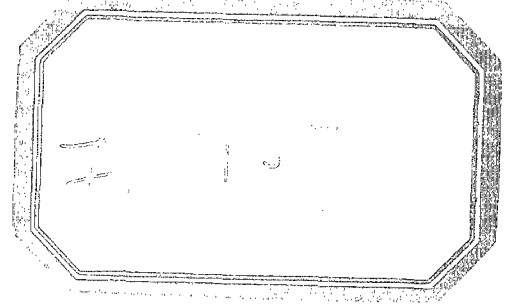


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ASD TECHNICAL REPORT 61-395



**DEVELOPMENT OF ORAL-NASAL MASKS,
OXYGEN, MC-1 AND MBU-5/P**

HENRY W. SEELER

LIFE SUPPORT SYSTEMS LABORATORY
AEROSPACE MEDICAL LABORATORY

AUGUST 1961

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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO



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HENRY W. SEELER

*LIFE SUPPORT SYSTEMS LABORATORY
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PROJECT No. 6352
TASK No. 63102

AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This development work was carried out under Project 6352, "Oxygen Dispensing Assemblies," Task 63102, "Oxygen Mask," and Contracts No. AF 33(600)-26382, AF 01(601)-20275, AF 33(600)-38997, and AF 33(600)-29804, with the General Tire and Rubber Company, Wabash, Indiana, as mask contractor, and the Sierra Engineering Company, Sierra Madre, California, as valve contractor.

Lt. Frank P. Soul and Mr. Milton Alexander from the Anthropology Section of the Aerospace Medical Laboratory accomplished the sizing program and a study of face contours to provide data for establishing the size and shape of the mask facepieces.

Mr. Robert D. McGuire, Mr. Konrad Weiswurm, and T/Sgt Robert S. Gray, of the Systems Branch, Life Support Systems Laboratory, Aerospace Medical Laboratory, have the author's highest gratitude for their valuable participation in making plastic face forms, dipping molds, mask samples, and modifications, and for conducting mask fittings on many Air Force pilots. Their suggestions and assistance in the development of the pressure-compensated, inhalation-exhalation valve and mask suspensions with quick-release mechanisms are greatly appreciated.

ABSTRACT

A small, lightweight, nonfreezing, oral-nasal, pressure-breathing oxygen mask for use at altitudes to 45,000 feet has been developed. The development program covered two masks, the single-size MC-1 mask and the four-size MBU-5/P mask. The one-size mask would not accommodate a large enough segment of the Air Force flying population. Pilots enthusiastically indorsed the MBU-5/P mask.

Each mask has a single, pressure-compensated, inhalation-exhalation valve as well as provisions for a small, lightweight, noise-suppressing microphone. A single-strap, self-oriented harness requiring only one buckle for adjustment was developed. An altitude-compensating, harness tension system and a quick-donning mask harness are described.

PUBLICATION REVIEW

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DEVELOPMENT OF ORAL-NASAL MASKS, OXYGEN, MC-1 AND MBU-5/P

INTRODUCTION

In 1954 work was begun on a lightweight, pressure-breathing oxygen mask for long-range, high-altitude flying. We hoped that the new mask would eliminate the fitting and comfort problems encountered with the MS-22001 (A-13A) mask. First, we investigated a one-size design (MC-1 mask). Later, a four-size mask (MBU-5/P) was developed. This report gives a brief description of the development of the two masks.

TYPE MC-1 OXYGEN MASK

One-Size Facepiece

The facepiece of the MC-1 mask is illustrated in figure 1. It was designed on the basis of the average facial configuration of 100 Air Force airmen. The lower sealing lip of the facepiece has the same radius as the chin, but in the opposite direction. With this sealing lip, the only fixed point for the mask fit was the bridge of the nose. The position of the facepiece against the chin depended upon the size and configuration of the wearer's face. Figure 1 shows the mask on a short face and a long face. The MC-1 mask facepiece was modified twice during the development program:

