AM 70-20

PROTECTIVE SMOKE HOOD STUDIES

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December 1970

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The Development of a Protective Passenger Smoke Hood

Ernest B. McFadden, M.S.

Introduction

Investigation of a number of recent transport aircraft accidents has indicated the need for protection of passengers and crew from the effects of toxic fumes, smoke, and flame. Of paramount importance is the protection of the human respiratory system and maintenance of the occupant in a conscious and mobile state so that evacuation may be accomplished before elevated temperatures render the cabin uninhabitable. This report describes the evaluation of a "get-me-out" device designed to provide protection of the respiratory tract from the effects of toxic smoke and fumes. In addition, the device, a polyimide hood which encloses the head, provides some degree of flame protection. A report on a preliminary version of this hood has already been published[3]; therefore, the concern of this report is with subsequent evaluations of this device.

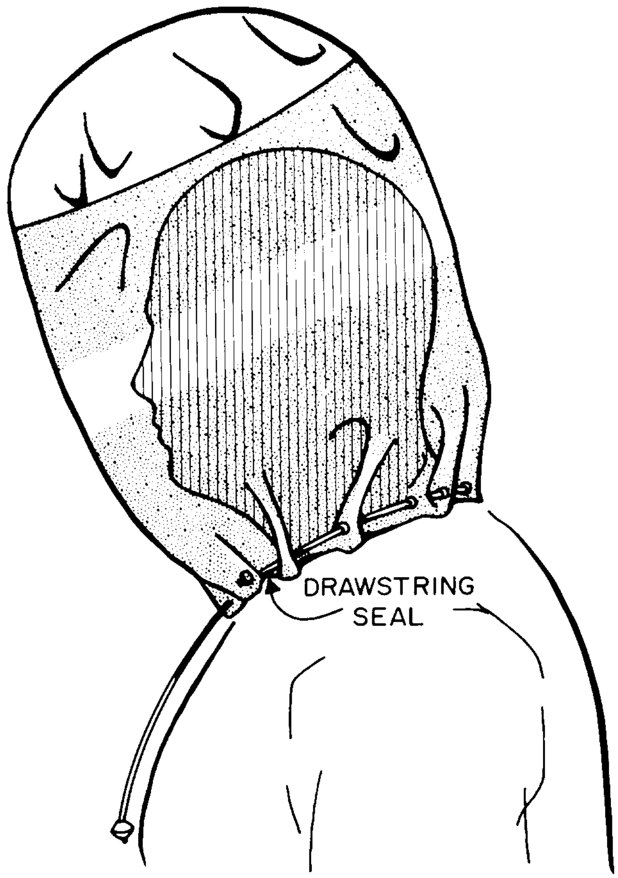

FIGURE 1. Type D (drawstring) protective hood.

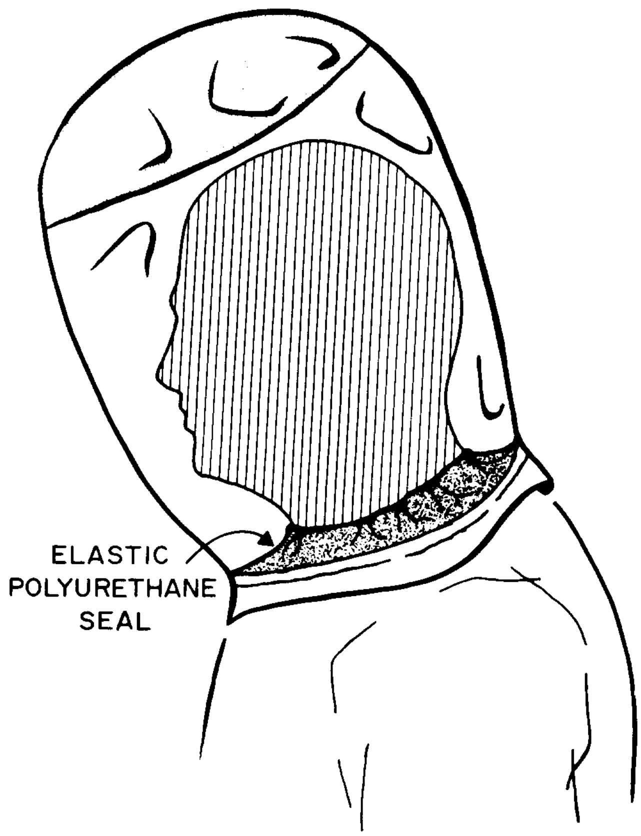

FIGURE 2. Type S (septal) protective hood.

Studies carried out by the Aerospace Industries Association[1], as well as the FAA Flight Standards full-scale evacuation tests[2], revealed specific design deficiencies in the original prototype (Figure 1). Although aluminization of the polyimide surface provided excellent radiant heat reflectance and sufficient transparency for adequate vision under normal levels of illumination, subjects experienced difficulties in vision when exposed to the .05 foot-candle emergency illumination as provided in jet transport aircraft. These evaluations also indicated that evacuees of aircraft could not be relied upon to consistently tighten the drawstring neck seal. Therefore, a new septal seal was designed which did not require voluntary tightening to effect an adequate and protective seal and aluminization of the hood was restricted to the upper portion of the hood outside of the range of vision (Figure 2).

In the reports that follow, the primary emphasis is upon the septal seal hood (hereafter called the Type S hood); however, data from advanced tests of the drawstring seal hood (Type D) have been included where the findings are relevant to the overall evaluation of the protective hood concept. These studies are addressed to three main points: (1) the degree of protection against incapacitating agents provided by the hood; (2) the limitations of the hood in terms of useful air supply, vision, and audition; and (3) the utility of the hood. The findings of these investigations are presented in the following chapters.

SECTION I

ENVIRONMENTAL PROTECTION

Chapter 1. Evaluation of Leakage in Protective Smoke Hoods

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I. Introduction.

This report presents the results of experiments designed to answer two important questions relating to the smoke hood: (1) what are its life support capabilities with respect to quality of the contained air supply and to the metabolic rate of the wearer; and (2) which of two styles of neck seal is more efficient in preventing leakage?

II. Methods and Procedures.

The two types of protective hoods evaluated were essentially identical except for the neck seal: Type D hoods possessed a drawstring seal, while the Type S hood had a septal (membrane) seal of heat-resistant urethane which fits closely but not uncomfortably about the neck. Ten* hoods of each type were tested. Each was used at least once and some were used as many as six times in order to evaluate the effect of multiple use. All hoods were obtained directly from the G. T. Schjeldahl Company and were not worn prior to testing.

TABLE 1.—Conditions of the Experiment

Temperature	Physical Exertion	
	Rest	Exercise
26° C (78.8° F)	5 Male 5 Female	5 Male 5 Female
60° C (140° F)	5 Male 5 Female	5 Male 5 Female

* One Type S hood (#482) was destroyed after only one trial; another new hood replaced it. Thus, eleven hoods of this type were used (see Table 2).

Conditions for the tests were varied according to a block design (Table 1).

The twenty male and twenty female subjects (described in Appendix A, Table 1), none of whom had any previous experience with the device, were divided equally among the four groups (see Table 1). Each received, shortly before the experiment, essentially the same instructions pertaining to the experimental procedure, donning and removal of the hood, etc.

Exercise was performed on a Godart bicycle ergometer, equipped with a magnetic eddy current brake resistance which was set at a constant load, so that 45 watts (0.06 hp) of power were generated at 45 rpm. This exercise, which may be considered as light to moderately heavy, was performed by all subjects in the appropriate groups. Subjects who did not exercise during exposure (rest groups) sat quietly in a chair for several minutes prior to donning the hoods and remained seated during the experiment.

Safety considerations dictated that exposure of subjects to high temperature be limited to 140 degrees F.

Each subject was prepared for physiological monitoring prior to entering the test chamber. Adhesive electrodes were affixed to the chest in the usual manner. The ground was located over the sternum in a direct inter-nipple line, with one electrode being located approximately 6 to 8 cm directly below the left nipple. This provided an excellent heart rate signal with minimum interference due to extraneous bioelectrical potentials developed during exercise.

Impedance pneumograph electrodes were placed on each mid-axillary line of the chest at approximately the tenth to eleventh rib. The impedance pneumograph provided a method of continuously monitoring the respiratory rate, and gave estimates of relative tidal volume.

All electrical apparatus were grounded.

Oxygen consumption and carbon dioxide production were measured continuously by drawing a stream of gas from the hood and passing it through a Beckman Infra-Red Carbon Dioxide Analyzer, Model LB-1, and a Beckman Oxygen Analyzer, Model F3M3-1A3A. The ECG, impedance pneumograph, and carbon dioxide signals were recorded on an E and M Physiograph Six Recorder using appropriate pre-amplifiers. Oxygen concentrations were recorded on a Brown Electronik, Series SY strip chart recorder.

Calibrations of the infra-red carbon dioxide and paramagnetic oxygen analyzers were conducted before and after the day's tests and whenever chamber temperature was changed.

The system for measurement of hydrocarbon concentration is also illustrated in Figure 1. The technical aspects of this system will be presented in a later report.

Loss of air during the experiment can be computed from the flow through the respiratory gas analyzers (132.1 ml/min) and flow into the hydrocarbon analysis system. As the total flow through the latter was shared equally by hood and exposure chamber, loss from the hood during each test was 132.1 + 42.25, or 174.35 ml/min. During a six-minute experiment, for example, an approximate volumetric change of 1046 ml, or 5% of the starting hood volume (approximately 20 liters), was obtained.

III. Results and Discussions.

Heart rate and respiratory changes seen during these tests were consistent with those known to be induced by exercise and/or carbon dioxide accumulation (see Appendix B, Tables 2–17). Heart and respiratory rates generally increased significantly during exercise, but as anticipated, the most marked change in respiration was the

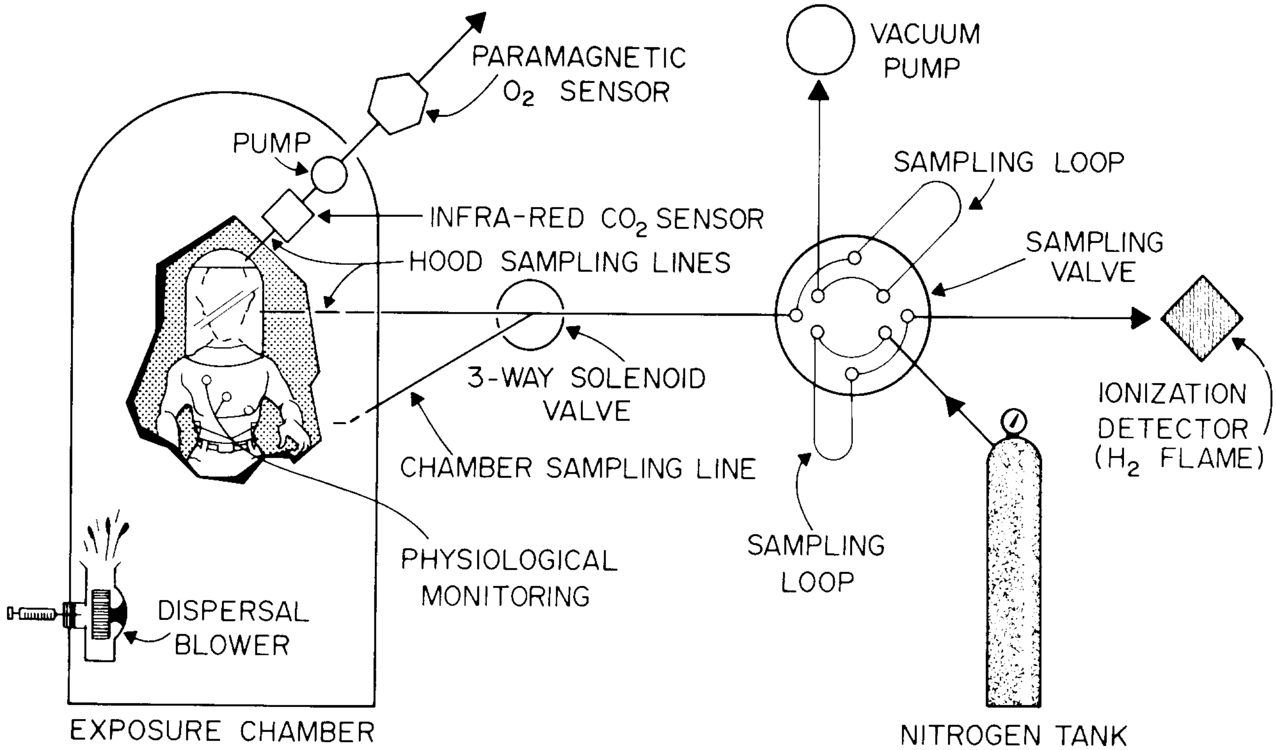

FIGURE 1. The experimental set-up for measuring physiological changes, respiratory gases, and hydrocarbon leakage during exposure to pentane fumes of human subjects wearing protective hoods. In the pentane detection system, samples of air from hood or chamber enter the gas train alternately via the 3-way solenoid valve. The sampling valve, operating simultaneously, turns 90° to switch sampling loops from the sample-vacuum pump line to the nitrogen detector line.

increase in the tidal volume or depth of breathing usually seen with elevated concentrations of carbon dioxide (Figure 2).

Analysis of the records of gas concentration indicated that uniform mixing of the gases within the hood was not usually obtained until hyperventilation developed; thus, earlier carbon dioxide values were more variable than similar measurements obtained toward the end of the experiment (Figure 2). The hood, being made of a pliable material, acts as a mixing pump when respiratory movements are great enough to operate it.

Termination of the experiment was ordered by an observer who accompanied the subject within the chamber. Discontinuation of the test, therefore, did not always indicate that the subject had attained maximum voluntary tolerance. The most marked difference between the septal and drawstring hoods was the observation that carbon dioxide accumulation and oxygen reduction in the septal type tended to progress in a

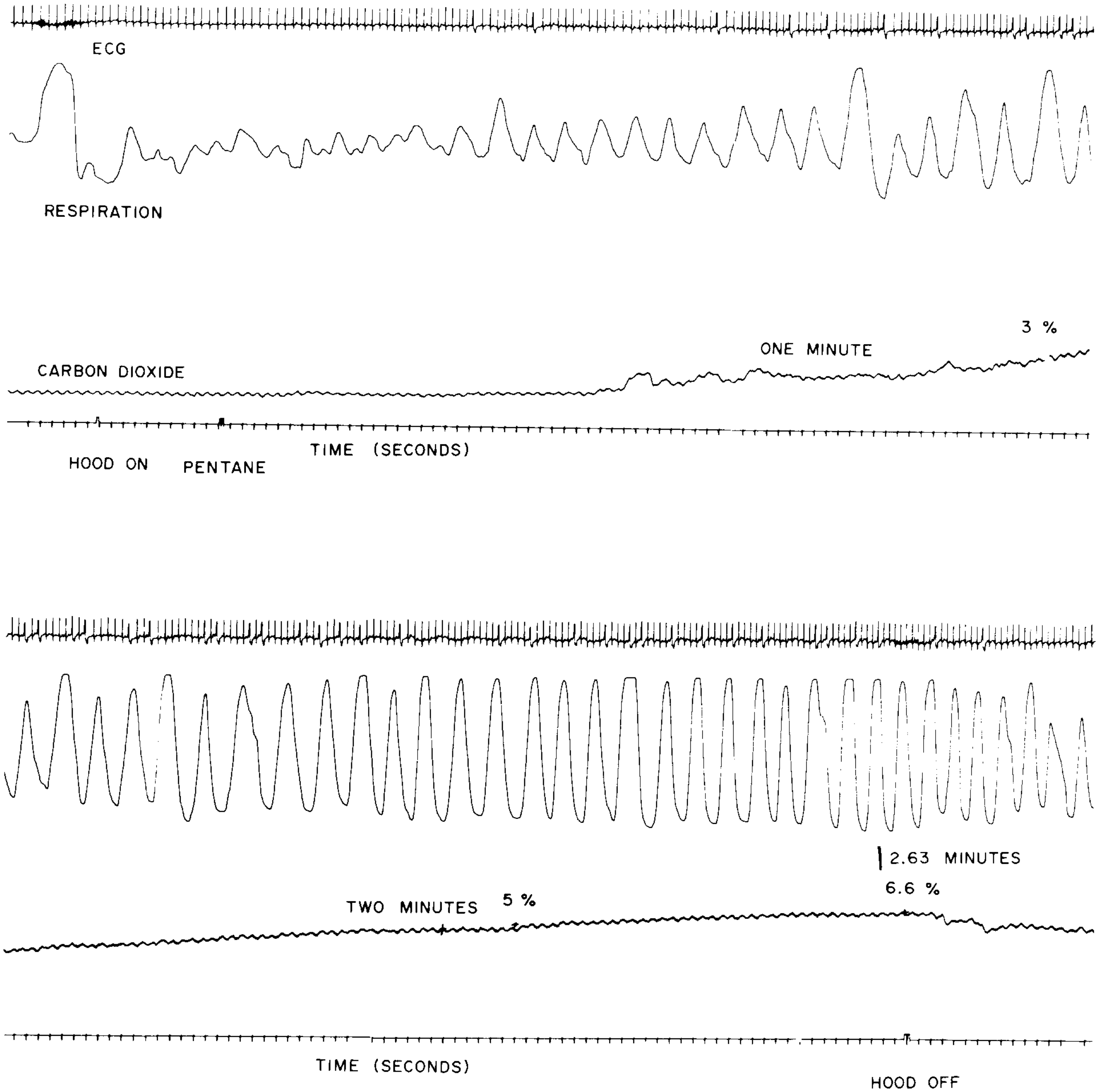

FIGURE 2. Representative continuous recording of female subject exercising at 26° C. (Subject number 10).

relatively uniform linear fashion, whereas with the drawstring hood this tendency was interrupted when the carbon dioxide concentration reached a level which induced hyperventilation. The increase in depth of breathing, or pumping action, of hyperventilation characteristically brought a gross leakage and leveling off of carbon dioxide concentrations, and the development of a plateau in both carbon dioxide and oxygen concentrations with the *drawstring* hood.

