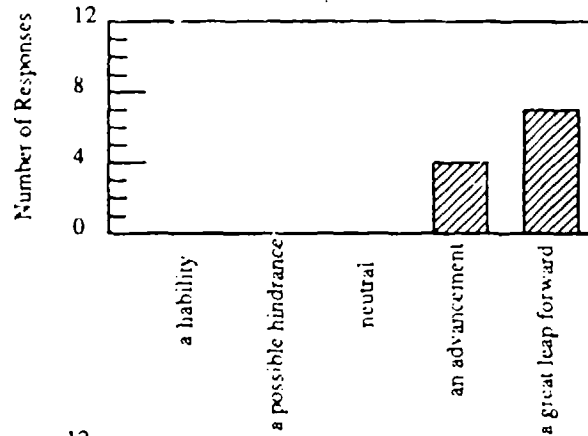
FIGURE 8.

Question #7.
Overall, how would you rate the COMBAT EDGE system as a MEANS OF G-PROTECTION:

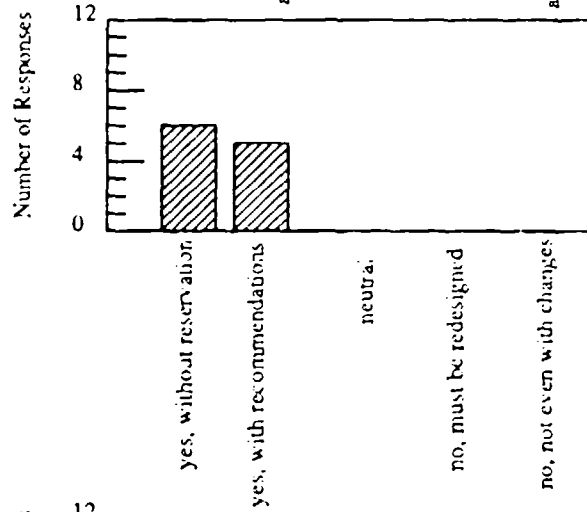
Overall Ratings

(continued)

(N=7) 11 runs total



Question #8.
Would you recommend the use of the COMBAT EDGE system in the fighter cockpit:



Question #9.
If you had a choice between wearing the standard anti-G suit and the COMBAT EDGE system, which would you choose:

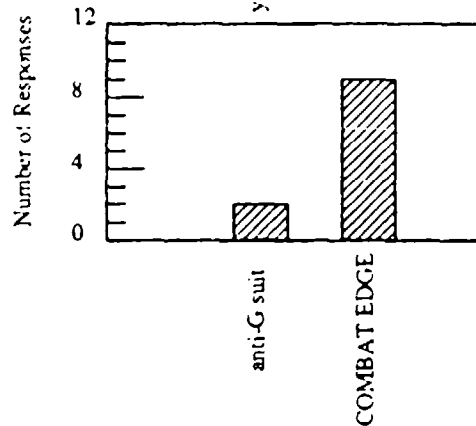


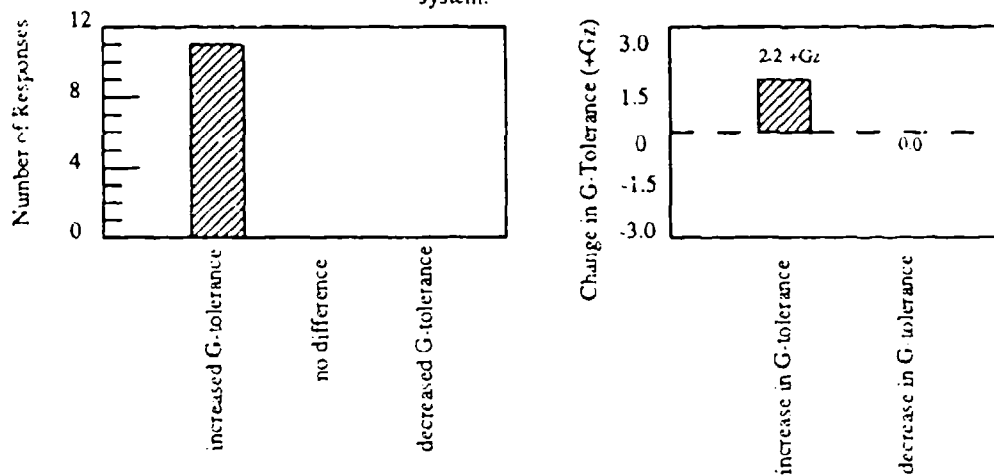
FIGURE 9.

