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THE DESIGN AND DEVELOPMENT OF MILITARY CLOTHING PART 2  
A SHIRT RANGE BASED UPON ANATOMICAL MEASUREMENTS(U)  
LOGISTIC COMMAND (QDD) MELBOURNE (AUSTRALIA) M G KING  
APR 82

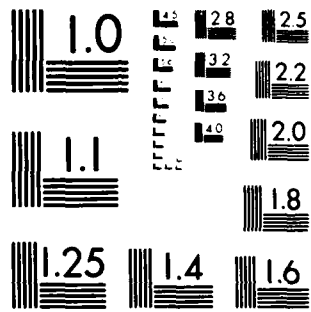
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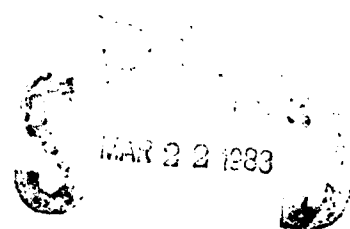
THE DESIGN AND DEVELOPMENT OF MILITARY CLOTHING

Part 2. A Shirt Range Based Upon Anatomical Measurements.

M.G. KING

Approved for public release

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16. ABSTRACT ↓ From the 1980 survey of the clothing related anatomical measurements of men in the Australian Army (CRAMS), those dimensions related to dress shirts are compared to the dimensions of the current in-service shirt. It is concluded: <u>B.</u> that the current size roll could be rationalized to provide shirts which fit a greater proportion of the population; <u>B.</u> that, especially for the larger collar sizes, the in-service shirt range is too large in both waist and chest; →			

This page is to be used to record information which is required by the Establishment for its own use but which will not be added to the data base unless this is specifically requested.

ASSAULT (CONT'D)

*CONF* → that the in-service shirt is too long; *and*  
the cuff circumference of the inservice shirt is too large.

Based upon these findings, it is recommended that a modified set of shirt dimensions should form the basis of a redesigned shirt, and that this redesigned shirt should be manufactured and trialled.

IMPRINT

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Melbourne.  
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THE DESIGN AND DEVELOPMENT OF MILITARY CLOTHING:

Part 2. A Shirt Range Based Upon Anatomical Measurements.

Dr Michael G. King

Quality Assurance Division  
HQ LOG COMD

## A SHIRT RANGE BASED UPON ANATOMICAL MEASUREMENTS

Dr M.S. King

### AIM

1. The aim of this report is to present a comparison of the shirt specified by DEF(AUST)5494 with the actual body dimensions of men in the Australian Army - the anatomical information being obtained from analysis of the 1980 CRAMS (Clothing Related Anatomical Measurement Survey) data.
2. The adequacy of the existing size rolls examined and some changes to the current range of sizes are recommended. Furthermore, the relationships between the various dimensions of the shirt and the distribution of relevant bodily dimensions are considered; where it is possible to improve the fit of the shirt, some alterations to the dimensional details of the shirt range are recommended.

### THE SIZE ROLL

3. The size of a shirt is specified by two values - the sleeve length and the collar size. In the case of the shirt DEF(AUST)5494, 16 collar sizes are offered, covering a range from 32 cm to 47 cm in 1 cm increments; the sleeve length (which is measured from centre back to bottom edge of the cuff) has a range of values from 74 cm to 89 cm, with the increment alternating between 2 and 3 cm for the seven sizes of sleeve length. Of the total 112 possible combinations of shirt and collar sizes, only 38 are currently offered (these are listed in Annex A).

### The Demand for Each Size

4. The CRAMS data provides the neck circumference, and the sleeve length of each of the 21824 subjects measured. By comparison of these values with the parameters defining the shirt size (collar,

- 2 -

and sleeve length) it is possible to estimate the demand for each size, and also the total percentage of the population of the population which is fitted by a particular size roll can be calculated. In the case of the size roll associated with DEF(AUST)5494, the 38 sizes offered provide shirts which fit 54% of the population. The distribution of demand for each size is indicated in Annex A.

