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A SIZING SYSTEM FOR HIGH ALTITUDE GLOVES

JAMES T. BARTER, A/2C, USAF
AERO MEDICAL LABORATORY

MILTON ALEXANDER, 1/LT, USAF
AERO MEDICAL LABORATORY

DECEMBER 1956

WRIGHT AIR DEVELOPMENT CENTER

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AERO MEDICAL LABORATORY
CONTRACT No. AF 18(600)-30
PROJECT No. 7214

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

The work described herein was performed by the Anthropology Section, Biophysics Branch, Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, under the authority of Project 7214, "Physical Anthropology" and at Antioch College, Yellow Springs, Ohio under Contract AF 18(600)-30. The work was done in support of Project 6333, "High Altitude Pressure Suit and Accessories".

The program was intiated by Lt. Frank P. Saul, USAF (MSC) as one part of a comprehensive survey of hand dimensions. Airman Barter and Mr. Irvin Emanuel made the basic decisions concerning the number of sizes, the range of dimensions to be covered in each size category, the inclusion of specific measurements, and the statistical procedures to be followed. The statistical reduction of the data was carried out by Antioch College under the direction of Mr. John B. Truett. The measurements were taken by or under the supervision of Mr. Edward I. Fry. The fit test of the finished products was carried out by Lt. Milton Alexander and Airman James T. Barter.

Many people contributed to the success of this program; first and foremost were our subjects who "lent a hand" when it was needed most. Mr. H.T.E. Hertzberg, Chief, Anthropology Section, offered many helpful suggestions which contributed materially to the completion of this program. Mr. Edmund Churchill provided many valuable suggestions on the statistical phases of this work. And finally our thanks go to all of the workers who performed the tedious tasks of measuring X-rays, running calculating machines, typing tables of figures and rough drafts of the report; Kathi Bernhardi, Nan Kaiser, Ted Lim, Bob Yuan, Dave Phail and Evelyn Klips. Mr. Horace B. Clark prepared the illustrations and aided materially in the physical preparation of the report.

This Report is UNCLASSIFIED.

ABSTRACT

This report presents the rationale for and procedures followed in the development of a sizing program for high altitude gloves. This program is based on four divisions of hand circumference, each subdivided into three divisions of hand length making a total of twelve sizes. A selected sample of 100 hands was measured to provide the thirty-one dimensions presented for design purposes. Summary statistics, regression equations, design dimensions, and a procurement tariff are presented in various tables throughout the report.

The results of a fit-test of two differing styles of gloves sized according to this program indicate that a high percentage of personnel can be fitted adequately in their indicated size. Detailed instructions for determining the indicated size of gloves are also included.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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SECTION I

Introduction

The problem of adequately protecting the hand at high altitudes by means of a partial pressure glove is complicated by the conflicting demands of conformity, comfort and mobility. The degree to which the glove conforms to the hand determines to a large extent the adequacy of protection. However, the very nature of the partial pressure glove is to some degree opposed to adequate mobility and comfort. A well-fitting glove, i.e., one which conforms closely to the dimensions of the hand, does much to improve mobility and comfort in an uninflated state, but when counter-pressure is applied, both mobility and comfort are decreased.

The current study is concerned with the development of a sizing program for partial pressure gloves. It is felt that the problems of comfort and mobility are primarily a matter of design and only secondarily related to sizing. In other words, if the sizing program can insure a well-fitting glove then the designer must assume responsibility of eliminating uncomfortable pressure points and incorporating easement factors to insure proper mobility. The extent to which the current sizing program meets the requirements of good fit is discussed in Section IV "Fit-Test Results".

The available anthropometric data on hand dimensions were considered inadequate for the following reasons:

1. The hand measurements taken by the Anthropology Section during its 1950 survey were not specifically planned for glove design purposes and therefore are not inclusive enough. An insufficient number of dimensions were taken by the 1950 survey to satisfy today's requirements.

2. The University of California at Los Angeles and Harvard surveys were taken on samples which could not be directly compared with Air Force personnel.

Therefore a new survey was planned whose specific purpose was to provide adequate design information for the construction of high altitude gloves. Tape and caliper measurements were taken for those dimensions difficult or impossible to secure from the X-ray.

Commercial glove sizing practices were thought to be inadequate for a glove which must conform to the hand in all dimensions. The prime dimension used by many manufacturers is hand circumference, which more or less corresponds to the anthropometric measurement, Hand Circumference at Metacarpal 2. Commercial sizes are stated in terms of glovers inches which in turn are based on the metric system in some obscure fashion. One glovers inch equals 27.0 millimeters or 1.06 English inches. A size 8 1/2 glove then is supposed to fit individuals whose hand circumference is 8 1/2 glovers inches or 230 millimeters. Usually commercial glove sizes range from 7 to 10 by glovers half-inch increments. This large number of sizes assures a reasonably good fit for hand circumference. The problem of hand length is solved by a series of even gradations up and down from the arbitrary length decided upon for the size 8 1/2 glove. Finger lengths are accommodated by having the fingers of the glove slightly short so that when the hand is inserted into the glove the tips of the fingers go to the end of the glove. The only problem here is that only one or two of the fingers are accommodated adequately. The manufacturer of leather gloves has the additional factor of natural stretch which helps the glove conform to the hand. Small variations in size are thus taken care of in the course of use.

SECTION II

Materials and Methods

The sample consisted of 100 Air Force and civilian personnel from Wright-Patterson Air Force Base. This sample was selected from a larger group of 150 subjects so as to correspond statistically with the 1950 survey sample (Hertzberg, Daniels and Churchill, 1954) for hand length and hand breadth.

A large number of individuals measured were or had been rated flying personnel. The selected sample represents a fair microcosm of the larger Air Force population.

Two techniques were utilized to secure hand dimensions. The first concerned taking standardized anthropometric measurements of the hand as well as some new measurements especially designed for this study. The second technique involved taking a roentgenogram of both outstretched hands. From the resulting X-ray a number of straight-line dimensions were obtained using a millimeter rule.

The hand was positioned on the X-ray casette so that the palm faced down on the surface, with the fingers extended, parallel and just slightly separated. The thumb was fully abducted (held away from the palm) in most cases. The wrist and forearm were arranged in a straight-line with the third finger.