Overall Ratings

(continued)

(N=7) 11 runs total

Question #10. When compared to the standard anti-G suit, estimate the DIFFERENCE IN YOUR PERSONAL G-TOLERANCE while wearing the COMBAT EDGE system:



Question #11. Estimate the MAXIMUM +Gz LEVEL you believe you could withstand with the standard anti-G suit and the COMBAT EDGE SYSTEM:

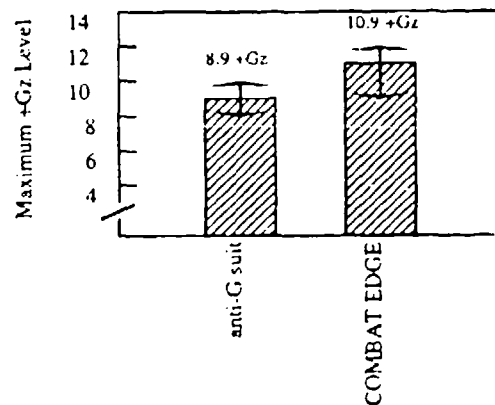


FIGURE 10.

DISCUSSION

Data From Regulator Check-Out Number One

These data provide a fairly good baseline point from which to predict problem areas during operational deployment of the COMBAT EDGE system. The first, and most prevalent, problem area documented from the first evaluation was that of arm pain. The counterpressure vest covered the trunk area, but did not provide coverage of the arms. Blood shunting and the attendant blood pressure increase in the unprotected extremities have been well documented (Ernsting, 1966). However, using arm counter-pressure similar to that found in the vest would severely restrict the range of movement during the time of pressurization. Arm wraps reduced, but did not completely eliminate, arm pain and petechiae in every subject. It is expected that most, if not all, pilots flying with the COMBAT EDGE positive pressure breathing system will experience some degree of initial arm pain.

Some subjects reported pain in the legs. Pain in the areas of the boot tops and at the back of the knee were the most common types of leg pain. The top of the boot would be the area where, mechanically, blood shunting would have the most effect since the G-suit only reached to this area. Pain behind the knee was found to be related to subjects' habits of tucking the G-suit laces into the open space behind the knee. When subjects were instructed not to tuck the laces, pain in this area was not found.

Ear pain was reported three times by one subject. This subject described the pain as "fullness" in the ears and neck, and as "popping" of the ears. This can be related to the increase in pressure in the oro-nasal cavities, as well as the Eustacian tubes from the throat to the inner ear during positive pressure breathing.

Buttock pain can be related to the design of the anti-G suit. There is a cut-out of material at the buttock area where no counterpressure occurs. As was found with the arms, body areas lacking counterpressure material usually suffer from blood shunting. An explanation for the lower incidence of reported pain in the buttock area can be related to the fact that subjects were being pushed down into the seat at high levels of +Gz, thereby creating counterpressure at the buttocks without a cover garment.

Rib pain and facial pain can be related to the high pressures around the rib cage due to the counterpressure vest and the high pressures of the mask and occipital bladder of the helmet, respectively. In effect, the vest "squeezed" the rib cage, and the mask/occipital bladder "squeezed" the facial area.

Another set of important findings obtained from this first study concerned straining maneuvers. Some subjects reported that their typical straining maneuver was not needed and was indeed "too much" during positive pressure breathing. The typical M-1 or L-1 maneuvers were reported only twice during high-G runs.

