

AD-A065 901

ANTHROPOLOGY RESEARCH PROJECT INC YELLOW SPRINGS OH  
GUIDELINES FOR FIT TESTING AND EVALUATION OF USAF PERSONAL-PROT--ETC (U)  
JAN 79 J T MCCONVILLE, I TEBBETTS

F/G 6/17

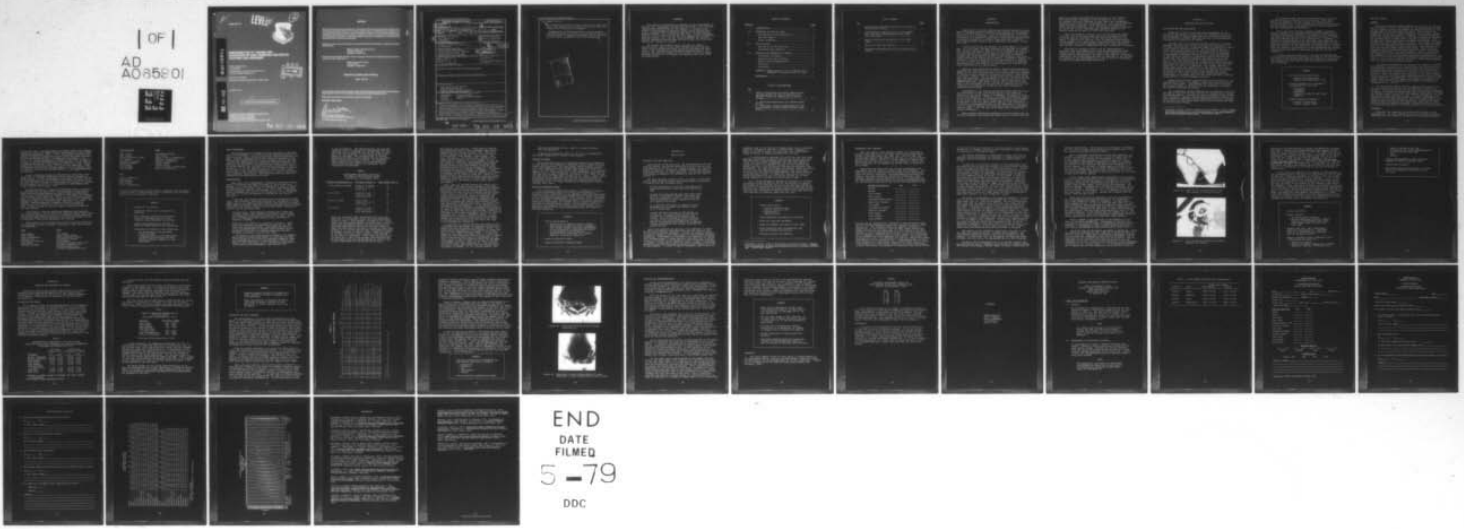
F33615-78-C-0508

UNCLASSIFIED

AMRL-TR-79-2

NL

| OF |  
AD A065 901  
NITE  
M.C.



END  
DATE  
FILMED  
5-79  
DDC

*[Handwritten signature]*

AMRL-TR-79-2

**LEVEL II**

②



ADA065901

**GUIDELINES FOR FIT TESTING AND  
EVALUATION OF USAF PERSONAL-PROTECTIVE  
CLOTHING AND EQUIPMENT**

*JOHN T. McCONVILLE  
ILSE TEBBETS*

*ANTHROPOLOGY RESEARCH PROJECT, INC.  
YELLOW SPRINGS, OHIO 45387*

*MILTON ALEXANDER  
AEROSPACE MEDICAL RESEARCH LABORATORY*



DDC FILE COPY

JANUARY 1979

Approved for public release; distribution unlimited.

AEROSPACE MEDICAL RESEARCH LABORATORY  
AEROSPACE MEDICAL DIVISION  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

79 03 13 063

## NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from Aerospace Medical Research Laboratory. Additional copies may be purchased from:

National Technical Information Service  
5285 Port Royal Road  
Springfield, Virginia 22161

Federal Government agencies and their contractors registered with Defense Documentation Center should direct requests for copies of this report to:

Defense Documentation Center  
Cameron Station  
Alexandria, Virginia 22314

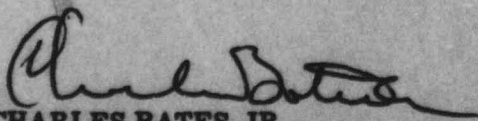
## TECHNICAL REVIEW AND APPROVAL

AMRL-TR-79-2

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

  
CHARLES BATES, JR.  
Chief  
Human Engineering Division  
Aerospace Medical Research Laboratory

| 19 REPORT DOCUMENTATION PAGE  |                       | READ INSTRUCTIONS BEFORE COMPLETING FORM   |        |
|---|-----------------------|--|--------|
| 1. REPORT NUMBER<br>18 AMRL-TR-79-2   | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER<br>9   |        |
| 4. TITLE (and Subtitle)<br>6 GUIDELINES FOR FIT TESTING AND EVALUATION OF USAF PERSONAL-PROTECTIVE CLOTHING AND EQUIPMENT   |                       | 5. TYPE OF REPORT & PERIOD COVERED<br>Technical Report                               |        |
| 7. AUTHOR(s)<br>10 John T. McConville, Ilse Tebbetts, Milton Alexander*   |                       | 6. PERFORMING ORG. REPORT NUMBER   |        |
| 8. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Anthropology Research Project, Inc. ✓<br>503 Xenia Avenue<br>Yellow Springs, Ohio 45387 407 444  |                       | 8. CONTRACT OR GRANT NUMBER(s)<br>15 F33615-78-C-0508                                |        |
| 9. CONTROLLING OFFICE NAME AND ADDRESS<br>Aerospace Medical Research Laboratory<br>Aerospace Medical Division, AFSC<br>Wright-Patterson AFB, Ohio 45433   |                       | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>16 62202F, 7184-08-26 | 17 487 |
| 11. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)<br>12 45 p1   |                       | 12. REPORT DATE<br>11 January 1979   |        |
|   |                       | 13. NUMBER OF PAGES<br>45  |        |
|   |                       | 15. SECURITY CLASS. (of this report)<br>Unclassified                                 |        |
|   |                       | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE   |        |
| 16. DISTRIBUTION STATEMENT (of this Report)<br>Approved for public release; distribution unlimited.   |                       |  |        |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)  |                       |  |        |
| 18. SUPPLEMENTARY NOTES<br>* Crew Station Integration Branch<br>Human Engineering Division<br>Aerospace Medical Research Laboratory<br>Wright-Patterson AFB, Ohio 45433   |                       |  |        |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Anthropometry      Protective garments<br>Evaluation          Personal-protective equipment<br>Fit Test            Sizing<br>Functional fit   |                       |  |        |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>Detailed procedures for the conduct of anthropometric fit tests are outlined in this document which is designed primarily for the use of engineering anthropologists and other technical personnel called upon to carry out fit tests and evaluations of personal-protective clothing and equipment. Suggestions are provided for the design of questionnaires, the selection of a representative test sample and the choice of dimensions to be measured. The authors outline step-by-step procedures for conducting the fit test itself. |                       |  |        |

SK

407 444

79 03 13 063 *elt*

20. ABSTRACT (cont'd)

and discuss various features of the test item which will require evaluation. These include protective capacity, fit, function, comfort and integration with other parts of an assemblage.

Recommendations for reporting significant results and suggested guidelines for approval or rejection of the test item are given in the concluding chapter. An appendix includes sample forms and supporting materials which are recommended for use by the investigator.

|                               |   |
|-------------------------------|---|
| ACQUISITION for               | White Section <input checked="" type="checkbox"/> |
|                               | Buff Section <input type="checkbox"/>             |
|                               |   |
|                               |   |
| CUSTOMER RESPONSIBILITY CODES |   |
|                               | SPECIAL   |
| A                             |   |

## FOREWORD

This report was developed in response to the requirements of Project 7184, "Man-Machine Integration Technology," Task 71841203, "Engineering Anthropology for Life Support." It was a joint effort of Crew Station Integration Branch, Human Engineering Division, Aerospace Medical Research Laboratory and Anthropology Research Project, Inc., Yellow Springs, Ohio. Project engineers were Dr. John T. McConville and Ms. Ilse Tebbetts for Anthropology Research Project, Inc., and Mr. Milton Alexander for the Crew Station Integration Branch under Contract F33615-78-C-0508, monitored by Mr. Charles E. Clauser.

The authors are grateful to Mr. Clauser, Dr. Melvin J. Warrick and Mr. Jean M. Ring, Human Engineering Division, for their valuable suggestions after critically reviewing the manuscript. Ms. Jane Reese of Anthropology Research Project, Inc., deserves the authors' thanks for her diligent efforts in typing multiple versions of the document and preparing the final draft for publication.