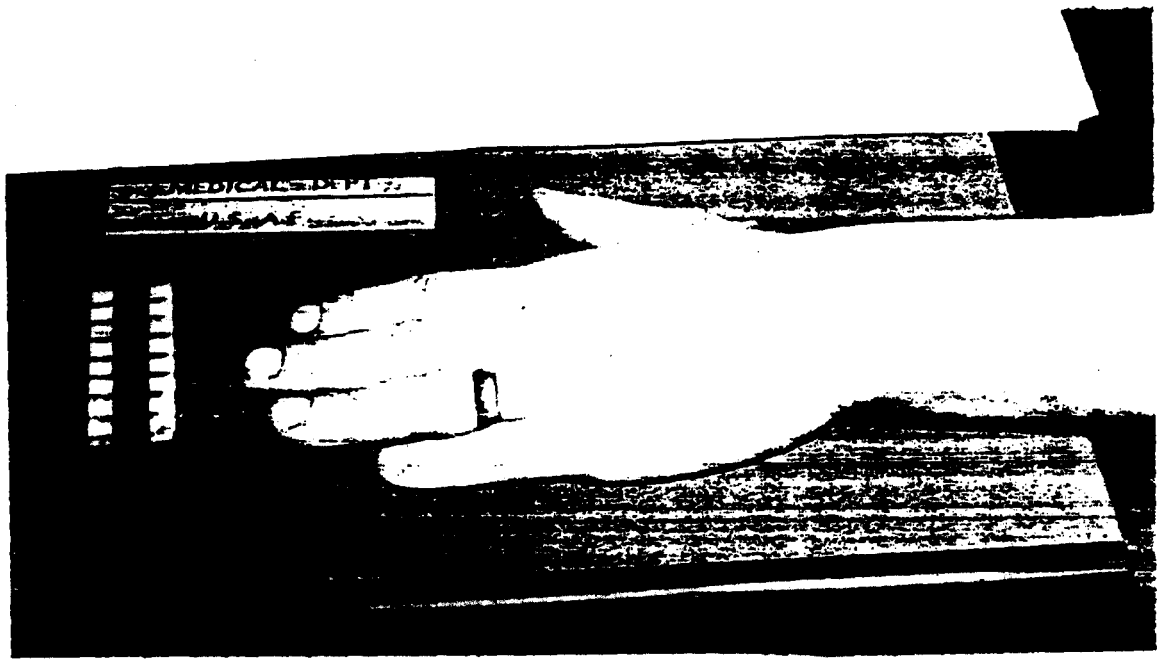

Figure 1. Placement of Hand on X-ray Casette

The X-ray of the right hand was used to determine dimensions for glove sizing. A baseline, passing transversely across the wrist, was established, from which all length measurements were determined. This baseline was constructed in the following manner. A vertical line was drawn from the middle of the tip of the distal phalanx to the center of the metacarpal-phalangeal joint of digit three. A perpendicular was drawn from this line so that it passed just tangent to the tip of the styloid process of the ulna, forming the baseline. Measurements were taken to the fleshy outline of the hand or to definite bony landmarks. Some dimensions were obtained indirectly by subtracting the height of the crotches from the overall height of the tip of the digit above the baseline. The X-ray measurements all have a constant error of 2% due to enlargement, but are probably as accurate as direct measurements because the factor of compressibility of the flesh is non-existent.

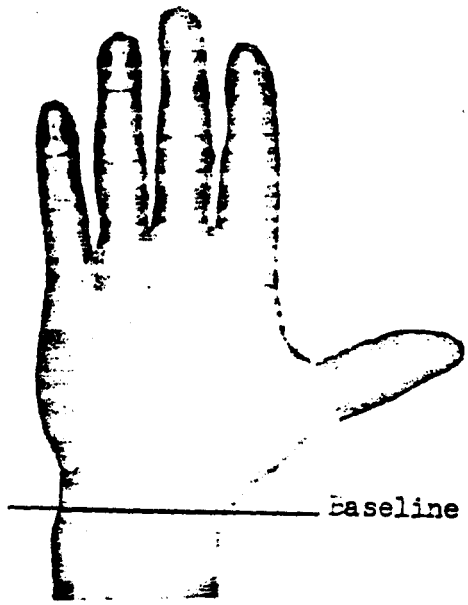

Figure 2. X-ray of The Right Hand

The following measurements were the basis for this sizing program. Summary Statistics accompany each verbal description and illustration. All dimensions are expressed in millimeters.

1. Hand Length: The hand is placed n the table with the palm facing upwards, he fingers outstretched and together. he measurement is taken with the sliding aliper from the proximal edge of the avicular bone (located by palpation) to he fleshy tip of the third digit.

Mean	188.10
Standard Deviation	9.35
r with Hand Circumference	.606

Figure 3. Hand Length

2. Hand Circumference at Metacarpal 2: The hand is placed palm down on the table, with the fingers outstretched and together. The thumb is held away from the hand. The measurement is taken with a millimeter tape around the hand at the base of the fingers, the tape passing over all four knuckles.

Mean	213.86
Standard Deviation	8.39
r with Hand Length	.606

Figure 4. Hand Circumference at Metacarpal 2

Figure 5. Hand Circumference at Thumb

3. Hand Circumference at Thumb: The hand is placed palm down on the table, with the fingers outstretched and together. The thumb is held loosely against the side of the hand. The measurement is taken with a steel millimeter tape. The tape passes at right angles to the long axis of the hand at the level of the metacarpal-phalangeal joint of the first digit.

Mean	251.07
Standard Deviation	10.95
r with Hand Length	.583
r with Hand Circumference	.810

H.C.T. = .170 H.L. + .941 H.C. + 17.85

4. Hand Breadth at Metacarpal 2: The hand is placed palm upward on the table, with the fingers outstretched and together. The thumb is held away from the hand. The measurement is taken across the hand from the area of the metacarpal-phalangeal joint of the second finger to the metacarpal-phalangeal joint of the fifth finger with the sliding caliper.

Mean	89.56
Standard Deviation	3.57
r with Hand Length	.671
r with Hand Circumference	.841

H.B. M.2 = .080 H.L. + .322 H.C. + 5.65

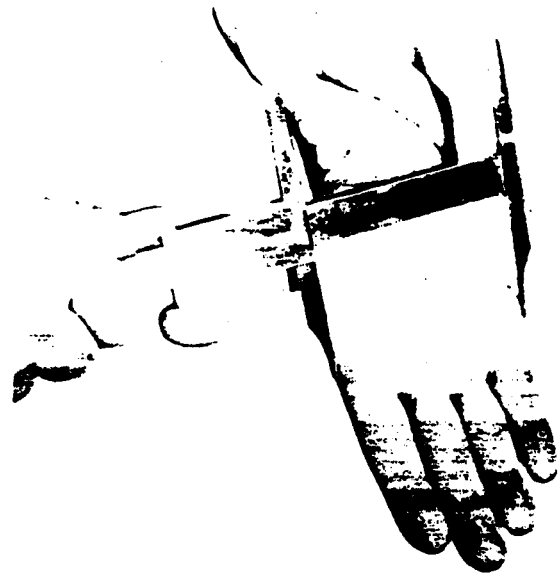

Figure 6. Hand Breadth at Metacarpal 2

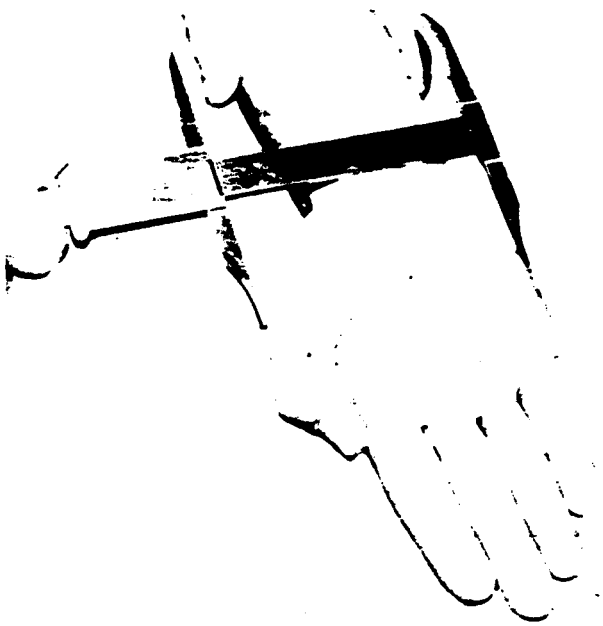

Figure 7. Hand Breadth at Thumb

5. Hand Breadth at Thumb: The hand is placed palm upward on the table with the fingers outstretched and together. The thumb is held loosely against the side of the hand. The measurement is taken across the hand, at right angles to the long axis, from the metacarpal-phalangeal joint of the first digit to the ulnar side of the hand with the sliding calipers.

