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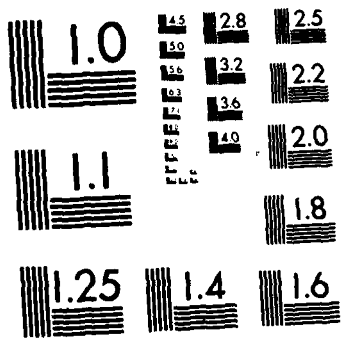

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THE OBJECTIVE EVALUATION OF AIRCREW PROTECTIVE BREATHING EQUIPMENT: V. MASK/GOGGLES COMBINATIONS FOR FEMALE CREWMEMBERS

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16. Abstract

A study was conducted to determine the degree of respiratory and visual protection given to the female crewmember by various crew oxygen mask/goggle combinations. The acceptance criteria for the mask/goggle combinations were for 10 of 12 test subjects to maintain a contaminant ratio of 0.05 or less in the oxygen mask and/or simultaneously 0.1 or less in the goggle while wearing eyeglasses. Of the 23 mask/goggle combinations tested with female subjects, 8 failed to meet the acceptance criteria for adequate protection. Comparison tests on anthropometric data from male and female subjects suggest that the failures may be due, in part, to size differences in cranial and facial dimensions.

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THE OBJECTIVE EVALUATION OF AIRCREW PROTECTIVE BREATHING EQUIPMENT: V. MASK/GOGGLES COMBINATIONS FOR FEMALE CREWMEMBERS

INTRODUCTION

The requirements for protective breathing devices and the rationale for equipment selection have been reviewed in previous publications (1,2,3,4). These same publications also presented the results of contaminant leak testing of 118 mask/goggles combinations designed for use by flight deck crewmembers. The acceptance criteria for the mask/goggles combinations were for 10 of 12 test subjects to maintain a contaminant ratio of 0.05 or less in the oxygen mask and/or simultaneously 0.1 or less in the goggles while wearing eyeglasses (2,4). These criteria were developed at joint meetings between the Federal Aviation Administration (FAA) and industry representatives held in Los Angeles, California, August 1974, and in Washington, D.C., September 1974 (5). Of the 118 mask/goggles combinations tested, 106 failed to meet the acceptance criteria. These tests demonstrated the necessity for venting the goggles, the need for application of some amount of positive pressure within the equipment, very high cylinder drainage rates for most combinations tested with positive pressure, and significant donning problems for goggles equipped with venting tubes.

At the request of the FAA Flight Standards Service, the testing program was continued to support the development of protective breathing devices that would meet the approved performance criteria. As a result of this test program, several major manufacturers and suppliers of oxygen mask/goggles combinations initiated developmental programs in an effort to correct the identified deficiencies.

This report presents the results of an evaluation made to determine the effectiveness of 23 mask/goggles/regulator combinations in providing protection for the female crewmember. Criteria evaluated include pass/fail ratios for the various combinations, cylinder drainage rates, and the influence of regulator delivery pressure on cylinder drainage. Since females generally have smaller facial dimensions than do males, and since most mask/goggles combinations are sized to fit the male face, a comparison between selected anthropometric parameters was made to determine the influence of face size on the pass/fail ratio of the various combinations tested.

METHODS

The general analytical method developed for testing of protective breathing equipment has been described elsewhere (4). Briefly, a simple exposure chamber of sufficient size to accommodate a subject and the equipment to be tested was used to contain the challenge atmosphere of 120 ppm n-pentane. Small needles were inserted into the protective breathing device and the goggles to provide for the collection of gas samples from specific locations. Small-bore flexible tubing, passed through the chamber wall, connected the sample needles to a selector valve located outside the chamber. The sample gas was drawn through a twin-loop collector valve where a known aliquot was collected and delivered to a gas chromatograph equipped with a hydrogen flame ionization detector. Nonexaggerated eyeglasses were worn by all subjects during testing. American Optical Corporation frames F9848SM, ranging in size from 46 x 20 mm to 48 x 22 mm, with plano lenses were used.

The subject population consisted of 23 females trained in test procedures and equipment use. Selected anthropometric measurements were taken for each subject and compared to measurements made on male subjects in prior evaluation tests (4). Eleven types of oxygen masks and five types of goggles were tested. All of these devices were designed for use with some amount of positive pressure applied to the mask. Four aircraft oxygen regulators, two mask-mounted and two panel-mounted, were used to provide pressure to the masks.

The protective breathing devices submitted by the Robertshaw Controls Company consisted of standard aviator's crew oxygen masks, goggles equipped with venting tubes that require positioning within the cone of the oxygen mask, and a Robertshaw mask-mounted regulator. The goggles (two pairs) differed only in the suspension strap--one pair having an adjustable head strap, and the other pair having a nonadjustable strap. The venting tubes included internal soft wires which provided for forming and positioning the tubes. In addition, the venting tubes had flow orifices approximately 1 in from the tube ends.