Subjects also reported a loss of control of the straining maneuver and a lack of bodily feedback from the anti-G suit. Typically, subjects reported that they needed to "relearn" their maneuvers. Some subjects simply used the positive pressure breathing in place of their straining maneuvers.

The most commonly reported straining maneuver consisted of straining with the legs and pushing against the G-suit and lower part of the counterpressure vest with the abdomen. Arm straining also occurred, but was mostly related to subjects' attempts to reduce arm pain. Whole body strains did occur, but were less common than the leg or abdomen strain. Tensing of the chest or buttocks was also less common.

There were seven instances where subjects forgot to strain during the onset of high-G. This has direct implications for training with positive pressure breathing. The subjects were concentrating more on their breathing techniques and subsequently forgot to strain.

An unexpected, exciting phenomenon was reported by two subjects. One subject forgot to strain, lost vision to the point of black-out, then spontaneously recovered vision at plateau. The other subject fell behind the curve on his straining maneuver, lost vision to black-out, then also spontaneously recovered at plateau. This means that positive pressure breathing may well help pilots recover from black-out or G-induced loss of consciousness during flight.

Reports of mask leakage centered mostly around the nose, eyes and chin, especially during the two +9Gz runs when the mask pressures were greatest (maximum 60 mmHg). However, these results should be interpreted with caution since the helmet/mask ensemble was not individually fit to each subject. For this study, only the small and large size helmets were available, and helmet fit was less than optimal for most subjects. Nevertheless, these results still point to potential problems concerning noticeable mask leakage.

A total of 9 instances of abnormally rapid and deep breathing occurred. Most of these instances occurred during the initial runs with the system. As subjects learned how to "breathe backwards" (passive inhalation, forceful exhalation), fewer difficulties were reported. Most subjects reported during later runs that breathing was much easier due to the lessening of mechanical "weight" on the chest and diaphragm during positive pressure breathing. Overall, subjects reported that breathing was much easier with the COMBAT EDGE system (a 63/35 ratio for ease over difficulty).

The two most common reasons for the termination of runs before the scheduled end time (through the subjects' B-stop) was the incidence of arm pain and breathing difficulty. This could be taken as evidence of the severity and importance of both arm pain and feelings of breathing difficulty for future training purposes.

Data From Regulator Check-Out Number Two

Five of the eight subjects used in this second session had experience with the COMBAT EDGE system during the first session. As such, subjective responses concerning the use of the COMBAT EDGE system were somewhat different during this session than the first. In addition, more examples of anecdotal evidence were available during the first session due to the nature of the open-ended verbal protocol. During this second session the format of the standard paper-and-pencil questionnaire discouraged the elicitation of anecdotal data.

Individual Profile Ratings. For high-G levels above +7Gz, breathing ease was rated easier with the COMBAT EDGE system than without, which supported the majority of the responses obtained during the first session. In addition, during both +9Gz runs, mask leakage was worse than at the lower G levels as was also found during the first session.

Much less effort was required for straining maneuvers while using the COMBAT EDGE system, and the types of straining maneuvers reported replicated the results found in the first session. Tensing of the buttocks and legs were used in conjunction with the M-1 maneuver, especially during the +9Gz runs. Tensing of the arms was also used to reduce incidence of arm pain.

The largest differences in results between the first and second sessions concerned the reports of body pain. For the first session, during approximately 40 percent of the runs subjects reported body pain with the majority occurring in the arms. For the second session, pain in the arms was again the most common type of pain but was reported on an average only 8 percent of the time. Subjects stated anecdotally after the second session that the increased experience with the COMBAT EDGE system seemed to decrease the incidence of pain in not only the arms, but also the legs and buttocks. These results have direct bearing on training issues before introducing COMBAT EDGE to the cockpit.

Overall Ratings. Eight of the 11 ratings for overall wearing comfort showed that the COMBAT EDGE system was better than the anti-G suit alone. Comfort could have been mediated by the presence of the counterpressure vest coverage, which is not present with the G suit alone. Even the presence of arm pain did not decrease the ratings of wearing comfort.