## TABLE OF CONTENTS

| <u>Section</u>   | <u>Page</u> |
|--|-------------|
| I INTRODUCTION.....  | 4           |
| II PREPARING FOR THE FIT TEST.....   | 6           |
| Site Selection and Preparation.....  | 6           |
| The Test Sample.....   | 8           |
| Setup Procedures.....  | 11          |
| III THE FIT TEST.....  | 15          |
| Setting Up at the Test Site.....   | 15          |
| Processing Test Subjects.....  | 17          |
| IV ANALYSIS AND REPORTING OF RESULTS.....  | 23          |
| Validating the Sample.....   | 23          |
| Reporting the Test Findings.....   | 25          |
| Results and Recommendations.....   | 29          |
| Tariffing.....   | 30          |
| Conclusion.....  | 31          |
| APPENDIX: Sample material to be prepared and/or<br>assembled in advance of the fit test... | 32          |
| REFERENCES.....  | 40          |

## LIST OF ILLUSTRATIONS

| <u>No.</u> |   |    |
|------------|---|----|
| 1          | Photos illustrating functional defects which surfaced during fit test of HGU-12/P and HGU-28/P helmet and communications carrier systems.....               | 20 |
| 2          | a. Waist-back separation with extreme reach motion.<br>b. Waist-back closure accomplished with the snap fasteners in place during extreme reach motion..... | 28 |

LIST OF TABLES

| <u>No.</u> |   | <u>Page</u> |
|------------|---|-------------|
| 1          | Establishing Indicated Sizes for a Fit Test of High Altitude Gloves.....                                    | 12          |
| 2          | Anthropometric Comparison of Fit Test Sample with 1967 USAF Flying Population for Hand Size Dimensions..... | 23          |
| 3          | Range of Hand Size Variability of Fit Test Sample.....  | 24          |
| 4          | MBU-12/P Flight Test Results.....   | 26          |
| 5          | Suggested Procurement Tariff for High Altitude Gloves.....  | 31          |



## SECTION I

### INTRODUCTION

Each item of Air Force clothing and personal-protective equipment is designed to meet a specific need and must fit and function within specified limits if it is to be considered as a successful solution to a given problem. Each is the end product of an intensive effort by a number of researchers, designers and manufacturers continuously engaged in a series of decisions over trade-offs involving function, comfort, cost, appearance and safety, to name but a few.

A major task facing the designer is establishment of a sizing system for the item: how many sizes will be required to accommodate the user population; what will be the dimensions of each size and, finally, how many of each size will be needed? The answers to these questions are usually based on body-size information gleaned from anthropometric surveys of USAF personnel from which sizing programs are statistically devised. Ultimately, however, the success of a sizing system can only be established by a hands-on fit test in which the garments or equipment are worn by subjects representing the size range of the user population, and are carefully evaluated for fit and function.

Ideally, close coordination between physical anthropologists, designers and fabricators should occur at every step in the development of the item, and some form of fit-testing should be employed at various critical stages of its design and sizing. This occurs only rarely, however, and the various steps are more often sequential than concurrent. Not uncommonly a fit test is called for only after problems have developed in the fit and/or function of the manufactured item. Most often, the fit test is the next-to-last step in the development of the item and is conducted prior to its production for purposes of validating the sizing program and establishing the tariff.

Anthropometric fit testing differs from human factors evaluation procedures in that its central object is to assess the capacity of the sizing system to accommodate the specified range of the user population. There is, of course, considerable overlap since fit and function are interlocking factors in the assessment of the item -- the fact that a given size of oxygen mask can be comfortably fitted to a small narrow face is of no consequence if it leaks at an unacceptable rate; by the same token, it is not a "fit" if chemical defense (CD) protective gloves slip comfortably over the hand ... but the user is no longer able to manipulate needed instruments.

Human factors evaluation procedures for every known piece of military equipment from trucks and turret guns to boilers and back

packs are exhaustively described by various U.S. Army and U.S. Navy publications (Anonymous, 1974 and Malone et al., 1976). Our purpose here is to describe in some detail the recommended procedures for conducting anthropometric fit tests and evaluations. These procedures have not, to our knowledge, been documented before and are assembled in part from existing reports of specific fit tests and in part from empirical knowledge gained by the authors carrying out such fit tests over the years.

While this manual is designed as a set of practical guidelines for the use of anthropometrists and technicians who will be called upon to participate in the design and conduct of fit tests, it should be of interest, also, to designers and manufacturers engaged in the fabrication of personal-protective clothing and equipment and to USAF program managers and other administrators who are ultimately responsible for their successful utilization.

Although the attempt is made to be as comprehensive as possible, each item undergoing fit testing and evaluation incorporates unique features that may require some modification or elaboration of the procedures outlined in this report. Flexibility, imagination and inventiveness are thus as important to the successful conduct of the anthropometric fit test as are the instruments, documents and procedures described herein.

## SECTION II

### PREPARING FOR THE FIT TEST

#### SITE SELECTION AND PREPARATION

Selection of the fit test site and arrangements for the facilities and subjects are basically the responsibility of the program manager at whose request the test is usually conducted. The investigator, however, must provide clear and comprehensive instructions for what will be needed.

The basic aim is to identify and gain access to available personnel who are a part of the projected user population. In all cases there must be a sufficient number of subjects to assure a full range of size variability. The investigator should inform the program manager of his specific needs in this area (e.g., we will require a total of 45 subjects to be presented at approximately 20-minute intervals over a three-day period). If the item to be tested is a one-piece coverall designed for ground crew, the choice of subjects and sites will be a wide one. If the item is designed for a specialized population, however, the test sample must be an operational group knowledgeable about the item to be tested and able to wear the item under conditions for which it is designed. For example, MBU-12/P oxygen masks which must remain on the face during high gravity pulls were tested on fighter pilots of the Tactical Air Command at Nellis Air Force Base, Nevada, under appropriate flight conditions.\* This group of pilots was selected because they represented the ultimate users of such a mask and were on current flying status in high performance aircraft.

Needed facilities and resources must also be specified. The above-mentioned test, for example, required five hours of flying time for each subject. Requirements for other test situations may be much simpler--a dressing room for disrobing or a scale--but should be outlined in advance.

The investigator should determine well in advance of the test how many of each size of test item will be required and so inform the program manager. For most fit tests a minimum of two of each size is ordered. Special circumstances occasionally dictate that every subject be supplied with an individual item, as in the case of the high altitude oxygen masks where pilots retained the masks for later flight testing.

---

\* Alexander, Milton, John T. McConville and Ernest A. Horns, Ground and Flight Evaluation of the Sizing/Design of the Developmental MBU-12/P Oral Nasal Oxygen Mask, unpublished report.

The program manager secures the appointment of a project officer who acts as liaison at the test site. While most advance arrangements are made through the program manager, the investigator will, in all probability, deal with the project officer directly over final details and last minute changes in the test requirements or scheduling.

If the test will involve a pressure chamber, simulated chemical agents or any procedure which has the possibility of affecting the health or safety of the subjects, the investigator should secure approval from a medical review board or human subjects committee at his or her organization. A protocol explaining the procedures to be undertaken, describing the subjects to be tested and detailing any risks which might arise, should be drawn up by the investigator and submitted to a medical board for review. At the same time, the project officer at the test site should be queried about local requirements for subject consent forms and asked to have them on hand for the test if necessary.

It should also be noted that in the case of specialized physiological protection equipment, an expert in the field should be a part of the investigative team for purposes of evaluating the capability of the item to function as specified under the test conditions.

#### SUMMARY

- Site selection alternatives:
  - general USAF population
  - specialized operational group
- Program manager to be informed of requirements at test site:
  - facilities
  - equipment
  - personnel
  - number and sizes of test items
  - subjects
- Human subjects protection:
  - medical review board
  - subject consent forms

## THE TEST SAMPLE

### Numbers

The size of the test sample depends on the nature of the item and the number of sizes to be tested, on the availability of operational personnel and on the numbers of subjects available at the extreme ends of the given body size range. While there is no formula for arriving at a proper number for a given case, several guidelines can be articulated. In general, less than 20-30 subjects will produce a biased sample unlikely to represent accurately the ultimate range of body sizes in the user population. Most garments and personal-protective equipment are designed in sizing systems which range from three to 12 sizes. The larger the number of sizes, the more subjects are required so as to assure at least three to five subjects in each sizing group. Most subjects will fall into the more common middle-size groups. While it may be desirable from a purely statistical point of view to have large numbers of subjects in all size categories, there is a limit to the numbers of military man hours which can be contributed for this purpose; in the case of highly specialized operational groups, there is a limit to the numbers of personnel available at all; and there is, in any case, a fairly low point at which larger numbers will no longer yield worthwhile returns.

One further consideration in selecting the number of subjects to be tested is the quality of fit required. More subjects will be needed when working with an oxygen mask which has a very close tolerance than would be required in fitting a one-piece flight coverall where exact conformity to the body at all points is not critical. Thus, 66 subjects participated in a fit test involving four sizes of an oral-nasal oxygen mask designed for high altitude flying (McConville and Alexander, 1975) while nine sizes of a disposable one-piece chemical defense undergarment, which does not require close fitting tolerances, were tested on 36 subjects (Alexander et al., 1977a).

The investigator should aim for a sample group covering 90-100% of body size variability for the particular variables of interest. The project officer at the test site cannot be expected, of course, to produce an anthropometrically perfect sample covering the desired range in hand sizes, for example, although he will have been asked to keep that goal in mind. In actual operation, the testing team carefully measures and tests about two-thirds of the subjects, and then asks the project officer to obtain additional subjects from a particular size category or categories if those sizes are thus far under-represented. While this involves a bit of last-minute scrambling, it has never proved to be very difficult.

### Variables

There are two categories of variables of interest to the investigators. Of prime importance is the set of key variables (sometimes only one) which is the basis for the sizing categories

of the test item. Air Force partial pressure gloves, for example, have been sized on the basis of hand circumference and hand length (Barter and Alexander, 1956). A U.S. Army chemical defense overgarment originally designed for men was sized for women according to a single dimension--waist circumference (Alexander et al., 1977b). It is this dimension or dimensions for which as complete a range of subjects as possible must be obtained. In the case of the protective gloves, a full range of overall body size, as represented by height and weight, is more or less irrelevant. What is important in obtaining a proper sample is to get subjects ranging from the first to the 99th percentiles in the hand dimensions of interest.

A note of caution should be inserted here concerning inconsistencies in measuring techniques with particular emphasis on waist and hip. If the investigator is not aware that the location of some dimensions may vary slightly from survey to survey, he or she would be wise to check on the variables of interest in a report of the original survey or in a compilation of measurement techniques (Garrett and Kennedy, 1971).

An expanded series of body size dimensions which can be said to interact with the test item is also measured on each subject. These additional measurements are usually taken as comparative data to use in determining the adequacy of the sample in representing the larger user population. Thus, in testing the MC-1 oxygen mask, lip length and total face length were the two key dimensions measured to obtain the indicated size (Emanuel et al., 1959). In addition, menton-subnasale, bizygomatic diameter, bigonial diameter and nose length were taken for use as comparative data. Height, weight and age are always routinely recorded for the same purpose.