A moderate exercise level was chosen so that all subjects might tolerate it for the duration of the experiment. However, several experiments were terminated due to subjects complaining of leg or other muscular cramps and exhaustion. Heart rates of 160–178 indicated that some sub-

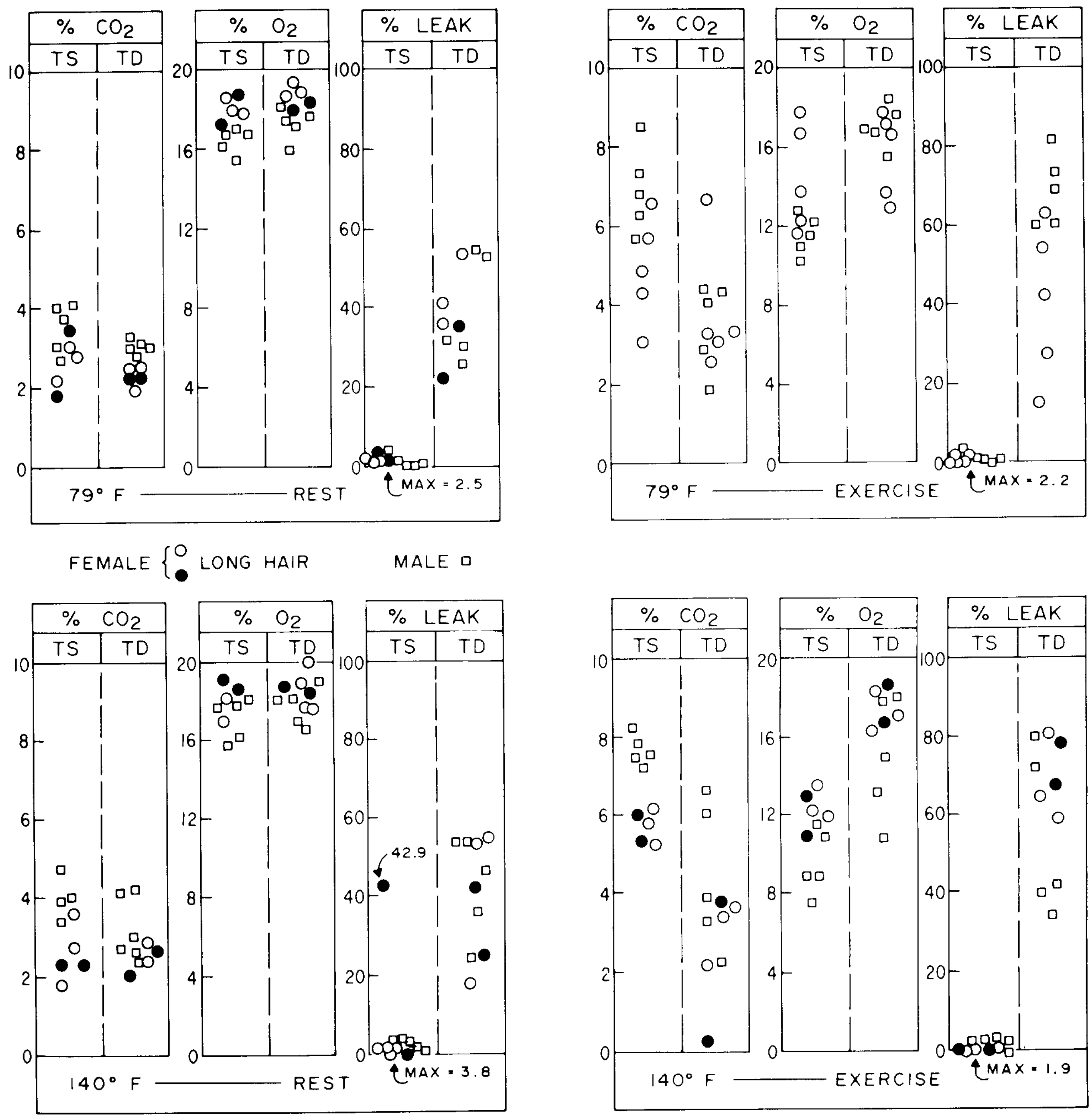

FIGURE 3. Plots of carbon dioxide and oxygen changes and pentane leakage at two minutes after donning in Septal (TS) and Drawstring (TD) hoods. Leakage is expressed as percent of chamber concentration (300–500 ppm as pentane). NOTE: Solid circles—long-haired females.

TABLE 2.—Estimation of Carbon Dioxide Production and Oxygen Consumption at Normal Temperatures assuming an Initial Hood Volume of 20 Liters and No Leakage of the Septal Hoods.

	SUBJECT	Temperature (° Centigrade)	CO_2 cc/min.	O_2 cc/min.	Time (Minutes)
Male Resting	1	26	277	436	4.18
	3	26	271	410	4.20
	4	26	301	186	4.32
	6	25.5	300	481	4.20
	7	25.5	244	316	4.50
Averages			279	366	4.28
Female Resting	2	26	235	303	4.43
	5	25.5	219	349	4.47
	28	27	248	273	4.83
	39	26	167	214	8.50
	29	27	354	431	3.22
Averages			245	314	5.09
Male Exercising	9	26	553	793	2.42
	12	26	609	866	2.10
	27	27	636	1000	2.42
	30	27	808	1001	2.08
	31	27	706	870	2.55
Averages			662	906	2.31
Female Exercising	13	25	509	784	2.63
	11	26	389	485	2.52
	10	26	502	1163	2.63
	8	26	417	403	2.83
	36	27	634	678	2.08
Averages			490	703	2.54

jects were approaching their maximal work capacity.

Female subjects exhibited lower rates of accumulation of carbon dioxide and consumption of oxygen (Figure 3 and Appendix B, Tables 2–17). This may be attributed in part to their smaller body size and surface area, but corrections of these data for variations in surface area did not entirely eliminate the difference; this finding is consistent with other reports that women, perhaps due to hormonal differences, possess a lower metabolic rate per unit of body surface.

As leakage from the septal hood was minimal and assuming that a uniform hood volume of 20 liters is acquired at the time of donning, an estimate of the rate of oxygen consumption and carbon dioxide production during the test may be derived (see Tables 2 and 3). A typical oxygen consumption curve is presented in Figure 4.

An examination of the measurements of pentane leakage (see Figures 5 and 6, as well as Tables 4 and 5) reveals a clear superiority of the Type S (septal) hood with respect to this variable. Carbon dioxide and oxygen concentrations were always consistent with hood pentane values: when sudden increases in pentane concentrations were noted, a commensurate rise in oxygen and fall in carbon dioxide occurred. This was especially apparent in tests of Type D hoods; sudden losses in seal integrity usually followed obvious increases in depth of respiration. This observation seems a clear demonstration of the susceptibility of the non-rigid material to be "pumped" by respiratory movements, a phenomenon which magnifies small imperfections in the seal. In only one test did significant leakage of Type S occur within two minutes of initial exposure, the female subject being one of those who possessed hair long enough to extend below the seal. Five other female subjects with equally

TABLE 3.—Estimation of Carbon Dioxide Production and Oxygen Consumption at Elevated Temperatures Assuming an Initial Volume of Twenty Liters and No Leakage of the Septal Hoods.

	SUBJECT	Temperature (°Centigrade)	CO_2 cc/min.	O_2 cc/min.	Time (Minutes)
Male Resting	17	58	—*	393	5.45
	15	56	364	328	3.90
	18	56.5	—*	449	5.08
	32	59.5	422	429	3.03
	33	57	435	645	3.13
Averages			407	449	4.12
Female Resting	20	60	271	296	5.82
	19	58	282	282	5.25
	16	59	261	383	6.05
	14	57	388	316	3.25
	40	60	238	271	7.31
Averages			288	310	5.54
Male Exercising	21	59	694	1107	2.42
	22	60	664	978	2.50
	23	62	676	1081	2.22
	24	60	676	1126	2.13
	25	60	—*	1027	3.00
Averages			677	1064	2.45
Female Exercising	26	60	476	801	2.52
	34	60	600	851	2.00
	35	60	650	843	1.85
	37	59	474	719	2.53
	38	60	492	846	2.60
Averages			538	812	2.30

*CO_2 concentration exceeded calibration.

long hair did not experience, during the first two minutes, significantly greater leakage than those with short hair. No male subjects with long hair were employed in these tests, as multiple use was intended, but it is possible that the male hair styles of this type could allow a somewhat greater leakage than was observed in this study. Observations made during the tests indicate that in long-haired subjects who did not experience leakage the hair lay quite flat and seemed to completely fill the space between neck and seal, whereas in the one subject who experienced leakage, the long strands became grossly separated to either side of the neck, providing a gap.

The results obtained from tests of the Type D (drawstring) hoods show considerably greater variability than those from Type S experiments, with an overall leakage far greater than Type S. The variability over the exposure period with Type D is probably due, in part, to variations in donning. Observers noted that some subjects did not draw the seal as tight as did other subjects; there was also some tendency for the drawstring to stick or foul. The particular drawstring used in these hoods was permanently attached at one end. This allows it to be drawn tight with one hand, but this refinement may have been confusing to some subjects who appeared to be searching for two ends as they tightened the seal. Type S hoods probably yielded more uniform results because less skill is required for efficient use and less variation in donning is allowed by the design; the Type S tended to be more fully inflated due to trapping of air by the seal as the device was pulled over the head.

Because of the limits on the number of naive subjects available, it was necessary to employ

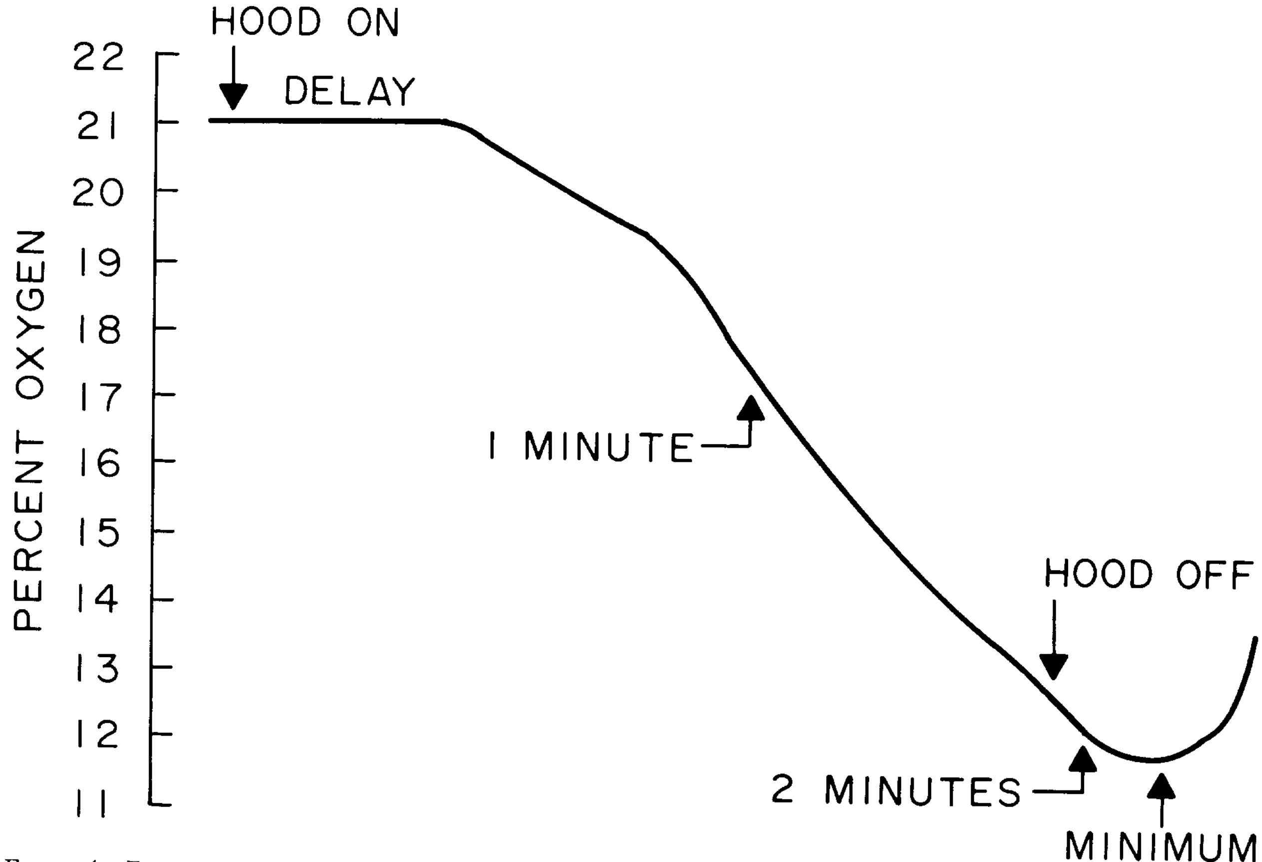

FIGURE 4. Representative recording of female subject exercising at 26° C. (Subject number 10). Delay is imposed by gas stream time factors and slow response time of paramagnetic oxygen analyzers.

each subject in tests of both hood types. This required that the effect of training be considered; a subject already experienced in the donning of one type, as well as in the experimental procedures, might be more proficient in the use of a second type and bias the comparison in favor of the latter. To counterbalance this possibility, preliminary tests with trained subjects were undertaken. These forecast the results of later experiments with naive subjects: a clear superiority of Type S hood. Therefore, later experiments were so organized that Type D was always tested *after* Type S so that the effects of training could be conferred on the inferior type; as the results indicate, the effect (if any) of training was of no apparent advantage to Type D.

Other preliminary experiments had demonstrated another convenience of testing Type S before Type D. As the latter leaked as much as 80% of exposure concentrations, the subject often inhaled a considerable amount of pentane over several minutes, including the time elapsing between removal of the hood and purging of the test chamber. Predictably, this exposure allowed a considerable amount of the fat-soluble pentane to accumulate in the subject's body so that, without a long rest period between tests, the subject would "give up" detectable amounts of pentane to the atmosphere of the second hood, presenting a false indication of leakage. With limitations on the time which subjects could devote to the test, relegating the hood more likely to leak to the second test provided a more economic use of subject time. Of course, when leakage did occur during the first test, an appropriate "wash-out" time was allowed before the next exposure.

The high solubility of pentane in the human body necessitated another consideration of data obtained from hoods demonstrating slight leakage. In these tests there is some possibility of false low readings, in that small amounts of pentane passing slowly into the hood could be absorbed by the subject at levels below the limits of the hydrogen flame detector. Such error would more likely obtain early in the exposure period, since absorption by the body would de-

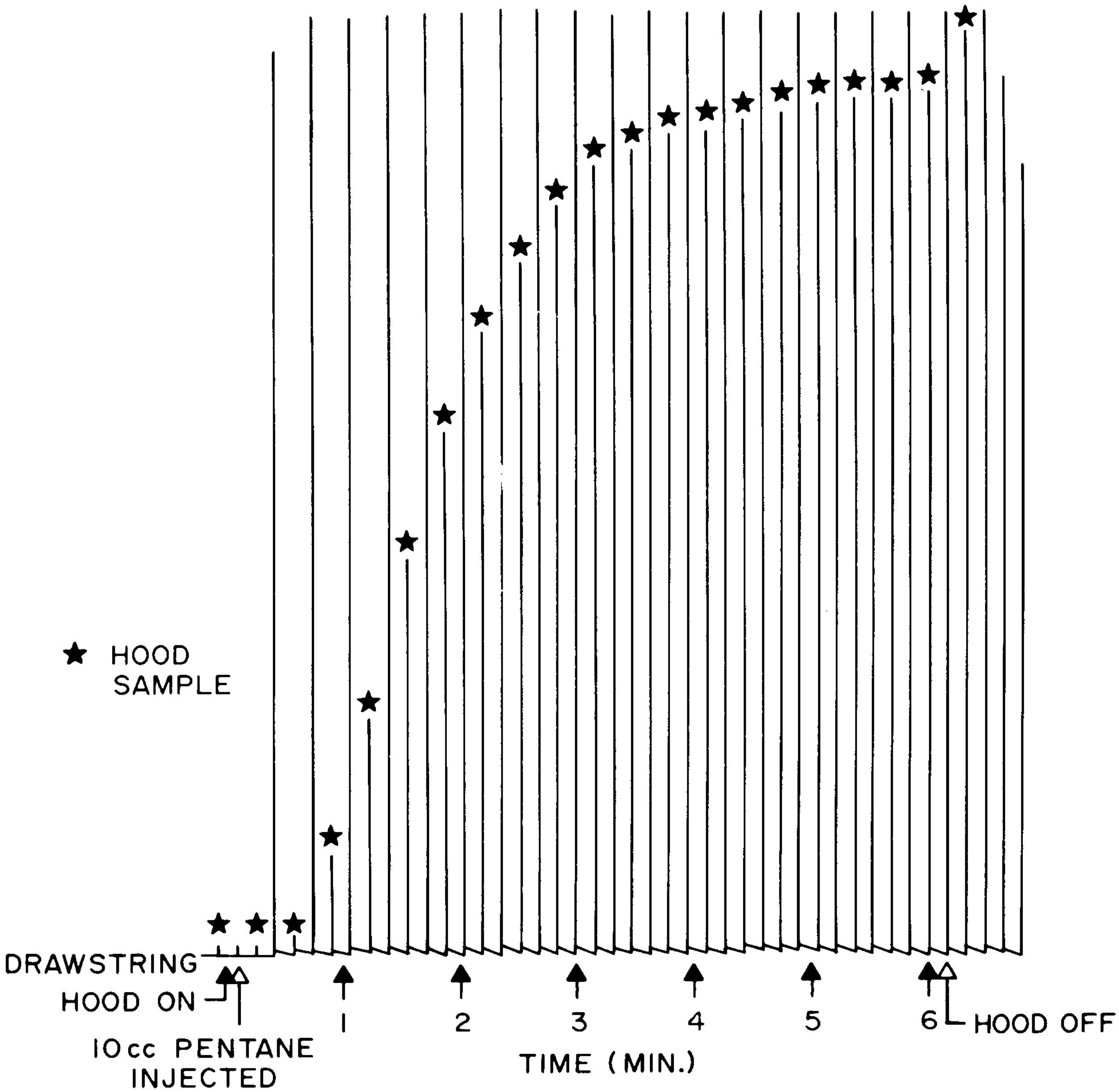

FIGURE 5. Scale copy of sample record of ionization detector responses to pentane in alternate samples from Type D hood and exposure. Stars denote hood samples. Note progressive leakage to near chamber concentration of 324 ppm. Reversed to provide left-to-right reading.

celerate exponentially as equilibrium was approached. A simple evaluation of detector sensitivity, however, demonstrates the minor significance of this possibility. As the effect of wearing perfumes, after-shave lotions, etc., on detector response was unknown, 1–2 microliters of "Royal Secret" bath perfume were placed into a clean hood and the air inside subjected to analysis. This amount of perfume, significantly less than the amount estimated to be worn by the average young lady, produced detectable responses. It was concluded from this, as well as from calibration data, that any leakage of practical significance would be detected and that any absorption by the body of concentrations below those levels would not be significant. To avoid artifacts due to perfumes, etc., all subjects were instructed not to use these substances on the day of the tests.

All hoods were numbered and an attempt was made to distribute them in a random fashion throughout all four experimental groups. As

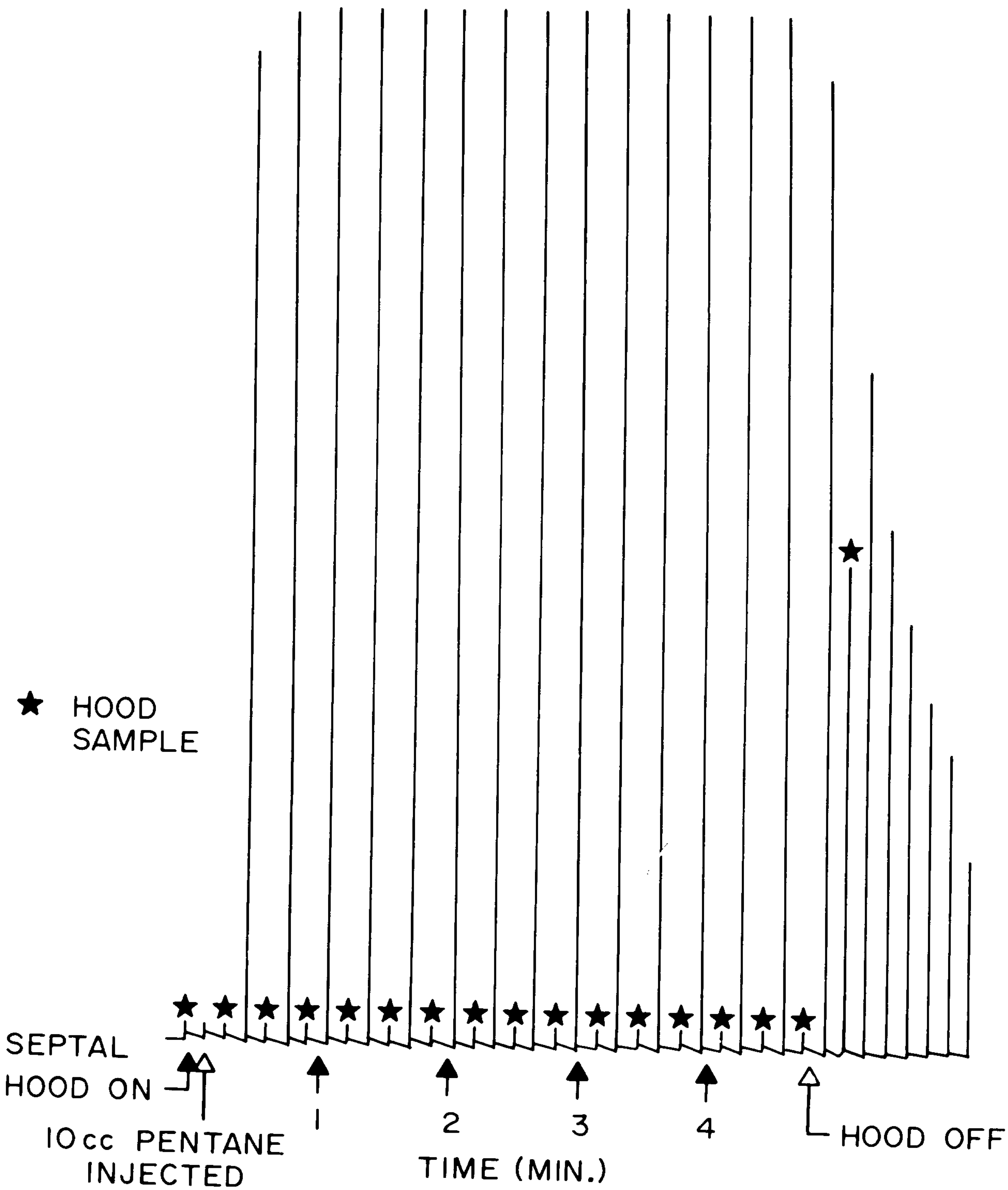

FIGURE 6. Scale copy of sample record (reversed to facilitate reading) of detector response to pentane in exposure chamber and Type S hood. Note absence of leakage in presence of 324 ppm.