Ratings of straining effort suggest that subjects found high-G exposures much less taxing while wearing the COMBAT EDGE system. This finding is further supported by the ratings of fatigue. Fatigue was rated much less while using COMBAT EDGE.

Seven of the 11 ratings for overall body pain showed that the COMBAT EDGE system was better than the anti-G suit alone, although as discussed earlier, body pain was much greater with the COMBAT EDGE system during the first session. Only four ratings

suggested that body pain was the same or worse with the COMBAT EDGE system. The severity of petechiae was rated the same or worse with the COMBAT EDGE system nine out of eleven times, which supports the anecdotal data obtained from the first session.

During the first session, some subjects stated that the counterpressure vest and positive pressure breathing removed or dampened the cues they normally used from the anti-G suit to begin their straining maneuvers and remain aware of the level of G to which they were being exposed. However, a question aimed directly at this issue did not yield any interpretable patterns. Three subjects reported some loss of control, five reported control was the same as the G suit and three reported control was better with COMBAT EDGE.

The last series of questions dealt with the subjects' perceptions of the COMBAT EDGE system as a means of G-protection, which was not addressed in the first session's data collection. Overwhelmingly, subjects rated the COMBAT EDGE as an advancement, and most subjects recommended it for use in the cockpit with only a few design suggestions. An extended training program was suggested by subjects as a means to familiarize pilots with system characteristics, such as initial body pain, breathing requirements, and the general "feel" of the system. Custom-fitting of the helmet and mask was also suggested to reduce any helmet discomfort or distracting mask leakage.

On all of the 11 runs, subjects stated that COMBAT EDGE increased their G-tolerance. The average estimated increase in G-tolerance over the standard anti-G suit was +2.2Gz.

CONCLUSIONS

The following is a list of possible problems with pilot opinion and acceptability that may occur with the introduction of the COMBAT EDGE system:

- Arm pain and increased petechiae.
- Pain in other body areas.
- Need for "relearning" of straining maneuver.
- Forgetting to strain because of novelty of the positive pressure breathing system.
- Distraction due to mask leakage.
- Need for "relearning" of breathing techniques.
- Incidence of hyperventilation.

The following is a list of advantages that the COMBAT EDGE system can confer to help increase pilot acceptability:

- Reduction of effort needed for straining maneuvers (from M-1 or L-1 maneuvers down to tensing legs and abdomen).
- Breathing ease is increased during high-G flight profiles.
- Spontaneous recovery from black-out and G-induced loss of consciousness.
- Average reported increase in G-tolerance of +2.2Gz.

To increase the list of advantages, or to neutralize the possibly negative points concerning the COMBAT EDGE system, it is highly recommended that a training program be implemented concerning the following points:

- Decrease the incidence of arm pain through repeated exposures to high-G with positive pressure breathing.
- Decrease breathing problems through practice.
- Train for relearning of straining maneuvers.
- Familiarization with the advantages of COMBAT EDGE (increased G-tolerance, reduced straining effort and fatigue) to ensure acceptance in the pilot community.

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APPENDIX A.

Individual Subjective Responses From Regulator Check-out Number One

SUBJECT TR

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

<u>Pain</u>	1	none	none	none	none
	2	none	none	none	none
	3	none	none	slight pain in left elbow	slight pain in both elbows
	4	none	none	none	none
	5	-----	a) none b) none	a) none b) none	-----
wrapped arms					
wrapped arms					
<u>Straining</u>	1	none	none	none	tensed legs to remove grey-out
	2	none	none	slight tensing of legs	tensed legs and abdomen on way to plateau none at plateau
	3	none	none	tensed legs	strained 3 times at top of plateau
	4	none	none	tensed legs	"played" with peripheral vision by tensing legs and abdomen
	5	-----	a) none b) none	a) none b) tensed legs	-----

SUBJECT TR

(Cont.)