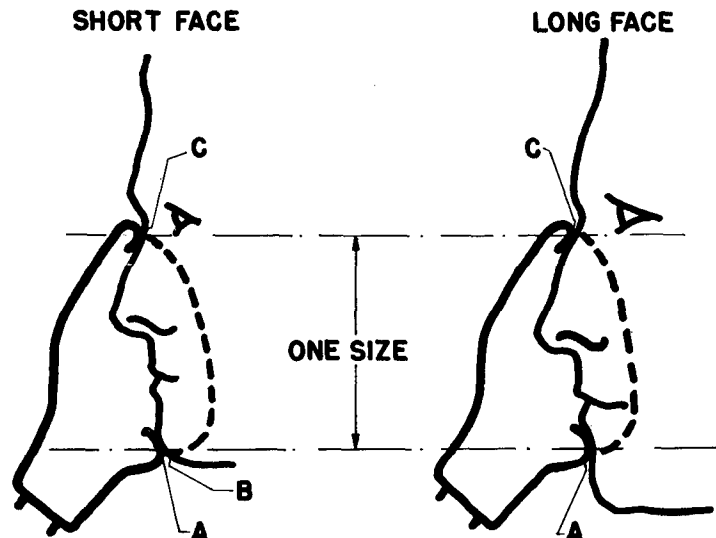


Figure 1. Facepiece, MC-1 Mask

a. The valve-supporting insert in the first design was too large and bulky. The angle between the face and mask permitted the mask to be pushed up on the face when the chin was lowered.

b. In the second design the smaller, valve-supporting insert and changed angle were not satisfactory. The face-sealing frame was too large.

First MC-1 Oxygen Mask

The first MC-1 mask was fabricated by Aeronautical Systems Division (ASD) personnel for a pilot whose facial configuration would not permit him to wear a standard mask. The facepiece was dipped* of latex and covered with a fiberglass shell (figure 2). The mask included one of the first pressure-compensated, inhalation-exhalation valves, and an ANB-M-C1 carbon microphone. The harness was made for temporary use only. This mask was worn successfully and satisfactorily until the dipped-latex facepiece disintegrated.

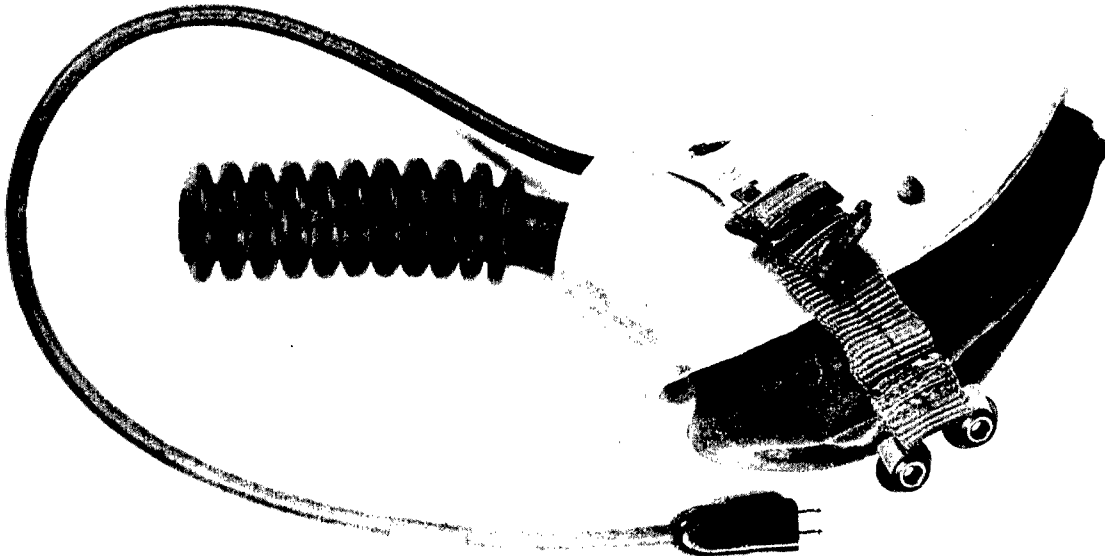


Figure 2. First MC-1 Mask

Mask Material

Under different contracts, one-size facepieces were produced for 156 test masks. Several were made by latex dipping. Silicone rubber, used for 56 of the masks, has properties far superior to any natural rubber compound. It has better resistance to high (225°F) and low (-100°F) temperatures, eliminates skin sensitization, perspiration, and skin oils, has practically no deteriorating effects if exposed to ozone, and can be worn many hours longer than any latex product. Reports indicate that no deformation or deterioration of the silicone facepiece occurs after more than 400 and, in some cases, up to 1200 flight hours, although latex pieces, used to connect the facepiece to the mask shell, deteriorate.

During the first years of the mask development, the silicone material had lower strength, especially lower tear resistance. This disadvantage was overcome by suitable indoctrination of airmen on the care of the mask. The silicone industry has since increased the strength and durability of the material.

*Dipped - The mask mold was repeatedly immersed in liquid latex and withdrawn at a controlled rate to "build up" the facepiece on the mold.