Mean	105.81
Standard Deviation	5.07
r with Hand Length	.640
r with Hand Circumference	.713

H.B.D.1 = .178 H.L. + .310 H.C. + 6.03

6. Wrist Circumference at Collateral Ligament: The hand is placed palm down on the table. The measurement is taken around the wrist, just distal to the radial and ulnar styloid processes, with the millimeter tape.

Mean	175.3
Standard Deviation	7.05
r with Hand Length	.502
r with Hand Circumference	.603

W.C.C.L. = .162 H.L. + .396 H.C. + 60.14

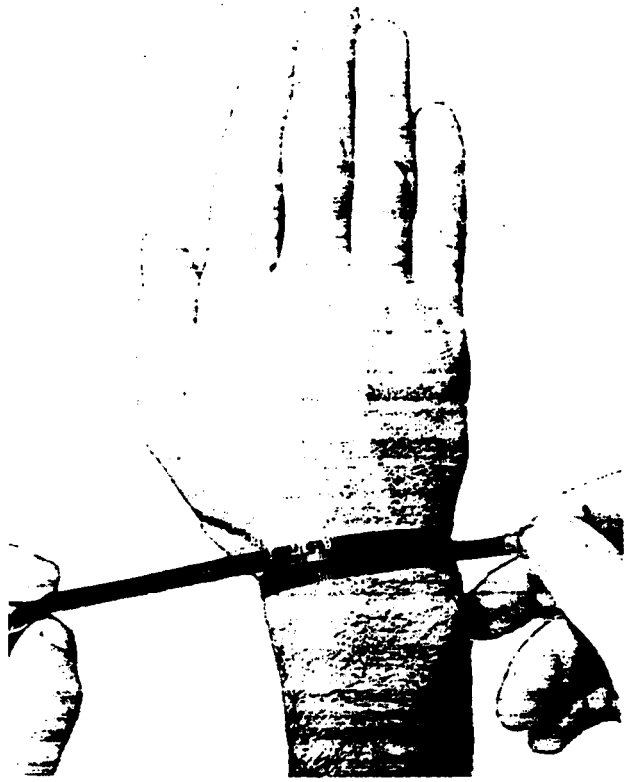

Figure 8. Wrist Circumference at Collateral Ligament

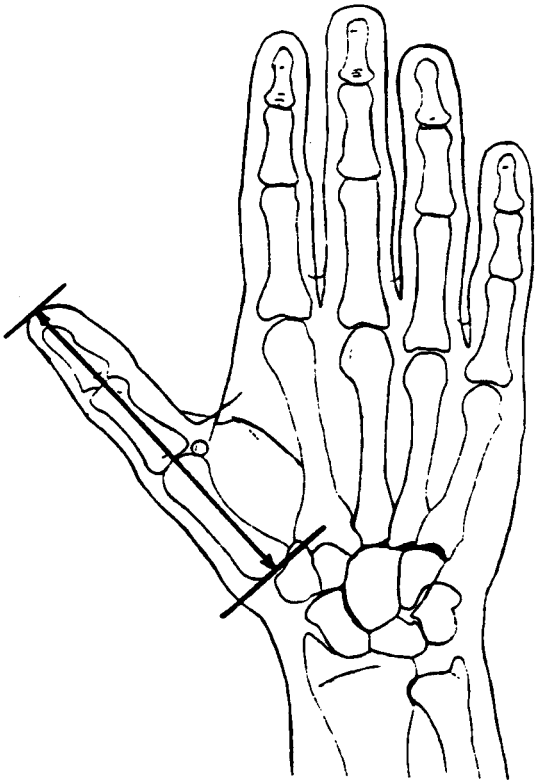

Figure 9. Total Length of Thumb

7. Total Length of Thumb: Measured on the X-ray from the base of the thumb at its junction with the wrist (metacarpal joint) to the fleshy tip of the thumb.

Mean	119.13
Standard Deviation	6.20
r with Hand Length	.805
r with Hand Circumference	.508

T.L.D.1 = .521 H.L. + .024 H.C. + 16.08

8. Length of Thumb from the Metacarpal-phalangeal Joint: Measured on the X-ray as the greatest distance between the metacarpal-phalangeal joint and the tip of the thumb.

Mean	62.08
Standard Deviation	3.35
r with Hand Length	.790
r with Hand Circumference	.531