5. The following rules were applied to determine the collar and sleeve size required by each man represented by a set of CRAMS measurements:

- a. the neck size (36 cm, for example) corresponds to a shirt with a collar 1 cm greater (37 cm circumference), and it was decided to assign size 36 shirts to those men with necks in the range equal or greater than 35.5 cm to less than 36.5 cm.
- b. for the sleeve sizes, the boundaries between each size were calculated (for example the boundaries for size 81 cm are 80 and 82.5 cm), and the demand for each size was given by the number of men equal to or less than the upper boundary, and greater than the lower boundary.
- c. for the shortest sleeve size, the demand for this size was given by the number of men equal to or less than the upper boundary, because in practice it would be found that the smallest sleeve size would be assigned to all men equal to or less than the size.

#### SUGGESTED CHANGES TO THE SIZE ROLL

6. Changes to the Collar Sizes. With the current size roll, the collar sizes are incremented in 1 cm steps. This means that whilst a 36 cm collar is designed to fit a 35 cm neck, in practice the difference (or allowance) between the wearer's neck and the shirt collar

may be between 0.5 and 1.5 cm. If it is accepted that this allowance is satisfactory at the smaller end of the scale, then it can be shown (See Annex B) that a larger allowance should be acceptable for larger neck sizes. A larger range in allowance means that the increment between successive sizes can be correspondingly larger. A practical application of this principle is embodied in the recommendation that up to and including collar size 40 cm, size increments should be in 1 cm steps, whilst above collar size 42 cm, increments should be in 1.5 cm steps.

7. Changes to sleeve length sizes. As with the collar increments, it is appropriate to use larger increments between the larger sizes, and this is in contrast with the current size roll which employs alternating 2 cm and 3 cm increments throughout the range of sleeve length sizes. Accepting that the 3 cm increment is satisfactory at the small end of the scale, it is suggested that this increment be maintained for the first three sizes (74 cm, 77 cm, and 80 cm); the next two increments should be 3.5 cm (to 83.5 cm and 87 cm) and, if required, the final increment should be 4 cm (to 91 cm).

8. The selection of sizes. The 21284 subjects whose data are listed in the CRAMS data bank were "fitted" by computer with the shirts defined by the new collar and sleeve length sizes. The frequency of demand for each size, based in the results of the computer fitting are shown in Annex C. It is suggested that where the predicted demand for a size exceeded 0.5% of the population (that is, approximately 100, based on the CRAMS sample size), then a shirt should be offered for that size. Based on this criterion, 43 of the cells in the collar : sleeve matrix are indicated as sizes - and these 43 sizes would fit 92.7% of the population.

### THE SHAPE OF THE SHIRT

9. In addition to collar and sleeve dimensions, the specification for the shirt DEF(AUST)5424 lists seven other measurements: chest, waist, seat, length, cuff, vent, back width. Apart from the sleeve vent, there are CRAMS measurements which correspond to each of the shirt dimensions and the descriptive statistics of the CRAMS measurements are presented in Annex D. The correlation matrix relating each of the CRAMS dimensions is also given at Annex D.

10. Annex E lists the nine measurements of each shirt in the current size roll for the in-service shirt.

### CHEST:COLLAR RELATIONSHIP

11. Reference to the dimensions in Annex E will indicate that for the in-service shirt the chest dimension increases with increasing collar size. Over the range of collar sizes 31 to 35 cm an increment of 2 cm in chest corresponds to an increment of 1 cm in collar; from collar size 36 cm to 46 cm the increment in chest is 4 cm for each 1 cm in neck. This relationship is represented by the solid line in figure 1. Also presented in figure 1 is a scattergram plot of a random 2% sample of the subjects measured in the CRAMS survey (for the sake of clarity the 21 824 subjects were not plotted on the scattergram).