TABLE 4.—Carbon Dioxide, Oxygen Concentration and Leakage at 2-Minutes in the Drawstring and Septal Type Hoods.

Group	Sex	Subject Number	% CO_2 Sept.	% CO_2 Drw.	% O_2 Sept.	% O_2 Drw.	% Of Leakage** Sept.	% Of Leakage** Drw.
Rest Cool	M	1	4.1	3.3	16.4	17.8	0.2	55.7
		3	3.2	3.4	17.6	16.3	0.2	26.0
		4	3.2	2.7	17.5	18.8	1.0	53.8
		6	4.2	3.2	15.7	17.9	0.2	31.4
		7	3.8	2.9	17.3	17.7	0.2	32.9
	F	2	2.9	2.5	18.8	18.8	0.2	37.2
		*39	1.8	2.3	19.0	18.2	2.5	22.8
		28	2.3	1.8	18.2	19.3	1.2	41.6
		*29	3.6	2.3	17.4	18.2	1.3	36.3
		5	2.8	2.5	17.9	18.9	0.2	54.5
MEAN ± S.E.M.			3.19 ± .24		17.58 ± .32		.72 ± .25	
Exer. Cool	M	9	5.8	4.4	13.1	16.7	0.6	61.4
		12	6.4	2.9	12.3	17.5	0.0	69.6
		31	6.9	3.2	11.6	16.7	1.2	74.3
		27	7.5	1.8	11.3	18.5	1.2	83.3
		30	8.7	4.1	10.5	15.6	2.2	60.7
	F	13	5.9	6.7	11.8	13.0	0.2	15.3
		8	4.3	3.1	16.8	17.5	0.4	54.5
		11	3.1	4.3	17.8	13.9	0.2	27.6
		10	4.9	2.6	12.1	17.7	0.4	63.6
		36	6.6	3.3	13.8	16.9	1.0	42.2
MEAN ± S.E.M.			6.01 ± .51		13.11 ± .76		.74 ± .21	
Rest Heat	M	15	4.0	4.3	17.8	16.5	0.5	36.3
		33	4.9	2.8	15.7	18.8	1.1	45.7
		17	3.5	3.0	18.1	18.4	2.1	53.5
		18	4.1	4.3	17.9	17.1	0.0	23.5
		32	6.4	2.8	16.1	18.3	3.8	54.4
	F	14	1.9	2.9	20.3	17.6	0.3	52.7
		16	3.7	2.7	17.3	17.9	0.3	53.1
		*19	2.4	2.7	19.3	18.7	0.0	24.3
		20	2.8	2.4	18.4	18.8	0.3	16.1
		*40	2.4	2.1	18.8	18.7	42.9	41.6
MEAN ± S.E.M.			3.74 ± .45		17.88 ± .48		.93 ± .42***	
Exer. Heat	M	21	8.3	6.1	9.2	13.6	1.9	42.9
		22	7.5	2.2	11.8	18.4	0.3	72.4
		23	7.8	3.9	8.9	15.3	0.5	41.7
		24	7.2	6.7	11.0	11.0	1.0	35.0
		25	7.5	3.3	7.4	17.9	1.3	81.0
	F	*35	6.0	0.1	13.1	18.4	1.2	79.4
		34	6.1	2.2	12.4	18.2	0.9	83.9
		*26	5.4	3.8	11.2	16.7	1.3	67.8
		37	5.8	3.4	13.8	16.8	1.3	59.9
		38	5.3	3.7	12.3	16.4	1.5	64.5
MEAN ± S.E.M.			6.69 ± .34		11.11 ± .64		1.12 ± .15	

*Indicates long hair.
**As % of Chamber Concentration (300–500 ppm)
*** Subject 40 (long hair) not included.

TABLE 5.—Time required for Carbon Dioxide Concentration to Reach 5% in the Septal Hood. Carbon Dioxide within the Drawstring Hood and Oxygen Concentration, Percent of Leakage for Both Types of Hoods at this Time is also Presented.

Group	Sex	Subject Number	Subject Area (M^2)	Time To 5% CO_2 In Sept.	% CO_2 In DRW At This Time	% O_2		% Leakage	
						Sept.	Drw.	Sept.	Drw.
Rest Cool	M	1	1.93	3.13	3.3	14.0	17.6	0.4	62.4
		3	1.94	3.55	3.2	13.5	16.1	0.5	50.1
		4	1.89	4.32	2.7	13.8	18.3	1.0	73.8
		6	1.83	3.13	3.5	13.2	17.2	3.0	46.4
		7	1.87	4.50	2.9	13.9	16.7	0.4	62.1
	F	2	1.71	4.32	2.6	14.2	18.7	0.9	66.8
		*39	1.44	5.00	4.4	15.7	15.0	6.6	42.8
		28	1.51	4.32	1.8	14.6	19.2	1.5	87.3
		*29	1.57	2.92	3.0	15.5	17.5	3.6	57.5
		5	1.56	4.47	2.8	13.1	18.5	0.2	74.7
MEAN ± S.E.M.				3.97 ± .23		14.15 ± .28		1.81 ± .64	
Exer. Cool	M	9	1.89	1.83	4.1	14.0	17.0	0.6	57.7
		12	1.99	1.43	2.8	15.5	17.9	0.0	59.8
		31	1.83	1.70	2.8	13.5	16.7	1.2	69.0
		27	2.01	1.50	1.5	14.6	19.1	1.2	71.4
		30	1.91	1.03	2.6	16.2	17.7	1.2	70.4
	F	13	1.69	2.08	6.7	11.5	12.7	0.2	15.3
		8	1.73	2.57	3.1	15.1	17.6	0.2	60.8
		11	1.61	2.52	4.7	15.1	12.6	0.2	32.7
		10	1.64	2.12	2.7	11.7	17.6	0.4	63.6
		36	1.56	1.67	3.0	13.8	17.7	1.0	27.1
MEAN ± S.E.M.				1.85 ± .15		14.10 ± .49		.62 ± .15	
Rest Heat	M	15	1.83	3.80	5.8	14.5	15.5	0.5	53.6
		33	2.18	2.10	2.8	15.3	18.7	1.1	45.7
		17	1.91	2.48	3.0	16.1	18.2	0.0	54.9
		18	2.12	2.60	4.3	15.7	16.5	0.3	32.7
		32	1.77	2.37	2.9	15.3	18.0	3.8	56.8
	F	14	1.84	2.92	2.9	17.3	17.3	1.8	65.3
		16	1.76	3.07	3.1	15.4	17.3	1.8	60.2
		*19	1.32	3.08	3.8	16.9	17.9	0.0	36.6
		20	1.52	4.08	2.8	14.9	18.1	2.3	38.5
		*40	1.54	4.00	3.4	15.3	17.4	20.9	67.4
MEAN ± S.E.M.				2.94 ± .22		15.71 ± .30		1.29 ± .42***	
Exer. Heat	M	21	1.86	0.78	3.9	17.7	17.8	0.0	20.1
		22	1.96	1.37	2.3	16.4	18.4	0.0	57.2
		23	2.05	1.22	3.0	12.6	17.2	0.3	32.4
		24	2.12	0.95	5.3	17.6	16.7	0.3	10.7
		25	1.87	1.23	3.2	12.3	18.2	1.0	63.0
	F	*35	1.74	1.58	1.4	15.0	17.8	1.2	71.3
		34	1.63	1.57	2.2	14.8	18.8	0.9	73.7
		*26	1.65	1.77	3.4	13.0	16.8	1.3	61.9
		37	1.73	1.65	3.3	13.2	17.3	1.3	52.8
		38	1.43	1.83	3.4	15.7	16.8	1.5	64.5
MEAN ± S.E.M.				1.40 ± .11		14.83 ± .64		.78 ± .18	

*Indicates long hair.

*** Subject 40 (long hair) not included.

only ten hoods of each type were available, there was an opportunity to evaluate the effects of multiple use. No apparent effect of repeated use was noted in Type D hoods, but an obvious trend toward increased leakage of Type S was apparent (Table 6). This trend, assumed to be caused by fatigue of the elastic polyurethane seal, is an important consideration for future large scale application; if hoods were to be donned repeatedly during precautionary evacuations, it is possible that an undetected compromise of the seals could occur. This risk can be avoided by replacing seals after the hoods have been used.

The results of these tests illustrate that no hood, designed to meet the important criteria of accessibility and economy of storage, can be ex-

TABLE 6.—Effects of Repeated use on Efficiency of Type S (Septal Closure) Hoods

Hood No.	Subject	Test Number	Condition	% Leakage at 2 Minutes
489	M	1	Resting—Cool	0.2
	M	2	Exercise—Cool	0.0
	M	3	Exercise—Heat Exposure	0.5
	M	4	Exercise—Heat Exposure	0.9
	F	5	Exercise—Cool	1.0
493	M	1	Resting—Cool	1.0
	F	2	Exercise—Cool	0.4
	M	3	Exercise—Heat Exposure	1.0
	M	4	Exercise—Cool	2.2
527	M	1	Resting—Cool	0.2
	F	2	Exercise—Cool	0.4
	M	3	Resting—Heat Exposure	0.0
	M	4	Resting—Heat Exposure	1.1
525	F	1	Resting—Cool	0.1
	M	2	Exercise—Cool	0.6
	F*	3	Resting—Heat Exposure	0.0
	M	4	Exercise—Heat Exposure	1.9
	M	5	Resting—Heat Exposure	3.8
	F	6	Exercise—Heat Exposure	1.5
490	M	1	Resting—Heat Exposure	0.5
	F*	2	Exercise—Heat Exposure	1.3
	M	3	Exercise—Cool	1.2
	F*	4	Resting—Cool	2.5
515	F	1	Resting—Heat Exposure	0.3
	F	2	Resting—Cool	1.2
	F*	3	Resting—Heat Exposure	42.9
513	M	1	Resting—Cool	0.2
	F	2	Exercise—Cool	0.3
	M	3	Exercise—Heat Exposure	1.3
	F*	4	Resting—Cool	1.3
509	F	1	Resting—Cool	0.2
	F	2	Exercise—Cool	0.2
	F	3	Resting—Heat Exposure	0.3
	F	4	Exercise—Heat Exposure	1.3
506	F	1	Resting—Heat Exposure	0.3
	M	2	Exercise—Cool	1.2
523	M	1	Resting—Heat Exposure	2.1
	M	2	Exercise—Heat Exposure	0.3
	F*	3	Exercise—Heat Exposure	1.2
482	M	1 only	Resting—Cool	0.2

* Indicates long hair.

pected to provide absolute protection and life-support for indefinite periods. For example, the data in Table 5 indicate that a carbon dioxide concentration of 5% was reached in Type S hoods within 1.4 to 4.0 minutes, depending on the temperature and degree of physical exertion. A projection of these data to 8%, the generally accepted maximum allowable concentration, is shown in Table 7.

Apparently, work output and, to a smaller degree, ambient temperature are important factors modifying the time available to an evacuee wearing this hood. Little information is available on the effects of low concentrations (1%–8%) of carbon dioxide on psychomotor efficiency or on the incidence in the flying population of idiosyncrasies to the gas. An exhaustive search of the medical literature yielded no information of this type. Reports of experiments with CO_2 concentrations above 8% are available; these indicate a compromise of psychomotor efficiency. This concentration of carbon dioxide, therefore, should be taken as the maximum acceptable concentration for the hood.

TABLE 7.—Time to Reach 8% CO_2 (Min.)*

Conditions	Rest	Exercise
Cool	6.4	3.0
Heat	4.9	2.2

*Calculated from mean time to reach 5%

No data are available on the metabolic rates of semi-hysterical people attempting to escape a burning aircraft, but there is no reason to expect that oxygen consumption under such conditions would exceed those of our exercising subjects. Therefore, the 8% tolerance time of approximately 120 seconds obtained for this group seems a conservative estimate of the time during which the average evacuee could benefit from the hood.

It is concluded, on the basis of the data obtained with pentane, that the wearer of the Type S hood is given excellent fume protection. This type of extrapolation is commonly employed by those who evaluate such devices, but a few small *caveats* are worth noting. Practical considerations dictated that these tests be confined to the study of a single substance as a leakage "model" and pentane was chosen as a compromise between gases of higher and lower molecular weight, fat solubility, and other chemical properties, and because it is reasonably safe for tests at concentrations up to 1.4% (flammability limit). However, toxic gases with greater diffusion potentials than pentane may occur in aircraft fires (e.g., HCN, CO, aldehydes, HCL); these findings must therefore be considered only as approximations of safety limits.

It should also be noted that, even with the best manufacturing controls, maintenance, etc., a device may occasionally fail to give protection. That this may occur with the best of designs is illustrated by an incident which occurred during an earlier test. An experienced investigator, wearing approved (Bureau of Mines) full-face regalia with air supply, became incapacitated by a leakage of lachrymator gas while serving as a safety man for another investigator who was wearing a Type S smoke hoood. The man equipped with the hood discovered the accident and led the visually incapacitated "safety man" from the chamber. Such experiences with approved rescue equipment are rare, but serve to point up the possibility that even the best devices may occasionally fail.

Furthermore, aside from a slight risk of leakage, individuals who, for various reasons, are abnormally insensitive to carbon dioxide, may suffer from insidious hypoxia when the oxygen is consumed; normal individuals will be forced to remove the hood by the sensation of suffocation which carbon dioxide normally evokes. Although a few accidents due to carbon dioxide hyposensitivity have been reported (e.g., in underwater swimmers), medical reports on the subject indicate that the incidence of dangerous hypoxia in those wearing the hood would be rare; in the present studies none of the 40 subjects exhibited any clear-cut signs of hypoxia.

The small risk of hypoxia becomes smaller still in comparison to the alternative of breathing a super-heated atmosphere containing mixtures of highly toxic gases. Those who are not killed outright by such an environment, risk pulmonary damage leading to a permanent debilitating respiratory distress.

It is concluded that the Type S hood is a simple, effective device which will increase the probability of survival from an aircraft fire.

Chapter 2. Smoke Hood Effectiveness in a Toxic Environment

Ernest B. McFadden, M.S.
Harry L. Gibbons, M.D.

I. Introduction.

The primary purpose of this study was to determine the effectiveness of the Type S protective smoke hood in preventing inhalation of toxic substances similar to those produced in the combustion of aircraft fuel and cabin interior materials. This report describes an experimental procedure wherein subjects were subjected to a toxic environment resulting from combustion of JP–4 and water-soluble oils. The test exposed subjects to an environment filled with heavy black smoke consisting of significant quantities of carbon monoxide and soot particles. Since the affinity of blood for carbon monoxide is well known (being several hundred times greater for carbon monoxide than for oxygen), and it is more easily passed through membranes due to its relatively small molecular size, it is especially important that the hood prevent inhalation of this gas. By blood samples, following exposure, it will be possible to determine the capability of the hood to protect the wearer from this type of toxic gas.

II. Methods.

Dense black smoke was produced in a large generator from the combustion of JP–4 and water-soluble oils. Carbon monoxide concentrations ranged from 450 to 950 ppm. Combustion was controlled by limiting the amount of oxygen available in order to produce these concentrations of carbon monoxide. Output of the generator was forced into a specially constructed smoke chamber (Figure 1). An octagonal maze was constructed, which consisted of eight separate lanes. The maze was designed to increase physical exertion and task complexity, so that performance under smoke conditions could be quantified and evaluated. At the end of each maze a switch and switch box were located. Each subject donned a Type S smoke hood, entered the maze, and was required to locate the first switch to his left in the dark black smoke and complete an on-off switching cycle. The subject then proceeded to the next station and completed a similar switching operation, progressing around the octagonal maze in a clockwise direction. In this way, external and internal safety observers could follow the subject's progress and be aware of his location in the smoke chamber at all times. The subjects continued to traverse the mazes until they had been subjected to at least a ninety-second exposure to the environment while wearing the hood.

Seven adult volunteer subjects (four male, three female) participated in this study. Due to the hostility of the environment, all subjects were exposed only while wearing hoods.

III. Results.

There was no evidence of change between blood carbon monoxide concentrations in five of seven subjects, as is shown in Table 1. Subject 6 smoked a cigar shortly before the tests (although all subjects were requested to refrain from smoking for one hour prior to the tests), and it was determined during a post-exposure interview that his *pre*-exposure blood sample was taken shortly after his smoking the cigar. Since his blood carbon monoxide level was *lower* following the experiment than before it, it would appear that he had eliminated a considerable amount of carbon monoxide during both the pre-test waiting period and the test itself. One female subject showed an increase in carbon monoxide saturation; however, the change was slight and of no significance as far as the final degree of saturation achieved. Furthermore, there was no subjective evidence of significant hood leakage, as she could not recollect smelling smoke or fumes within the hood when questioned following the experiment.

During their exposure within the chamber, subjects were able to traverse linear distance ranging from 108 to 220 feet and performed from 11 to 25 double switching operations.

TABLE 1.—Blood Carbon Monoxide Saturation Prior to and Following Exposure of Subjects Wearing Smoke Hoods in a Smoke Chamber

			Percent Carbon Monoxide Saturation	
Subject	Sex	Hemoglobin	Pre-exposure	Post-exposure
1	M	16.4 gm. %	0.00	0.00
2	F	14.0 gm. %	2.46	4.93
3	M	16.8 gm. %	0.00	0.00
4	F	14.0 gm. %	0.00	0.00
5	M	17.4 gm. %	3.96	3.96
6	M	17.4 gm. %	5.96	1.98
7	F	15.2 gm. %	0.00	0.00

IV. Discussion and Conclusions.

Since the variations in the blood carbon monoxide saturation obtained in this study were of a magnitude which is not significant, it must be concluded that the smoke hood provided the subjects with adequate protection from the respiratory effects of a toxic environment. Furthermore, it was shown that even with hoods on, subjects were able to travel linear distances which would usually exceed those required in the movement to emergency exits in aircraft. It is also notable that these hooded subjects were able to perform a relatively large number of discrete switching operations under these conditions. Since effective evacuation requires manipulation of exits, etc., as well as movement to exit areas, the ability of subjects to perform these operations in a toxic environment while wearing hoods was tested and confirmed.