L.T.F.M-P.J. = .265 H.L. + .033 H.C. + 5.18

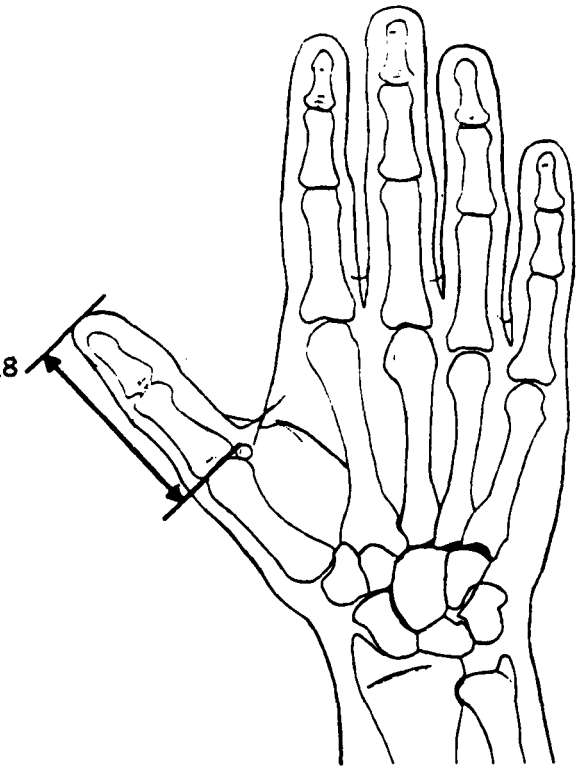

Figure 10. Length of Thumb from the First Crotch

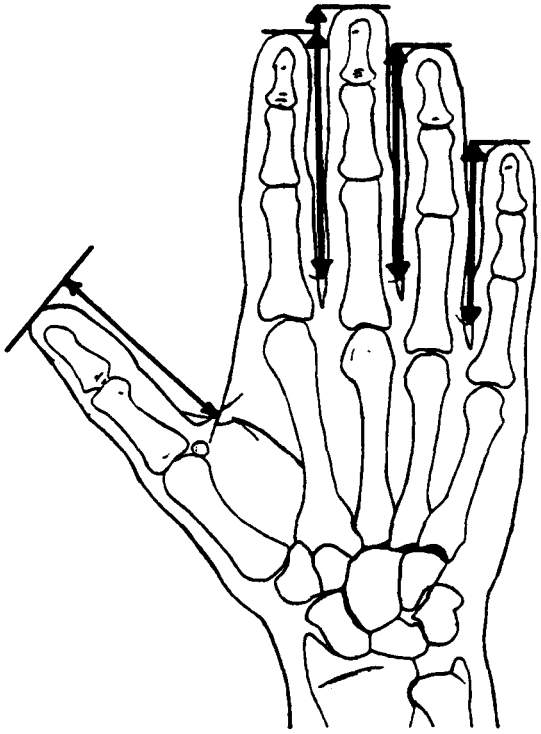

Figure 11. Length of Digits 1 to 5

9. Length of Digits 1 to 5: Measured on the X-ray, from the fleshy outline of crotches 1 to 5 to the tip of the digit (digits 2 and 3 from C-2, digit 4 from C-3 and digit 5 from C-4).

L.D.1 = .299 H.L. + .107 H.C. + 25.57
L.D.2 = .256 H.L. + .035 H.C. + 16.78
L.D.3 = .345 H.L. + .019 H.C. + 15.46
L.D.4 = .352 H.L. - .004 H.C. + 8.02
L.D.5 = .321 H.L. + .000 H.C. - 4.41

	1	2	3	4	5
Mean	58.93	72.42	84.42	73.38	55.97
Standard Deviation	4.42	5.17	5.22	4.40	4.88
r with Hand Length	.526	.499	.406	.742	.617
r with Hand Circumference	.190	.399	.637	.444	.374

10. Height of Crotches, 1 to 4 above Baseline: Measured on the X-ray as the perpendicular distance from the baseline to the fleshy outline of crotches 1 to 4.

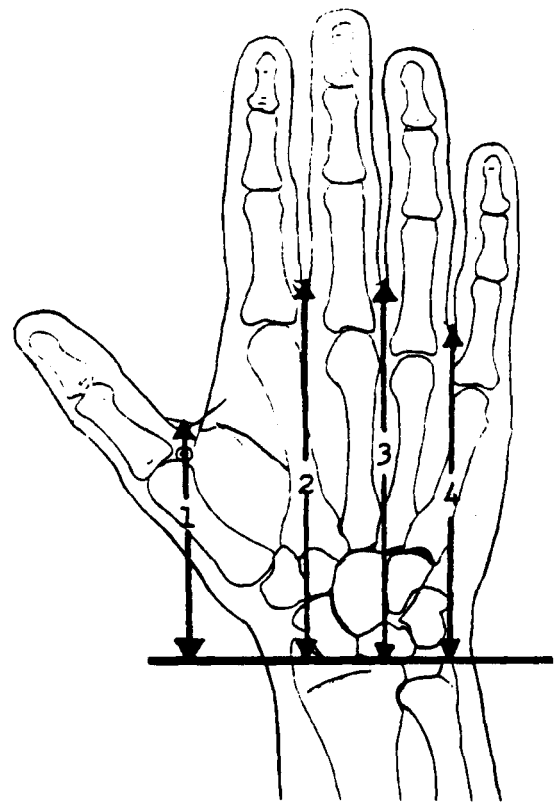

Figure 12. Height of Crotches, 1 to 4 above Baseline

$$Ht.C.1 = .261\ H.L. + .123\ H.C. - .14$$
$$Ht.C.2 = .542\ H.L. + .068\ H.C. + .30$$
$$Ht.C.3 = .564\ H.L. + .064\ H.C. - 2.70$$
$$Ht.C.4 = .525\ H.L. + .023\ H.C. + 1.90$$

	Ht.C.1	Ht.C.2	Ht.C.3	Ht.C.4
Mean	75.26	116.79	117.08	105.57
Standard Deviation	7.53	7.06	7.12	6.98
r with Hand Length	.409	.787	.769	.721
r with Hand Circumference	.335	.525	.518	.455

11. Breadth of Proximal Knuckle of Digit 1: The thumb is placed lightly on the edge of the table, volar side down. The transverse diameter of the proximal joint is measured with the sliding calipers in light contact with the skin.

Mean	23.79
Standard Deviation	1.49
r with Hand Length	.395
r with Hand Circumference	.472

B.P.K.1 = .027 H.L. + .065 H.C. + 4.81

Figure 13. Breadth of Proximal Knuckle of Digit 1

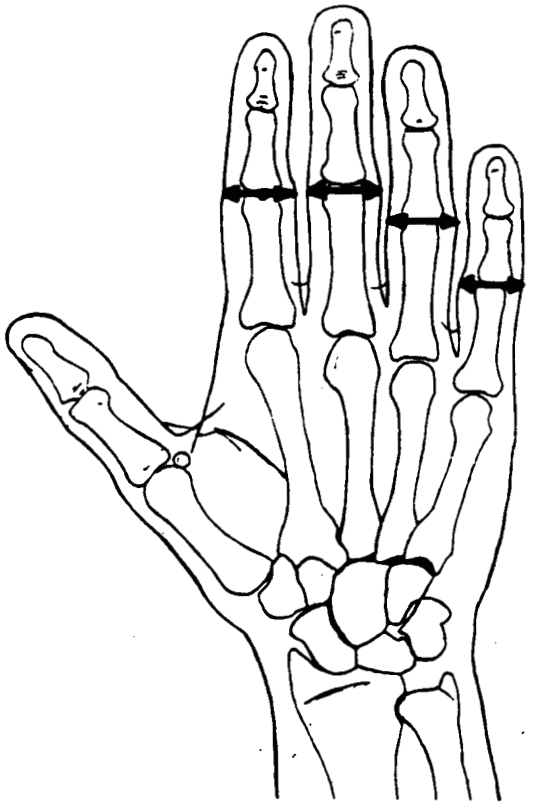

Figure 14. Breadth of Proximal Knuckles of Digits 2 to 5

12. Breadth of Proximal Knuckles of Digits 2 to 5: Measured on the X-ray as the greatest width of the fleshy outline of the finger at the proximal knuckle.

B.P.K.2 = .008 H.L. + .065 H.C. + 4.81
B.P.K.3 = .022 H.L. + .064 H.C. + 4.72
B.P.K.4 = .016 H.L. + .045 H.C. + 8.48
B.P.K.5 = .017 H.L. + .040 H.C. + 6.78

	B.P.K.2	B.P.K.3	B.P.K.4	B.P.K.5
Mean	22.59	22.55	21.11	18.53
Standard Deviation	1.10	1.07	.93	.99
r with Hand Length	.402	.496	.407	.367
r with Hand Circumference	.588	.620	.504	.436

13. Thickness of Proximal Knuckle of Thumb: Measured on the X-ray as the greatest thickness of the fleshy outline of the thumb at the proximal joint.