The devices submitted by the Sierra Engineering Company consisted of standard Sierra crew oxygen masks and a prototype, S/N 358-1028V, designed to fit the smaller dimensions of the female face. All masks were modified to include manually activated flow valves in the upper portion of the nose cups. These valves, when opened, and with positive pressure applied to the mask, directed a venting flow of air into the goggles. The goggles were a standard Sierra product. A Robertshaw mask-mounted regulator and two Bendix panel-mounted regulators were used for testing Sierra equipment.

The devices submitted by the Puritan Equipment Company consisted of standard Puritan crew oxygen masks modified to include automatically activated flow valves in the upper portion of the nose cups. These valves, when opened by the pressure of the goggles and with positive pressure applied to the mask, directed a venting flow into the goggles. The goggles were a new Puritan product. A Robertshaw mask-mounted regulator and two Bendix panel-mounted regulators were used for testing the equipment.

The protective breathing devices submitted by the Scott Company consisted of an Eros mask provided with a mask-mounted regulator and a manually activated valve which provided venting to the goggles. The mask is of a quick-don type which utilizes the aircraft oxygen system to inflate an expandable harness by means of a triggering mechanism positioned under the nose cup. The harness is then slipped over the head and the triggering mechanism released, resulting in a deflation of the harness which secures the mask to the face. The goggles provided were an experimental model designed specifically to fit the mask.

RESULTS

Of the 23 mask/goggles combinations tested, 8 failed to meet the accepted criteria of maintaining a contaminant ratio of less than 0.1 for the goggles and simultaneously 0.05 in the mask when there were 3 failures in 12 or fewer tests (Table 1). All of these failures were attributed to failures in the goggles. Several identifiable factors contributed to these failures.

TABLE 1. Types of Mask/Goggles Combinations Tested and a Summary of the Results

Mask P/N	Goggles P/N	Regulator	Pressure in H_2O*	Pass/Fail	Cylinder Drainage (L/min)
Robertshaw Controls Company					
595-900-051	595-900-058	Robertshaw	1.7	11/1	15.2
595-900-051	595-900-057	Robertshaw	1.7	11/1	11.3
595-900-049-01	595-900-058	Robertshaw	1.7	11/1	10.7
595-900-049-01	595-900-057	Robertshaw	1.7	10/2	12.3
595-900-046	595-900-058	Robertshaw	1.7	11/1	9.6
595-900-046	595-900-057	Robertshaw	1.7	11/2	9.5
595-900-029	595-900-058	Robertshaw	1.7	12/0	12.7
595-900-029	595-900-057	Robertshaw	1.7	12/0	11.0
Sierra Engineering Company					
358-1028V**	322-01	Robertshaw	1.7	12/0	10.2
358-1028V**	322-01	Bendix	1.5	11/1	9.3
358-1028V**	322-01	Bendix	3.5	9/3	15.9
358-1025	322-01	Robertshaw	1.7	10/2	9.3
358-1025	322-01	Bendix	1.5	10/2	8.3
358-1025	322-01	Bendix	3.5	10/2	11.0
358-1223	322-01	Robertshaw	1.7	8/4	12.6
358-1223	322-01	Bendix	1.5	8/4	8.8
358-1223	322-01	Bendix	3.5	8/4	18.7
Puritan Equipment Company					
114322-03	118072-01	Robertshaw	1.7	10/2	18.2
114120-51	118072-01	Bendix	1.5	4/6	10.3
114120-51	118072-01	Bendix	3.5	8/5	25.8
114020-40	118072-01	Robertshaw	1.7	8/4	10.4
114020-40	118072-01	Bendix	1.5	12/0	8.3
Scott Company					
Eros (MC-1022-EX)	36864-21 (MXP-210)	Eros	1.8	9/3	9.0

*1 in H_2O = 0.249 kN/M^2
**Not tested on male subjects

Among those noted most often were a failure of the goggles to mate with the contour of the oxygen mask, gaps caused by penetration of the eyeglasses frames at the goggles/temple interface, and improper goggles/face mating due to either goggles design or the facial dimensions of the subject.

It would appear that the data in Table 1 indicate a much higher failure rate for the 3.5 in H_2O pressure regulator than for the two lower pressures (1.5 and 1.7 in H_2O). But, in order to make meaningful comparisons for the failure rates between the highest pressure and the two lower pressures, the data should be evaluated only for those mask/goggles combinations tested using the highest pressure regulator and at least one of the two lower pressure regulators. There are four such mask/goggles combinations listed in the table. The results are summarized below.