Occasionally, specific additional dimensions are measured for other reasons. In the case of the MBU-12/P oxygen mask, nasal root breadth was added to the list of variables because questions concerning leakage around the base of the nose had arisen and fit of the mask at this point appeared to be critical.

While there are no hard and fast lists of variables which can be prescribed for use in testing a particular item, the following are suggested:

Head

head length  
head breadth  
head circumference  
saggital arc  
bitragion-coronal arc  
head height  
bitragion breadth

Face

lip length  
total facial height  
menton-subnasale length  
bizygomatic breadth  
nose length  
bitragion-minimum frontal arc  
bitragion-subnasale arc  
bitragion-menton arc  
bitragion-submandibular arc

### Face and Head

face length  
nose length  
menton-subnasale length  
lip length  
bizygomatic breadth  
bigonial breadth  
head length  
head breadth  
nose breadth

### Body

biacromial breadth  
hip breadth  
chest or bust circumference  
buttock circumference  
thigh circumference  
sleeve length  
crotch height  
vertical trunk circumference  
waist circumference

### Hand

hand circumference  
hand length  
hand breadth  
palm length  
wrist circumference

Ultimately, the choice of dimensions to supplement the key dimensions is based on common sense, general knowledge and particular problems of fit which are indicated.

#### SUMMARY

- Minimum of 30 subjects
- Minimum of three to five subjects for each size
- More subjects required for items with close fit tolerance than for items requiring less conformity to the body
- Sample group should cover 90-100% of body size range found in user population
- Dimensions of interest in two categories:
  - key dimensions on which garment sizing is based
  - a selected group of 3-10 associated variables to be measured for comparative purposes (sample vs. user population)

## SETUP PROCEDURES

While questions to be asked will vary and steps to be undertaken in the conduct of a fit test will be modified according to the item to be tested, the basic procedure remains essentially the same. Subjects representing as wide a range as possible of the ultimate user population will try on indicated sizes of the test item and the investigator will ascertain from both objective observation and subjective reactions how well each subject can be fitted and whether the item functions and/or protects the user as specified. It is also desirable for the investigator to verify, in the field, that the sample population does, in fact, span a broad range of the larger user population in terms of the significant dimensions under study. The following materials should be prepared before beginning the fit test.

### Questionnaire

This form, to be custom-made in advance of each test, represents the skeleton upon which the study of the fit test will depend. It is essential that it be planned with care; it should be comprehensive in scope, clear in its intent and should leave room for possible additions to be made in the field. Information can be discarded later if it is not needed, but it can seldom be retrieved if it was not observed or recorded at the time of the test.

A form for each subject should solicit the following information: identification; sufficient descriptive information to allow comparison of the sample with the ultimate user population; sizing data; observations and reactions of the investigator and the subject relative to the comfort, mobility and safety factors involved in the fit test of the given item.

*Identification:* This category includes only a name and a subject number which should be assigned to each subject for purposes of simplifying analysis of the data. If the test is conducted at more than one site, the location should be included.

*Descriptive information for comparative purposes:* This should include rank and occupation as well as, in every case, age, height and weight. Also appearing here is a list of measurements to be made which includes the key dimension(s) and the 3-10 related dimensions selected for their interaction with the test item.

The section of the questionnaire devoted to the measurements should include blank spaces for recording the population percentile into which the measured dimension falls. The indicated percentile is obtained from a table in the hands of the investigator and is recorded for purposes of field-checking the measurements (see Section III).



*Sizing information:* The indicated size, the size successfully fitted if upgrading or downgrading from the indicated size is required, and the fact that no available size fits properly, if that should be the case, appear on the form. The indicated size is usually determined by measuring the subject for the key dimensions on which the sizing is based. The following table taken from the report of a sizing system for high altitude gloves (Barter and Alexander, 1956) illustrates the procedure.

TABLE 1

ESTABLISHING INDICATED SIZES FOR A  
FIT TEST OF HIGH ALTITUDE GLOVES  
(From Barter & Alexander, 1956)

| <u>If Hand Circumference is</u> | <u>And Hand Length is</u> | <u>Then Glove Size is</u> |
|---------------------------------|---------------------------|---------------------------|
| 7-7/8 inches or below           | 6-5/8 to 7 inches         | A                         |
|                                 | 7-1/8 to 7-1/2 "          | B                         |
|                                 | 7-5/8 to 8 "              | C                         |
| 8 to 8-3/8                      | 6-3/4 to 7-1/8 "          | D                         |
|                                 | 7-1/4 to 7-3/4 "          | E                         |
|                                 | 7-7/8 to 8-1/4 "          | F                         |
| 8-1/2 to 8-7/8                  | 7 to 7-3/8 "              | G                         |
|                                 | 7-1/2 to 7-7/8 "          | H                         |
|                                 | 8 to 8-3/8 "              | I                         |
| 9 to 9-1/4                      | 7-1/8 to 7-1/2 "          | J                         |
|                                 | 7-5/8 to 8-1/8 "          | K                         |
|                                 | 8-1/4 and above "         | L                         |

Often the technical order accompanying the test item specifies in considerable detail how such measurements should be taken. This document, provided to the investigator by the program manager or manufacturer, contains fully detailed descriptions of the item including its specified dimensions at each size and other essential specifications such as the need to overlap or cover other garments or to protect against some environmental hazard. An example of such a technical order, issued in support of the MBU-12/P oxygen mask, appears in the Appendix. In the case of a prototype, a tech order may not yet be available but a copy of the product specifications may be obtainable from the program manager or from the contractor responsible for the design of the item.

*Observations and reactions:* Three areas of inquiry are associated with fit tests, although they are not necessarily all involved in every test. The first order of business is the actual fit of the item--is it long enough...wide enough...loose enough...too long...toonarrow...too restrictive. Results of the investigator's examination of the garment fit (in such areas as torso fit, crotch placement, sleeve and leg length in a one-piece overgarment) would appear briefly noted on the questionnaire, which may list particular areas of fit to be checked off or merely provide space for the examiner's comments. The matter of comfort is largely a subjective judgment. Some individuals prefer snugly fitting garments while others are bothered by any area of tight fit. Good fit or comfort is best ascertained by asking such open-ended subjective questions as "Is the mask comfortable?" or "In terms of fit and comfort, which oxygen mask do you prefer?"

Then, since the subject wearing the item is not a static model, the next group of queries, especially when dealing with bulky protective equipment, revolves around the mobility of the subject wearing the test item and his or her ability to perform required tasks. In the case of a fit test for 14-inch gauntlet butyl rubber protective gloves, tests for dexterity and tactility were made on the subject (Alexander and McConville, 1977). The subject was queried as to her ability to perform her routine and necessary flight-line duties while wearing the gloves, and answers were recorded on the questionnaire. It is important for the investigator to ascertain in advance what functional tasks or capability could conceivably be impaired by wearing the test item (this would include visibility in head gear or respiratory equipment) and devise tests to ascertain what, if any, impairment occurs. In this connection it is useful to obtain from the program manager the relevant Air Force Specialty Code (AFSC), a job description issued by the Air Force for each of its occupational categories.

A third area of inquiry involves the safety of the individual when the garment or equipment is designed to protect the user from some environmental threat. One would need to ascertain not only whether an oxygen mask fits the face comfortably but whether it fits snugly enough at all points to prevent leaks. It should be added here that questions concerning the item's capability for protection must cover its performance at the outer limits of the environmental threat the equipment is designed to offset. Thus, in the case of the MBU-12/P oxygen mask, such questions as: "Did the mask provide a satisfactory facial seal and provide breathing safety in flight? If 'no', please comment" and

"Was the performance of the...mask in a high-G environment satisfactory?"

A sample questionnaire, used in a fit test of the MBU-12/P oral-nasal oxygen mask is shown in the Appendix.

#### Percentile Table

Having selected the list of variables which will be measured on each subject for purposes of comparing the test sample with the larger user population, the investigator should prepare a percentile table showing the first through 99th percentile values for each of the variables in the overall USAF population or in selected segments of it. These data will, in all likelihood, come from the 1965 and 1967 surveys of USAF men (Churchill et al., 1978) or from the 1968 survey of USAF women (Clauser et al., 1972). Such a table, illustrated in the Appendix, will be used in field-checking the measurement data as they are obtained (see Section III) and for insuring that the test sample represents a comprehensive range of relevant body sizes.

#### Bivariate Frequency Table

The investigator should also secure, in advance of the test, a bivariate frequency table for the key sizing variables. A bivariate table (illustrated in the Appendix) shows how individuals from a given population are distributed over the entire size range of any two selected measurements. Each subject, as he is measured, will be "entered" in the appropriate spot on the table, thus providing the investigator, at a glance, with a graphic indication of the range of subjects being tested. By this means he will be alerted to the necessity for securing additional subjects in size categories which may be under-represented during the course of the test procedures.

#### SUMMARY

- Devise questionnaire:
  - identification (name and subject number)
  - descriptive information (rank, occupation, age, height, weight, selected measurements)
  - sizing information (indicated size based on measurement of key dimensions)
  - observation and reactions (fit comfort, mobility, protective capability)
- Draw up percentile table
- Draw up bivariate frequency table

### SECTION III

#### THE FIT TEST

##### SETTING UP AT THE TEST SITE

Upon arrival at the test site, the investigators will meet with the project officer and check over with him that all the requirements for the test--i.e., adequate space, the requisite number of subjects, any special testing equipment and associated personnel--are, in fact, available. If anything has been overlooked, arrangements can probably be made at this time to provide it.