Pressure-Compensated, Inhalation-Exhalation Valve

To simplify and reduce size and weight, the three valves used in the MS-22001 mask (two inhalation and one exhalation) were combined into one pressure-compensated, inhalation-exhalation valve for use in the MC-1 mask. Figure 3 shows the valve during inhalation and exhalation (described in ASD Technical Report 61-396, ref. 5).

The location of the valve within the mask and the freezing of condensed water within the valve has been a problem in cold-temperature flying. The MC-1 mask structure was designed with a nonfreezing chamber, in which the valve is imbedded and cannot be exposed to freezing temperatures. The pressure-compensated, inhalation-exhalation valve is located in the lower part of the mask structure and is constantly in contact with warm exhalation air (figure 3).

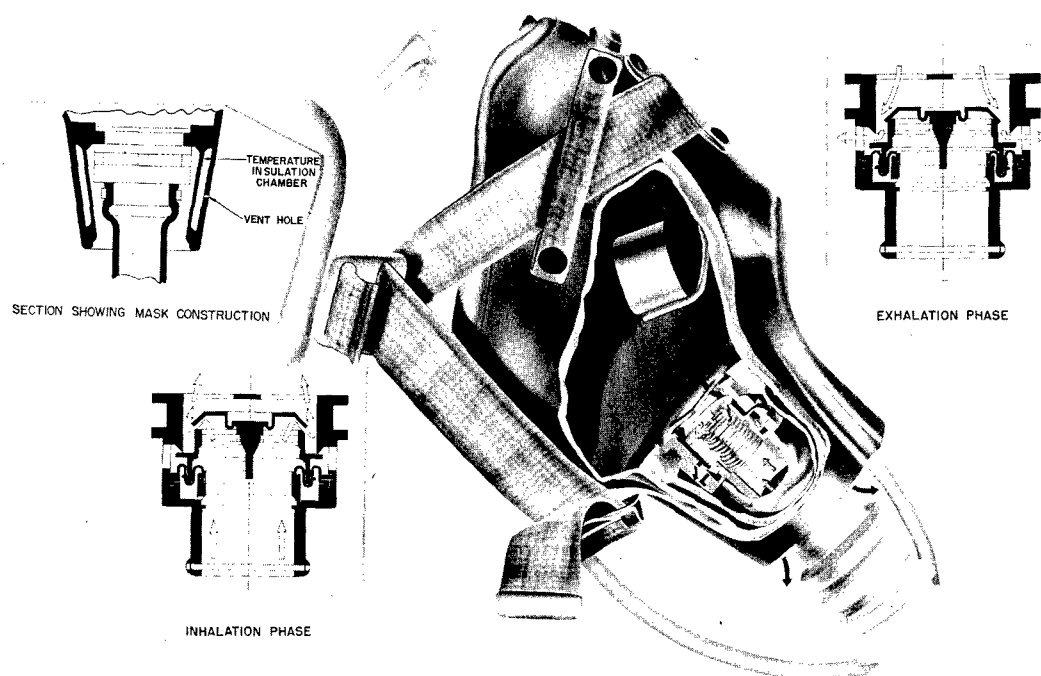


Figure 3. Pressure-Compensated, Inhalation-Exhalation Valve

Microphones

A smaller, lightweight microphone was needed to replace the M32/AIC, the modified M32/AIC, and the modified M33/AIC (figure 4). The M76/AIC microphone, capable of being adjusted to the wearer by bending a conduit between the microphone and mounting, was developed but proved unsatisfactory at high altitude. Another moving-coil, dynamic-type microphone was then modified to fit the MC-1 mask. After modification it was designated the M100/AIC microphone. During high-altitude chamber and flight tests, the M100/AIC proved highly superior to other available microphones.