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

<u>Mask Quality</u>	1	none	none	none	none
	2	slight leakage	none	none	none
	3	leakage at +7.5Gz	none	leakage at plateau around nose and eyes	none
	4	leakage at peak around nose and eyes	"chatter" in mask	none	"chatter" in mask
	5	-----	a) none b) none	a) none b) none	-----
<u>Breathing Ease</u>	1	very easy	very easy	very easy	outstanding
	2	very easy	very easy	very easy	outstanding
	3	very easy	very easy	very easy	outstanding
	4	very easy	very easy	very easy	very easy
	5	-----	a) very easy b) very easy	a) very easy b) very easy	-----
<u>Talking Ability</u>	1	-----	-----	-----	can't talk
	2	-----	-----	-----	can't talk
	3	-----	-----	-----	very difficult to understand
	4 and 5 not determined				

SUBJECT BE

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

<u>Pain</u>	1	none	fullness in ears	-----	pain in left elbow
	2	pain in both elbows	fullness in ears and helmet too tight	pain in both arms	none
	3	tensing of arms reduced pain	pain in both arms and ear popping	pain in both elbows	pain above both elbows and inside arms
	4	none	none	none	none

<u>Straining</u>	1	straining with abdomen against G-suit	none	-----	pushed on pedals with legs
	2	none	none	none	pushed on pedals with legs
	3	pushed on pedals with legs	none	straining with abdomen against G-suit	straining with arms, legs and abdomen
	4	pushed on pedals with legs and straining with abdomen	none	tensed legs	M-1 and tensed legs to "push lights back out"

<u>Mask Quality</u>	1	none	movement of jaw resealed mask	-----	none
	2	leakage at plateau around nose and eyes	none	none	slight leakage
	3	leakage at ~ +7Gz	none	none	leakage at plateau around nose and eyes
	4	leakage at ~ +6Gz	none	slight leakage	leakage at plateau around nose and eyes

SUBJECT BE

(Cont.)

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	----------------	----------	----------	----------	----------

Breathing Ease

1	very hard	hard	-----	very easy
2	hard	easy	very easy	very easy
3	hard	very easy	very easy	very easy
4	hard	very easy	very easy	outstanding

Talking Ability

- not determined -

SUBJECT SC

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
<u>Pain</u>	1	none	none	-----	pain in left knee behind joint
	2	pain in both forearms	none	pain in both forearms	pain in both forearms
	3	tensing of arms reduced pain	pain in both arms	pain in left and right elbows	** "funny" bone sore on both arms
	4	-----	-----	pain in left forearm and elbow	pain in left forearm and elbow
<u>Straining</u>	1	tensed legs	none	-----	"spontaneous" recovery of vision during black-out, no straining
	2	slight M-1	tensed legs at first, then stopped	tensed legs	tensed legs to push out peripheral vision
	3	straining with legs and abdomen	none	none	** (aborted due to arm pain)
	4	-----	-----	straining with arms and legs	straining with arms and legs
<u>Mask Quality</u>	1	leakage at plateau around eyes	none	-----	none
	2	none	none	none	none
	3	leakage at ~ +8-9Gz around nose and eyes	none	none	** (aborted due to arm pain)
	4	-----	-----	none	none

** Subject stopped high-G exposure before normal end of run.

SUBJECT SC

(Cont.)

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

Breathing Ease					
1	very hard	hard	-----		easier
2	easy	easy	slight hyperventilation, talked down		easy
3	easy	slight hyperventilation	slight hyperventilation	** (aborted due to arm pain)	
4	-----	-----	easy		hyperventilation (too fast and deep)
Talking Ability					
- not determined -					

** Subject stopped high-G exposure before normal end of run.

SUBJECT PO

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

Pain

1	pressure too high in G-suit (pain in legs)	pressure too high in G-suit (pain in legs)	none	pain in both arms
2	pain in arms and legs	none	pain in arms and legs	numbness in lips
3	pain in right arm against armrest	pain in right elbow	pain in right elbow	pain in right elbow