The area assigned to the fit test is usually a conference room or ready room and should have enough space and furniture to arrange into the following areas:

- A table and chairs for initial interview of subjects and sufficient floor space for measuring them.
- An area for trying on the test item (this would include a screened-off dressing area when subjects are required to strip). The test items, clearly labelled for size, should be laid out on a table in this area.
- If a simulated work space or special testing equipment will be used, this should be set up in a third area.
- A table and chair for use of the subject in filling out the questionnaire should also be arranged in a relatively distraction-free corner. Since a continuous flow of subjects is likely to be moving through the test procedure, this seating area should be in addition to that provided for the initial interview and measuring step.

Before the beginning of the test, it is essential to check out both the measuring instruments and the test items as well as any special testing equipment. A scale for weighing subjects is usually checked by the simple means of investigators weighing themselves. Anthropometric instruments are inspected and checked with standard gauges to guard against a careless error in assembling an instrument or the possibility that it may have been bent in transit. An antiseptic solution, such as alcohol, and sponges should be available for cleansing measuring instruments after use on each subject. If there is special equipment, such as an A-14

regulator used in the testing of oxygen masks, then a technician should be assigned by the base to operate this equipment, to check it out and to assure, at this time, that a sufficient supply of oxygen is readily available for the test.

It is particularly important to verify that the test items supplied are properly sized and labelled and to make sure that they meet their various dimensional and functional specifications. The tech order accompanying the test item should be scanned to see if it instructs the user in how to select the proper size and if its instructive sections are generally comprehensible. At least one of each size garment should be tested. In a fit test for chemical defense gloves, such a pre-check turned up the fact that the glove marked 8½ was larger than the so-called size 9 glove.\* In addition, only one of a pair of gloves was marked with the size so that as soon as its mate became separated it became an unsized question mark.

If it can be arranged in advance of the test, it is useful to conduct a briefing session for all the subjects to explain the purpose of the exercise and to outline the test procedures which will be carried out with their aid in the next day or two. This briefing, along with an ensuing question and answer period, increases the likelihood of obtaining more intelligent and relevant responses to questions about the test item.

#### SUMMARY

- Check testing area:
  - initial interview area
  - area for trying on item
  - testing area
  - debriefing area
- Check measuring instruments for accuracy
- Check out auxillary equipment
- Check out numbers and sizes of test items
- Check technical order accompanying test item for accuracy and clarity
- Briefing session with subjects

---

\* Alexander, Milton, John T. McConville and Russell Carlson, Design/Sizing Evaluation of Seiberling Neopreme Glove for Chemical Warfare Use. Unpublished report.

## PROCESSING TEST SUBJECTS

When the subject first presents himself, an investigator briefly interviews him for the basic background information required on the form--name, age, rank, etc. At this time, the investigator explains the nature of the test if a prior briefing has not taken place. While it is often tedious to repeat this explanation over and over again, it is essential to secure the full cooperation of the subject and serves, also, to put him or her at ease.

Experience has shown that two trained investigators are required at various critical points of the test procedure. The first such point is measuring of the subject which takes place after the initial interview. One anthropometrist measures the subject; the other records the called-out dimensions, simultaneously observing and checking for errors. As noted earlier, the questionnaire provides spaces for the given measurement and for the population percentile into which that measurement falls:

| <u>Measured Dimensions</u> | <u>mm</u> | <u>%ile</u> |
|----------------------------|-----------|-------------|
| Height                     | _____     | _____       |
| Weight                     | _____     | _____       |
| Face Length                | _____     | _____       |
| Nose Length                | _____     | _____       |
| Subnasale-Menton Lgth      | _____     | _____       |
| Nasal Root Breadth         | _____     | _____       |
| Lip Length                 | _____     | _____       |
| Bizygomatic Breadth        | _____     | _____       |
| Bigonial Breadth           | _____     | _____       |
| Head Length                | _____     | _____       |
| Head Breadth               | _____     | _____       |
| Nose Breadth               | _____     | _____       |

Percentiles are determined by reference to the percentile tables for the relevant dimensions which were prepared in advance (see Section II). The recorder watches for apparent anomalies in proportions as, for instance, head and face length percentiles widely at variance with each other or a face length in the 90th percentile with a subnasale-menton length in the 20th percentile. Such an apparent contradiction is quietly called to the attention of the measurer who then remeasures the subject. The anomaly may have been an error in the measuring but may also reflect the actual configuration of the subject's face. Disproportionality is carefully noted by the investigator since it may affect the fit of the item designed for a more normal proportion of bodily dimensions. In fact, the unusual relationship of dimensions often has no effect

on the fit of the test item but it can later explain a particular observation or comment concerning undue pressure or oxygen leakage at some point of a protective mask.

The subject undresses for measurements except when hand or head and face anthropometry is concerned. In these cases, the subjects' height and weight are recorded as reported by him or her.

In addition to continuous scanning of the measurement data, the recorder also locates each subject on the previously prepared bivariate table with which he is armed (see Section II). By this means, investigators can keep track of the distribution of the test subjects as the test proceeds, and assure that a reasonably representative number of individuals spanning about 90-100% of the user population will be tested. If the number of subjects goes much past the halfway mark without beginning to cover the desired distribution, the liaison officer is asked to beat the bushes for additional subjects known to approximate a specified size range--it may be that tall women are needed or men likely to have small heads or hands. Such subjects can usually be found through informal contacts on the base. The liaison officer, other personnel assisting with the test, or other subjects usually know of people fitting into the requisite dimensional category and all past experience points to a high degree of success in obtaining additional subjects via this "grapevine" method.

Following the measurement, from which the subject's indicated size is derived, one investigator accompanies the subject to the table where the test items are displayed. Here the investigator makes sure that the subject gets the right size, helps him don the garment and explains a little about the special features of the item. It may be, for example, a new oxygen mask designed especially to alleviate slippage under high-G conditions. If the item differs from what the subject is currently using, the investigator explains how it is intended to fit differently so that the subject knows what to expect and does not reject the item on those grounds. If it is a brand new item, such as a new chemical defense protective garment, the investigator explains its purpose and why it is to be added to the inventory. In all cases, the investigator helps the subject adjust the item properly but it may be immediately apparent at this point that it is much too big or too small for the subject. In that case, the size is up- or down-graded from the indicated size and this change is recorded.

The subject is now informally questioned: how does it fit? are there any pressure points? is there any discomfort? The investigator probes for specific details to elucidate any complaints. At this point, too, if the subject is obviously uncomfortable, the size is up- or down-graded and that fact recorded.

It may as well be stressed here as it has been earlier that all observations and all comments and reactions by subjects should be recorded since memory, however sharp, is never a substitute for

recorded observations. While much of the information assembled at a fit test may later be discarded if not needed, very little can reliably be reconstructed if needed.

When a reasonably satisfactory fit has been achieved, the subject is exercised in any one of a variety of means selected to test the fit and function of the garment in actual use. Flight garments and equipment are usually tested in a simulator although on some bases arrangements are made to accompany the subject to the flightline and observe his movements in an actual cockpit. In the case of oxygen masks, the subject is usually put through tests on a console designed to test leakage. For garments designed for ground crew, a simple set of calisthenics is designed. Subjects in protective gloves will be asked to manipulate various objects.

In all cases, both investigators participate in this stage of the test watching carefully from all angles for any noteworthy details. These include decrements in the ability to perform necessary functions or interferences with mobility as well as stress lines of the garment itself during the exercises. The observer watches for riding up at the crotch or bunching up at waist or armhole. Uppermost in the investigators' minds should be the function of the garment. If it is designed to protect, are there gaps: at the waist? between the wristband and the glove? does the mask seal?

Often the test item is designed as part of an assemblage. The investigators must study the nature of the integration with other garments or pieces of equipment. Can the subject wear glasses with it? In one fit test the edge rolls of a test helmet butted up against the flyers' goggles to such a degree that the goggles were pushed away from the face (Gillespie, 1977). Are garments, designed to be worn over or under other garments, too restrictive? Do they cause undue bunching of fabric in the secondary garment? If the subject does not comment on the integration of the test item, the investigator should make a point of asking specifically how it fits vis-a-vis other garments.

While a camera is not essential to the conduct of a fit test, it is highly recommended. Photographs of stress lines and defects are excellent means of documenting and illustrating findings. A photograph is often clearer and more convincing than several paragraphs of detailed description (see Figure 1).

The final step in the testing procedure is debriefing. After the subject has removed the test item, he is given the questionnaire to fill out. When that is completed, the subject is asked to stay while the investigator goes over the filled-out form to make sure all the responses are clear and to the point. The investigator will often ask several more questions to clarify responses on the form. Even at this late point in the proceedings sizing may be up- or down-graded. It is not altogether uncommon for a subject who has been apparently satisfactorily fitted to



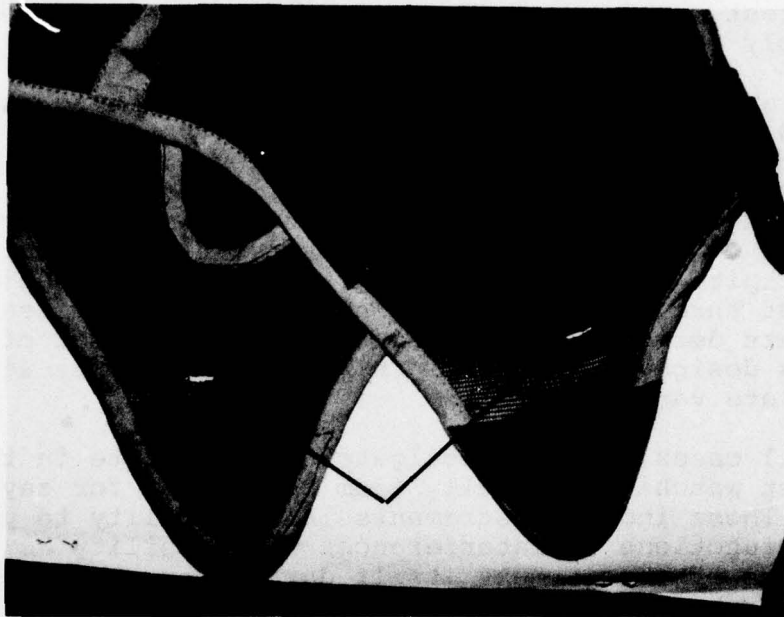


Figure 1a. Seam failure on lower edge of ear cup receptor of HGU-28/P helmet.