Mean	19.38
Standard Deviation	1.14
r with Hand Length	.427
r with Hand Circumference	.529

T.P.K.1 = .020 H.L. + .058 H.C. + 3.21

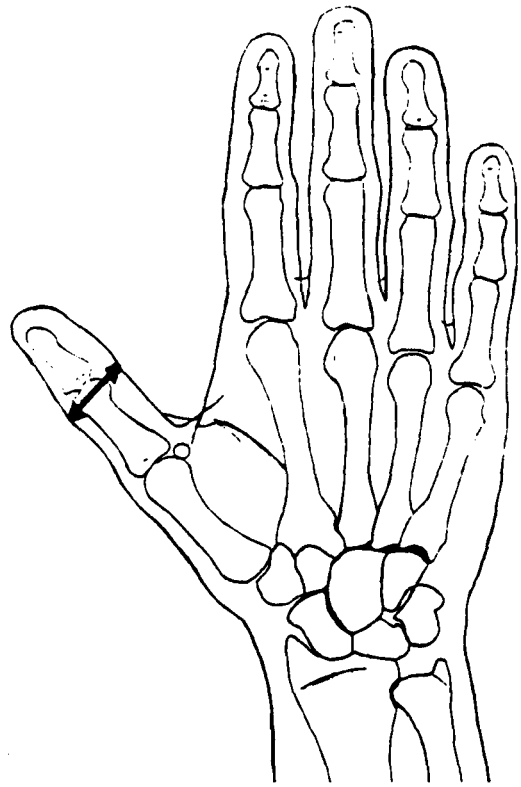

Figure 15. Thickness of Proximal Knuckle of Thumb

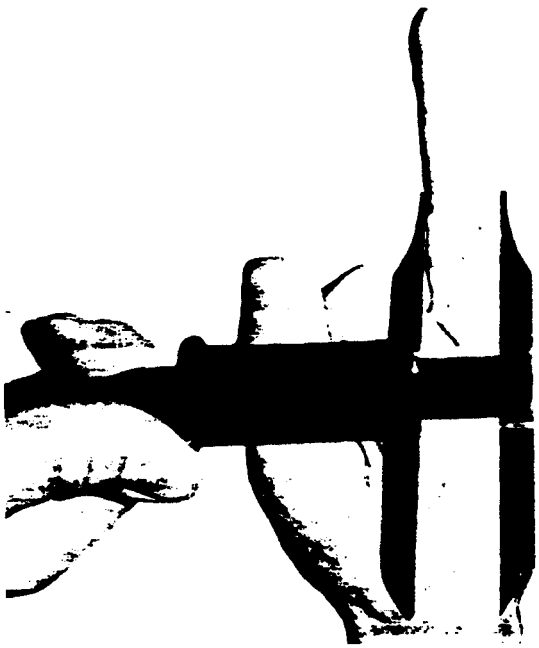

Figure 16. Thickness of Proximal Knuckle of Digits 2 to 5

14. Thickness of Proximal Knuckle of Digits 2 to 5: The subject rests the right elbow on the table with the fingers extended along the forearm and pointing up. The anterior-posterior diameter of each finger is measured with the sliding caliper. After each finger is measured it is folded down out of the way and held by the other hand.

T.P.K.2 = .049 H.L. + .034 H.C. + 2.26
T.P.K.3 = .054 H.L. + .043 H.C. + .19
T.P.K.4 = .026 H.L. + .034 H.C. + 6.24
T.P.K.5 = .008 H.L. + .042 H.C. + 5.53

	T.P.K.2	T.P.K.3	T.P.K.4	T.P.K.5
Mean	18.75	19.54	18.40	16.02
Standard Deviation	1.05	1.22	1.04	1.08
r with Hand Length	.505	.594	.398	.265
r with Hand Circumference	.541	.546	.414	.368

15. Height Above Crotches of Proximal Knuckles of Digits 2 to 5: Measured on the X-ray as the height above the crotches of a horizontal line passing through the middle of each proximal joint of digits 2 to 5.

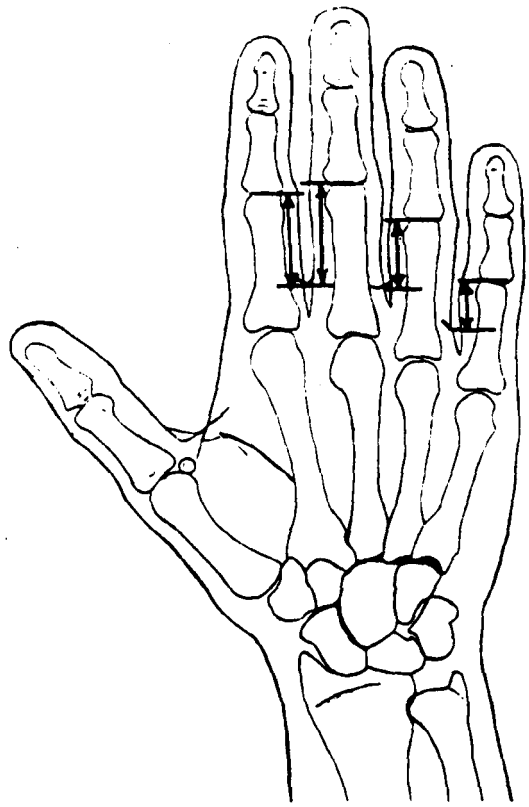

Figure 17. Height Above Crotches of Proximal Knuckles of Digits 2 to 5

$$Ht.P.K.2 = .153\ H.L. - .027\ H.C. + 2.44$$
$$Ht.P.K.3 = .151\ H.L. + .002\ H.C. + 2.15$$
$$Ht.P.K.4 = .113\ H.L. - .005\ H.C. + .50$$
$$Ht.P.K.5 = .062\ H.L. + .082\ H.C. - 14.37$$

	Ht.P.K.2	Ht.P.K.3	Ht.P.K.4	Ht.P.K.5
Mean	25.45	30.98	20.69	14.83
Standard Deviation	3.78	2.67	3.28	3.26
r with Hand Length	.264	.387	.434	.397
r with Hand Circumference	.196	.267	.224	.276

16. Height of Digit 2 Above Crotch I: Measured on the X-ray as the greatest distance between the fleshy outline of the first crotch to the tip of digit 2.