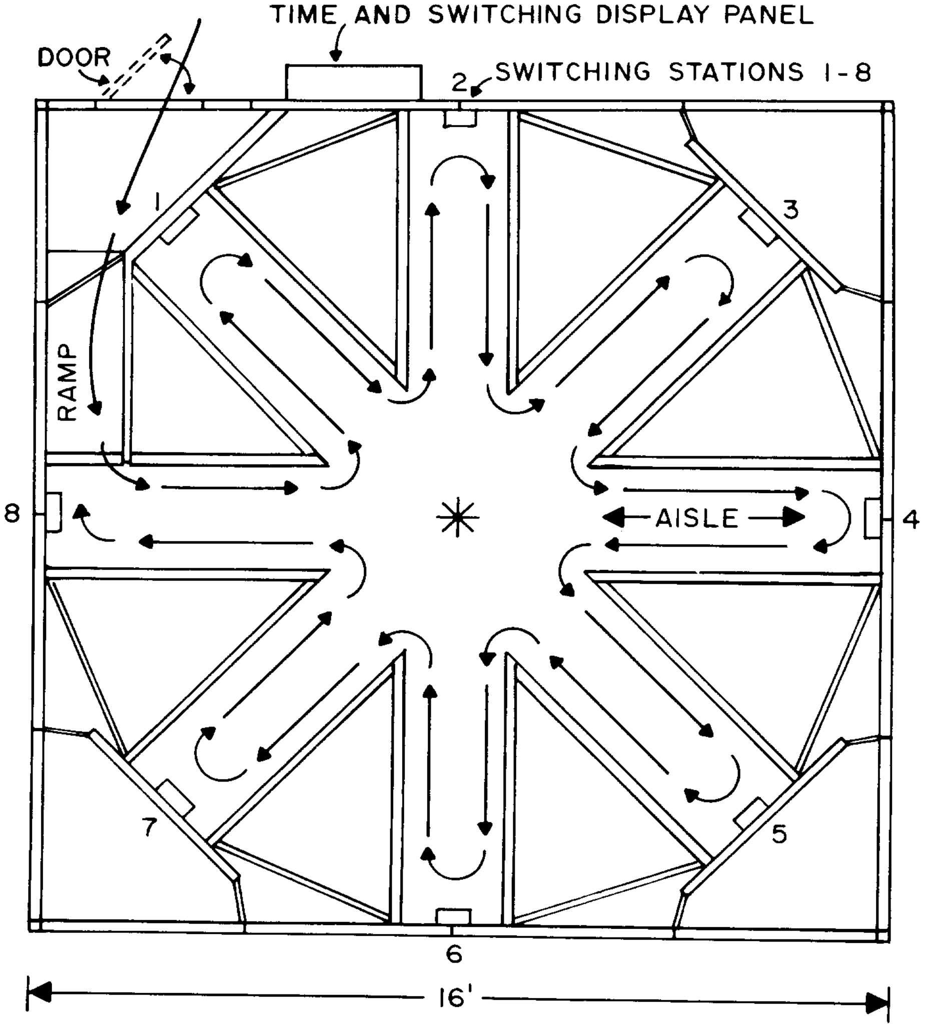

FIGURE 1. Diagram of smoke chamber. Arrows indicate maze pathway.

SECTION II

SENSORY EFFECTS

Chapter 3. Vision Through Smoke Hoods

Mark F. Lewis, Ph.D.

I. Problem.

Although the optical transmission of the Schjeldahl smoke hoods has been determined by spectrophotometric measurement[3], it remained necessary to determine the effects of the smoke hood on the vision of human observers. The current study examines the optical transmission of the hood by visual photometry and examines the hood's effect on visual acuity.

II. Method.

In the determination of optical transmissions, two samples of smoke hood materials were used, one without aluminization (from Type S hoods), the other aluminized with a clear band (from Type D hoods). From the first sample, three test patches were used. From the second sample, four test patches were used. Determinations of optical transmission were made by measuring the change in luminance produced by interposing the test patches between the light source (spectra 100-foot-Lambert reference source) and the measuring instrument (Macbeth illuminometer).

The tests of visual acuity were designed to represent a worst-case situation. Accordingly, subjects were adapted to an illumination in excess of that provided by normal aircraft interior lighting. This "normal" illumination was set at 30-foot-candes, measured at seat level down the center line of the laboratory. This exceeds the 15- to 25-foot-candles provided by aircraft reading lights and the 5- to 15-foot-candles general illumination at aircraft armrest height. Emergency illumination was simulated by adjusting the voltage to a tungsten lamp to provide 0.05-foot-candle illumination at the target. In accord with industry procedures, illuminations were measured with a Photo Research Corporation Milli-Candela foot-candle meter.

Nine male and three female adults with varying basal acuity were used as subjects. Those subjects whose acuity was less than normal wore either corrective spectacles or contact lenses. The test procedure was as follows: With normal illumination on, the subject was seated 10 feet from the test target and adapted to normal illumination for one minute. Basal acuity was measured using a standard Bausch and Lomb test chart (Snellen Rating; illiterate-direct reading, number 713598–102ND). Following measurement of basal acuity, the subjects were instructed to wait for the lights to go out and then to read each test card as quickly as possible. Subjects were instructed that they were to guess about the items on each test even if they were unsure of their responses. Prior to tests with hoods, subjects were shown how to don the hoods and how to look through them. Following one-minute adaptation to general illumination, the lights were turned out. Test runs began 10 seconds after the lights went out and each run was complete within one minute. Following completion of each run, the lights were immediately turned on and another one-minute pre-adaptation period began. Each run consisted of serial presentation of targets from the Bausch and Lomb test chart. These were individually mounted on white stock and corresponded to decimal acuities of 0.25, 0.33, 0.40, 0.50, 0.67, 0.80, 1.00, and 1.33. Targets were presented in ascending order of difficulty in each run.

Eight runs were made for each subject, four in the no-hood condition and four with hoods. For half the subjects, hood tests preceded no-hood tests. This condition was reversed for the other half of the subjects. For hood tests, the subjects were instructed to put the hoods on as soon as the lights went out, and to remove the hoods as soon as the lights came back on. They were told to look through the non-aluminized portion of the hood. With each subject two hoods were used and were alternated on successive runs to reduce fogging. For four of the subjects, four additional runs were made at the conclusion of the test session in which the subjects were instructed to view through the aluminized portion of the hoods.

III. Results.

Table 1 shows the optical transmission of the smoke hood samples; each value is the average of four determinations made by each of four observers for each test patch.

Figure 1 shows the frequency of correct response for all subjects as a function of the decimal acuity required to identify the test targets under emergency illumination with and without hoods. These data indicate the acuity is reduced under emergency illumination to 0.68; with clear smoke hoods (Type S), acuity is further reduced to 0.55; and with aluminized hoods (Type D), reduced beyond the measurement capacity of the tests employed.

TABLE 1.—Optical Transmission of Test Patches

Test Patch	Transmission	Density	Comment
1	79.7%	0.0985	Patch from edge of uncoated sample.
2	80.3%	0.0953	Patch from center of uncoated sample
3	80.1%	0.0964	Patch from edge of uncoated sample.
A	76.2%	0.118	Clear area from aluminized sample.
B	75.1%	0.124	Clear area from aluminized sample.
C	11.1%	0.955	Aluminized patch.
D	11.3%	0.947	Aluminized patch.

Table 2 shows the decimal acuity of each subject under all conditions. For each subject, acuity was reduced under emergency illumination and was progressively reduced with clear and aluminized smoke hoods.

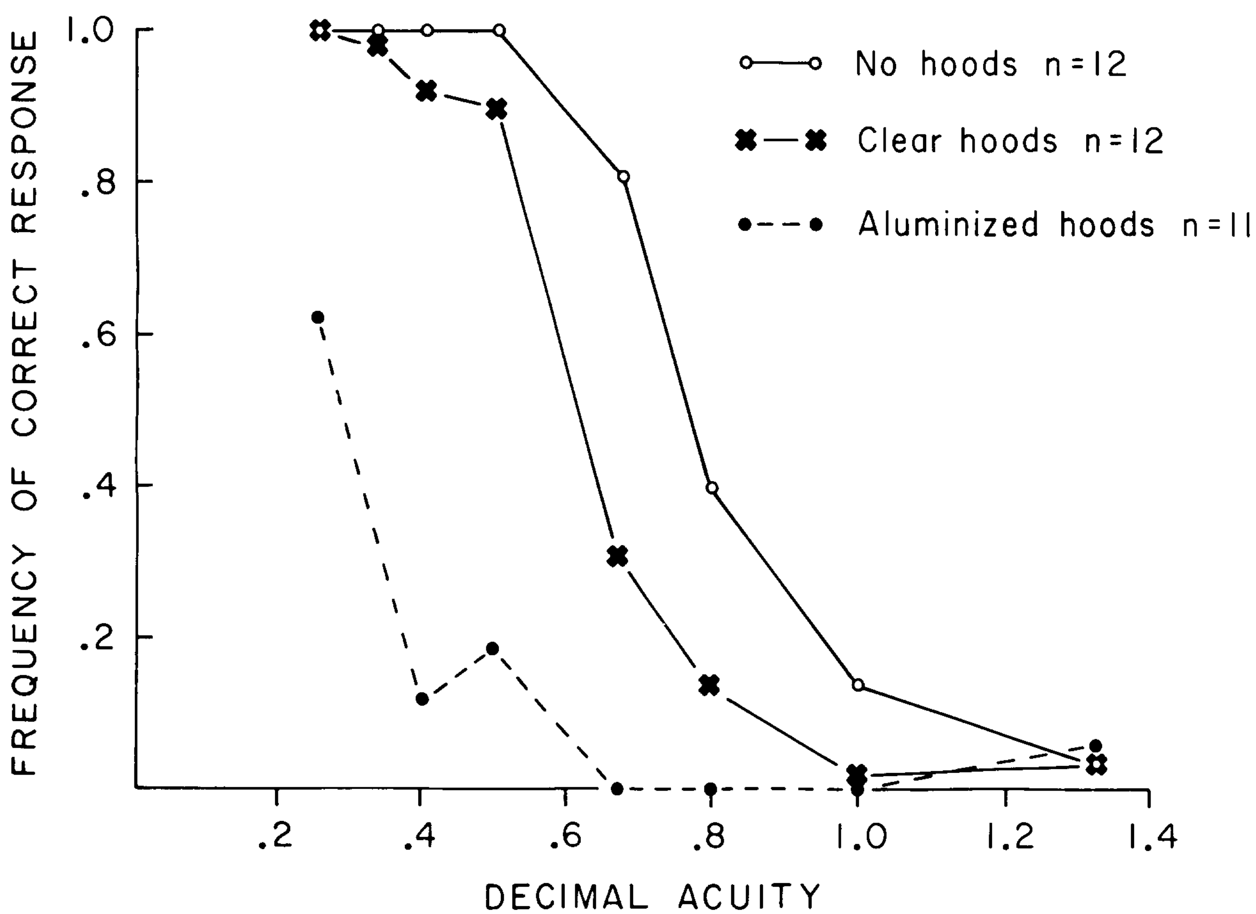

FIGURE 1. Frequency of correct test target identifications for all subjects with and without hoods under emergency illumination.

TABLE 2.—Decimal Acuity Under Test Conditions

	Normal Illumination	Emergency Illumination		
Sex	No Hood	No Hood	Clear Hood (Type S)	Aluminized Hood (Type D)
M	1.33	.67	.50	—
M	1.33	.67	.50	—
M	1.33*	.50*	.33*	—
M	1.33	.80	.50	—
M	1.33	.80	.40	—
M	1.33	.50	.50	—
M	1.00**	.67**	.50**	—
M	1.00	.67	.50	—
F	1.33	.80	.67	.25
F	1.33**	.67**	.50**	Off Scale**
M	1.33	.67	.50	Off Scale
F	1.00*	.67*	.50*	.25*

* Corrected with contact lenses

**Corrected with spectacles

IV. Discussion.

Clear smoke hoods (Type S) have optical transmissions of approximately 75–80 per cent; these values are similar to the transmission of optical glass sunglasses. The approximately five per cent difference between the uncoated samples and the clear areas from aluminized samples (Table 1) was probably due to the coating used to protect the aluminized surface.

These transmissions, together with the data of Figure 1 and Table 2, indicate that vision in emergency illumination is so reduced with aluminized hoods (Type D) as to make such hoods visually unusable. Visual capacity is significantly affected by wearing clear hoods under emergency illumination, but a 20–25 per cent increase in the level of emergency illumination would compensate for the transmission loss through the non-aluminized hoods.

Chapter 4. Smoke Hood Tests: Acoustic Attenuation*

Jerry V. Tobias, Ph.D.

I. Introduction.

During aircraft evacuation studies, the question arose of the protective smoke hood's possible interference with speech. If the hood blocks much sound, passengers will have difficulty hearing instructions from the aircraft crew. A study was done to determine the extent to which the smoke hood acts as a barrier to the transmission of sound.

II. Method.

The procedure followed American Standard Z24.22–1957, "American Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold,"[5] except that thirty subjects (men and women between the ages of 21 and 50) were given two experimental trials

* The assistance of R. Lance Christie during the conduct of this study is gratefully acknowledged.

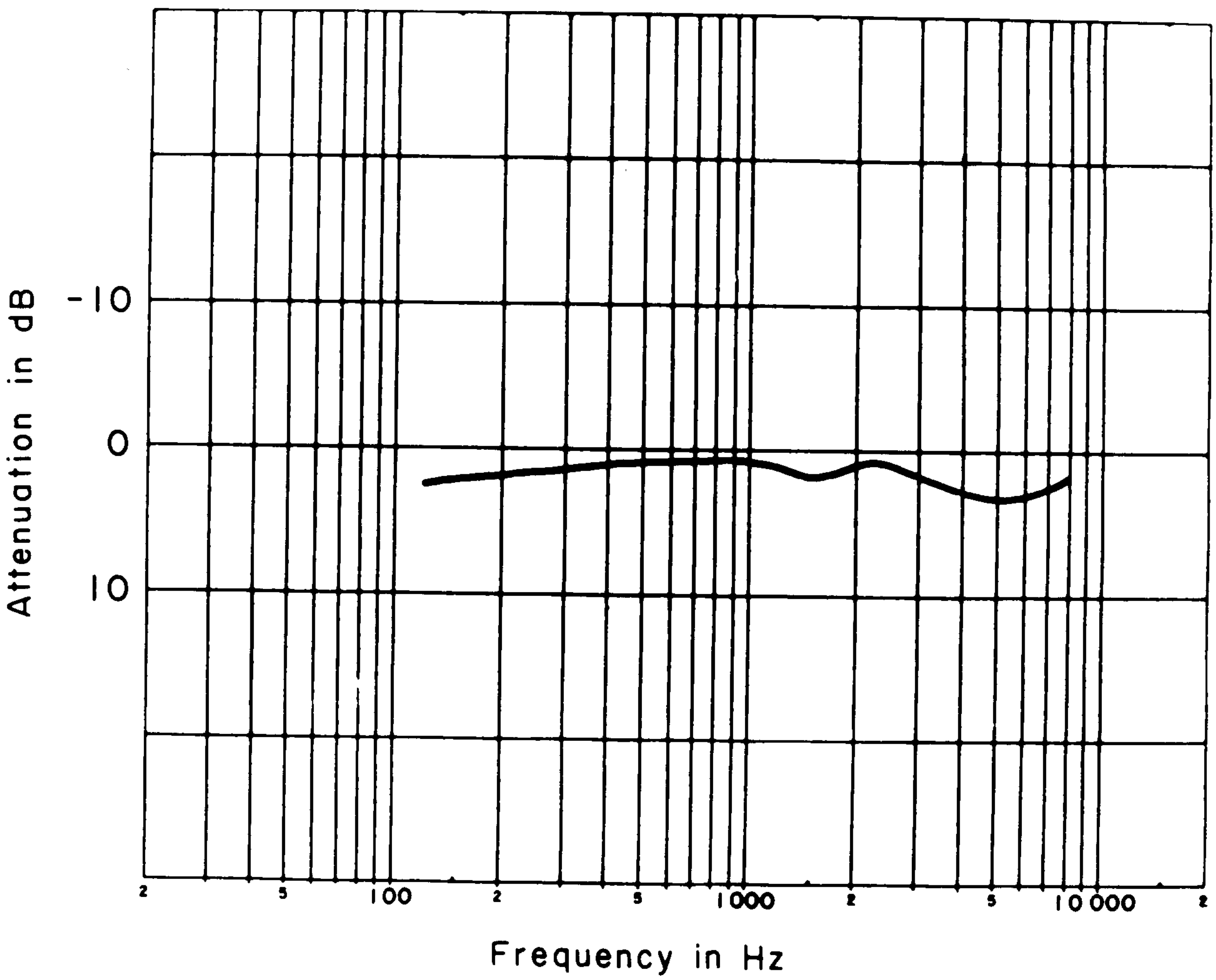

FIGURE 1. 30 subjects' free-field threshold is plotted as zero line. Standard experimental variation in audiometric experiments is plus or minus five decibels. The curve represents the free-field threshold of the 30 subjects with the smoke hood on, as compared to their threshold without it.

each. (The Standard calls for six trials for each of ten subjects.) The tests were made in the CAMI anechoic chamber, with a Grason-Stadler Model E800 Békésy Audiometer, a McIntosh MC–240 power amplifier, and a Heath AS–41U loudspeaker and baffle assembly.

Each subject was tested twice—once with and once without the hood over his head. Whether the first trial was with or without the hood was randomly determined. In the tests *with* the hood, each subject put it on in the test chamber (after instructions) and took it off for a moment halfway through the test, in order to prevent an uncomfortable accumulation of carbon dioxide. A subject had the hood on for two periods of one minute, forty seconds during that trial.

The listener was provided with a microswitch to depress when he could hear the test tone, and to release when he could not. The switch controlled the recording attenuator of the Békésy Audiometer, automatically increasing and decreasing intensity of the pure-tone signal while simultaneously graphing the setting of the attenuator. During this procedure, the frequency of the signal was changed at a constant rate to cover the range from 100 to 10,000 Hz. From this continuous spectrum, nine frequencies were selected for analysis: 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz.

III. Results and Conclusion.

As shown in Figure 1, the CAMI smoke hood does not interfere with the transmission of sound waves. At most, the threshold shift is 3 dB at 5000 Hz, an amount that is barely discriminable.

SECTION III
OPERATIONAL CONSIDERATIONS

Chapter 5. Effects of Variations in Safety Briefings Upon Use of Protective Smoke Hoods*

Roger C. Smith, Ph.D.

I. Introduction.

While the protective smoke hood[3] has been shown to be effective in preventing the inhalation of smoke, toxic gases, and flame, the utility of the hood in an actual evacuation is largely dependent upon the passenger's success in using it, and his success, or lack of it, is likely to be a function of the effectiveness of the preflight safety briefing. It was the major purpose of this study, therefore, to determine how present airline safety briefings might be modified to best promote successful passenger performance with the safety hood. The following questions were considered:

(1) To what extent does increasing the amount of information presented during safety briefings influence the degree of hood-donning success (as measured by both ease and speed of donning and the extent of hood inflation), incidence of positive and negative feelings about hoods, and willingness to use hoods?

(2) How much of the information presented during briefings is retained, as a function of the amount presented, and the use of demonstrations?

(3) Does practice with a safety device (the safety hood in this case) result in performance improvement of practical significance?

(4) Are there differences between men and women in hood-donning ability?

II. Method.

Thirty-five females (F) and sixty-eight males (M) between the ages of 17 and 31 who had never flown in a commercial aircraft were used as subjects for this experiment. In addition, subjects were restricted to individuals who had no connection with the FAA and had no prior knowledge of the safety hoods.

Twenty-two observers were trained prior to the onset of the study for observation of the behavior of the experimental subjects. Observers were familiarized with the experimental procedures and their duties during the experiment. These duties included timing of the subjects' hood donning, rating of the subjects' performance on a variety of variables listed in the observer's rating sheet (see Appendix B, Part 3), and administration of the post-experimental questionnaires to the subjects.