Figure 1b. Poor integration between test helmet assembly and goggles.

indicate on the questionnaire or during the debriefing conversation that "I really can't stand anything tight against my body." Thus, while the item theoretically "fits," the subject would, in practice, always choose a larger size. It is useful then for the investigator to suggest that the subject come back to the table where the test items are laid out and undergo a re-test in a larger size. If the subject is more comfortable and the item retains optimum function (i.e., protects as specified), then this becomes the subject's preferred size. In any case, the record then shows that while the subject can be fitted in the size indicated by his dimensions, he is likely to opt for the larger or smaller size.

If the officer in charge of the squadron or base requests it, the investigators meet with him at the conclusion of the fit test and deliver a tentative statement of results of the test insofar as they can be estimated prior to data analysis. It is, in any case, desirable to hold such a meeting with the liaison officer and any other observers or base personnel who have taken part in the test to report on the success of the enterprise and receive any feedback. Such a meeting is essential in the case of any negative findings important enough to alert people about immediately. In one fit test, a two-piece chemical defense garment was found to gape at the waistline with bending and, because of an elasticized band, stay separated after bending (Alexander et al., 1977c). Since this garment was already in use for another branch of the service, an observer from that branch was informed and production subsequently stopped while the garment was modified.

#### SUMMARY

- Initial interview
- Measure subject:
  - one investigator measures
  - second investigator records, checks accuracy of measurements and tracks total sample group to insure full size range
- Subject dons test item; investigator checks on preliminary fit. Indicated size up- or down-graded if indicated size is obviously a misfit
- Subject undergoes test(s) observed by two investigators who check for:
  - protective capacity
  - loss of functional capability by subject (mobility, agility, visibility, etc.)

- areas of stress on the item
  - integration with associated garments to be worn with the test item
  - fit
  - comfort
- 
- Subject photographed in test item with emphasis on photo of problem areas
  - Debriefing of subject
  - Debriefing meeting with officer in charge and/or base personnel who took part in fit test

## SECTION IV

### ANALYSIS AND REPORTING OF RESULTS

Analysis of the fit test results takes place in two steps: documenting the representativeness of the test sample, and analyzing the results of the test with a view toward recommending acceptance, modification or rejection of the item under consideration.

#### VALIDATING THE SAMPLE

It is important that the representativeness of the sample be established if the reader of the test report is to be confident that the results obtained, in terms of fit and function, can be extrapolated from the small test sample to the larger user population. Perhaps the best method of establishing the representativeness of the test sample is to compare the anthropometric profile of the sample with that of the user population. The Aerospace Medical Research Laboratory Anthropometric Data Bank at Wright-Patterson Air Force Base contains all the anthropometric data available for men and women of the various U.S. military populations. It is thus possible to draw from the data bank a survey population or sub-population which will characterize the body size variability of a particular user population. In the sizing evaluation of a chemical defense eight-size commercial overglove for flight personnel, selected dimensions of the test sample were compared to those of the USAF flying population as surveyed in 1967 with the following results:

TABLE 2

ANTHROPOMETRIC COMPARISON OF FIT TEST SAMPLE  
WITH 1967 USAF FLYING POPULATION FOR HAND SIZE DIMENSIONS  
(Alexander and McConville, 1977)

| Variable*                       | Fit Test<br>Sample (n=33) |       | USAF Flying<br>Population (n=2420) |       |
|---------------------------------|---------------------------|-------|------------------------------------|-------|
|                                 | $\bar{X}$                 | S.D.  | $\bar{X}$                          | S.D.  |
| Height (reported)               | 70.47                     | 2.78  | 69.58                              | 2.37  |
| Weight (reported)               | 172.80                    | 26.10 | 173.06                             | 19.65 |
| Hand Length                     | 19.17                     | 0.80  | 19.11                              | 0.82  |
| Palm Length                     | 11.11                     | 0.55  | 10.83                              | 0.54  |
| Hand Breadth                    | 8.91                      | 0.38  | 8.90                               | 0.41  |
| Hand Thickness<br>at Meta III** | 3.01                      | 0.25  | 2.97                               | 0.12  |
| Hand Circ                       | 21.31                     | 0.82  | 21.55                              | 0.94  |
| Wrist Circ                      | 16.97                     | 1.09  | 17.59                              | 0.92  |

\* Height in inches, weight in pounds, all other values in centimeters.

\*\* From USAF flight population--1950.

As can be seen, the test sample closely mirrored the user population.

When specialized items are under consideration for specific segments of the population, it is useful to draw relevant sub-groups from the survey data. The same USAF survey cited above contained 803 rated subjects assigned to the Strategic Air Command. This group could be--and has been--used to characterize the body size variability of the user population for items specifically designed for SAC aircrew.

The test sample may be additionally characterized by stating the percentile coverage of the sample in terms of the target population. Table 3, below, reports such data obtained in the fit test of chemical defense protective overgloves described above.

TABLE 3

RANGE OF HAND SIZE VARIABILITY OF  
FIT TEST SAMPLE  
(Alexander and McConville, 1977)

| <u>Variable</u>     | <u>Percentile Range</u> |
|---------------------|-------------------------|
| Hand Length         | 2nd - 99th              |
| Palm Length         | 4th - 99th              |
| Hand Breadth        | 3rd - 92nd              |
| Hand Thickness      |                         |
| at Meta III*        | 2nd - 99th              |
| Hand Circumference  | 3rd - 90th              |
| Wrist Circumference | 1st - 93rd              |

\* From USAF flight population--1950.

In some instances, the sampling strategy may call for "n" individuals to be tested for each size of a particular item. As the extreme sizes (extra-short and extra-large) may be purposely designed to cover only a few percent of the individuals in the design population, the sample will be of a plateau type and the standard deviations of the test series may well be as much as double those of the design population. Yet the mean values of the test and target population may remain the same. Such a result is not cause for concern as the purpose of the test is to consider as much variability or more in the test sample as exists in the design population, but not less.

The whole purpose of the initial data analysis is to be able to establish that the "test" population, in terms of relevant body size variability (or perhaps other parameters such as age), can be considered an adequately representative micro-population for purposes of the test.

### SUMMARY

- Compare measured variables of sample with those obtained in survey of appropriate user population
- Check distribution of measured variables with those obtained in survey of user population to verify adequate size range of sample

### REPORTING THE TEST FINDINGS

The anthropometric fit test usually represents the final hurdle to be negotiated before an item goes into full production. The final report must provide to those who will make the decisions about the item, information which is to-the-point and which covers all the areas of concern. If the findings cannot be classified as altogether objective, they should at least be accurate and illuminating in their reflection of the facts as observed by the investigator and reported by the subjects. To this end the investigator should summarize the material garnered from the questionnaires, presenting results, wherever possible, in quantitative terms. One means is a tabular format illustrated in Table 4 which summarizes findings from the report of a fit test for the MBU-12/P oxygen mask. It should be noted that when findings are transmitted, subjects are identified only by their numbers; names are retained confidentially in the files of the investigator.

With the results compiled, it is up to the investigator to study them and report on significant trends. It is important, for example, to note if certain difficulties crop up across the whole gamut of sizes or seem concentrated in one sector of the size range. It may be found, for example, that the edge rolls of a para-rescue helmet are set too close together to permit the jump goggles to be properly fitted to the face (see Figure 1b) but that this deficiency exists only with the smaller sized helmet.

While the major concern of the test revolves around fit, function and integration, the subjects' comments regarding comfort and preference are also of concern. If an item is good in terms of fit and function but repeatedly causes a pressure point that would rapidly become intolerable, the item is unacceptable until that problem can be resolved. It is here that it becomes important to have experienced test subjects who are familiar with the item or class of item under consideration. No one particularly looks