Mean	114.28
S.D.	7.80
r with Hand Length	.695
r with Hand Circumference	.381

H.D.2A. Cl = .612 H.L. - .059 H.C. + 11.78

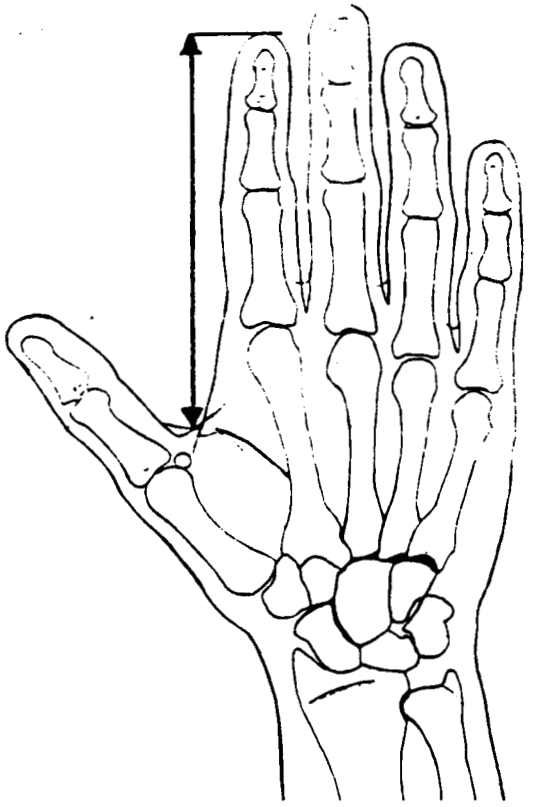

Figure 18. Height of Digit 2 Above Crotch I

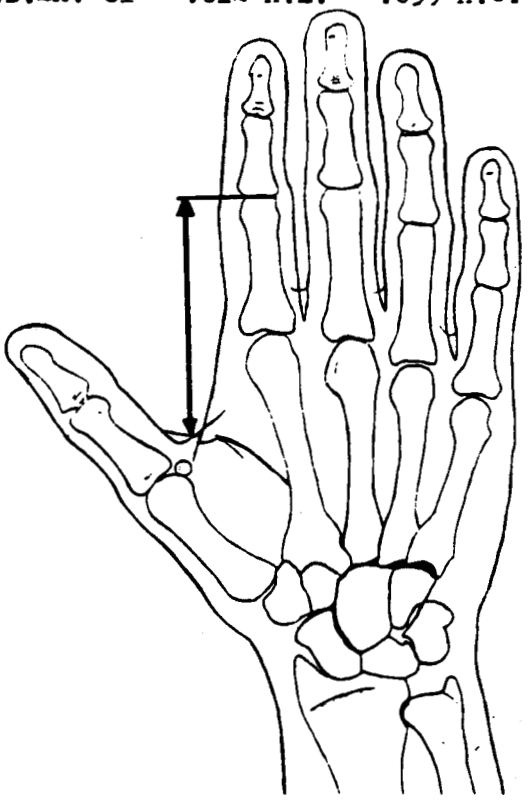

Figure 19. Height of Proximal Knuckle of Digit 2 Above Crotch I

17. Height of Proximal Knuckle of Digit 2 Above Crotch I: Measured on the X-ray as the greatest vertical distance between the fleshy outline of the first crotch to the middle of the proximal joint of the second digit.

Mean	66.98
S.D.	6.48
r with Hand Length	.562
r with Hand Circumference	.274

H.P.K. 2 A. Cl = .433 H.L. - .081 + 2.86

Once these measurements had been determined for each subject the dimensions were transferred to punch cards for machine analysis. Section III presents an outline of the statistical procedure and the resulting sizing program.

SECTION III

Analysis of the Data and Results

Any valid sizing program must accommodate a large (90-95%) percentage of the population and provide a reasonable tolerance of fit. For each sizing problem there is an optimum number of sizes. This optimum may be defined as the fewest number of sizes which will fit the largest number of people. It is important to realize that, contrary to popular belief, a large number of sizes does not necessarily improve the quality of fit or the proportion of the group accommodated. The optimum number is arrived at by a statistical analysis of the means and variabilities of the various dimensions, and hence is a fairly lengthy process. The deadline for the current sizing program, was such that no investigation into the optimum number of sizes could be attempted. A twelve-size system was chosen arbitrarily, because it was felt that this definitely would be usable, and because it equalled the number of sizes of the partial pressure suits.

The two basic dimensions, hand length and hand circumference were chosen because they correlated reasonably well with most of the other hand dimensions. Figure 20 is a theoretical bivariate distribution of about 1000 cases for two variables having a correlation coefficient of .60. As the two basic dimensions used correlate .606, this bivariate probably depicts the actual relationships with a high degree of accuracy. The use of a theoretical bivariate was dictated because an actual bivarate using the small number of subjects (100) available in this sample would not portray the population characteristics as accurately.

The bivariate has been divided into twelve size categories, each category defined by definite ranges of the basic dimensions. These ranges were determined by the requirements of the proportion to be fitted and the allowable tolerance of fit. It is to be noted that not all of the categories are enclosed by equal ranges.

Once the number of sizes had been decided and the requisite hand dimensions had been transferred to punch cards, analysis of the data was completed. The punch cards for the 100 subjects were run through the IBM 602-A calculator to secure the mean, standard deviation, and correlation of each dimension with hand length and hand circumference.

With hand length and hand circumference as the independent variables, regression equations were computed for the other 31 dimensions as dependent variables. Once these equations had been obtained, midpoints of the size ranges of the two basic dimensions were substituted in order to obtain group mean values for the other dimensions. To each of these mean values one within-size standard deviation was added to obtain the design value. The within-size standard deviation is the same for all twelve sizes. It may be thought of as an average standard deviation. The regression equations for all of the dependent variables are to be found accompanying the description of the measurements.

Table I summarizes the design values of the 12-size system for partial-pressure gloves. These values are designed to accommodate the size means plus one and minus two within-size standard deviations. Design dimensions have been rounded to the nearest millimeter. In some cases this may represent greater accuracy than pattern makers or manufacturers can utilize.

HAND LENGTH

HAND CIRCUMFERENCE: Millimeters	—165	165–169	170–174	175–179	180–183	184–188	189–193	194–197	198–202	203–207	208–211	212—
235 -							1	1	1	1	1	1
231–234						1	2	3	4	4	2	1
226–230					1	3	7	10	10	7	4	1
222–225				1	4	11	19	22	18	10	4	1
218–223			1	4	13	26	36	34	22	10	3	1
214–217		1	3	11	26	42	46	36	19	7	2	
210–213		2	7	19	36	46	42	26	11	3	1	
205–209	1	3	10	22	34	36	26	13	4	1		
201–204	1	4	10	18	22	19	11	4	1			
197–200	1	4	7	10	10	7	3	1				
193–196	1	2	4	4	3	2	1					
-193	1	1	1	1	1							

Figure 20. Theoretical Bivariate for Hand Length and Hand Circumference at Metacarpale (r = .60)

TABLE I - DESIGN VALUES FOR 12-SIZE SYSTEM FOR HIGH ALTITUDE GLOVES
(All Dimensions in Millimeters)