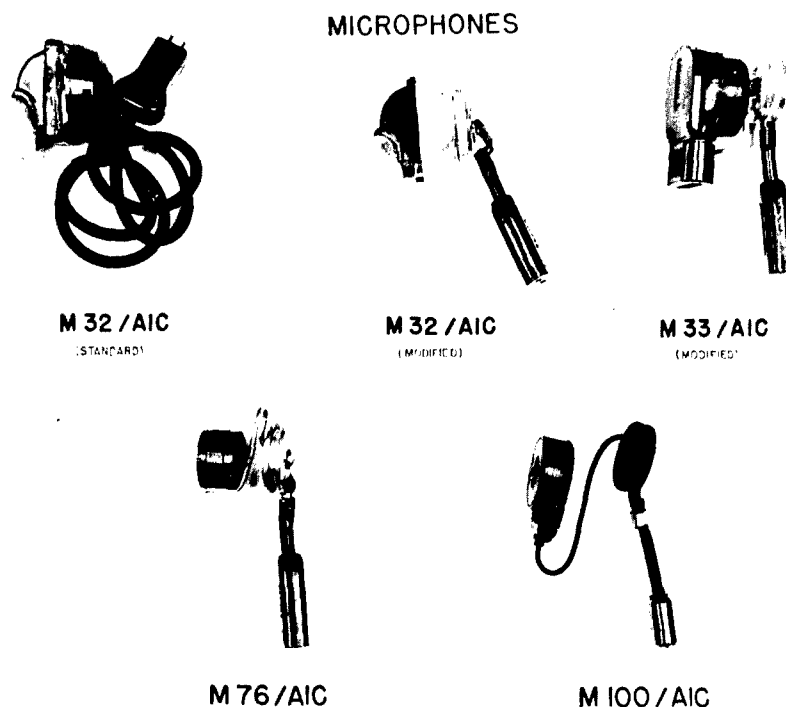


Figure 4. Microphones

Mask Harness

The objectives in the development of a harness for the MC-1 mask were:

- (a) A quick-donning, lightweight, easily adjustable harness
- (b) A harness that could be used by all pilots regardless of size or facial configuration
- (c) A harness that would remain in position under high g-loads and on exposure to windblast
- (d) A harness that would not interfere with the pilot's vision
- (e) A harness that would be compatible with the P-4 and HGU-2/P hardshell helmets

One design is shown in figure 5. The harness has, at the front of the mask, a lock with a cam-action type lever to permit adjusting the mask to any desired position and tension. To provide maximum comfort at low altitudes, where pressure breathing is not required, the lever is left in the up position (left view, figure 5). At higher altitudes, where the mask must provide a tight seal against the face, the lever is moved to the down position.

The harness design shown in figure 5 was received favorably by many pilots during flight testing. Several others, however, reported the mask would not remain stable during the g-forces encountered during flights and during tests conducted on the centrifuge. To overcome this deficiency, a new suspension was designed (figure 6). In this harness, a single strap was routed across the nose section of the mask shell, through the quick-release connectors, and under the mask shell chin section. A buckle was installed on the strap for adjusting the harness. The single strap allows the mask to be moved easily into position for a comfortable fit over the face. A lever for controlling the fit of the mask was not practical with this harness.



a. Lever in Up Position



b. Lever in Down Position

Figure 5. MC-1 Mask Harness Adjuster



a. Harness Suspension at Low Altitude



b. Harness Suspension at High Altitude

Figure 6. Altitude-Controlled Harness

For the attachment of the mask harness to the hardshell helmet a lightweight, quick-release connector was designed by ASD personnel (figure 7). In the first model the release mechanism was incorporated in the section of the connector which was permanently attached to the harness strap. In the final design, the release mechanism was incorporated in the section which snaps to the helmet. In both designs, the release mechanism is actuated by pressing the release tabs simultaneously with thumb and index finger. This releases the tongue of the connector and allows separation of the two sections.