The experiment was conducted in a mock-up of an airplane fuselage whose interior dimensions were comparable to those of present day commercial jet airliners. The mock-up was arranged as a normal passenger compartment except that the aircraft seats were removed from one side of the passenger compartment, so that the observers could sit facing the subjects for an unobstructed view of the subjects' behavior. A packet containing a compactly folded Type S smoke hood (overall packet dimensions approximately 6″ x 7″ x 1½″) was securely taped on the seat-back in front of each subject. The packet was positioned so that the upper portion would tear off when a subject pulled on one of either of two red tabs located at the upper corners of the packet.

Subjects were met and initially instructed prior to their entry into the mock-up. During the initial instructions, they were told that they would be participating in an experiment to test the effectiveness of airline safety briefings, and that they would be asked to use one of the safety devices described in the briefing. Each subject was then assigned to an observer who escorted him into the cabin area, seated him and obtained basic data from him. Observers noted the subject's age, his educational level, whether or not

* The assistance of Sharon Bowles, Robert Lewis, and Richard Mooney in conducting this study is gratefully acknowledged, as are the many contributions of E. B. McFadden, J. D. Garner, J. Simpson, and J. Anderson, of the Protection and Survival Laboratory, CAMI.

he wore glasses, and whether or not he had any significant physical defects.

Once the preliminary data had been obtained, the subjects were instructed by the experimenter concerning the experimental procedure. They were told that they would hear a tape recording of a briefing which would be similar to those used aboard commercial airliners while a "stewardess" (a college-age female selected and trained in stewardess behavior) would demonstrate the safety devices described in the briefing.

At the conclusion of the instructions, the experimenter started the tape recording of the briefing appropriate for each group. There were six groups in all, representing six variations in the recorded briefings (see Appendix B, Parts 1 and 2 for all briefings). Group 1 (G1; N=10M, 5F) heard the least elaborate briefing which consisted of a greeting, statement of emergency exit locations, description of use of the oxygen mask, and a statement of the location and purpose of the safety hood. During this, and all other, brefings the "stewardess" pointed out the exit locations, demonstrated the use of the oxygen mask, and demonstrated the donning of the safety hoods. Each subsequent briefing, with a different group of subjects present, increased the amount of informaton given about the donning of the smoke hood, although the stewardess gave the same demonstration during all briefings. Group 2 (G2; N=12M, 9F) heard the same briefing as G1 except that subjects in G2 were also told how to remove the hood from its packet and how to spread the neck seal while putting it on. Group 3 (G3; N=11M, 5F) was told to shake the hood out to fill it with air, in addition to the other information supplied to them. G oup 4 (G4; N=12M, 7F) was told to pull the hood down over their heads as they would a shower cap, while Group 5 (G5; N=11M, 4F) was told, instead, about how to clear their glasses when donning the hoods. Group 6 (G6; N=12M, 5F) was given the most elaborate donning instructions, as well as more elaborate descriptions of emergency exit procedures and water landing safety devices (which were not demonstrated). At the conclusion of each briefing, the subjects were told that, on the experimenter's signal, they were to put on the smoke hoods which were located on the backs of the seats directly in front of them, as quickly and as well as they could. At the signal, the subjects put on their hoods and the observers determined the length of time it took for each hood-donning. The subjects remained seated during the entire hood-donning exercise.

After the completion of the hood-donning all subjects were given a questionnaire appropriate to the briefing which they had heard. The first questionnaire was the same for all groups (see Appendix B, Part 4) and dealt primarily with the smoke hood and the subject's reaction to it. Subjects were asked if they had difficulty putting on the hood, if they had negative feelings about the hood, and if they felt they would use it in an emergency. The second questionnaire (see Appendix B, Part 5) included questions about the subject's attitude towards safety briefings in general, and assessed their retention of the material presented to them in the briefing.

Group 6, in addition to completing the tasks described above, also donned the hood a second time. For the second donning, the experimenter reviewed the procedure for donning the hood with them after they had completed their questionnaires. They were then supplied with new hoods and were told again to put on their hoods when signalled by the experimenter. As before, the observers timed and rated each subject's performance.

III. Results.

Briefing Effectiveness

Hood-Donning Efficiency. Nearly all subjects (95.2%) felt that the instructions presented to them were clear with respect to the use of protective hoods. Most subjects were less than perfectly efficient, however, in donning the hood. According to the observers' ratings, 90.3% of the subjects encountered some sort of problem in donning the hoods, although all were able to get the hood on satisfactorily and quickly. As can be seen in Table 1, no group seemed to have more problems than any other group (note that column totals may exceed N in any group, since a subject could be rated as having more than one kind of problem). Subjects seemed to have the greatest difficulty in competely inflating the hood (so that it woud contain a maximum amount of air), although they also seemed to have some problems with finding and spreading the elastic neck seal. Seventeen of twenty-eight bespectacled subjects had no problems getting the hoods

TABLE 1.—Problems Encountered in Hood-Donning, as Judged by Observers, for Each Briefing Group

Reason	Group G1 (N=15)	G2 (N=21)	G3 (N=16)	G4 (N=19)	G5 (N=15)	G6 (N=17)	Total
Removing from packet	4	6	5	2	5	4	26
Finding neck seal	3	6	6	4	6	5	30
Spreading neck seal	4	5	7	5	7	6	34
Distending hood	10	15	9	12	10	11	67
Pulling over head	2	4	6	6	6	5	29
Getting over hair	2	0	0	0	1	1	4
Getting over glasses	1	2	2	4	0	2	11
Getting over nose, chin	0	0	1	1	1	1	4
Total	26	38	36	34	36	35	205

on over their glasses. Of the eleven bespectacled subjects who did have some difficulty with this, only two were in the briefing groups (G5 and G6) which were given specific directions for getting the hoods over their glasses. Although analysis of this distribution did not reveal a significant instructions effect, largely because most subjects had no difficulty at all with their glasses, the trend is in the direction which suggests that giving subjects information about ways to get the hoods over their glasses is helpful.

Since subjects were most likely to have problems getting their hoods fully inflated, they were judged on how well they accomplished this in donning the hoods. A subject was judged to have a fully inflated hood if the hood formed an even cylinder from top to bottom around his head. A rating of "minimally inflated" was assigned whenever the hood touched the face or side of the head. If the hood was not fully distended (i.e., did not form a relatively smooth cylinder) but was away from the head and face, a rating of "partially inflated" was made. Table 2 presents the distribution of the ratings for subjects in each group. It can be seen that 40%

TABLE 2.—Occurrences of Fully, Partially, and Minimally Inflated Hoods, as Judged by Observers, Within Each Briefing Group

Degree of Inflation	Group G1	G2	G3	G4	G5	G6	Total
Fully inflated	3	6	9	12	4	8	42
Partially inflated	8	11	5	7	3	9	43
Minimally inflated	4	4	2	0	8	1	18

of the subjects achieved fully distended, or "perfect", hood-donning, while 41% had "partially inflated" and 18% had "minimally inflated" hoods. It appears that groups G3, G4, and G6 were most successful with this aspect of donning. Analysis of the distribution of judgments across groups supported the conclusion that these groups generally achieved more fully inflated hoods than the others, $X^2(5)=12.01$, $p<.05$. Not unexpectedly, 54 of the 61 subjects given "partial" or "minimum" ratings also had problems getting the hoods distended before putting them on, according to observers' judgments.

Apparently, increasing the amount of information presented in the briefings had little effect on the time it took to don hoods, as can be seen in Table 3.

TABLE 3.—Mean and Range of Hood Donning Times in Seconds for Each Briefing Group

	Group G1	G2	G3	G4	G5	G6
Mean	19.40	17.64	15.58	16.53	16.97	17.11
Range	12–26	8–50	7–25	10–25.5	12–26	7–27

The nine subjects who donned their hoods without problems took an average of 12 seconds, while the remaining subjects took an average of 17 seconds. This difference was highly reliable, $t(16)=5.02$, $p<.001$.

Affective Reaction to Hoods and Briefings. Increasing the amount of information presented about the hoods seemed to result in more positive feelings about them, as can be seen in Table 4. Analysis of the distribution of subjects having no negative feelings versus those with negative feelings across groups revealed a trend that ap-

TABLE 4.—Reactions of Subjects to Using the Safety Hoods

Response	Group						
	G1	G2	G3	G4*	G5	G6*	Total
No negative feelings	8	12	14	11	14	12	71
Had negative feelings	7	9	2	7	1	5	31

*One subject did not respond.

proached significance including all six groups ($X^2(5)=10.45$, $p<.10$), and achieved statistical significance ($X^2(4)=10.41$, $p<.05$) when G6 (the only group to receive an increase in general safety information in addition to hood information) was excluded. Of the 31 subjects (30.4%) who had some negative feelings about the hoods, 19 of them indicated they had some fear of a shortage of air in the hoods, 11 felt reluctant to put a plastic bag over their heads, 7 said they had some "panicky" feelings while wearing the hoods, and 5 reported some feelings of claustrophobia (note that a subject could indicate more than one kind of concern). It should be noted that all of these 31 subjects, although expressing some reservations about using the hoods, willingly donned and wore the hoods. In fact, of 103 subjects, 98 replied that they would use the hoods in an emergency, if requested to do so.

Generally (81.5%), subjects reported that they did not feel that the briefings would be anxiety-arousing prior to an actual flight. The 19 subjects who did anticipate some increase in anxiety were proportionally distributed across groups. Thirteen of them were concerned by the pointing out of potential emergencies, while six were uneasy about the amount of material presented.

Retention of Safety Information. Overall, the subjects were correct on 73.4% of their responses to the multiple choice questions assessing retention. The proportions of correct test answers were approximately equal for all groups; therefore, the amount of information presented did not seem to have much effect on retention.

There was no difference between the retention rates for demonstrated and nondemonstrated items. In fact, subjects in Groups G1 through G5 did less well on the demonstrated than nondemonstrated items.

There were marked differences among questions in terms of percentage of correct answers. The subjects did extremely well (correct 90% or more of the time) when asked about the location of the emergency exit information cards, the use of the oxygen mask, the location of the hoods, the procedures for inflating (G2 through G6) and putting hoods on over glasses (G5 and G6), and the types and use (for G6 only) of water safety equipment. They did most poorly on questions related to exits, and on how long to wear the hood.

Effects of Previous Hood-Donning Experience

When the subjects in G6 were required to don the hoods a second time, marked improvement was noted. The mean donning time was reduced significantly from 17.41 seconds for the first attempt to 13.23 seconds for the second attempt, $t(16)=3.15$, $p<.01$. Of the 17 subjects, 11 reduced their donning times by more than two seconds, while only 2 subjects showed increases of more than two seconds. Of these latter two subjects, one had an initial donning time of nine seconds which increased to twelve seconds on the second trial. This represents a change from an exceptionally fast time to a faster-than-average time. The other subject was the only one in the study with a signficant physical defect (a malformed arm and hand), and her time on the second trial was increased because she dropped the hood. Even with the defect, it is noteworthy that her first trial resulted in a very acceptable donning time. Perhaps the most important thing to note with respect to the effect of a second trial upon donning time is that of the six slowest subjects on the first trial (mean time of 24.5 seconds), five of them reduced their times by an average of 10.5 seconds.

The second trial also brought about a significant reduction in the number of subjects who encountered some problem in donning the hood from 13 to 8, $X^2(1)=7.00$, $p<.01$. Additionally, the number of subjects who did not get their hoods fully distended decreased from 10 on the first trial to 4 on the second trial, again a significant reduction, $X^2(1)=4.50$, $p<.05$.

Sex Differences

Men and women did not differ in the time it took to don hoods or the number of problems they had in putting on the hoods. Not surprisingly, females indicated that they had some problems getting the hoods over their hair more often than did males, $X^2(1)=4.96$, $p<.05$. Females were, however, superior to males in getting the hood fully distended, as 20 of 35 women (57%) completely inflated their hoods, while only 22 of 67 men (33%) did so, the difference being highly significant, $X^2(1)=7.81$, $p<.02$.

Seat Position

Incidental observations suggested that it might be more difficult for subjects seated next to windows to go through the procedures for donning the hood (due to limitations in space) than for subjects seated on the aisle. However, comparison of "window" and "aisle" subjects on the variables of time and the number of problems encountered in donning revealed no significant differences or trends. There was a difference, however, in the number of subjects judged by observers to have had difficulty removing the safety hood from its packet, the "window" subjects having proportionally more occurrences of this particular problem, $X^2(1)=4.09$, $p<.05$.

IV. Discussion.

Briefing Effectiveness. The findings from this study suggest that increasing the amount of information presented during briefings about the use of the protective smoke hoods resulted in several benefits. As the instructions became more detailed, subjects tended to achieve more fully distended hoods, have fewer problems with donning hoods over glasses, and perhaps most significantly, have more positive feelings about using the hoods. This latter finding may have relevance to briefings in general, since it may be that more elaborate explanations of other safety devices would also improve passenger feelings about them.

Although some subjects expressed some reservations about using the hoods, almost all stated that they would use the hoods in an emergency. The specific concern most often mentioned was a fear of a shortage of air in the hoods. One solution to this problem might be the inclusion of additional information in the briefings about the adequacy of the air supply. Feelings of "claustrophobia" or "panic" seem to be rather rare with this type of hood.

In general, the briefing variations had little effect upon hood-donning times. The average donning time of approximately 17 seconds was comparable to donning times noted in previous research using the Type D hoods[2]. It should be noted that the times in the present study were taken with the subjects remaining seated at all times, and thus cannot be used as a measure of the effects of hood-donning on overall evacuation speed. Findings from the previous study[2] suggest that evacuation times are probably not significantly impaired by use of the hood, since subjects are able to put on hoods while moving toward exits. In view of the comparability of overall donning times for subjects in this and the previous studies, it must be expected that hoods with the septal seal will not impede evacuation to any significant degree.

It is clear that subjects who encounter no problems in opening and putting on the hood are likely to be much more rapid than those who do encounter problems. The major difficulty with this type of hood seems to be finding and spreading the neck seal in order to get the hood unfolded and distended. Although subjects generally were able to distend the hood sufficiently for an adequate air supply, making the opening of the neck seal more easily identifiable, perhaps by outlining it in a contrasting color, might do much to alleviate this problem. The development of some type of automatic device to distend the hood upon removal from its packet should also be considered. It may also be that present packaging procedures could be modified, perhaps by using a slightly larger, less tightly packed hood container, for improved hood-donning efficiency.

Aside from modifications in the hood itself, the findings from this study suggest that giving the subjects some experience with the hood is extremely effective in improving their efficiency in use of the hoods. The number of problems encountered, the degree of final inflation, and the overall donning speed were markedly improved when the subjects had a second trial with the hoods. Perhaps most importantly, the subjects with the poorest first trial performances improved the most on the second attempt. If this finding is found to generalize to other safety devices, changes in briefing procedures toward giving passengers first-hand experience with safety devices should be considered.

Retention of Information. The overall retention rate of the safety information presented was a respectable 73%, while the retention rate for specific questions ranged from approximately 30% to 100%. It seems significant that demonstration of items did not seem positively to influence the amount of information retained. This suggests that either present techniques of demonstration could be improved, or that the passive attitude of the passenger in receiving the briefing information limits retention. It is, however, more important to consider the relationship between retention of information and subsequent performance. It may be assumed (perhaps incorrectly) that subjects who do not retain much of the information will not be able to function well with the safety devices. However, it is not clear that retention of information about the device will result in adequate performance with it. In fact, subjects were almost perfect in their responses to the question about how to distend the hood fully; but, as noted above, this activity was a main source of inefficiency in hood-donning. In other words, retention of specific bits of information *per se* is probably of little significance in evaluating briefing effectiveness. Instead, there is a trend for greater understanding of what kinds of experience have the greatest influence upon passengers' subsequent performance with safety devices, whether they be briefings or practical exercises.

Finally, it appears that women have greater success than men in donning hoods. This is a replication of previous findings[4] and might be accounted for by prior experiences with bathing caps and hair nets, activities foreign to most men. There have as yet been no suggestions about how to share this experience with males.

Recommendations. In sum, the following recommendations would seem warranted on the basis of the data obtained in this experiment:

(1) General safety briefings should probably contain more information about use of safety devices.

(2) The portion of the briefings dealing with safety hoods should include some mention of the adequacy of the air supply.

(3) The opening in the hood's elastic neck seal should be modified to make it easier to find.

(4) Consideration should be given to using a larger, less compact hood package, with possible enclosure of self-distending devices.

(5) Further consideration should be given to developing practical ways in which passengers could obtain first-hand experience with safety devices.

Chapter 6. Evacuation Testing Using Dense Theatrical Smoke

Ernest B. McFadden, M.S.

I. Introduction.

It was the purpose of this investigation to determine the reactions of a naive group of subjects to the use of the protective smoke hoods during evacuations in the presence of smoke.

II. Method.

Subjects were obtained from the University of Oklahoma Research Institute under contract. A majority of the subjects were obtained through the use of newspaper advertisements. Generally, the individuals were from lower economic groups and unfamiliar with air travel.

Specifications of age and sex of the subjects were as follows:

Ten percent were to be over age 60.

Eight to ten percent were to be under age 12.

The remainder were to be within the 12–60 age bracket.

Thirty percent were specified to be females.

All subjects were paid for their participation in the experiment.

Sixty-four seats were installed in an obsolete Constellation L–749 fuselage, per the attached drawing. Minimal or less than minimal aisle widths were incorporated in the seating plan (Figure 1).

Exits available in this aircraft consist of the overwing exits, small crew door, and the main cabin door at the left aft portion of the fuselage. In order to assure longer duration exposures in the environment, only the aft main cabin door was utilized.

Motion picture cameras were used to record behavior during evacuations. One camera was located inside the cabin and two were positioned outside the cabin. All tests were carried out under outdoor daylight conditions.

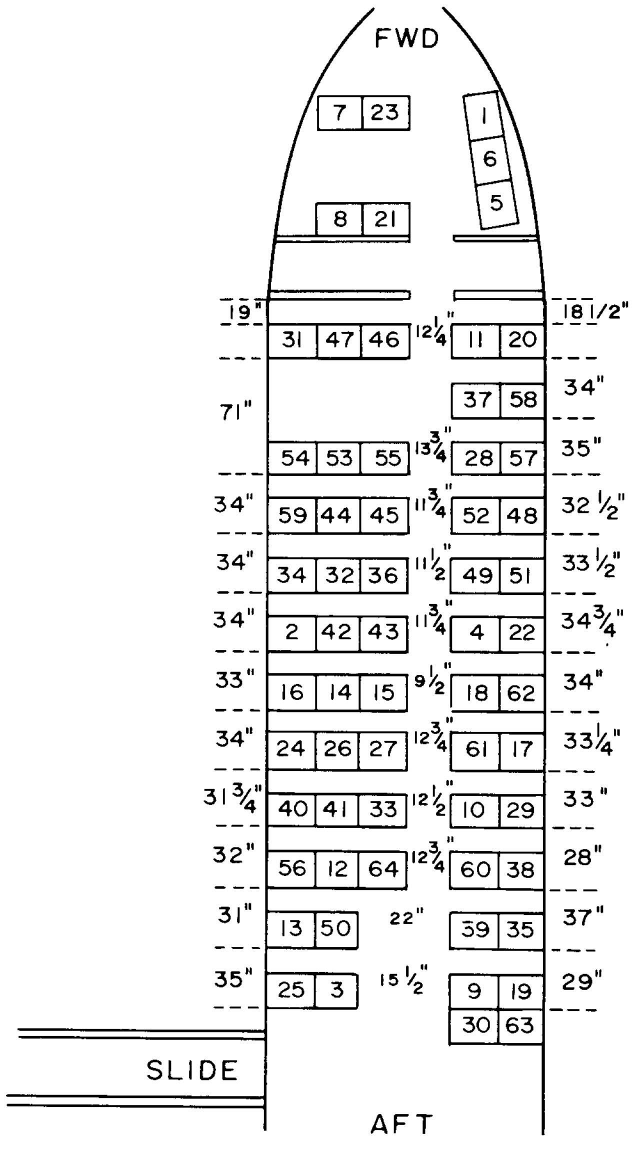

Figure 1. Seat spacing and aisle width configuration of the test aircraft. Numbers in seat blocks refer to location of subjects in tests A1 and A2.