**TABLE 4**  
**MBU-12/P FLIGHT TEST RESULTS**

| Subj No. | Rank | Age | Aero | Flight Hrs. | Air-craft | MBU-12/P Size | Mis-sions | Hrs Seal | Leak | Perform-ance | Vision Loss | Accept-able Fit | Com-fort | Pres-sure | Pref-erence | Comments  |  |
|----------|------|-----|------|-------------|-----------|---------------|-----------|----------|------|--------------|-------------|-----------------|----------|-----------|-------------|---|--|
|          |      |     |      |             |           |               |           |          |      |              |             |                 |          |           |             |   | Accept-able                            |
| 1        | Capt | 32  | P    | 1500        | F-4       | R             | 4         | 3.2      | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Better fit/comfort for high 'G'.                |  |
| 2        | Maj  | 33  | N    | 3600        | F-4       | R             | 8         | 5.6      | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Cheek flap/helmet interface.                    |  |
| 3        | Capt | 33  | N    | 2400        | F-4       | R             | 6         | 5.4      | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Lighter/more comfort/better seal.               |  |
| 4        | Capt | 32  | P    | 1500        | A-10      | L             | 10        | 20.2     | Yes  | Yes          | No          | Yes             | Yes      | Yes       | 12/P        | Pressure on cheeks fr Lomb. edgeroll.           |  |
| 5        | Maj  | 39  | P    | 3200        | F-15      | R             | 12        | 11       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Commun. bad/sounds like in a barrel.            |  |
| 6        | Col  | 37  | P    | 2500        | F-15      | L             | 6         | 5        | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | No comments.                                    |  |
| 7        | Maj  | 35  | P    | 3000        | F-4       | NO RESPONSE   |           |          |      |              |             |                 |          |           |             |   | Leak under rt eye, nose area; face pr. |
| 8        | Capt | 35  | N    | 2500        | F-4       | XL            | 4         | 2.8      | Yes  | Yes          | Yes         | Yes             | Yes      | Yes       | 5/P         |   |  |
| 9        | Capt | 31  | P    | 1800        | F-15      | NO RESPONSE   |           |          |      |              |             |                 |          |           |             |   | Side interf w/hel; integr w/Prot. hel. |
| 10       | Capt | 33  | P    | 2600        | F-4       | L             | 11        | ^8       | Yes  | No           | No          | No              | No       | Yes       | *           | Superior by far.                                |  |
| 11       | Capt | 28  | P    | 1500        | F-5       | R             | 40        | 21       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | No comments.                                    |  |
| 12       | Capt | 30  | P    | 2000        | F-4       | L             | 15        | 13       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Prob w/microphone cord.                         |  |
| 13       | Maj  | 37  | P    | 4000        | F-15      | L             | 16        | 13       | Yes  | Yes          | Yes         | Yes             | Yes      | No        | *           | Mask doesn't fall away fr face.                 |  |
| 14       | Capt | 27  | P    | 1100        | F-4       | L             | 9         | 10       | Yes  | Yes          | No          | Yes             | Yes      | No        | *           | An excellent mask.                              |  |
| 15       | Capt | 33  | P    | 2300        | F-4       | L             | 22        | 17       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | No comments                                     |  |
| 16       | LCol | 39  | P    | 3600        | F-4       | R             | 5         | 5        | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Too tight on nose; chose Cust 5/P.              |  |
| 17       | Capt | 33  | P    | 2000        | F-4       | L             | 5         | 6        | Yes  | Yes          | No          | No              | Yes      | Yes       | Custom      | Mask caused face to sweat around chin.          |  |
| 18       | Capt | 34  | N    | 1700        | F-4       | XL            | 5         | 2.5      | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Leak at 41M, side of nose.                      |  |
| 19       | Maj  | 33  | P    | 1950        | F-4       | L             | 6         | 8.3      | Yes  | Yes          | Yes         | Yes             | Marg     | No        | 12/P        | Minor pr pt on top of nose.                     |  |
| 20       | Maj  | 35  | P    | 2500        | F-4       | L             | 5         | 6.0      | Yes  | Yes          | No          | Yes             | No       | Yes       | 12/P        | Too tight for comfort; pr pts on cheeks         |  |
| 21       | Capt | 30  | N    | 1400        | F-4       | L             | 14        | ?        | Yes  | Yes          | No          | Yes             | No       | Yes       | *           | Great. Buy it.                                  |  |
| 22       | Capt | 28  | P    | 1100        | F-5       | R             | 25        | 20       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Mike touched; pr valve sticks.                  |  |
| 23       | Capt | 32  | P    | 2400        | F-4       | R             | 6         | 8        | Yes  | Yes          | No          | No              | No       | No        | 5/P         | Baynt difficult/2 hands needed; hangs on cheek. |  |
| 24       | Capt | 33  | P    | 2600        | F-15      | R             | 21        | 16.6     | Yes  | Yes          | No          | No              | ?        | Yes       | 12/P        |   |  |
| 25       | Maj  | 37  | P    | 2500        | F-15      | NO RESPONSE   |           |          |      |              |             |                 |          |           |             |   | Mask width/baynt hook-up problems.     |
| 26       | Maj  | 34  | P    | 3100        | F-15      | R             | 10        | 15       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | A must for high 'G'.                            |  |
| 27       | Capt | 30  | P    | 1500        | F-15      | XL            | 190       | 200      | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Leak arnd nose; uncomftble on cheek.            |  |
| 28       | Capt | 32  | P    | 2000        | F-15      | L             | 10        | 8        | Yes  | Yes          | Yes         | Yes             | No       | No        | 5/P         | Ex. for 'G'; pref'd 12/P by far.                |  |
| 31       | Capt | 33  | P    | 3200        | F-15      | L             | 50        | 28       | Yes  | Yes          | No          | Yes             | Yes      | No        | 12/P        | Too wide/uncomftble on cheek, etc.              |  |
| 36       | Maj  | 35  | P    | 2900        | F-15      | L             | 25-30     | 17-20    | Yes  | Yes          | No          | No              | No       | Yes       | 5/P         | Peripheral vision affected.                     |  |
| 51       | Capt | 35  | N    | 1700        | F-4       | R             | 20        | 25       | Yes  | Yes          | Yes         | Yes             | Yes      | No        | 12/P        |   |  |

\* Subject's preference was divided between the MBU-12/P and the MBU-5/P masks.

forward to wearing multiple items of flight clothing and personal-protective equipment. A test subject who has had no experience wearing a three-pound-plus flight helmet can rarely be objective with regard to comfort or preference whereas the aircrew member who may have worn such an item for several thousand flight hours will take a more useful view of the matter and can rapidly determine if the item is better or worse than similar items he is used to. More importantly, he will be able to determine if the test item will integrate with the other items of the personal-protective clothing and equipment normally worn and whether it will allow him to function effectively.

There is always a danger that the detailed documentation of test results will inevitably give the reader of the report a negative opinion of the item being evaluated because of the emphasis placed on any deficiencies that appear in the test item during the evaluation. Positive features may be covered in a few brief sentences stating that the item under consideration provided a comfortable, functional fit for the majority of the test sample and that no integration problems were noted. The report may then begin to enumerate in considerable detail the number, types, and degree of the problems noted. This highlighting of defects or alleged defects is unavoidable. The intent of the test is to establish the merit of the item prior to extensive procurement. By highlighting the deficiencies, attention is directed to problems that may be resolvable before production takes place or which may actually hold back procurement until a solution can be found.

It may be possible to effect a fix during the test itself. In the fit test and evaluation of a two-piece chemical warfare protective overgarment to be worn by Air Force ground personnel, a gap in the waist-back between the overblouse and the trousers occurred when the subject bent over or extended his arms for extreme reach (Figure 2a). Since the garment was designed to act as a physical barrier, such a gap was unacceptable and was cause for rejection of the item. Three snap fasteners were affixed to the garment and were found in subsequent testing to be effective in preventing the separation of the blouse and trousers (Figure 2b). The solution devised during the fit test was then incorporated in the procurement.

#### SUMMARY

- Detailed documentation of observations and subject reactions in terms of:
  - protection
  - function
  - fit
  - integration
  - comfort
- Note significant problems and trends



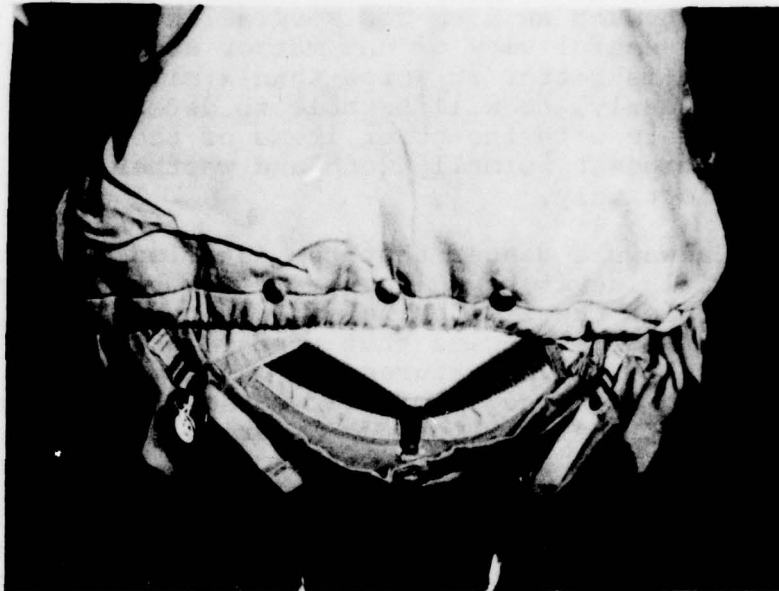


Figure 2a. Waist-back separation with extreme reach motion.

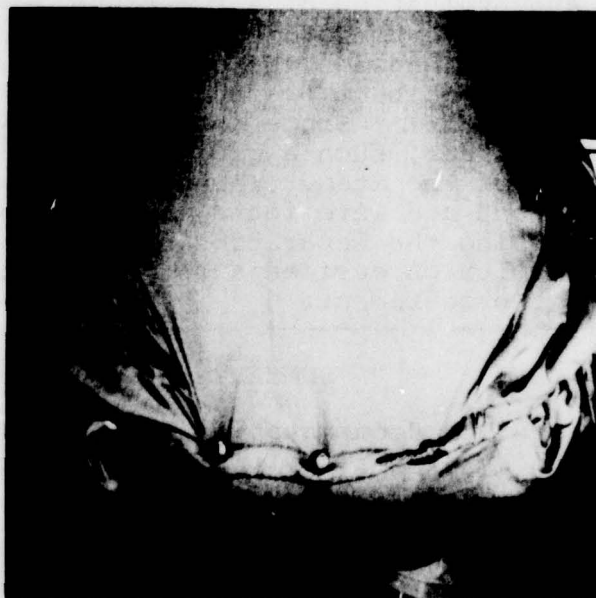


Figure 2b. Waist-back closure accomplished with snap fasteners in place during extreme reach motion.

## RESULTS AND RECOMMENDATIONS

Unlike school examinations, fit tests do not incorporate a grading system in which definitive cutoff points indicate whether an item has "passed" or "failed." There are, nevertheless, guidelines which can be suggested and the following discussion is intended to provide the investigator with a framework for considering his recommendations.

When the purpose of an item, such as a respirator or chemical defense garment, is to ward off a life-threatening hazard, then the investigator must determine with assurance that the item will achieve this end for at least 98% of the user population. If there are grounds to suspect that the protective quality of the item may be compromised in any segment of the size range, it must be rejected in its present form, although often the investigator can suggest a modification of the design which will better meet the need.

More often, the problems lie in the fit of the garment, the comfort of the subject and/or some resulting decrement in mobility, agility or visibility. In a test of chemical defense protective gloves, for example, some 19% of the subjects were unable to obtain a satisfactory functional fit and investigators concluded that "the fit test for Glove A for USAF ground support males is believed to be marginally adequate. While protection can be afforded to all personnel with this glove, such protection is possible only with a loss in the user's (hand) function" (Alexander et al., 1977b). It might be suggested as a rough rule of thumb that unless at least 80% of the test sample can be properly fitted, further consideration of the item in its present form would be called into question.