Straining

1	straining with abdomen	none	none	straining with abdomen
2	"fighting" against G-suit	"fighting" against G-suit and pushing against pedals with legs	pushed against pedals with legs	hard, whole body strain
3	straining with abdomen	slight tensing of abdomen	none	tensed arms and legs

Mask Quality

1	none	none	slight leakage at chin	none
2	leakage at ~ +7Gz around eyes	none	none	none
3	none	none	none	slight leakage at nose

Breathing Ease

1	hard	hard	easier	easier
2	not in control of straining/breathing	not in control of straining/breathing	not in control of straining/breathing	lack of normal bodily feedback
3	hard to breathe with pressure against abdomen	easier	easier	very easy

Talking Ability

- not determined -

SUBJECT WH

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

<u>Pain</u>	1	** pain in both elbows	pain in right elbow	pain in both elbows	** pain in both elbows
	2	** pain in left arm	none	none	** pain in both arms
	3	pain in left arm and in left side of ribs (jerkin pressure)	pain in left calf and ankle	pain in left leg and right arm	pain in left leg and right arm
<u>Straining</u>	1	** straining forgotten	straining forgotten	straining forgotten	** straining forgotten
	2	** none	slight whole body strain	slight whole body strain	** hard, whole body strain
	3	tensed arms and legs instead of using M-1	pushed abdomen against G-suit	pushed abdomen against G-suit	straining is no different than at lower G-levels
<u>Mask Quality</u>	1	** none	none	none	** leakage at chin
	2	** none	none	leakage at chin	** none
	3	leakage at ~ +8Gz around chin	none	leakage at nose and eyes	leakage at nose and eyes
<u>Breathing Ease</u>	1	** punched out because of breathing difficulty	cannot breathe in passively	asked for coaching on breathing	** punched out after losing vision due to breathing difficulty
	2	** punched out due to hyperventilation	taking in too much air	"much too hard" to breathe correctly	** punched out after losing vision due to breathing difficulty
	3	easier	easy	hard (thought about breathing too much)	easy
<u>Talking Ability</u>		- not determined -			

** Subject stopped high-G exposure before normal end of run.

SUBJECT SH

Category	Session No	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	------------	----------	----------	----------	----------

Pain

1	** a) punched out because of high pressures in G-suit ** b) punched out because of pain in arms and buttocks	none	-----	** punched out because of pain in arms
2	** punched out because of arm pain--subject withdrew from study immediately	-----	-----	-----

Straining

1	** a) none ** b) none	none	-----	** tensing of arms and legs
2	** - missing -	-----	-----	-----

Mask Quality

1	** a) none ** b) none	none	-----	** none
2	** - missing -	-----	-----	-----

Breathing Ease

1	** a) could not exhale ** b) not breathing "right"	none	-----	** not breathing "right"
2	** - missing -	-----	-----	-----

Talking Ability

1	-----	-----	-----	can't talk
2	- not determined -			

** Subject stopped high-G exposure before normal end of run.

SUBJECT CA

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

Pain

1	none	none	-----	pain in arms and buttocks
2	pain in left arm	none	pain from lifting arm to re-position mask	none

Straining

1	straining forgotten	slight strain with arms and legs	-----	lost vision and spontaneously recovered without straining
2	slight straining at +6.5Gz	none	straining with arms and legs	straining with arms and legs

Mask Quality

1	none	none	-----	slight leakage adjusted by facial movement
2	mask "popped out" away from face	none	"popped out" again at ~+6Gz	slight leakage, changed jaw position

Breathing Ease

1	hyperventilated, was talked down	easier	-----	much easier
2	easy	very easy	easy	very easy

Talking Ability

- not determined -

SUBJECT FA

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

<u>Pain</u>	1	-----	none	** a) left arm pain b) pain in both arms (kept left hand on opposite shoulder to elevate arm)	-----
-------------	---	-------	------	--	-------

wrapped arms	2	none	none (kept left hand on shoulder to elevate arm)	** a) none b) none	arm pain came and went with tensing of arms
--------------	---	------	--	-----------------------	---