In addition, sound recordings were made by means of a tape recorder, with the effective microphone being placed in the middle of the cabin.

The slide was in place, inflated, and the door was partially open in order to reduce the variability induced by crew members' actions in performing these tasks, and to allow comparison between individual tests.

A protective smoke hood folded in a single vertical fold was inserted in the seat-back pocket of each seat prior to passenger boarding. The Type D hoods were used in this experiment. Crew members were equipped with hoods of similar design but lacking the aluminized coating of the Type D hood. Passengers were randomly seated and the numbers noted by the cabin attendant after boarding. Passenger location and seating diagrams for the tests are attached (see Figure 1).

Before each evacuation in which hoods were to be used, the cabin attendant gave a brief demonstration of the correct procedure for donning the hood.

For one group of sixty-four subjects (Group A), the first evacuation test (Test A1) was carried out with no smoke in the cabin and without using the hoods. The second test (Test A2) was carried out with dense smoke injected into the cabin from fore and aft positions and hoods were donned by the subjects and worn during escape. All actions (i.e., smoke, hood donning, evacuation, and timing) were initiated upon activation of an audio alarm system.

The sixty-four subjects in the second group (Group B) made their first evacuation (Test B1) under smoke conditions while wearing the hoods. The second evacuation (Test B2) was made without use of hoods or the presence of smoke.

To control for the effects of smoke on evacuation independently of the presence of hoods, the subjects in Group B were evacuated once while wearing the hoods (Test C1), but without the presence of smoke.

Smoke was produced by means of a theatrical smoke generator. It was produced to such an

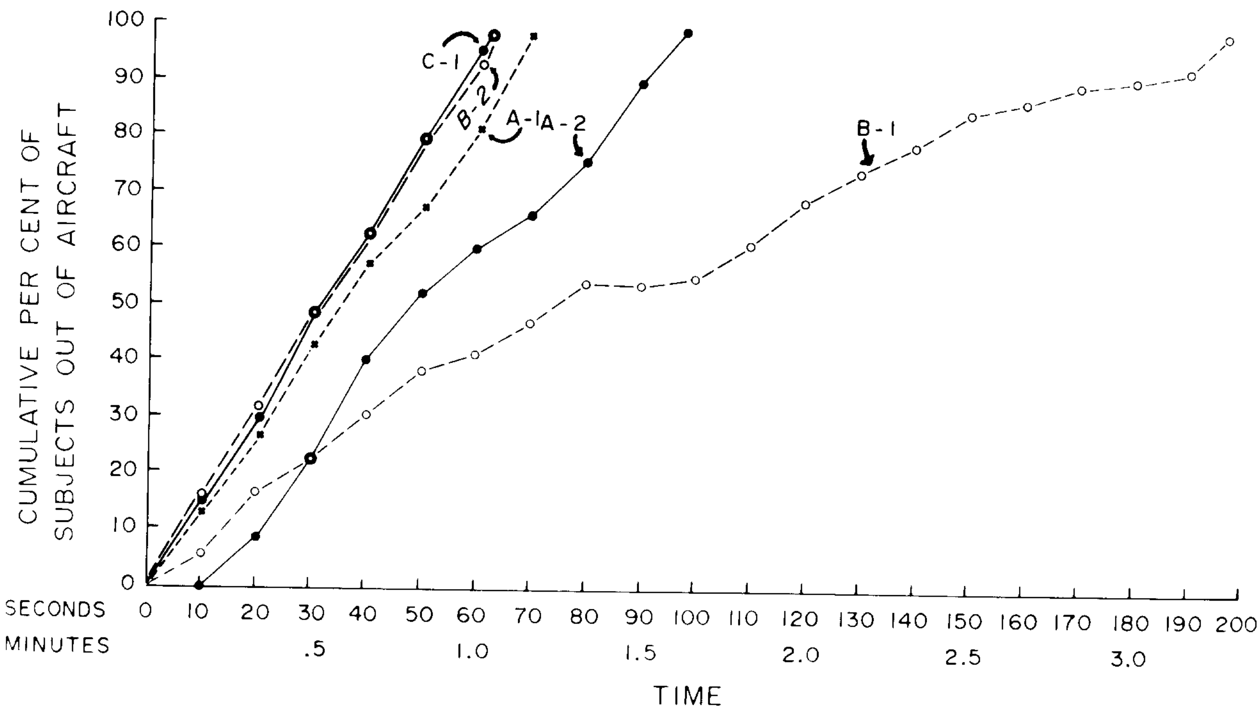

FIGURE 2. Comparison of evacuation flow from a Constellation 749 fuselage of 64 occupants from the aft main cabin door. Test A1: No smoke; no hoods—initial evacuation experience. Test B2: No smoke; no hoods—one previous evacuation experience from smoke-filled aircraft using hoods. Test C1: No smoke; don hoods. Test A2: Cabin filled with smoke; don hoods—second evacuation experience. Best B1: Cabin filled with smoke; don hoods—initial evacuation experience.

extent as to virtually eliminate visual cues for evacuation.

After completion of the tests, each subject was given a questionnaire in a self-addressed envelope to be filled out and mailed to the principal investigator.

These evacuation tests were designed to measure the flow of a maximum number of passengers through only one exit and were not designed to measure evacuation of an aircraft as an entity through one-half or other prescribed number of exits available. Total times cannot be directly compared to requirements for such tests or demonstrations.

TABLE 1.—Percentage of Subjects Choosing Each Response Alternative to Items in a Post-Evacuation Smoke Hood Questionnaire

Question	Test Group	Percent Responding			
		Yes	No	Maybe	None
1. Feeling of real emergency	A*	50.0	40.6	9.4	0
	B**	35.9	50.0	14.1	0
2. Would have acted differently in actual accident	A	57.8	39.0	1.6	1.6
	B	60.9	26.6	9.4	3.1
3a. Felt panic	A	23.4	70.3	6.3	0
	B	21.9	71.9	6.2***	0
3b. Observed panic in others	A	18.7	70.3	9.4	1.6
	B	51.6	45.3	0	3.1
4a. Stewardess's instructions clear	A	98.4	1.6	0	0
	B	98.4	1.6	0	0
4b. Heard instructions	A	98.4	1.6	0	0
	B	98.4	1.6	0	0
5. Expected more instructions	A	12.5	87.5	0	0
	B	15.6	84.4	0	0
6. Heard passengers give commands and assist others	A	32.8	67.2	0	0
	B	23.4	76.6	0	0
7. Much confusion was apparent	A	29.7	68.7	1.6	0
	B	48.4	51.6	0	0
8. Level of illumination was adequate for evacuation	A	84.4	10.9	0	4.7
	B	84.4	15.6	0	0
9. Hood was easy to put on	A	96.9	0	3.1	0
	B	98.4	1.6	0	0
10. Could see well through hood	A	90.6	9.4	0	0
	B	87.5	12.5	0	0
11. Hood affected breathing	A	25.0	75.0	0	0
	B	14.0	84.4	0	1.6
12. Felt hood protected from smoke inhalation	A	96.9	3.1	0	0
	B	95.3	4.7	0	0
		None	Slight	Considerable	Complete
13. Degree vision obscured by smoke	A	21.9	34.4	35.9	7.8
	B	4.7	7.8	42.2	43.7
		Before Smoke	Smoke Started	Heavy Cabin Smoke	No Answer
14. Hood donning	A	39.0	59.4	1.6	0.0
	B	42.2	53.1	0.0	4.7

*Includes subjects in Tests A1 and A2
**Includes subjects in Tests B1, B2 and C1
***During smoke only

II. Results and Discussion.

The findings from the evacuations are portrayed graphically in Figure 2. It can be seen that the presence of smoke was the primary variable influencing speed of evacuation, as both evacuations with smoke were much slower than those undertaken without smoke. The use of hoods alone did not seem to have a significant effect on evacuation rate, as can be seen by comparison of the curve for C1 with those of A1 and B2.

The poor performance during the B1 test relative to the A2 test (both with smoke and hoods), was caused, at least in part, by a young child whose hood drawstring became entangled in a seat near the exit (this could not occur with the newer type hoods). While the child was being freed, the remaining subjects in the cabin (about two-thirds of the subjects in that evacuation) were prevented from making progress toward the exit. None of those passengers who remained for extended periods in the fuselage suffered any apparent adverse effects due to carbon dioxide accumulation or oxygen depletion.

Responses to the questionnaires are summarized in Table 1. Significant differences in response tendencies between groups were noted for the second part of Question 3, Question 7, and Question 13. The summation of these trends indicated that more subjects *appeared* to panic, there was more confusion, and there was greater reported difficulty with vision in the B group than the A group. Apparently, the experience gained without smoke had a beneficial effect when subjects were asked to evacuate under smoke conditions.

Elaborations of the questions were frequent, and generally indicated that some subjects did not care for the rebreathing of the warm air within the hood; however, only one subject reported any experience of increased breathing rate. It should be noted that although several subjects had minor complaints about wearing the hoods, none of them became uncomfortable enough to actually remove their hoods while in smoke.

The data from the interior motion picture films were noncontributory, since the smoke completely obscured visibility during the test trials. Exterior film shots were also nonremarkable.

Information gained from the tape recordings indicated that the noise generated by donning the hoods persisted for no more than approximately seven seconds. While this noise might have some short-term interference effect, there was no evidence of difficulty in communication between the cabin attendant and passengers once the hood had been donned.

In sum, it appears, that while the hood cannot serve to increase visibility in smoke other than by preventing eye irritation, it does protect the individual from the respiratory effects of smoke and provides them with an air sample which is relatively uncontaminated and adequate for evacuation purposes.

The results of the studies by McKenzie, *et al.* (Chapter 1), and McFadden and Gibbons (Chapter 2), clearly establish the effectiveness of the Type S hood in preventing the penetration of noxious substances into the air sample enclosed within the hood. The necessity for maintaining effective septal seals was also noted; however, this should present no particular problem since the hoods are not now anticipated as a "try on" device. In sum, it may be concluded that a passenger wearing a hood will not become incapacitated due to smoke, flame, or toxic fume inhalation, should these be present in an aircraft due to an accident.

There are certain limitations to the hood; however, these studies have shown them to be of little consequence when considered in terms of the function of the hood as a "get-me-out" device. The data confirm the obvious fact that the supply of usable air which is enclosed within a hood is not inexhaustible. What is important is that the supply is adequate for time which is likely to be required in the successful evacuation of an aircraft.

The final question, and ultimately the most important one, is that of how effective the hood would be if used by the inexperienced passenger during an evacuation. The results of the various tests which have been conducted suggested that, even with a minimal briefing (Chapter 5), most passengers should be able to use the hood adequately enough during an evacuation. One objection sometimes raised with respect to the use of these hoods is that they may be a "panic"-inducing agent. There is presently no evidence to generally support this proposition. However, the findings from the AIA report[1] and our studies indicate that "panic" in tests where subjects were wearing hoods occurred when smoke was introduced. Since the presence of smoke seems to be the relevant variable, it must be concluded that the hoods as such do not induce panic. As a matter of fact, they may prevent panic, since respiratory distress is absent when hoods are used in a noxious environment. Nonetheless, the hoods can be improved by the incorporation of a self-contained oxygen supply and carbon dioxide removal agent. Research into such devices is being undertaken; however, until suitable supplies of these agents are available, it should not be forgotten that the protection afforded by the hood itself is significant and worthwhile.

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APPENDIX A

TABLE 1.—Description of Subjects

Subject	Age	Sex	Height (Inches)	Weight (Lbs.)	Hair Length
1	25	M	69	170	Short
2	25	F	67	135	Short
3	19	M	70.5	165	Short
4	27	M	69	160	Short
5	25	F	63.5	118	Short
6	27	M	70.5	145	Short
7	24	M	71.5	150	Short
8	25	F	66	140	Short
9	22	M	71	155	Short
10	27	F	66	125	Short
11	24	F	63.5	128	Short
12	22	M	71	175	Short
13	22	F	69	123	Short
14	40	F	65.5	169	Short
15	28	M	69	150	Short
16	28	F	68.5	138	Short
17	20	M	70	160	Short
18	25	M	74.5	185	Short
19	21	F	55	100	Long
20	27	F	64	110	Short
21	22	M	72	145	Short
22	21	M	70	172	Short
23	22	M	74	175	Short
24	22	M	73.5	190	Short
25	21	M	68.5	160	Short
26	22	F	63.5	135	Long
27	21	M	72	175	Short
28	23	F	64	108	Short
29	17	F	63.5	120	Long
30	19	M	72	155	Short
31	28	M	68	155	Short
32	22	M	66	150	Short
33	25	M	70	220	Short
34	21	F	66.5	120	Short
35	21	F	68	137	Pony Tail
36	22	F	65	115	Short
37	22	F	68	134	Short
38	22	F	62	100	Short
39	21	F	61	105	Long
40	26	F	63.5	115	Long

TABLE 2.—SEPTAL HOOD—MALE—NORMAL TEMPERATURE—RESTING

SUBJECT #1 Age: 25 Surface Area: 1.93 Sq. M Temperature: 26°C Hood #000489

	TIME—MINUTES					
	0	1	2	3	4	4.18
% CO_2	.03	2.5	4.1	4.7	5.6	5.8
% O_2	20.9	18.5	16.4	14.2	12.0	11.8
HR	101	111	97	111	92	114
Resp	11	11	9	12	16	18

SUBJECT #3 Age: 19 Surface Area: 1.94 Sq. M Temperature: 26°C Hood #000513

	0	1	2	3	4	4.20
% CO_2	.03	2.0	3.2	5.2	5.6	5.7
% O_2	20.9	19.7	17.6	14.7	12.6	12.3
HR	100	80	75	78	89	95
Resp	15	14	14	13	16	20

SUBJECT #4 Age: 27 Surface Area: 1.89 Sq. M Temperature: 26°C Hood #000493

	0	1	2	3	4	4.32
% CO_2	.03	1.7	3.2	4.0	4.5	6.5
% O_2	20.9	19.5	17.5	15.7	13.8	16.9
HR	75	72	72	74	74	72
Resp	15	14	14	14	15	18

SUBJECT #6 Age: 27 Surface Area: 1.83 Sq. M Temperature: 25.5°C Hood #000527

	0	1	2	3	4	4.20
% CO_2	.03	3.1	4.2	4.9	5.8	6.3
% O_2	20.9	18.2	15.7	13.5	11.2	10.8
HR	77	72	75	78	87	90
Resp	13	11	11	12	14	18

SUBJECT #7 Age: 24 Surface Area: 1.87 Sq. M Temperature: 25.5°C Hood #000482

	0	1	2	3	4	4.50
% CO_2	.03	2.4	3.8	4.2	4.7	5.0
% O_2	20.9	19.0	17.3	15.9	14.3	13.8
HR	61	58	55	58	60	62
Resp	11	16	18	19	20	20

TABLE 3.—SEPTAL HOOD—FEMALE—NORMAL TEMPERATURE—RESTING

SUBJECT #2 Age: 25 Surface Area: 1.71 Sq. M Temperature: 26°C Hood #000525

	TIME—MINUTES					
	0	1	2	3	4	4.43
% CO_2	.03	1.9	2.9	4.1	4.8	5.2
% O_2	20.9	20.0	18.8	16.7	14.9	14.2
HR	81	85	81	84	91	96
Resp	21	15	16	18	24	30

SUBJECT #5 Age: 25 Surface Area: 1.56 Sq. M Temperature: 25.5°C Hood #000509

	0	1	2	3	4	4.47
% CO_2	.03	1.8	2.8	3.9	4.7	4.9
% O_2	20.9	19.8	17.9	15.8	13.6	13.1
HR	88	89	88	91	104	99
Resp	11	15	11	13	14	18

SUBJECT #28 Age: 28 Surface Area: 1.51 Sq. M Temperature: 27°C Hood #000515

	0	1	2	3	4	4.83
% CO_2	.03	0.4	2.3	3.0	4.5	6.0
% O_2	20.9	20.3	18.3	16.7	15.0	14.3
HR	86	86	80	84	88	94
Resp	14	15	17	17	21	24

SUBJECT #39 Age: 21 Surface Area: 1.44 Sq. M Temperature: 26°C Hood #000499

	0	1	2	3	4	5	6	7	8	8.50
% CO_2	.03	1.0	1.8	2.8	3.7	5.0	5.2	6.1	7.0	7.1
% O_2	20.9	20.2	19.0	17.9	16.7	15.7	14.5	13.5	12.4	11.8
HR	68	72	68	74	74	76	82	78	82	82
Resp	17	16	18	17	16	14	15	15	19	21

SUBJECT #29 Age: 17 Surface Area: 1.57 Sq. M Temperature: 27°C Hood #000513

	0	1	2	3	3.22
% CO_2	.03	2.4	3.6	5.5	5.7
% O_2	20.9	19.8	17.4	15.2	14.6
HR	84	84	76	84	88
Resp	23	21	21	22	28

TABLE 4.—SEPTAL HOOD—MALE—NORMAL TEMPERATURE—EXERCISING

SUBJECT #9 Age: 22 Surface Area: 1.89 Sq. M Temperature: 26°C Hood #000525

	TIME—MINUTES			
	0	1	2	2.42
% CO_2	.03	3.3	5.8	6.7
% O_2	20.9	18.5	13.1	11.3
HR	94	104	119	126
Resp	11	20	19	26

SUBJECT #12 Age: 22 Surface Area: 1.99 Sq. M Temperature: 26°C Hood #000489

	0	1	2	2.10
% CO_2	.03	3.8	6.4	6.4
% O_2	20.9	17.8	12.3	11.8
HR	124	128	129	120
Resp	13	21	19	20

SUBJECT #27 Age: 21 Surface Area: 2.01 Sq. M Temperature: 27°C Hood #000506

	0	1	2	2.42
% CO_2	.03	2.2	7.5	7.7
% O_2	20.9	18.3	11.3	8.8
HR	80	81	91	96
Resp	11	18	20	33

SUBJECT #30 Age: 19 Surface Area: 1.91 Sq. M Temperature: 27°C Hood #000493

	0	1	2.08
% CO_2	.03	4.9	8.4
% O_2	20.9	16.3	10.5
HR	88	80	98
Resp	14	14	15

SUBJECT #31 Age: 28 Surface Area: 1.83 Sq. M Temperature: 27°C Hood #000499

	0	1	2	2.55
% CO_2	.03	3.2	6.9	9.0
% O_2	20.9	16.9	11.6	9.8
HR	86	82	88	88
Resp	12	22	24	30

TABLE 5.—SEPTAL HOOD—FEMALE—NORMAL TEMPERATURE—EXERCISING

SUBJECT #13 Age: 22 Surface Area: 1.69 Sq. M Temperature: 25°C Hood #000513

	TIME—MINUTES			
	0	1	2	2.63
% CO_2	.03	2.8	5.4	6.7
% O_2	20.9	17.3	11.8	10.6
HR	84	99	102	112
Resp	20	19	17	20

SUBJECT #11 Age: 24 Surface Area: 1.61 Sq. M Temperature: 26°C Hood #000509

	0	1	2	2.52
% CO_2	.03	.7	3.1	4.9
% O_2	20.9	20.3	17.8	14.8
HR	124	138	125	126
Resp	20	17	20	22

SUBJECT #10 Age: 27 Surface Area: 1.64 Sq. M Temperature: 26°C Hood #000493

	0	1	2	2.63
% CO_2	.03	2.0	4.9	6.6
% O_2	20.9	17.2	12.1	11.7
HR	82	92	105	118
Resp	21	21	19	22

SUBJECT #8 Age: 25 Surface Area: 1.73 Sq. M Temperature: 26°C Hood #000527

	0	1	2	2.83
% CO_2	.03	1.3	4.3	5.9
% O_2	20.9	19.5	16.8	15.2
HR	95	115	124	142
Resp	17	21	25	34