12. From Figure 1 it can be seen that where a man is fitted with a shirt by collar size, in no case is the shirt too small in the chest. However the cost of achieving this situation is that in many cases the shirts may be rather loose in the chest - and this is particularly so for men with the larger sizes of collar. Figure 1 shows that the in-service shirt size range has been designed with the underlying assumption that men with larger necks (39 cm and above) have increasingly large chests. This assumption is not supported by the CRAMS data.

In fact, there is very little systematic increase in chest dimension for men with neck sizes greater than 39 cm.

13. Suggested Changes. Considering the limited association between chest and collar dimensions in the larger sizes, it is suggested that the chest size corresponding to a 39 cm collar be maintained for all larger collar sizes. That is, for collar sizes 39 to 46, the chest should be 120 cm. Furthermore, from the distribution of measurements in the region below the collar size 35 cm, there appears to be little justification in departing from the 4:1 ratio between chest and collar increments (represented by the continuous line between collar size 35 and 39 cm). Therefore it is suggested that the 4:1 ratio be continued through the smaller collar sizes. This would lead to a chest dimension of 88 cm corresponding to the smallest collar size (31 cm). These suggested modifications are illustrated by the broken line in Figure 1. It can be seen from this figure that the suggested range of shirts still effectively caters for most of the population: the advantage of better fit is not at the cost of a great number of unfitted subjects. The suggested modifications are detailed in Annex F.

#### WAIST:COLLAR RELATIONSHIP

14. The approach and the results of this analysis closely parallels the investigation of chest:collar relationships. The waist and collar dimensions of the random 2% sample are illustrated in the scattergram in figure 2. Also represented in this figure, by a solid line, is the relationship between waist and collar in the in-service shirt. It can be seen from this sample that in some instances a man may be fitted by collar size, but he may find that the shirt is too tight in the waist region - and this is more frequently the case in the middle range of collar sizes. For the larger collar sizes, the shirts are unnecessarily voluminous in the waist.

15. Suggested Changes. As with the chest:collar data, there is little evidence of the need for systematic increase in waist size corresponding to increasing collar size beyond a collar size of 33 cm. It is therefore suggested that a constant waist dimension of 110 cm be adopted for all shirts of collar size 33 cm and above. For collar sizes 31 to 32 cm it is suggested that a ratio size should be accompanied by an increment of 5 cm in the waist of the shirt, starting from a waist of 95 cm with the smallest collar size of 31 cm. These modifications are represented by the broken line in figure 2. The suggested modifications are detailed in Annex B.

THE CUFF

16. Tailoring conventions suggest that an allowance of approximately 7 cm (the excess of the circumference of shirt cuff over the wrist circumference) is acceptable. The current specification has cuffs ranging from 21 cm to 28 cm - the increase being associated with increasing collar size. From the CRAMS data, the statistical data relating to wrist and collar are given by the linear regression equation:

$$\text{wrist} = 0.19 \text{ collar} + 10$$

17. From the above relationships, for each collar size the 99th centile (maximum) wrist circumference and the average wrist circumference were calculated for each collar size. Bearing in mind the target of an average 7 cm allowance, and the practical need for whole number dimensions where possible, the cuff dimensions incorporated in the draft specification, Annex E, were computed. In no case does the allowance for the 99th centile man fall below the limit of 5 cm.

### LENGTH

19. Although the current shirt range features lengths from 78 to 88 cm (the increase being associated with increasing collar) the DRAMS data suggests that these shirts are too long. The mean man's body length is 70 cm, and the standard deviation is 3.5 cm. The relationship between bodylength and the two defining variables (collar and sleeve length) is given by the multiple regression equation:

$$\text{length} = 0.513 \text{ collar} + 0.032 \text{ sleeve} + 31$$

with the multiple regression coefficient  $R = 0.49$

20. From the residual variance (after the application of the above regression equation), the 99th centile length was calculated for each sleeve and collar combination. These maximum values were rounded to the nearest 5 cm increment (in keeping with standard tailoring practice), and the recommended shirt lengths listed in Annex E are equal to the rounded 99th centile body length for that size.