At the other end of the scale, if more than 90% of the sample achieves a functional fit, this can be considered to be a good result. It should be stressed that no design will fit every user and the investigator must be alert to those subjects with unusual dimensions or proportionality who, if they cannot be fitted, should not overly influence the results. Some subjects are so sensitive to discomfort that their reactions should receive less weight than those of most others. In this category we would find Subject #17 in Table 4 who wore only a custom-made oxygen mask.

In the "grey" area in which 80-90% of the sample are well-fitted, the investigator will usually give a qualified approval to the test item. Here, it is important to the sponsoring agency that the investigator interpret the results and recommendations as clearly and objectively as possible. While isolated subject complaints are not necessarily significant, a problem which presents itself more than once or twice bears looking into. Demonstrable design defects--such as the microphone in an oxygen mask touching the lips--are easy to deal with. Loss of operating capacity--the ability to grasp levers in a protective glove, or loss of visibility in a helmet or oxygen mask--is often associated

with particular sizes of the test item and should be reported clearly as such, if that is the case. Where problems of integration with other gear crop up, it is important to note whether this difficulty occurs with a specific type or make of associated item or whether the difficulty appears to originate in the design of the test item itself. Other difficulties such as persistent complaints about specific areas of discomfort are less clear-cut but should be reported by the investigator along with his judgment of their significance.

#### SUMMARY

- When item is designed to protect from life-threatening hazard, it must achieve this protection for at least 98% of the user population
- For all other garments and functions, if at least 90% of sample population achieve a functional fit, it can be considered a good result
- At least 80% of sample must achieve functional fit or production of garment in present form is called into question
- 80-90% functional fit means qualified approval
- Meaningful defects should be clearly described and recommendations should be made for needed or desirable modifications

#### TARIFFING

The final element of the fit test report is establishment of the procurement tariff--that is, how many items of each size should be manufactured for the accommodation of the user population. Following is a sample tariff for high altitude gloves (Barter and Alexander, 1956):

TABLE 5  
SUGGESTED PROCUREMENT TARIFF FOR  
HIGH ALTITUDE GLOVES PER THOUSAND PAIRS  
(Barter and Alexander, 1956)

| <u>Size</u> |     | <u>Size</u> |     |
|-------------|-----|-------------|-----|
| A           | 55  | G           | 74  |
| B           | 62  | H           | 167 |
| C           | 34  | I           | 84  |
| D           | 140 | J           | 24  |
| E           | 208 | K           | 43  |
| F           | 80  | L           | 29  |

This tariff was based on the number of subjects included in each size category of the hand circumference/hand length bivariate table expressed as a percentage of the total sample. The percentages were then adjusted so the sum of the total equalled exactly 100 percent. The fit test is used to verify the tariff by demonstrating that test subjects are fitted in their indicated sizes. Tariffs can be adjusted at this time as necessary.

#### CONCLUSION

Ultimately the responsibility for the further disposition of the item lies with the program manager. It is the central purpose of the fit test report to provide the program manager the wherewithal to arrive at his decision and if this is not possible then either the test or the report must be considered deficient. In either case, additional time and money may be required to provide the needed information. It is thus incumbent on the anthropometric fit test team to invest the initial test with adequate planning, conduct and reportage the first time around.

APPENDIX

Sample material  
to be prepared  
and/or assembled  
in advance of  
the fit test.

EXCERPT FROM SAMPLE TECHNICAL ORDER

RDT & E Equipment Manual  
Pressure Demand Breathing Oxygen Mask  
USAF Type MBU-12/P  
Sierra Engineering Co.  
15 February 1977

5. MASK SIZE SELECTION

a. General

The Type MBU-12/P oxygen mask is manufactured in four sizes from which to choose the proper fit for the face (refer to table 1). The mask sizing caliper, Sierra Engineering Co. Part No. 450-100, (3, figure 13), is an aid in determining proper fit and choice of mask size for an individual. To select mask size, proceed as outlined in paragraph 5.b.

NOTE

If a mask sizing caliper is not available, choose the mask size that most closely follows the contours of the face when the mask is held to the face with little or no pressure.

b. Measurement and Selection Procedure

As illustrated in figure 7, measure the total face length. Subject's facial muscles are relaxed and his jaws lightly closed. Measure the vertical distance from the tip of the bottom surface of the chin to the point of maximum depression of the nasal root. Table 1 lists the indicated mask sizes for various ranges of total face lengths.

NOTE

The appropriate size mask for individuals with borderline total face lengths should be determined by checking out both mask sizes per paragraph 4b.

Table 1. Part Number and Mask Size Designations

| Part No. | Size       | Total Face Length |                |
|----------|------------|-------------------|----------------|
|          |            | Millimeters       | (Inches)       |
| 834-01   | Short      | 102.5 (4.05)      | - 111.5 (4.39) |
| 834-02   | Regular    | 111.5 (4.39)      | - 120.5 (4.74) |
| 834-03   | Long       | 120.5 (4.74)      | - 129.5 (5.10) |
| 834-04   | Extra-Long | 129.5 (5.10)      | - 138.5 (5.45) |

**QUESTIONNAIRE**  
(Investigator to fill out)

**SIZING/DESIGN EVALUATION**  
**MBU-12/P ORAL NASAL OXYGEN MASK**

NAME \_\_\_\_\_ AGE \_\_\_\_\_ SUBJECT NO. \_\_\_\_\_  
 AeroRating \_\_\_\_\_ Career Flight Hours \_\_\_\_\_  
 Operational Squadron \_\_\_\_\_ Command \_\_\_\_\_  
 Current A/C \_\_\_\_\_  
 Helmet Size \_\_\_\_\_ Type Liner \_\_\_\_\_ Bayonet Style \_\_\_\_\_  
 Current Size Mask \_\_\_\_\_

| <u>Measured Dimensions</u> | <u>mm</u> | <u>%ile</u> |
|----------------------------|-----------|-------------|
| Height                     | _____     | _____       |
| Weight                     | _____     | _____       |
| Face Length                | _____     | _____       |
| Nose Length                | _____     | _____       |
| Subnasale-Menton Lgth      | _____     | _____       |
| Nasal Root Breadth         | _____     | _____       |
| Lip Length                 | _____     | _____       |
| Bizygomatic Breadth        | _____     | _____       |
| Bigonial Breadth           | _____     | _____       |
| Head Length                | _____     | _____       |
| Head Breadth               | _____     | _____       |
| Nose Breadth               | _____     | _____       |

INDICATED MBU-12/P

|               |               |               |               |
|---------------|---------------|---------------|---------------|
| 102.5 - 111.5 | 111.5 - 120.5 | 120.5 - 129.5 | 129.5 - 138.5 |
| Short         | Regular       | Long          | X-Long        |

PRESSURE CHECK

|        |     |     |     |      |
|--------|-----|-----|-----|------|
| Safety | 41M | 43M | 45M | >45M |
|--------|-----|-----|-----|------|

Subject's Comments \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

(Minimum of 4 hours are desired for flight test)



QUESTIONNAIRE  
(Subject to fill out)

FLIGHT EVALUATION

Sizing/Design Evaluation  
MBU-12/P Oral Nasal Oxygen Mask

SUBJECT NUMBER \_\_\_\_\_

DATE \_\_\_\_\_

NAME \_\_\_\_\_

OPERATIONAL SQUADRON \_\_\_\_\_

Size MBU-12/P mask tested: \_\_\_\_\_

Number of missions flown with MBU-12/P mask: \_\_\_\_\_

Total number of flight hours MBU-12/P mask was worn: \_\_\_\_\_

1. Did the mask provide a satisfactory facial seal and provide breathing safety in flight?

YES \_\_\_\_\_ NO \_\_\_\_\_

If "NO", please comment: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

2. Was any leakage noted?

YES \_\_\_\_\_ NO \_\_\_\_\_

If "YES", what pressure setting was in use? \_\_\_\_\_ ft.

On what part(s) of the face did the leakage occur? \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

3. Was the performance of the MBU-12/P mask in a high-G environment satisfactory?

YES \_\_\_\_\_ NO \_\_\_\_\_

Comments: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

FLIGHT EVALUATION (continued)

4. Was there visual degradation while wearing the mask?

YES \_\_\_\_\_ NO \_\_\_\_\_

If "YES", please comment: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. Was the fit of the MBU-12/P mask acceptable?