SUBJECT #36 Age: 22 Surface Area: 1.56 Sq. M Temperature: 27°C Hood #000489

	0	1	2	2.08
% CO_2	.03	3.5	6.6	6.6
% O_2	20.9	16.5	13.8	13.8
HR	94	108	120	
Resp	18	22	20	

TABLE 6.—SEPTAL HOOD—MALE—ELEVATED TEMPERATURE—RESTING

SUBJECT #17 Age: 20 Surface Area: 1.91 Sq. M Temperature: 58°C Hood #000523

	TIME—MINUTES						
	0	1	2	3	4	5	5.45
% CO_2	.03	2.2	3.5	6.1	8.3	9.0+	9.0+
% O_2	20.9	20.0	18.1	15.1	12.6	10.4	10.2
HR	96	96	82	88	90	96	90
Resp	16	14	12	8	10	13	16

SUBJECT #15 Age: 28 Surface Area: 1.83 Sq. M Temperature: 56°C Hood #000499

	0	1	2	3	3.90
% CO_2	.03	2.6	4.0	5.8	7.1
% O_2	20.9	19.6	17.8	15.9	14.5
HR	—	80	84	87	90
Resp	—	7	8	12	14

SUBJECT #18 Age: 25 Surface Area: 2.12 Sq. M Temperature: 56.5°C Hood #000527

	0	1	2	3	4	5.08
% CO_2	.03	2.1	4.1	7.4	7.9	9.0+
% O_2	20.9	19.4	17.9	13.8	11.4	9.5
HR	—	74	72	74	78	82
Resp	—	12	12	11	12	14

SUBJECT #32 Age: 22 Surface Area: 1.77 Sq. M Temperature: 59.5°C Hood #000525

	0	1	2	3.03
% CO_2	.03	3.1	6.4	6.4
% O_2	20.9	18.4	16.1	14.4
HR	76	80	70	76
Resp	—	10	9	9

SUBJECT #33 Age: 25 Surface Area: 2.18 Sq. M Temperature: 57°C Hood #000527

	0	1	2	3	3.13
% CO_2	.03	3.0	4.9	6.2	6.8
% O_2	20.9	19.8	15.7	11.9	10.8
HR	84	84	82	88	
Resp	22	13	11	17	

TABLE 7.—SEPTAL HOOD—FEMALE—ELEVATED TEMPERATURE—RESTING

SUBJECT #20	Age: 27		Surface Area: 1.52 Sq. M			Temperature: 60°C		Hood #000509
	TIME—MINUTES							
	0	1	2	3	4	5	5.82	
% CO_2	.03	2.1	2.8	3.8	4.6	6.7	7.9	
% O_2	20.9	19.6	18.4	16.9	15.1	12.8	12.3	
HR	92	86	82	80	84	100	102	
Resp	16	13	11	13	14	16	16	

SUBJECT #19	Age: 21		Surface Area: 1.32 Sq. M			Temperature: 58°C		Hood #000525
	0	1	2	3	4	5	5.25	
% CO_2	.03	1.6	2.4	4.6	6.0	7.4	7.4	
% O_2	20.9	20.5	19.3	17.1	15.2	13.6	13.5	
HR	102	106	102	100	106	108	112	
Resp	—	—	—	—	—	—	—	

SUBJECT #16	Age: 28		Surface Area: 1.76 Sq. M			Temperature: 59°C		Hood #000515
	0	1	2	3	4	5	6.05	
% CO_2	.03	2.1	3.7	5.0	6.2	7.1	7.9	
% O_2	20.9	19.3	17.3	15.5	13.1	10.7	9.3	
HR	—	104	74	80	80	90	86	
Resp	—	15	12	14	13	14	18	

SUBJECT #14	Age: 40		Surface Area: 1.84 Sq. M		Temperature: 57°C	Hood #000506
	0	1	2	3	3.25	
% CO_2	.03	1.9	1.9	5.5	6.3	
% O_2	20.9	20.7	20.3	17.0	15.8	
HR	—	83	87	89	102	
Resp	—	21	17	19	24	

SUBJECT #40	Age: 26		Surface Area: 1.54 Sq. M			Temperature: 60°C			Hood #000515
	0	1	2	3	4	5	6	7	7.31
% CO_2	.03	2.3	2.4	4.0	5.0	4.9	6.0	8.6	8.7
% O_2	20.9	19.5	18.8	16.9	15.3	15.0	14.0	11.5	11.0
HR	80	78	78	80	82	84	92	102	104
Resp	12	13	13	15	15	16	17	19	20

TABLE 8.—SEPTAL HOOD—MALE—ELEVATED TEMPERATURE—EXERCISING

SUBJECT #21 Age: 22 Surface Area: 186 Sq. M Temperature: 59°C Hood #000525

	TIME—MINUTES			
	0	1	2	2.42
% CO_2	.03	6.0	8.3	8.4
% O_2	20.9	16.2	9.2	7.5
HR	136	152	144	162
Resp	6	14	17	34

SUBJECT #22 Age: 21 Surface Area: 1.96 Sq. M Temperature: 60°C Hood #000523

	0	1	2	2.50
% CO_2	.03	4.9	7.5	8.3
% O_2	20.9	17.3	11.8	8.7
HR	110	116	102	112
Resp	—	17	18	26

SUBJECT #23 Age: 22 Surface Area: 2.05 Sq. M Temperature: 62°C Hood #000489

	0	1	2	2.22
% CO_2	.03	3.0	7.0	7.5
% O_2	20.9	14.3	8.9	8.9
HR	100	104	122	128
Resp	17	11	15	32

SUBJECT #24 Age: 22 Surface Area: 2.12 Sq. M Temperature: 60°C Hood #000493

	0	1	2	2.13
% CO_2	.03	6.2	7.2	7.2
% O_2	20.9	17.3	11.0	8.9
HR	124	144	140	120
Resp	16	21	30	32

SUBJECT #25 Age: 21 Surface Area: 1.87 Sq. M Temperature: 60°C Hood #000513

	0	1	2	3.00
% CO_2	.03	4.3	7.5	9.0+
% O_2	20.9	14.6	7.4	5.5
HR	98	106	112	126
Resp	16	12	16	26

TABLE 9.—SEPTAL HOOD—FEMALE—ELEVATED TEMPERATURE—EXERCISING

SUBJECT #26 Age: 22 Surface Area: 1.65 Sq. M Temperature: 60°C Hood #000499

	TIME—MINUTES			
	0	1	2	2.52
% CO_2	.03	2.3	5.4	6.0
% O_2	20.9	17.8	11.2	10.8
HR	——	86	104	114
Resp	——	24	23	26

SUBJECT #34 Age: 21 Surface Area: 1.63 Sq. M Temperature: 60°C Hood #000489

	0	1	2.00
% CO_2	.03	2.3	6.0
% O_2	20.9	19.1	12.4
HR	106	106	132
Resp	——	11	19

SUBJECT #35 Age: 21 Surface Area: 1.74 Sq. M Temperature: 60°C Hood #000523

	0	1	1.85
% CO_2	.03	3.1	6.0
% O_2	20.9	18.8	13.1
HR	120	120	158
Resp	32	32	42

SUBJECT #37 Age: 22 Surface Area: 1.73 Sq. M Temperature: 59°C Hood #000509

	0	1	2	2.53
% CO_2	.03	2.3	5.8	6.0
% O_2	20.9	19.6	13.8	11.8
HR	108	102	140	144
Resp	——	18	20	28

SUBJECT #38 Age: 22 Surface Area: 1.43 Sq. M Temperature: 60°C Hood #000525

	0	1	2	2.60
% CO_2	.03	2.5	5.3	6.4
% O_2	20.9	18.0	12.3	11.0
HR	104	120	138	150
Resp	24	20	24	28

TABLE 10.—DRAWSTRING HOOD—MALE—NORMAL TEMPERATURE—RESTING

SUBJECT #1 Age: 25 Surface Area: 1.93 Sq. M Temperature: 26°C Hood #000282

	TIME—MINUTES					
	0	1	2	3	4	4.43
% CO_2	.03	3.1	3.3	3.3	3.3	3.4
% O_2	20.9	18.3	17.8	17.6	17.6	17.6
HR	113	107	107	100	91	99
Resp	14	10	10	10	9	12

SUBJECT #3 Age: 19 Surface Area: 1.94 Sq. M Temperature: 26°C Hood #000270

	0	1	2	3	4	5	6	6.50
% CO_2	.03	2.0	3.4	3.2	3.2	3.2	3.2	2.7
% O_2	20.9	18.3	16.3	16.3	16.4	16.6	16.8	16.8
HR	76	80	81	80	82	80	82	76
Resp	14	15	16	16	17	17	16	18

SUBJECT #4 Age: 27 Surface Area: 1.89 Sq. M Temperature: 26°C Hood #000380

	0	1	2	3	4	5	6	6.28
% CO_2	.03	2.2	2.7	2.7	2.7	2.7	2.8	2.9
% O_2	20.9	19.7	18.8	18.5	18.3	18.3	18.3	18.3
HR	75	70	71	72	70	72	70	72
Resp	14	14	16	16	17	17	16	15

SUBJECT #6 Age: 27 Surface Area: 1.83 Sq. M Temperature: 25.5°C Hood #000247

	0	1	2	3	4	5	6	6.47
% CO_2	.03	2.2	3.2	3.5	3.6	3.7	3.7	3.7
% O_2	20.9	19.3	17.9	17.2	17.0	16.8	16.9	16.9
HR	77	72	71	76	75	75	74	90
Resp	14	12	11	12	12	12	13	12

SUBJECT #7 Age: 24 Surface Area: 1.87 Sq. M Temperature: 25.5° C Hood #000252

	0	1	2	3	4	5	6	6.33
% CO_2	.03	2.2	2.9	2.9	2.9	2.9	3.8	3.5
% O_2	20.9	19.0	17.7	17.2	16.8	16.8	16.5	16.5
HR	61	60	56	58	58	58	59	60
Resp	13	17	19	22	23	24	23	24

TABLE 11.—DRAWSTRING HOOD—FEMALE—NORMAL TEMPERATURE—RESTING

SUBJECT #29 Age: 17 Surface Area: 1.57 Sq. M Temperature: 27°C Hood #000329

	TIME—MINUTES							
	0	1	2	3	4	5	6	6.25
% CO_2	.03	1.1	2.3	3.0	3.0	3.0	3.0	3.0
% O_2	20.9	20.1	18.3	17.5	17.7	17.4	17.7	17.7
HR	80	78	80	76	78	76	76	80
Resp	22	20	21	20	19	24	24	24

SUBJECT #28 Age: 23 Surface Area: 1.51 Sq. M Temperature: 27°C Hood #000282

	0	1	2	3	4	5	6	6.43
% CO_2	.03	1.0	1.8	1.8	1.8	1.8	1.8	1.8
% O_2	20.9	20.1	19.3	19.3	19.3	19.2	19.3	19.3
HR	88	86	82	76	84	80	80	90
Resp	—	15	16	16	17	17	18	20

SUBJECT #5 Age: 25 Surface Area: 1.56 Sq. M Temperature: 25.5° C Hood #000327

	0	1	2	3	4	5	6	6.43
% CO_2	.03	1.6	2.5	2.5	2.4	3.1	2.5	1.9
% O_2	20.9	19.8	18.9	18.6	18.5	18.2	18.5	18.4
HR	82	91	87	85	83	81	81	81
Resp	22	20	22	19	21	20	22	24

SUBJECT #2 Age: 25 Surface Area: 1.71 Sq. M Temperature: 26°C Hood #000239

	0	1	2	3	4	4.50
% CO_2	.03	1.5	2.5	2.6	2.6	2.6
% O_2	20.9	19.6	18.8	18.8	18.7	18.7
HR	86	97	95	84	81	84
Resp	19	26	26	21	18	26

SUBJECT #39 Age: 21 Surface Area: 1.44 Sq. M Temperature: 26° C Hood #000282

	0	1	2	3	4	5	6	7	8	9	10.50
% CO_2	.03	1.2	2.3	3.7	4.4	4.4	4.7	5.1	5.0	5.3	5.3
% O_2	20.9	19.9	18.2	16.7	15.5	15.0	14.8	14.5	14.5	14.5	14.2
HR	74	72	70	88	70	72	74	78	78	74	74
Resp	20	12	16	15	18	18	17	20	18	19	19

TABLE 12.—DRAWSTRING HOOD—MALE—NORMAL TEMPERATURE—EXERCISING

SUBJECT #9 Age: 22 Surface Area: 1.89 Sq. M Temperature: 26°C Hood #000282

TIME—MINUTES

	0	1	2	3	4	5	6.00
% CO_2	.03	3.1	4.4	4.4	4.7	4.7	4.7
% O_2	20.9	18.7	16.7	16.2	15.5	14.8	14.7
HR	90	104	121	122	125	128	127
Resp	15	20	18	20	20	22	22

SUBJECT #12 Age: 22 Surface Area: 1.99 Sq. M Temperature: 26°C Hood #000327

	0	1	2	3	4	5	6	6.43
% CO_2	.03	2.7	2.9	2.7	2.8	2.7	2.8	3.3
% O_2	20.9	18.5	17.5	17.5	17.8	17.6	17.6	17.5
HR	112	124	122	122	124	123	125	120
Resp	14	20	19	16	14	18	16	15

SUBJECT #27 Age: 21 Surface Area: 2.01 Sq. M Temperature: 27°C Hood #000380

	0	1	2	3	4	5	6.05
% CO_2	.03	1.2	1.8	2.2	3.0	2.4	2.4
% O_2	20.9	19.8	18.5	18.0	17.3	17.3	17.5
HR	74	79	87	89	93	95	94
Resp	18	15	16	17	19	21	19

SUBJECT #30 Age: 19 Surface Area: 1.91 Sq. M Temperature: 27°C Hood #000239

	0	1	2	3	4	5	6	6.18
% CO_2	.03	2.6	4.1	5.2	5.9	5.9	5.9	5.9
% O_2	20.9	17.8	15.6	14.2	14.0	14.2	14.2	14.2
HR	82	82	96	104	106	106	110	112
Resp	15	15	16	18	20	19	22	24

SUBJECT #31 Age: 28 Surface Area: 1.83 Sq. M Temperature: 27° C Hood #000361

	0	1	2	3	4	5	6.30
% CO_2	.03	1.9	3.2	3.5	3.5	3.2	3.2
% O_2	20.9	18.0	16.7	16.2	16.2	17.1	17.1
HR	82	80	90	94	96	92	96
Resp	——	25	24	26	27	28	29

TABLE 13.—DRAWSTRING HOOD—FEMALE—NORMAL TEMPERATURE—EXERCISING

SUBJECT #8 | Age: 25 | Surface Area: 1.73 Sq. M | Temperature: 26°C | Hood #000252

	TIME—MINUTES							
	0	1	2	3	4	5	6	6.23
% CO_2	.03	2.3	3.1	3.1	3.2	3.2	3.2	3.2
% O_2	20.9	18.7	17.5	17.5	17.6	17.6	17.5	17.5
HR	97	117	135	146	143	149	151	144
Resp	17	19	23	25	26	27	35	36

SUBJECT #13 | Age: 22 | Surface Area: 1.69 Sq. M | Ttemperature: 25°C | Hood #000239

	0	1	2	2.50
% CO_2	.03	3.9	6.7	8.0
% O_2	20.9	17.8	13.0	10.4
HR	86	114	126	112
Resp	18	15	22	24

SUBJECT #11 | Age: 24 | Surface Area: 1.61 Sq. M | Temperature: 26°C | Hood #000247

	0	1	2	3	3.17
% CO_2	.03	3.4	4.3	5.0	5.0
% O_2	20.9	17.1	13.9	11.8	11.8
HR	121	138	125	132	
Resp	17	12	18	23	

SUBJECT #10 | Age: 27 | Surface Area: 1.64 Sq. M | Temperature: 26°C | Hood #000380

	0	1	2	3	4	5	6	6.18
% CO_2	.03	2.6	2.6	3.3	3.0	3.6	3.6	3.0
% O_2	20.9	19.0	17.7	17.3	17.4	17.4	16.9	16.9
HR	88	96	105	116	121	125	128	
Resp	20	20	22	22	24	24	24	

SUBJECT #36 | Age: 22 | Surface Area: 1.56 Sq. M | Temperature: 27°C | Hood #000270

	0	1	2	3	3.68
% CO_2	.03	2.2	3.3	4.3	4.4
% O_2	20.9	19.8	16.9	15.4	14.7
HR	82	102	118	120	96
Resp	23	20	18	24	26

TABLE 14.—DRAWSTRING HOOD—MALE—ELEVATED TEMPERATURE—RESTING

SUBJECT #15 Age: 28 Surface Area: 1.83 Sq. M Temperature: 59°C Hood #000361

	TIME—MINUTES						
	0	1	2	3	4	5	6.17
% CO_2	.03	2.9	4.3	4.4	5.8	5.8	5.8
% O_2	20.9	18.1	16.5	15.9	15.3	14.9	14.6
HR	—	85	84	86	90	94	94
Resp	—	18	13	13	13	15	14

SUBJECT #17 Age: 20 Surface Area: 1.91 Sq. M Temperature: 57°C Hood #000270

	0	1	2	3	4	5	6	6.43
% CO_2	.03	3.0	3.0	3.0	3.4	3.2	3.4	3.4
% O_2	20.9	19.2	18.4	18.2	18.0	18.1	18.0	18.0
HR	94	98	96	94	96	98	96	100
Resp	16	14	13	13	12	12	14	10

SUBJECT #18 Age: 25 Surface Area: 2.12 Sq. M Temperature: 56°C Hood #000327

	0	1	2	3	4	5	6	6.33
% CO_2	.03	2.9	4.3	4.3	4.3	4.3	4.3	4.3
% O_2	20.0	18.5	17.1	16.3	16.5	16.5	16.4	16.4
HR	70	78	76	78	82	78	80	80
Resp	—	16	14	13	13	12	13	15

SUBJECT #32 Age: 22 Surface Area: 1.77 Sq. M Temperature: 60°C Hood #000252

	0	1	2	3	4	5	6.08
% CO_2	.03	2.2	2.8	3.0	3.6	3.2	3.5
% O_2	20.9	19.3	18.3	17.9	17.8	18.2	18.2
HR	80	74	74	76	78	80	82
Resp	—	10	11	11	11	11	12

SUBJECT #33 Age: 25 Surface Area: 2.18 Sq. M Temperature: 60°C Hood #000327

	0	1	2	3	4	5	6	6.30
% CO_2	.03	2.8	2.8	3.0	3.0	2.8	2.8	3.0
% O_2	20.9	19.6	18.8	18.1	18.1	18.3	18.5	18.6
HR	96	94	90	92	90	94	94	92
Resp	10	9	6	7	11	16	15	16

TABLE 15.—DRAWSTRING HOOD—FEMALE—ELEVATED TEMPERATURE—RESTING

SUBJECT #40 Age: 26 Surface Area: 1.54 Sq. M Temperature: 60°C Hood #000252

	0	1	2	3	4	5	6	7	8	9	9.53
% CO_2	.03	1.2	2.1	3.1	3.4	3.8	4.1	3.4	3.2	3.4	3.4
% O_2	20.9	19.6	18.7	17.7	17.4	17.4	17.4	17.6	18.2	18.2	18.2
HR	80	78	86	86	84	84	90	94	92	94	94
Resp	14	—	—	18	16	16	16	18	17	17	11

SUBJECT #20 Age: 27 Surface Area: 1.52 Sq. M Temperature: 60°C Hood #000252

	0	1	2	3	4	5	6	6.40
% CO_2	.03	1.7	2.4	2.8	2.8	2.8	2.8	2.8
% O_2	20.9	19.8	18.8	18.3	18.1	18.1	18.1	18.1
HR	86	86	86	88	90	90	94	92
Resp	—	11	13	13	13	13	12	12