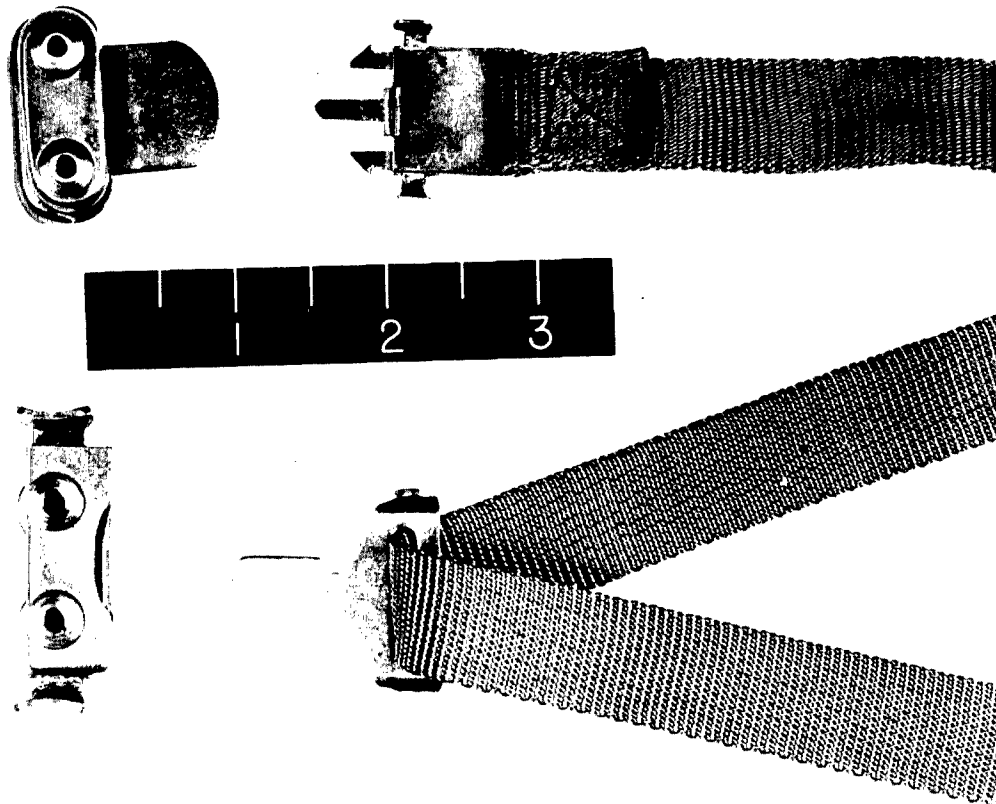


Figure 7. Mask-to-Helmet Connectors

Altitude-Controlled Harness

To eliminate manual adjustment of the mask to the face during flight, an altitude-compensated harness suspension is under development (ref. 3). A laboratory model to illustrate the technique is shown in figure 6. A closed cellular foam pad or a rubber bag partially filled with air, inserted in the rear interior of the flying headgear and connected to the mask harness, will expand at altitude and exert a tension on the mask harness to tighten the mask against the wearer's face. The tension will be reduced at a lower altitude. A squeeze bulb of the type shown in the laboratory model could be used for pressurizing the air bag. A suitable regulating device in the oxygen pressure-breathing system could serve the same purpose.

Headset and MC-1 Mask Combination

Figure 8 illustrates one way in which the MC-1 mask may be worn with a typical headset for long-range flying. In the figure, the pilot uses a No. 733 boom microphone. The mask is worn in a semirigid manner, resting near the left shoulder, ready for instant donning. Thus, the pilot is relieved of much of the mask's weight. The mask will only partially follow the pilot's head movements. This is more comfortable and convenient than a rigidly designed harness where the full weight of the mask hangs continuously on the headset and the mask follows every movement of the pilot's head.



Figure 8. MC-1 Mask and Boom Microphone

To connect or disconnect the electrical circuit to the boom and mask microphone, a micro-switch was inserted into the system. Lifting the mask moves the boom mike up and out of the way, disconnects the boom mike, and makes electrical connection with the mask mike. The sequence is reversed when the mask is lowered.

Centrifuge Tests

Centrifuge tests of up to 5.5 g were conducted on the MC-1 mask during the development program. The mask with the harness shown in figure 5 would slip from the wearer's nose when tested at 4.8 g. This arrangement, however, proved stable at 5.2 g after the mask shell was anchored to the hardshell helmet with a narrow strap of lightweight webbing. The strap passed above the nose and between the eyes. Many pilots stated that this method of anchoring the mask

interfered with their vision. More consideration should be given this arrangement since it has been used successfully by a major foreign Air Force for many years. The mask with the self-oriented, one-strap harness shown in figure 6 proved satisfactory when tested at 5.5 g. A strap to anchor the mask shell to the helmet would probably retain the mask at even higher accelerations.

The centrifuge tests revealed that under g-loads all masks tend to move on the nose. Heavy masks, which must be drawn tightly against the face to withstand the g-loads, numb the nose so that the movement is not apparent. The lightweight MC-1 mask, which requires much less harness tension than other masks, does not numb the nose. Consequently, every movement of the mask on the nose can be felt.

Windblast and Ejection Tests

The MC-1 mask (attached to a softshell helmet) withstood windblasts up to 582 knots on a test stand (figure 9). With a P-4 helmet, the MC-1 mask performed satisfactorily on an anthropomorphic dummy ejected from an F-94 aircraft flying at an altitude of 300 feet and a speed of 325 knots. The mask was not damaged or torn from position in either test.