Company	Mask P/N	Goggles P/N	Pass/Fail by Regulator Pressure 1.5	1.7	3.5
Sierra Engineering Company	358-1028V	322-01	11/1	12/0	9/3
			(The 3.5 pressure had the highest failure rate.)		
	358-1025	322-01	10/2	10/2	10/2
			(The failure rates were identical for all three pressures.)		
	358-1223	322-01	8/4	8/4	8/4
			(The failure rates were identical for all three pressures.)		
Puritan Equipment Company	114120-51	118072-01	4/6	N/A	8/5
			(The 3.5 pressure had the lower failure rate.)		

Thus, a higher failure rate for the 3.5 in pressure is evident in only one mask/goggles combination; it is the same for two combinations; and it is actually lower for one combination. Therefore, we cannot state that the failure rate for the highest pressure is consistently greater.

For all of the other mask/goggles combinations there were only one or two of the lower pressures used and no data were available from the highest pressure regulator. Therefore, no comparisons could be made. It is evident from the data, however, that those mask/goggles combinations which did not use the highest pressure regulator, had better pass/fail ratios than those combinations tested using the 3.5 in H_2O pressure regulator. But, because the lower pressures produced failure rates similar to the highest pressure's rates when tested with identical mask/goggles combinations, the amount of pressure delivered to the mask/goggles probably had little effect on the failure rate. The differences seen are most likely due to the differences in the design and the fit of the various mask/goggles combinations.

Comparisons of the facial and cranial dimensions of the female subjects used in this study (Table 2) to those of U.S. Air Force women (7) showed them to be generally within the 5th to 95th percentiles of the reference population. However, when the same data were compared to the anthropometric measurements of the group of male subjects used in the prior test to evaluate the mask/goggles/regulator combinations (4), it was found that the dimensions of the male face and cranium were larger for all selected parameters than those of the females, and that the differences were statistically significant at the $p < .05$ level (Table 3).

TABLE 2. Selected Anthropometric Measurements, in Millimeters, of Subject Population Compared to U.S. Air Force Women (1972)

Subject No.	Head Length	Head Breadth	Face Length	Face Breadth
1	200	148	108	126
2	181	139	109	123
3	193	156	105	136
4	184	155	109	135
5	191	145	108	128
6	188	140	112	126
7	184	140	111	127
8	193	148	111	134
9	195	151	104	136
10	183	144	100	127
11	190	150	115	134
12	189	145	118	131
13	186	141	113	124
14	185	142	113	130
15	187	140	113	128
16	179	147	106	134
17	180	147	107	136
18	192	154	103	141
19	197	147	114	130
20	175	142	101	128
21	192	149	120	135
22	197	149	108	138
23	189	144	109	122
U.S. Air Force Women (1972)				
5%	173	135	96	119
95%	195	155	117	138

TABLE 3. Comparison* of Selected Anthropometric Measurements, in Millimeters, of Female and Male Subjects

Parameter	N	Mean	S.D.	t	p
Head Length					
Female	23	188	6		
Male	12	198	4	4.93	<.05
Head Breadth					
Female	23	146	5		
Male	12	153	3	4.42	<.05
Face Length					
Female	23	109	5		
Male	12	120	7	5.32	<.05
Face Breadth					
Female	23	131	5		
Male	12	141	4	5.60	<.05

*Analysis of variance, two independent samples

SUMMARY

With modern aircraft operating at ever-increasing altitudes, the performance and facial fit of crew oxygen masks becomes more critical if acceptable protection is to be provided. In addition, the possibility of toxic cargo spills, or the possibility of in-flight fires with the release of toxic combustion products and smoke, make protection of the visual processes another important factor for consideration in the design of protective equipment for crewmembers. The increasing number of female pilots in the civil air fleet make it imperative that existing equipment, as well as new designs, be evaluated for their suitability and efficiency in affording protection to the female crewmember.

Several of the protective breathing devices included in this study that provided venting to the goggles by means of a valve incorporated into the mask have passed the proposed acceptance criteria, are reasonably easy to don, and do not cause high cylinder drainage rates. These systems have been designed so as not to compromise the oxygen mask when used for decompression purposes. Every protective breathing device that has passed the proposed acceptance criteria has required some amount of positive pressure within the device. Therefore, a regulator with positive pressure output probably should be included in the system and the regulator outlet pressure specified for a given system. If the regulator does not provide positive pressure

automatically, the crewmember should be trained to manually set the regulator to 100 percent oxygen and to positive (emergency) pressure.

Every mask/goggles combination tested in this study had passed the proposed acceptance criteria for male subjects in the prior study (6). The comparative statistical analyses of the anthropometric data gathered from male and female subjects suggest that improper sizing of protective equipment was the cause for failures. To provide adequate protection for both sexes will require: (1) equipment that will accommodate the different facial and cranial sizes, or (2) different sized equipment for the two groups.

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