YES \_\_\_\_\_ NO \_\_\_\_\_

If "NO", please comment: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

6. Was the MBU-12/P mask comfortable?

YES \_\_\_\_\_ NO \_\_\_\_\_

If "NO", please comment: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

7. Were pressure points noted on the face during use of MBU-12/P mask in flight?

YES \_\_\_\_\_ NO \_\_\_\_\_

If "YES", please comment: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

8. In terms of fit and comfort, which oxygen mask do you prefer?

MBU-12/P \_\_\_\_\_

MBU-5/P \_\_\_\_\_

Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

PERCENTILE TABLE\*  
(1967, USAF Survey)

| Variable              | 1     | 2     | 3     | 5     | 10    | 15    | 20    | 25    | 30    | 35    | 40    | 45    | 50    |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Height                | 163.2 | 164.8 | 165.9 | 167.3 | 169.4 | 170.9 | 172.1 | 173.1 | 174.0 | 174.9 | 175.7 | 176.5 | 177.3 |
| Weight                | 127.5 | 132.6 | 135.8 | 140.2 | 146.9 | 151.5 | 155.3 | 158.6 | 161.6 | 164.4 | 167.1 | 169.7 | 172.4 |
| Face Length           | 10.7  | 10.8  | 10.9  | 11.0  | 11.3  | 11.4  | 11.5  | 11.6  | 11.7  | 11.8  | 11.9  | 12.0  | 12.03 |
| Nose Length           | 4.23  | 4.35  | 4.42  | 4.51  | 4.65  | 4.75  | 4.83  | 4.89  | 4.95  | 5.0   | 5.05  | 5.09  | 5.14  |
| Subnasale-Menton Lgth | 5.7   | 5.8   | 5.9   | 6.0   | 6.2   | 6.4   | 6.5   | 6.54  | 6.6   | 6.69  | 6.76  | 6.83  | 6.89  |
| Nasal Root Br (1965)  | 1.28  | 1.33  | 1.36  | 1.41  | 1.50  | 1.55  | 1.60  | 1.64  | 1.68  | 1.72  | 1.75  | 1.79  | 1.82  |
| Lip Length            | 4.33  | 4.44  | 4.51  | 4.60  | 4.75  | 4.84  | 4.92  | 4.98  | 5.04  | 5.09  | 5.14  | 5.19  | 5.24  |
| Bizygomatic Breadth   | 13.0  | 13.2  | 13.3  | 13.4  | 13.6  | 13.7  | 13.8  | 13.9  | 13.95 | 14.0  | 14.1  | 14.2  | 14.22 |
| Bigonial Breadth      | 10.2  | 10.4  | 10.5  | 10.6  | 10.9  | 11.0  | 11.1  | 11.3  | 11.4  | 11.44 | 11.5  | 11.6  | 11.7  |
| Head Length           | 18.3  | 18.5  | 18.6  | 18.8  | 19.0  | 19.2  | 19.3  | 19.4  | 19.5  | 19.6  | 19.7  | 19.8  | 19.86 |
| Head Breadth          | 14.4  | 14.5  | 14.6  | 14.7  | 14.9  | 15.0  | 15.1  | 15.2  | 15.3  | 15.4  | 15.5  | 15.52 | 15.6  |
| Nose Breadth          | 2.93  | 2.99  | 3.04  | 3.10  | 3.19  | 3.25  | 3.30  | 3.35  | 3.38  | 3.42  | 3.46  | 3.49  | 3.52  |
| Variable              | 55    | 60    | 65    | 70    | 75    | 80    | 85    | 90    | 95    | 97    | 98    | 99    |       |
| Height                | 178.1 | 178.9 | 179.7 | 180.6 | 181.5 | 182.6 | 183.8 | 185.4 | 187.7 | 189.2 | 190.2 | 191.8 |       |
| Weight                | 175.1 | 177.9 | 180.8 | 183.9 | 187.4 | 191.3 | 195.9 | 201.8 | 210.7 | 216.6 | 220.9 | 227.7 |       |
| Face Length           | 12.1  | 12.2  | 12.3  | 12.4  | 12.44 | 12.5  | 12.7  | 12.8  | 13.0  | 13.2  | 13.3  | 13.5  |       |
| Nose Length           | 5.18  | 5.23  | 5.28  | 5.33  | 5.38  | 5.44  | 5.51  | 5.6   | 5.74  | 5.84  | 5.91  | 6.03  |       |
| Subnasale-Menton Lgth | 6.96  | 7.03  | 7.1   | 7.18  | 7.26  | 7.35  | 7.46  | 7.59  | 7.78  | 7.9   | 7.98  | 8.10  |       |
| Nasal Root Br (1965)  | 1.85  | 1.88  | 1.92  | 1.96  | 2.0   | 2.04  | 2.10  | 2.16  | 2.27  | 2.35  | 2.40  | 2.50  |       |
| Lip Length            | 5.28  | 5.33  | 5.38  | 5.43  | 5.48  | 5.54  | 5.61  | 5.70  | 5.84  | 5.93  | 6.00  | 6.12  |       |
| Bizygomatic Br        | 14.3  | 14.4  | 14.42 | 14.5  | 14.6  | 14.66 | 14.75 | 14.9  | 15.1  | 15.2  | 15.3  | 15.5  |       |
| Bigonial Breadth      | 11.8  | 11.9  | 12.0  | 12.09 | 12.2  | 12.3  | 12.5  | 12.7  | 12.9  | 13.1  | 13.2  | 13.4  |       |
| Head Length           | 19.9  | 20.0  | 20.1  | 20.2  | 20.3  | 20.4  | 20.6  | 20.7  | 21.0  | 21.2  | 21.3  | 21.5  |       |
| Head Breadth          | 15.7  | 15.73 | 15.8  | 15.88 | 15.9  | 16.0  | 16.2  | 16.3  | 16.5  | 16.7  | 16.8  | 16.9  |       |
| Nose Breadth          | 3.56  | 3.60  | 3.63  | 3.67  | 3.72  | 3.77  | 3.83  | 3.92  | 4.05  | 4.14  | 4.22  | 4.34  |       |

\* Weight in pounds.  
All other dimensions in centimeters.

A BIVARIATE FREQUENCY TABLE FOR  
STATURE AND WEIGHT  
1968 USAF WOMEN

| STATURE(IN) | WEIGHT(LB) |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | TOTAL |       |       |       |       |       |       |     |
|-------------|------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
|             | 85.0       | 90.0 | 95.0 | 100.0 | 105.0 | 110.0 | 115.0 | 120.0 | 125.0 | 130.0 | 135.0 | 140.0 | 145.0 | 150.0 | 155.0 | 160.0 | 165.0 | 170.0 | 175.0 | 180.0 |       | 185.0 | 190.0 | 195.0 | 200.0 | 205.0 | TOTAL |     |
| 72.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 1     |     |
| 71.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 2   |
| 71.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 7   |
| 70.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 5   |
| 70.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 13  |
| 69.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 9   |
| 69.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 26  |
| 68.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 39  |
| 68.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 51  |
| 67.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 65  |
| 67.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 87  |
| 66.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 109 |
| 66.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 126 |
| 65.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 123 |
| 65.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 143 |
| 64.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 158 |
| 64.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 149 |
| 63.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 158 |
| 63.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 124 |
| 62.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 130 |
| 62.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 113 |
| 61.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 100 |
| 61.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 56  |
| 60.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 52  |
| 60.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 42  |
| 59.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 11  |
| 59.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 4   |
| 58.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 7   |
| 58.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 1   |
| 57.5        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 1   |
| 57.0        |            |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 1   |
| TOTAL       | 1          | 4    | 22   | 61    | 119   | 182   | 208   | 221   | 241   | 291   | 181   | 142   | 122   | 72    | 49    | 30    | 17    | 14    | 7     | 3     | 7     | 2     | 2     | 2     | 2     | 2     | 1805  |     |

1968 USAF WOMEN  
 MEAN ST DEV R REGRESSION EQUATIONS  
 WEIGHT(LB) 127.28 16.59 0.533 = (3.737)STATURE(IN)+(-111.21)  
 STATURE(IN) 63.82 2.36 0.533 = (0.076)WEIGHT(LB)+(54.15)  
 STD ERROR 14.04  
 2.00

## REFERENCES

Alexander, Milton, John T. McConville and Russell Carlson, 1977a, "Validation of Sizing of Chemical Warfare (CW) Nine-Size United Kingdom Undergarment." Published in: Guidry, Roland D. and Stephen R. Schick, 1977, Chemical Warfare Equipment and Procedures, TAC Project 74E-057T, Tactical Air Command, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida.

Alexander, Milton, John T. McConville, Russell Carlson, 1977b, "Sizing Design Validation Test of Personal-Protective Equipment for Chemical Warfare." Published in: Guidry, Roland D. and Stephen R. Schick, 1977, Chemical Warfare Equipment and Procedures, TAC Project 74E-057T, Tactical Air Command, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida.

Alexander, Milton, John T. McConville, Russell Carlson, 1977c, "Fit-Test Evaluation of Chemical Warfare Six-Size U.S. Overgarment." Published in: Guidry, Roland D. and Stephen R. Schick, 1977, Chemical Warfare Equipment and Procedures, TAC Project 74E-057T, Tactical Air Command, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida.

Alexander, Milton and John T. McConville, 1977, "Sizing Evaluation of Chemical Warfare Eight-Size Commercial Overglove (Edmont-Wilson, Model 29-845) for Flight Personnel. Published in: Guidry, Roland D. and Stephen R. Schick, 1977, Chemical Warfare Equipment and Procedures, TAC Project 74E-057T, Tactical Air Command, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida.

Anonymous, 1974, U.S. Human Factors Engineering Data Guide for Evaluation, U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Aberdeen, Maryland.

Barter, James T. and Milton Alexander, 1956, A Sizing System for High Altitude Gloves, WADC Technical Report 56-599 (AD 110589), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Churchill, Edmund, Thomas Churchill and Paul Kikta, 1978, Intercorrelations of Anthropometric Measurements: A Source Book for USA Data, AMRL-TR-77-2 (AD A058616), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Clausen, Charles E., Pearl E. Tucker, John T. McConville, E. Churchill, Lloyd L. Laubach and Joan A. Reardon, 1972, Anthropometry of Air Force Women, AMRL-TR-70-5 (AD 743113), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Emanuel, Irwin, Milton Alexander and Edmund Churchill, 1959, Anthropometric Sizing and Fit Test of the MC-1 Oral-Nasal Oxygen Mask, WADC Technical Report 58-505 (AD 150964), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Garrett, John W. and Kenneth W. Kennedy, 1971, A Collation of Anthropometry, AMRL-TR-68-1 (AD 723-629), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Gillespie, Kent W., 1977, Pararescue Radio Components Helmets Evaluation, TM-ENEC-77-1, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

Malone, Thomas B., Sheldon W. Shenk and William F. Moroney, 1976, Human Factors Test and Evaluation Manual, Volumes I-III, Report No. TP-76-11A, Pacific Missile Test Center, Point Mugu, California.

McConville, John T. and Milton Alexander, 1975, "Anthropometric Sizing Program for Oral-Nasal Oxygen Masks Based on 1967 U.S. Air Force Survey Data," Aviation, Space and Environmental Medicine, Vol. 46(11), 1383-1389.