Figure 9. Windblast Test Stand

While the tests indicate the MC-1 mask is satisfactory when subjected to windblasts and ejections of the magnitude shown, the results might have been different had human subjects been used in the testing in lieu of dummies. The resiliency of the human flesh and the breathing pressure inside the mask could have changed the performance of the mask. In actual service the performance of the mask during an emergency will be influenced by: (a) the type of ejection seat used, (b) the type of helmet worn, (c) the fit of the mask, (d) the tension of harness, (e) the magnitude and direction of forces against the mask-helmet combination, and (f) many other factors. Wind screens or capsules appear to be the only method for securing satisfactory mask-performance and retention during high-speed bailouts. To provide a lightweight mask that is easily adjustable and comfortable during hours of flight and that will also withstand the forces of high-velocity windblasts is regarded as an impossibility.

Flight Tests

Approximately 200 MC-1 oxygen masks were flight tested. The test reports revealed a great variance in the acceptability of the masks. Some pilots reported the mask as leakproof and comfortable; some felt insecure because of the small size of the mask. In many cases the reports were contradictory. The report prepared by the Air Proving Ground Command (ref. 2) was accepted as the most authoritative. A summary of the report follows:

Summary:

A. The MC-1 oxygen mask is satisfactory at all altitudes to 43,000 feet provided a suitable facial seal is obtained. Since the single-sized mask was not adaptable to all facial contours, and the mask had a tendency to slip down on the face during g-force maneuvers, various mask sizes and an improved harness are needed to correct these conditions. The mask caused no appreciable interference with vision while being worn, and the noise-canceling microphone was compatible with the communications systems of all aircraft in which the mask was tested. The mask required no unscheduled maintenance during the normal conduct of the test nor at extreme temperatures, except for the removal of the slight excess of adhesive which had formed around the inhalation-exhalation valve receptacle.

B. The MC-1 oxygen mask was more comfortable than the standard MS-22001 oxygen mask because of its lighter weight and smaller facial-covering area, and because it is not necessary to fit the mask tightly to effect a good seal.

TYPE MBU-5/P OXYGEN MASK

Four-Size Facepiece

Knowledge and skills gained during the MC-1 mask program were used to develop the MBU-5/P mask. The basic facepiece, shell, pressure-compensated, inhalation-exhalation valve, harness, and other components of the MC-1 mask were incorporated in the MBU-5/P mask. The difference between the two was primarily in the sizing. The MC-1 mask had a one-size facepiece and a one-size shell for all pilots. The MBU-5/P had four sizes of each.

Facepiece and Mask Shell

It became apparent during the testing of the MC-1 mask that one size would not be suitable for all pilots. Using the statistical data obtained during anthropometric sizing and fit-testing of the MC-1 mask (ref. 4), six face forms representing the Air Force flying population were constructed.

Further study revealed that four forms would be adequate for MBU-5/P mask sizing. The face forms were used to produce molds (figure 10) which were used in dipping the facepieces. After stripping the facepieces from the molds and curing them, the mask components—shell, valves, harness, etc.—were assembled. A mask shell was provided for each of the four sizes of facepieces. The shells are a semirigid plastic material.



Figure 10. Face Forms and Mask Mold

The MBU-5/P facepiece is illustrated in figure 11. Comparing it with the facepiece of the MC-1 mask shown in figure 1, a more positive seal can be attained with the MBU-5/P mask because the facepiece follows more closely the contour of the nose, cheeks, jaws, and chin. With the MC-1, there is only one point, the nasal root, on which the facepiece will fall on all individuals. With the MBU-5/P there are two points: the nasal root and the tip of the bottom of the chin. The distance between these points and the width of the mouth are used in sizing the MBU-5/P mask.