		A	B	C	D	E	F	G	H	I	J	K	L
1.	Hand Length	172	182	192	176	188	200	180	192	204	185	197	209
2.	Hand Circumference	200	200	200	210	210	210	220	220	220	230	230	230
3.	Hand Circumf. at Thumb	242	244	246	253	255	257	263	265	267	273	275	277
4.	Hand Breadth at Meta 2	86	87	87	89	90	91	93	94	95	96	97	98
5.	Hand Breadth at Thumb	103	105	106	107	109	111	110	113	115	114	117	119
6.	Wrist Circumf. at Collateral Lig.	173	175	176	178	179	181	182	184	186	187	189	191
7.	Total Length of Thumb	117	122	127	119	126	132	122	128	134	125	131	137
8.	Total Length of Thumb from First Crotch	60	63	66	60	63	67	60	63	67	60	64	67
9.	Length Digit 1	60	62	65	61	64	67	62	66	69	64	67	70
10.	Length Digit 2	72	75	77	74	77	80	75	78	81	77	80	83
11.	Length Digit 3	83	86	90	84	89	93	86	90	94	88	92	96
12.	Length Digit 4	71	74	78	72	76	81	74	78	82	75	80	84
13.	Length Digit 5	55	58	61	56	60	64	57	61	65	59	63	66
14.	Height of Crotch 1 above Baseline	76	79	81	79	82	85	81	84	87	83	86	90
15.	Height of Crotch 2 above Baseline	112	117	123	115	121	128	118	124	131	121	128	134
16.	Height of Crotch 3 above Baseline	112	118	123	115	122	128	118	124	131	121	128	135
17.	Height of Crotch 4 above Baseline	102	107	112	104	111	117	107	113	119	109	116	122
18.	Breadth of Proximal Knuckle Digit 1	24	24	24	24	25	25	25	26	26	26	26	27
19.	Breadth of Proximal Knuckle Digit 2	22	22	23	23	23	23	24	24	24	25	25	25
20.	Breadth of Proximal Knuckle Digit 3	22	22	23	23	23	23	24	24	24	24	25	25
21.	Breadth of Proximal Knuckle Digit 4	21	21	21	22	22	22	22	22	22	22	23	23
22.	Breadth of Proximal Knuckle Digit 5	19	19	19	19	19	19	19	20	20	20	20	20
23.	Thickness of Proximal Knuckle Digit 1	19	19	20	20	20	20	21	21	21	21	21	22
24.	Thickness of Proximal Knuckle Digit 2	18	19	19	19	19	20	19	20	21	20	21	21
25.	Thickness of Proximal Knuckle Digit 3	19	20	20	20	20	21	20	21	22	21	22	22
26.	Thickness of Proximal Knuckle Digit 4	18	19	19	19	19	19	19	20	20	20	20	20
27.	Thickness of Proximal Knuckle Digit 5	16	16	16	17	17	17	17	17	17	18	18	18
28.	Height of Proximal Knuckle of Digit 2 above Baseline	26	28	29	27	29	30	27	29	31	28	29	31
29.	Height of Proximal Knuckle of Digit 3 above Baseline	32	33	35	32	34	36	33	35	36	34	35	37
30.	Height of Proximal Knuckle of Digit 4 above Baseline	22	23	24	22	23	25	22	24	25	23	24	26
31.	Height of Proximal Knuckle of Digit 5 above Baseline	16	17	18	17	18	19	18	19	20	20	20	21
32.	Height of Digit 2 above Crotch 1	112	117	123	113	120	128	115	122	130	117	125	132
33.	Height of Proximal Knuckle Digit 2 above Crotch 1	67	71	75	68	73	78	68	74	79	70	75	80

A suggested procurement tariff for gloves sized according to this program is found in Table II. This tariff is based on the number of subjects included in each size category of the theoretical bivariate expressed as a percentage of the total sample.

TABLE II - Suggested Procurement Tariff

Number of Pairs Per Thousand

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

SECTION IV

Fit Test Results

An important step in the development of any clothing item is the fit test. It is after this phase is accomplished that the success, or failure of a developmental sizing program is realized. Only then, after this final step, in a long progression of experimentation, which begins with the gathering of body dimensions, progresses with transforming the raw data into a usable sizing system, followed by integrating the sizing system into the actual item, can the article be judged from a practical standpoint - how it fits and protects the wearer.

The fit test of the partial pressure gloves was conducted on fifty-one (51) Aero Medical Laboratory personnel. Two sets of gloves, fabricated by different manufacturers but sized according to identical sizing systems, were tested. The main purpose of the test was to determine the adequacy of the sizing program, not to compare two manufacturing techniques, nor to evaluate comfort. Although comfort and fit are interrelated, only general comfort observations were recorded, since the gloves were worn only for short periods of time during the test. Of the fifty-one (51) subjects tested thirteen (13) wore Manufacturer I gloves only, ten (10) wore Manufacturer II gloves only and the remainder wore both types.

In an item of this importance, a sample of fifty-one (51) people serves only as a good indication of the adequacy of the sizing system. A larger sample would give greater confidence in the efficiency of the sizing system. However, the range of sizes of gloves tested did cover the entire range of hand sizes in the Air Force.

Procedure: The procedure used for fitting and testing both types of gloves was identical. It consisted of taking two dimensions, hand circumference and hand length, on the right hand of each subject in the following manner:

Hand Circumference: The hand circumference was taken by placing the measuring tape on a table or other flat surface with the numerals facing downward. The subject placed his right hand, palm down and fingers together, in the middle of the tape so that the tape could pass straight across the hand just beneath the knuckles. The circumference was measured to the nearest eighth of an inch.

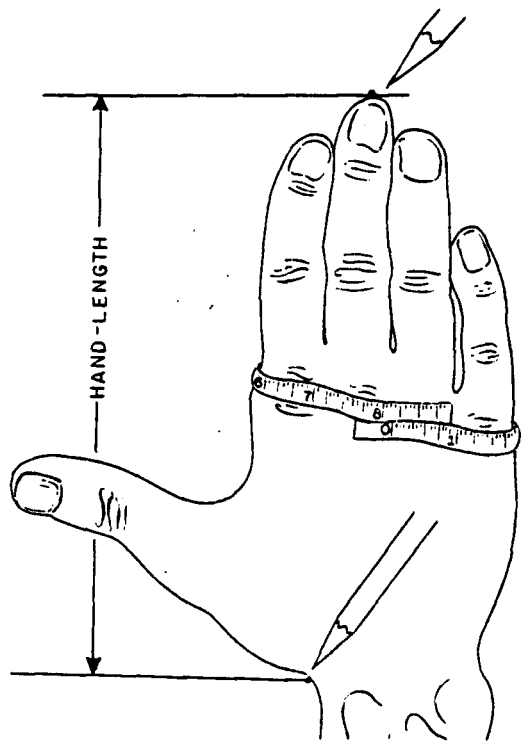

Figure 21. Method of Taking Hand Dimensions for Selection of Proper Glove

Hand Length: The hand length was taken by placing the subject's hand, palm down, on a piece of paper with the fingers together and the hand and arm in a straight line. The thumb was extended to the side as far as possible. The paper was marked at the tip of the longest, or digit 3, finger. Then, the pencil was placed in the notch at the base of the thumb where the thumb joins the wrist, and the paper marked. The straight line distance between the two points was measured to the nearest eighth of an inch.

The measurements taken were then compared with glove sizing charts and the proper, or indicated, glove size determined.

The selection criteria were as follows:

If Hand Circumference is	And Hand Length is	Then Glove Size is
7-7/8 or below	6-5/8 to 7	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 7-7/8	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

The glove was donned and first evaluated in the uninflated state. It was decided to evaluate three main areas for dimensional fit; the finger lengths, hand circumference and wrist circumference.