### CONCLUSION

20. Consideration of the current size roll leads to the following conclusions:

- a. the current size roll affords a good fit to 54% of the population, with 38 sizes being specified;
- b. a rationalization to the increments between successive collar sizes, and between successive sleeve sizes is justified, with larger increments being specified between the larger sizes;
- c. by adopting a rationalized size roll structure, and selecting sizes in high demand, it is possible to provide shirts to fit approximately 93% of the Australian Army with 43 sizes.

- i. Each of the 33 specified sizes has a predicted demand of at least 0.5% of the population.
1. The in-service shirt specified by DEF(AUST) 5494 has been compared with data from GRAMS. With regard to the ratios of chest to collar, and waist to collar, it is concluded that:
  - a. for the larger sizes (greater than collar size 39) the shirts are too large in both chest and waist;
  - b. the adoption of minor modifications to the scale of ratios between waist:collar and chest:collar should result in a better fit for a greater proportion of the population;
  - c. the length of in-service shirt is too great, in a number of sizes, and a rationalized recommendation provides a shirt length which will fit the 99th centile man for each size;
  - d. the cuff circumference has been altered to provide a satisfactory allowance (average 7 cm, minimum 5 cm) for each size.

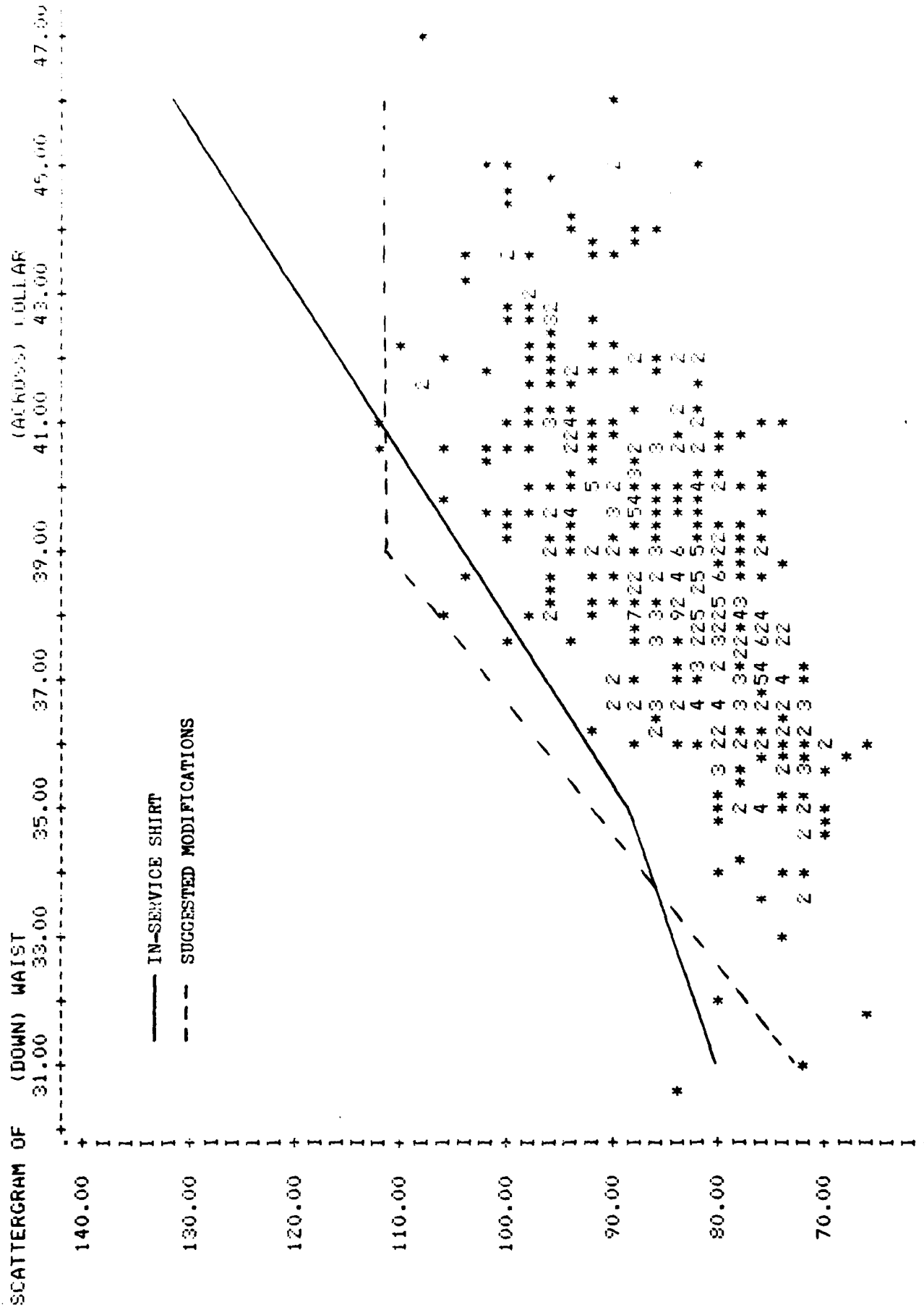
RECOMMENDATIONS

22. That the specifications of the Shirt, Mens, Polyester/Cotton described by DEF(AUST) 5494 be re-examined by tailoring and design professionals with a view to modifying the design parameters.
23. That the suggestions detailed in Annex F be considered by tailoring and design experts and - if compatible with tailoring and design conventions - these suggestions should form the basis of modifications to the design parameters of the Shirt.