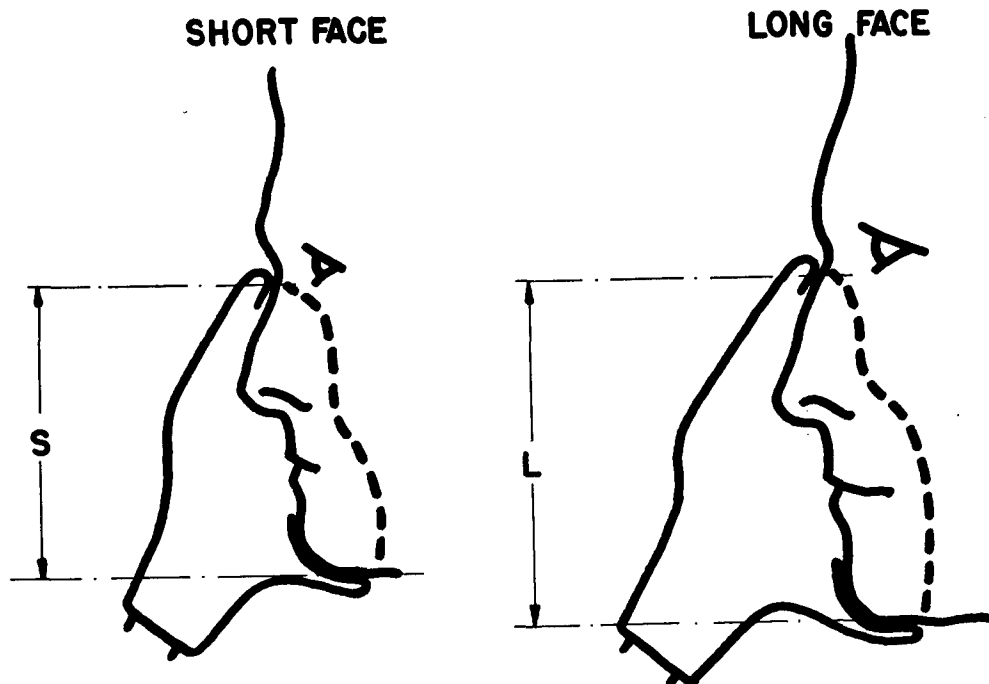


Figure 11. Facepiece, MBU-5/P Mask

On the basis of the above measurements the sizes listed below were established for the MBU-5/P mask. The percentages shown represent the distributions made to 600 pilots in a recent mask fit test.

Regular Narrow	45%
Regular Wide	25%
Long Narrow	20%
Short Narrow	10%

After the MBU-5/P mask was issued for service, about 1 out of 100 pilots could not wear any of the four sizes because of unusual facial configuration or deformations resulting from broken bones and scar tissue. For these pilots, custom-fitted masks must be provided when authorized by medical officers.

Harness

At the beginning of the MBU-5/P development program, the MC-1 harnesses shown in figures 6 and 8 were used. On flight-test maneuvers where g-loads were imposed, the harness strap would slip in the adjustment buckle and allow the mask to slip off the nose. To correct this, a different type of buckle was installed and the material for the strap was changed. In addition, the strap was moved down the mask to the front of the shell (figure 12). Moving the strap from "across the nose" to the "end of the nose" provided greater stability of the mask.



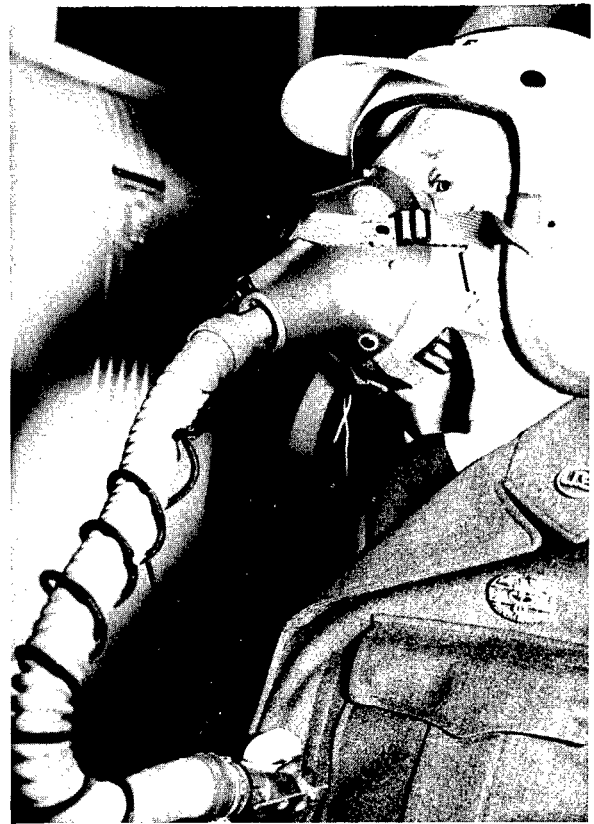
Figure 12. MBU-5/P Mask with Harness Arrestor and Inside Helmet Connector

The MBU-5/P mask can be worn off the face in the same manner as the MC-1 mask shown in figure 8 without interfering with the visibility or movements of the wearer. To keep the harness in its adjusted position after removal from the face, a spring-type arrestor was installed in the harness loop on the front of the mask shell. Pressing the arrestor will allow moving the mask on the harness so it will hang closer or farther from the face.