Finger Lengths: The fit of each glove finger, from the crotch to the finger tip, was evaluated. It was noted whether the glove finger was long, short, or adequate.

Hand Circumference: The tightness or looseness of the material about the palm and back of the hand, was noted. The tightness of the material in this area tended to restrict mobility, or cause pressure points if the glove was worn for a long period of time.

Wrist Circumference: The elastic wrist band on the gloves was evaluated for tightness, looseness, or adequacy. Restriction of the wrist joint decreases mobility considerably so that tightness of this band is important.

These areas were evaluated while the hand was in several positions. Although mobility was not quantitatively evaluated, it was taken into consideration because of the effect fit has on mobility.

The entire procedure was repeated while the glove was inflated with particular emphasis on general comfort and mobility observations.

The results of the test indicate that a high percentage (over 95%) of the tested subjects can be fitted in their indicated size providing correct selection procedures are employed.

Thirty-nine (39) of forty (40) subjects were fitted adequately in Manufacturer I's gloves, while 34 out of 35 were fitted adequately in Manufacturer II's gloves. The remaining individual's hand measured below the sizing range in both hand circumference and hand length. It is expected that persons whose hand dimensions lie outside the sizing range will be custom-fitted as they represent a very small percentage, (less than 2%) of the total flying population.

Two subjects were not fitted in their indicated size gloves. Their hand dimensions, hand length and hand circumference, were on the borderline between two sizes. When fitted in the glove size with longer fingers, the subjects' fingers did not go to the tip of the glove fingers. By downgrading, a glove was selected which maintained the same hand circumference but decreased in finger length. In both cases, an adequate overall fit resulted. The procedure for upgrading and downgrading is shown in Table III.

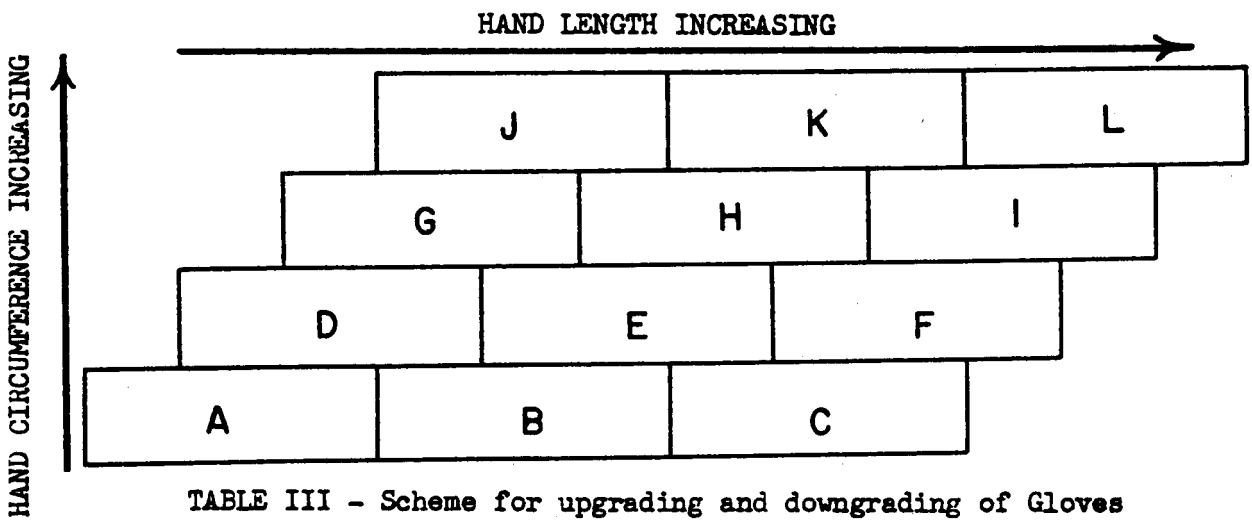

TABLE III - Scheme for upgrading and downgrading of Gloves

Glove Sizes D, E and F all have the same hand circumference. However size F is longer than size E which is longer than size D. With this in mind one can upgrade and downgrade when necessary to secure a proper fitting glove. For example, if an individual's hand circumference and hand length measurement indicates that a size E glove should be worn but this size in fact does not fit properly the following choices are open for upgrading and downgrading, D and F, B and H. Suppose that the hand circumference is adequate but the fingers do not go to the tip of the glove. Then size D should be tried because it has the same circumference but is shorter. If the glove fingers are short then size F is the first choice. However, should the glove circumference be tight but the length is adequate then one can upgrade to the size H glove. If the glove circumference is loose but the length is alright than one downgrades to the size B glove. There is extreme flexibility in upgrading and

downgrading possible and if a logical procedure is followed, then a much larger proportion of individuals can be fitted with a comfortable glove.

TABLE IV PRESENTS THE FINAL TABULATION OF RESULTS OF THE FIT TEST

TABLE IV

SIZE	DIGIT I LENGTH	DIGIT II LENGTH	DIGIT III LENGTH	DIGIT IV LENGTH	DIGIT V LENGTH	HAND CIRCUMF.	WRIST CIRCUMF.	ESTIMATE OF FIT	TOTAL SUBJECTS
	SHORT GOOD LONG	SHORT GOOD LONG	SHORT GOOD LONG	SHORT GOOD LONG	SHORT GOOD LONG	LOOSE GOOD TIGHT	LOOSE GOOD TIGHT	POOR GOOD	
A MAN* 1	1 2	2 1	2 1	2 1	2 1	1 2	1 2	1 2	3
MAN 2	2	2	2	2	2	1 1	1 1	1 1	2
B MAN 1	3	3	3	2 1	2 1	3	3	3	3
MAN 2	3	2 1	3	3	2 1	3	2 1	3	3
C MAN 1									
MAN 2									
D MAN 1	1	1	1	1	1	1	1	1	1
MAN 2	1	1	1	1	1	1	1	1	1
E MAN 1	1 7	8	8	8	6 2	8	8	8	8
MAN 2	8 1	9	9	9	8 1	9	9	9	9
F MAN 1	1 8	9	9	9	5 4	9	9	9	9
MAN 2	1	1	1	1	1	1	1	1	1
G MAN 1	1	1	1	1	1	1	1	1	1
MAN 2	1	1	1	1	1	1	1	1	1
H MAN 1	3 1	4	4	4	3 1	3 1	1 3	4	4
MAN 2	8	7 1	8	8	1 7	8	8	8	8
I MAN 1	5	5	5	5	4 1	5	5	5	5
MAN 2	7	6 1	7	7	5 2	7	6 1	7	7
J MAN 1									
MAN 2									
K MAN 1	2	2	2	1 1	1 1	2	2	2	2
MAN 2	1	1	1	1	1	1	1	1	1
L MAN 1	4	4	4	2 2	2 2	4	1 3	4	4
MAN 2	4	4	4	4	4	4	4	4	4
TOTAL MAN 1	336 1	39 1	39 1	35 5	26 14	2 39 1	4 36	1 39	40
MAN 2	36 1	34 3	36 1	36 1	1 31 5	1 35 1	1 34 2	1 36	37

*MANUFACTURER

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