SUBJECT #19 Age: 21 Surface Area: 1.32 Sq. M Temperature: 59°C Hood #000360

	0	1	2	3	4	5	6	6.22
% CO_2	.03	2.2	2.7	3.8	3.8	3.8	3.8	3.8
% O_2	20.9	20.0	18.7	17.9	17.6	17.6	17.3	17.3
HR	106	104	102	100	100	100	100	116
Resp	—	13	11	11	15	15	16	26

SUBJECT #16 Age: 28 Surface Area: 1.76 Sq. M Temperature: 57° C Hood #000329

	0	1	2	3	4	5	6	6.28
% CO_2	.03	2.7	2.7	3.1	3.1	3.1	3.1	3.1
% O_2	20.9	18.6	17.9	17.3	17.2	17.3	17.3	17.3
HR	—	98	80	92	90	91	90	96
Resp	—	13	14	13	14	13	14	16

SUBJECT #14 Age: 40 Surface Area: 1.84 Sq. M Temperature: 55°C Hood #000360

	0	1	2	3	4	5	6.05
% CO_2	.03	2.2	2.9	2.9	3.0	2.7	2.8
% O_2	20.9	19.2	17.6	17.3	17.3	17.8	17.8
HR	—	81	79	79	81	80	88
Resp	—	22	18	17	18	15	18

TABLE 16.—DRAWSTRING HOOD—MALE—ELEVATED TEMPERATURE—EXERCISING

SUBJECT #21 Age: 22 Surface Area: 1.86 Sq. M Temperature: 59°C Hood #000239

	TIME—MINUTES							
	0	1	2	3	4	5	6	6.18
% CO_2	.03	4.9	6.1	6.6	6.7	6.7	6.7	6.7
% O_2	20.9	17.0	13.6	12.3	11.8	12.3	12.3	12.3
HR	154	152	154	162	164	166	176	
Resp	12	13	18	24	24	26	36	

SUBJECT #22 Age: 21 Surface Area: 1.96 Sq. M Temperature: 61°C Hood #000247

	0	1	2	3	4	5	6	6.33
% CO_2	.03	2.4	2.2	2.2	2.8	2.8	2.8	2.8
% O_2	20.9	18.9	18.4	18.3	18.1	17.8	17.5	17.5
HR	108	124	122	122	126	122	126	136
Resp	—	18	19	17	18	19	19	20

SUBJECT #23 Age: 22 Surface Area: 2.05 Sq. M Temperature: 62.5°C Hood #000282

	0	1	2	2.80
% CO_2	.03	2.8	3.9	6.5
% O_2	20.9	17.5	15.3	13.5
HR	102	108	128	140
Resp	18	12	16	26

SUBJECT #24 Age: 22 Surface Area: 2.12 Sq. M Temperature: 60°C Hood #000380

	0	1	2	3	4	4.53
% CO_2	.03	5.3	6.7	6.7	6.7	6.7
% O_2	20.9	16.4	11.0	9.0	8.9	8.9
HR	108	126	134	142	160	164
Resp	22	20	29	37	40	42

SUBJECT #25 Age: 21 Surface Area: 1.87 Sq. M Temperature: 60°C Hood #000361

	0	1	2	3	4	5	6	6.25
% CO_2	.03	3.2	3.3	3.9	3.3	3.3	3.3	3.3
% O_2	20.9	18.7	17.9	17.7	17.4	17.9	18.1	17.6
HR	106	108	120	122	128	134	140	144
Resp	16	14	9	9	13	12	12	22

Table 17.—DRAWSTRING HOOD—FEMALE—ELEVATED TEMPERATURE—EXERCISING

SUBJECT #26 Age: 22 Surface Area: 1.65 Sq. M Temperature: 60°C Hood #000329

	TIME—MINUTES							
	0	1	2	3	4	5	6	6.20
% CO_2	.03	1.7	3.8	3.6	4.4	4.4	7.6	4.4
% O_2	20.9	18.4	16.7	16.3	15.8	15.1	14.1	15.0
HR	—	94	106	114	116	126	—	132
Resp	—	23	21	24	23	27	28	30

SUBJECT #34 Age: 21 Surface Area: 1.63 Sq. M Temperature: 60°C Hood #000247

	0	1	2	3	4	5	6	6.33
% CO_2	.03	2.2	2.2	2.2	2.6	2.7	3.0	2.9
% O_2	20.9	19.2	18.2	17.8	18.0	18.0	17.9	17.8
HR	—	116	128	142	142	150	148	156
Resp	—	16	16	17	22	21	22	26

SUBJECT #35 Age: 21 Surface Area: 1.74 Sq. M Temperature: 60°C Hood #000360

	0	1	2	3	4	5	6	6.12
% CO_2	.03	3.0	0.1	0.3	0.1	3.0	1.0	3.0
% O_2	20.9	18.2	18.4	18.1	18.4	17.8	17.7	17.7
HR	120	144	158	166	170	178	184	
Resp	28	40	40	44	42	45	48	

SUBJECT #37 Age: 22 Surface Area: 1.73 Sq. M Temperature: 60°C Hood #000360

	0	1	2	3	4	5	6	6.22
% CO_2	.03	2.9	3.4	3.7	4.1	4.2	4.3	4.3
% O_2	20.9	18.4	16.8	16.6	16.6	16.4	16.4	16.4
HR	114	134	146	160	164	172	172	168
Resp	18	19	19	25	26	29	29	40

SUBJECT #38 Age: 22 Surface Area: 1.43 Sq. M Temperature: 60°C Hood #000247

	0	1	2	3	4	4.40
% CO_2	.03	2.4	3.7	4.4	4.4	4.4
% O_2	20.9	19.4	16.4	14.9	14.4	14.2
HR	112	134	150	158	160	160
Resp	30	24	23	25	28	31

APPENDIX B

Part 1. Briefings Groups 1 through 5

We would like to welcome you aboard International Flight #49, nonstop jet service from Oklahoma City to Chicago. Our flying time will be approximately 1 hour and 45 minutes and we will be flying at an altitude of approximately 28,000 feet.

We would now like to take a moment to point out the safety features of this aircraft. There are two exit doors in the forward cabin and two in the aft cabin, all equipped with slides. In addition, there are four window exits over the wings. Please refer to the information card located in the seat pocket in front of you for further information.

Individual oxygen masks are located in the compartment above your seat. In case of any rapid change in cabin pressure, an oxygen mask will drop down in front of you. Extinguish all cigarettes, grasp the cup, and pull it to your face. Put it over your nose and mouth, and breathe normally.

(Safety hood instructions inserted here. See Note A for the specific wording of each group's instructions.)

Please fasten your seatbelts now, and observe the no smoking sign until the captain turns it off. Also bring your chair backs and tray tables to an upright position for take-off.

We hope you have a pleasant flight. If we can do anything to make your trip more comfortable, please don't hesitate to call upon us.

NOTE A

Group 1. Safety hoods, located on the backs of the seat in front of you, have been provided for your added protection in the event of an emergency. Should an emergency evacuation be required, please put on these hoods, as the stewardess is now demonstrating, prior to departing the aircraft. Remove the hood when you are safely away from the aircraft.

Group 2. Safety hoods, located on the back of the seat in front of you, have been provided for your added protection in the event of an emergency. They are to be used only in the event of an emergency evacuation, or upon direction of a crew member. The stewardess will now demonstrate their use. To remove the hood from its package, pull up on either red tab. Open the hood to its maximum size by spreading the neck seal with your hands. Then quickly pull the hood down over your head. Remove the hood after you are safely away from the aircraft.

Group 3. Safety hoods, located on the back of the seat in front of you, have been provided for your added protection in the event of an emergency. They are to be used only in the event of an emergency evacuation, or upon direction of a crew member. The stewardess will now demonstrate their use. To remove the hood from its package, pull up on either red tab. Open the hood to its maximum size by spreading the neck seal with your hands and shaking it out as the stewardess is now doing to fill it with air. Then quickly pull the hood down over your head. Remove the hood after you are safely away from the aircraft.

Group 4. Safety hoods, located on the back of the seat in front of you, have been provided for your added protection in the event of an emergency. They are to be used only in the event of an emergency evacuation, or upon direction of a crew member. The stewardess will now demonstrate their use. To remove the hood from its package, pull up on either red tab. Open the hood to its maximum size by spreading the neck seal with your hands and shaking it out as the stewardess is now doing to fill it with air. Then quickly pull the hood down over your head as you would a shower cap. Remove the hood after you are safely away from the aircraft.

Group 5. Safety hoods, located on the backs of the seats in front of you, have been provided for your added protection in the event of an emergency. They are to be used in the event of an emergency evacuation, or upon direction of a crew member. The stewardess will now demonstrate their use. To remove the hood from its package, pull up on either red tab. Open the hood to its maximum size by spreading the neck seal with your hands and shaking it out as the stewardess is now doing to fill it with air. Then quickly pull the hood down over your head. For those of you wearing glasses you may find it easier to put the hood on the back of your head first, then pull the opening of the seal forward, stretching it to clear your glasses as the stewardess is now demonstrating. Remove the hood after you are safely away from the aircraft.

APPENDIX B

Part 2. Briefing for Group 6

We would like to welcome you aboard International Flight #49, nonstop jet service from Oklahoma City to Chicago. Our flying time will be approximately 1 hour and 45 minutes and we will be flying at an altitude of approximately 28,000 feet.

We would like to take a moment to point out the safety features of this aircraft. There are two exit doors in the forward cabin and two in the aft cabin, all equipped with slides. In addition, there are four window exits over the wings. To use the door mounted slides, lift the door handle up and push the door out, the slide will then automatically fall out. Pull the red handle on the slide to inflate it. It will then be ready to use.

The window exits are operated by pulling the cover open on top and grasping the red handle inside. Pull the handle inward and down. After grasping the handle and the bottom of the window, lift the window in, discarding it on the seat in front of the window area.

In the event of a water landing several safety devices are provided for you. Your life jacket is located under your seat. It fits over your head and the rear straps are fastened to the front and tightened. It is inflated after leaving the aircraft by pulling on the two black knobs. In addition, the cushion you are sitting on is designed to keep you afloat. Grasp it at the rear, pull it forward, and take it with you.

Individual oxygen masks are located in the compartment above your seat. In case of any rapid change in cabin pressure, an oxygen mask will drop down in front of you. Extinguish all cigarettes, grasp the cup, and pull it to your face. Put it over your nose and mouth, and breathe normally.

Safety hoods, located on the back of the seat in front of you, have been provided for your added protection in the event of an emergency. They are to be used only in the event of an emergency evacuation, or upon direction of a crew member. The stewardess will now demonstrate their use. To remove the hood from its package, pull up on either red tab. Open the hood to its maximum size by spreading the neck seal with your hands and shaking it out as the stewardess is now doing to fill it with air. Then quickly pull the hood down over your head as you would a shower cap. For those of you wearing glasses you may find it easier to put the hood on the back of your head first, then pull the opening of the seal forward, stretching it to clear your glasses as the stewardess is now demonstrating. Remove the hood after you are safely away from the aircraft.

Please fasten your seatbelts now, and observe the no smoking sign until the captain turns it off. Also bring your chair backs and tray tables to an upright position for take-off.

We hope you have a pleasant flight. If we can do anything to make your trip more comfortable, please don't hesitate to call upon us.

APPENDIX B

Part 3. Observer Rating Sheets

Subject name ____________________________. Group I, II, III, IV, V, VI

Subject number __________. Age __________. Sex M_________. F__________.

Education ____________________________. Physical Disabilities __________________.

Glasses Yes ________ No ________

1. Attention level during briefing.
   - (a) Attentive at all times.
   - (b) Attentive most of the time.
   - (c) Attentive about half of the time.
   - (d) Attentive for only a short time.
   - (e) Attentive at no time.
2. Time to put on hood from command ______________________________
3. Observed difficulties in donning the hood.
   - (a) Removing from packet.
   - (b) Finding neck seal.
   - (c) Spreading neck seal.
   - (d) Filling with air.
   - (e) Pulling over head.
   - (f) Getting over hair.
   - (g) Getting over glasses.
   - (h) Getting over nose, mouth, or chin.
   - (i) Other (explain). ______________________________
4. Adjustments of hood after donning.
   - (a) Neck seal.
   - (b) Re-positioned hood.
   - (c) Tried to further inflate hood.
   - (d) Other (explain). ______________________________
5. Final fit of hood.
   - (a) Hood on, fully inflated.
   - (b) Hood on, partially inflated.
   - (c) Hood on, minimally inflated.
   - (d) Poor seal.
   - (e) Not able to put on.
   - (f) Other (explain). ______________________________
6. Observer's comments. ______________________________

APPENDIX B

Part 4. Questionnaire Part I

1. Were the instructions given by the stewardess clear with respect to use of the safety hoods?

   __________Yes __________No

   If your answer is no, please explain why below.

   ____

2. Please rate the hood as to comfort on the scale below.

very uncomfortable	moderately uncomfortable	neither comfortable or uncomfortable	moderately comfortable	very comfortable

3. Did you find the hood difficult to put on? __________Yes __________No

   If your answer is yes, please indicate the reasons for your difficulty below.

   (a) Getting over hair.
   (b) Getting over glasses.
   (c) Getting hood off.
   (d) Getting hood open.
   (e) Filling hood with air.
   (f) Spreading neck seal.
   (g) Getting out of storage packet.
   (h) Other (explain). ____

4. Did you have any negative feelings about using the safety hood?

   __________Yes __________No

   If your answer is yes, please indicate the reasons below.

   (a) Claustrophobic feeling.
   (b) Fear of shortage of air.
   (c) Reluctance to put "plastic" bag over head.
   (d) Began to feel panicky with hood on.
   (e) Other (explain). ____

5. If you were to be involved in an emergency in an aircraft, do you think you would use the safety hood if requested to do so?

   __________Yes __________No

APPENDIX B

Part 5. Briefing Questionnaire Part II

1. Do you think that the instructions given you would tend to raise your anxiety or make you feel uneasy prior to an actual flight?

   ________Yes ________No

   If you answered yes to question 1, what was it about the instructions that would have that effect?

   (Check as many as are applicable)

   (a) The language of the instructions.

   (b) The pointing out of possible emergencies.

   (c) The amount of material presented.

   (d) Other factors? (Please explain below.)

   ____

2. Have you ever flown in any aircraft before? ________Yes ________No

   If the answer to question 2 is yes, please answer the questions under (a); if the answer is no, please answer those under (b).

   (a) For those who have flown before.

   (1) What were your reactions prior to your first flying experience? (Please mark the point on the scale below which *best* describes your feelings.)

Extremely tense and uneasy	Moderately tense and uneasy	Some anticipation and excitement but no fear	Moderately at ease and relaxed	Completely at ease and relaxed

   (2) Do you want to fly again?

Will never fly again	Would not like to fly again	Don't care if I fly again or not	Would like to fly again	Will fly again

   (3) How do you think you would feel prior to your next flight if it was to be on a commercial airliner?

Extremely tense and uneasy	Moderately tense and uneasy	Some anticipation and excitement but no fear	Moderately at ease and relaxed	Completely at ease and relaxed

   (b) For those who have not flown.

(1) How do you think you would feel prior to your first flight?

Extremely tense and uneasy	Moderately tense and uneasy	Some anticipation and excitement but no fear	Moderately at ease and relaxed	Completely at ease and relaxed

(2) Do you plan to fly in the future? ______Yes ______No

(3) Why haven't you flown up to now?

(a) No opportunity.

(b) Fear of flying.

(c) High cost of air travel.

(d) Other. (Please explain below.)

3. How many exit doors were there in the aircraft?

(a) 8

(b) 6

(c) 4

(d) 10

4. Where were they located?

(a) Two in forward cabin, two in aft cabin, and four over wings.

(b) Two in forward cabin, two in aft cabin, and two over wings.

(c) Two in forward cabin, two in aft cabin.

(d) Two in forward cabin, two in aft cabin, two in galley, and 4 over wings.

5. How many doors were equipped with slides?

(a) Two in forward cabin, two in aft cabin.

(b) Two in forward cabin, two in aft cabin, two in galley.

(c) Two in forward cabin.

(d) Two in aft cabin.

6. Further information on using emergency doors was availabe (G1 thru G5 only)

(a) At the doors.

(b) From the stewardess.

(c) On the information card in the seat pocket.

7. To use door mounted slides (G6 only)

(a) Just open the door and the slide will fall into place ready for use.

(b) Pull the red handle to inflate the slide, then open the door.

(c) Open the door then pull the red handle to inflate the slide.

8. To use window exits (G6 only)

(a) Grasp the window, top and bottom, then throw it out in front of you.

(b) Pull the cover open on the top, pull the red handle inward and down, and holding the bottom of the window, lift it in and set aside.

(c) Pull cover open, lift the top and bottom parts in and set it aside.
(d) Pull the cover open on the top, pull the red handle inward and up, and holding the bottom of the window, lift it in and set it aside.

9. In a water landing you are supplied (G6 only)
   (a) A life jacket.
   (b) A flotation cushion.
   (c) A life raft.
   (d) A life jacket and flotation cushion.

10. To put on a life jacket (G6 only)
    (a) Put it around your body and snap the neck fasteners.
    (b) Pull it over your head.
    (c) Put it around your waist and fasten the top straps.
    (d) Put it over your head and fasten the rear straps to the front.

11. To inflate the life jacket (G6 only)
    (a) Pull the red handle.
    (b) Put it on, it will inflate automatically in the water.
    (c) Pull the two black knobs.

12. To take out the flotation cushion (G6 only)
    (a) Tilt the seat back, then pull the front up.
    (b) Pull up on the front and rear at the same time.
    (c) Take hold of the rear of the cushion and pull it forward.

13. Individual oxygen masks are for use if
    (a) There is a crash.
    (b) There is fire and smoke.
    (c) The cabin loses pressure.
    (d) Your stomach gets upset.

14. If an oxygen mask drops in front of you, you should
    (a) Extinguish all cigarettes, grasp the cup, pull it to your face, place it over your nose and mouth, and breathe normally.
    (b) Pull the cup to your face, put it over your nose and breathe normally.
    (c) Pull the cup to your face, place it over your nose and mouth, and breathe normally.
    (d) Wait for a stewardess to give instructions.

15. Safety hoods are located
    (a) Under your seat.
    (b) In the compartment above your seat.
    (c) In your headrest.
    (d) In the back of the seat in front of you.

16. Safety hoods are for use

(a) When oxygen level drops.
(b) When an emergency evacuation is required.
(c) When you feel airsick.

17. To remove the hood from its package and open it you (G2 thru G6 only)

(a) Pull the red tab and unfold the hood.
(b) Pull the red tab and spread the neck seal with your hands.
(c) Pull the red tab and put the hood over your head quickly.
(d) Pull the red tab, unfold the hood, pull it quickly over your head.

18. To fill the hood with air you (G3 thru G6 only)

(a) Pull it quickly and hard over your head.
(b) Unfold it and blow in it.
(c) Put it over your head and fluff it out.
(d) Shake it out.

19. If you wear glasses the easiest way to put on the hoods is (G5 & G6 only)

(a) To pull it over your chin, then back over your head.
(b) To stretch the seal as far as it will go pulling it over your head.
(c) To put it on the back of your head, then pull it over your glasses by stretching it with your hands.
(d) By putting it on like a shower cap.

20. You should wear your hood, if needed, until

(a) The stewardess tells you to take them off.
(b) You can barely breathe.
(c) You can no longer see any smoke.
(d) You are safely away from the aircraft.

21. When taking off you should

(a) Fasten your seatbelt, put out your cigarettes, and bring your chairback and your tray tables upright.
(b) Fasten your seatbelt, and bring your chairback and tray table upright.
(c) Fasten your seatbelt, put out your cigarettes, and bring your tray table upright.
(d) Extinguish your cigarettes, and bring your chairback and tray table upright.