<u>Straining</u>	1	-----	none	** a) straining forgotten-went grey and punched out b) tensing with arms and legs	-----
	2	strained with legs and abdomen	slight strain with legs	** a) straining forgotten-went grey and punched out b) strained with legs, chest and abdomen	strained with legs and chest

<u>Mask Quality</u>	1	-----	none	** a) none b) leakage at plateau around chin	-----
	2	none	none	** a) none b) pressures from mask not noticeable	none

<u>Breathing Ease</u>	1	-----	held breath	** a) none b) none	-----
	2	more "natural"	easy	** a) grey-out, doesn't remember b) easy	very easy

<u>Talking Ability</u>	- not determined -
------------------------	--------------------

** Subject stopped high-G exposure before normal end of run.

SUBJECT LP

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
----------	-------------	----------	----------	----------	----------

<u>Pain</u>	1	pain in both arms	none	pain in both arms	** extreme pain in both arms (punched out due to vertical nystagmus)
NOTE: for 1 to 3 days after session, subject couldn't raise left arm, and withdrew from study					
<u>Straining</u>	1	general straining at ~ +7Gz	none	none (general visual dimming and "seeing worms")	** general body straining
<u>Mask Quality</u>	1	leakage around nose and eyes	none	leakage around nose and eyes	** none
<u>Breathing Ease</u>	1	easy	breathing slightly too fast	easy	** easy
<u>Talking Ability</u>	- not determined -				

** Subject stopped high-G exposure before normal end of run.

SUBJECT WA

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
<u>Pain</u>	1	pain in both elbows (going to "blow up")	reduced pain by tensing arms	pain in both arms	** pain in both arms
<u>Straining</u>	1	straining with arms and legs	slight strain with legs	straining with legs, arms and buttocks ("played" with visual dimming)	** lost strain in chest and buttocks, punched out due to fatigue and grey-out
<u>Mask Quality</u>	1	leakage around chin at ~ +7Gz	none	extreme leakage around chin at plateau	** none
<u>Breathing Ease</u>	1	breathing "backwards" is difficult	easier	much easier	** doesn't remember (grey-out)
<u>Talking Ability</u>	- not determined -				

** Subject stopped high-G exposure before normal end of run.

SUBJECT HU

Category	Session No.	+9Gz GOR	+5Gz ROR	+7Gz ROR	+9Gz ROR
<u>Pain</u>	1	none	none	none	pain in both elbows
<u>Straining</u>	1	none	slight strain with legs	straining with legs and abdomen	whole body strain to push visuals back out at onset -- relaxed at plateau
<u>Mask Quality</u>	1	none	none	none	none
<u>Breathing Ease</u>	1	"couldn't believe I was at 9 G"	outstanding	outstanding	outstanding
<u>Talking Ability</u>	- not determined -				

APPENDIX B.

Questionnaire 1: Individual Profile Ratings from
Regulator Check-Out Number Two

QUESTIONNAIRE #1 FOR THE COMBAT EDGE EVALUATION

Name: _____ Date: _____

Individual Profile Ratings (Please Circle Appropriate Profile)

+9Gz slow onset (GOR)

+5Gz fast onset (ROR)

+7Gz last onset (ROR)

+9Gz fast onset (ROR)

- 1) When compared to the standard anti-G suit, please rate **breathing ease** while wearing the COMBAT EDGE system:

much	somewhat	same	somewhat	much
harder	harder		better	better

- 2) Please rate the quality of the **mask seal** of the COMBAT EDGE system:

extreme	noticeable	acceptable	slight	no
leakage	leakage	leakage	leakage	leakage

- 3) When compared to the standard anti-G suit, please rate the **degree of straining required** while wearing the COMBAT EDGE system:

much more	somewhat	same	somewhat	much less
effort	more effort		less effort	effort

- 4) While **straining**, which **body areas or techniques** did you use the most with the COMBAT EDGE system? (You may use the same rating number for more than one selection.)