The MBU-5/P mask with a self-orienting, one-piece-strap, single-buckle harness (figure 13a) was compared with an identical mask with a proposed nonorienting, eight-piece-strap, four-buckle harness (figure 13b). The same test subject, helmet, and mask pressure were used in testing each harness. With the mask pressure set for breathing at an altitude of 45,000 feet, the self-oriented harness with a slight tension effected a comfortable leaktight seal between the mask and the face. To effect the required seal with the proposed harness, the four straps had to be pulled down so tightly that the mask was extremely uncomfortable, especially in the area of the chin strap. The wide spacing of the harness straps allowed the facepiece to balloon under the chin and at the cheeks.



a. Self-Orienting, One-Piece-Strap, Single-Buckle Harness



b. Nonorienting, Eight-Piece Strap, Four-Buckle Harness

Figure 13. Comparison of MBU-5/P Harnesses

Microphones

Virtually all MBU-5/P masks fabricated during the development program were equipped with the M32/AIC or M33/AIC microphone. Both had to be modified for installation in the masks (figure 4). A sufficient quantity of the smaller, lightweight M100/AIC microphone was not available. A few, however, were used in the flight test program. Figure 14 shows the M100/AIC microphone installed in an MBU-5/P mask.

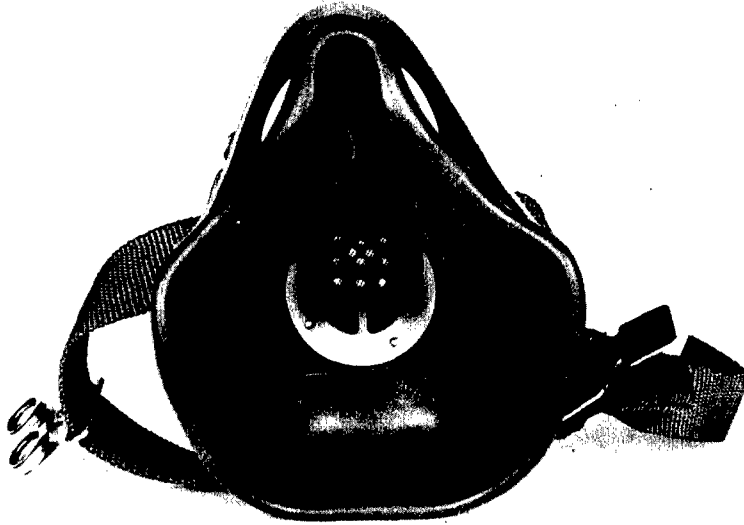


Figure 14. MBU-5/P Mask with M100/AIC Microphone

Flight Testing

To obtain data concerning service use and acceptability of the MBU-5/P mask, 400 were delivered to the Strategic Air Command for evaluation (ref. 1). The tests revealed that a majority of crew members enthusiastically endorsed the mask as being better than the MS-22001, extremely comfortable, or the best mask they had worn. Comfort with adequate pressurization seal and light weight made the mask extremely popular.

Proposed Mask-to-Helmet Connectors

A mask-to-helmet connector must:

- (a) Be a quick-release type that can be easily actuated by a gloved hand
- (b) Provide a positive connection during high-speed bailouts
- (c) Keep the harness close to the face (an inside-the-helmet connector may be required)
- (d) Not press into the wearer's face

Several connectors for attaching the MBU-5/P mask to the helmet have been evaluated. Figures 12 and 13 show two inside-the-helmet connectors. Pushing the "button" over the wearer's ear releases the connection. Pushing the male portion on the mask harness into a slot inside the helmet engages the connector.

Proposed Quick-Donning Masks

Various proposed harness systems designed to convert the MBU-5/P mask to a quick-donning type have been evaluated. Figure 15 shows one harness system with the HGU-2/P helmet. The sequence used in donning the mask is shown in the figure. Harness tension may be adjusted by moving the slide buckle on each cord to the helmet connector and by turning the knurled knob at the end of the mask lever.



Figure 15. Sequence for Donning MBU-5/P Mask with HGU-2/P Helmet

Proposed Oxygen-Breathing System

An oxygen-breathing system using the MBU-5/P mask with a built-in, altitude-controlled, pressure-breathing regulator has been constructed (figure 16). With the system, the mask face-piece and shell do not have to be modified and a standard mask harness can be used. The combination inhalation-exhalation valve is replaced by the regulator and the conventional, convoluted hose is replaced by a smaller hose (shown in figure 16 across the subject's right shoulder) which "feeds" the regulator. An oxygen pressure-controlled diluter valve can be incorporated in the system.



Figure 16. MBU-5/P Mask with Built-in Regulator

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