- 1 - Used all the time
- 2 - Used most of the time
- 3 - Used periodically
- 4 - Used rarely
- 5 - Didn't use at all

ARMS _____

BUTTOCKS _____

M-1 _____

LEGS _____

L-1 _____

Other _____

CHEST _____

- 5) While under high-G stress with the COMBAT EDGE system, in which **body areas** did you experience the most **pain**? (You may use the same rating number for more than one selection.)

- 1 - Pain all the time
- 2 - Pain most of the time
- 3 - Pain periodically
- 4 - Pain rarely
- 5 - No pain at all

HEAD	_____	HANDS	_____
EARS	_____	CHEST	_____
NOSE - THROAT	_____	BACK	_____
FACE	_____	ABDOMEN	_____
NECK	_____	BUTTOCKS	_____
SHOULDERS	_____	THIGHS	_____
ELBOWS	_____	KNEES	_____
WRISTS	_____	ANKLES	_____
ARM (wrist to elbow)	_____	FEET	_____
ARM (elbow to shoulder)	_____		

APPENDIX C.

Questionnaire 2: Overall Ratings from
Regulator Check-Out Number Two

QUESTIONNAIRE #2 FOR THE COMBAT EDGE EVALUATION

Name: _____ Date: _____

Overall Ratings

- 1) When compared to the standard anti-G suit, please rate the **overall wearing comfort** of the COMBAT EDGE system:

|-----|-----|-----|-----|
much worse somewhat worse same somewhat better much better

- 2) When compared to the standard anti-G suit, please rate the **overall straining effort** required while wearing the COMBAT EDGE system:

|-----|-----|-----|-----|
much more effort more effort same less effort much less effort

- 3) When compared to the standard anti-G suit, please rate the **overall severity of body pain** while wearing the COMBAT EDGE system:

|-----|-----|-----|-----|
much worse somewhat worse same somewhat better much better

- 4) When compared to the standard anti-G suit, please rate the severity of the tiny red spots (**petechiae**) that appear on your body after wearing the COMBAT EDGE system:

|-----|-----|-----|-----|
much worse somewhat worse same somewhat better much better

- 5) When compared to the standard anti-G suit, rate your **overall level of fatigue** while wearing the COMBAT EDGE system:

|-----|-----|-----|-----|
much greater somewhat greater same somewhat less much less

- 6) When compared to the standard anti-G suit, did you experience the feeling of **loss of control of bodily feedback** due to the COMBAT EDGE system characteristics?

- ☐ Yes, total loss of control
☐ Yes, some loss of control
☐ No difference
☐ No, control same as G-suit
☐ No, control better than G-suit

Comments: _____

- 7) Overall, how would you rate the COMBAT EDGE system as a means of G-protection?

_____ a liability _____ a possible hindrance _____ neutral _____ an advancement _____ a great leap forward

- 8) Would you recommend the use of the COMBAT EDGE system in the fighter cockpit?

- _____ Yes, without reservation
 _____ Yes, with recommendations
 _____ Neutral
 _____ No, must be redesigned
 _____ No, not even with changes

Comments _____

- 9) If you had a choice between wearing the standard anti-G suit or the COMBAT EDGE system, which would you choose?

- _____ Anti-G Suit
 _____ COMBAT EDGE

Please explain the criteria you used to make your choice:

- 10) When compared to the standard anti-G suit, estimate the difference in your personal G-tolerance while wearing the COMBAT EDGE system.

- A. _____ increased by _____ G
 B. _____ no difference
 C. _____ decreased by _____ G

- 11) Estimate the maximum +Gz level you believe you could withstand with:

- A. - the Anti-G Suit _____ +Gz _____ use the one that is G per second onset rate,
 B. - COMBAT EDGE _____ +Gz _____ 15 second plateau profile

- 12) Any comments or recommendations concerning the COMBAT EDGE system?
 Any qualities we missed?

THANKS FOR YOUR COOPERATION!!!

**END
FILMED**

DATE:
3-91

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