SCATTERGRAM OF COTTON/POLY SHIRT (DEF.AUST 5494)

FIGURE 2





THE VARIATION IN CIRCUMFERENTIAL ALLOWANCE  
FOR A RANGE OF COLLAR SIZES

1. The allowance of a shirt collar is the difference between collar circumference and neck circumference. If the collar is pulled tight as illustrated in the accompanying diagram, figure 1, then the allowance is given by:

$$D/2 = r \tan \phi - r\phi \quad (1)$$

where D is collar - neck  
and  $\phi$  is the angle shown in

figure 1.

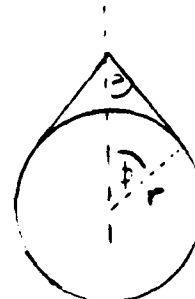


figure 1

2. If the concept of fit/non-fit is defined by a limiting value of the angle  $\theta$  which is formed by the excess material when the collar is pulled tight, then a maximum and a minimum value for  $\phi$  can be calculated for any neck size. In particular, if the maximum allowance which is acceptable for a 32 cm circumference neck is 1.5 cm, then:

$$1.5 = 32 (\tan \phi - \phi) / \pi$$

$$\text{thus } (\tan \phi - \phi) / \pi = 0.0469.$$

From this value the maximum allowances may be obtained for other neck sizes; similarly the minimum tolerance values may be calculated using the criterion of 0.5 cm for a 32 cm neck. The range of maximum and minimum allowances are listed in Table 1 of this Annex.

ANNEX B

3. An allowance of 1.5 cm maximum corresponds to collar increments of 1 cm, whilst a 2 cm maximum allowance corresponds to 1.5 cm collar increments (assuming that a 0.5 cm minimum allowance is used). In keeping with the goal of avoiding fractional measurements where possible, it was decided to recommend that for neck sizes up to 41 cm (that is, collar sizes of 42 cm) a 1 cm collar increment should be used, whilst for the larger sizes a 1.5 cm increment should be adopted.

Table 1

The Range of Maximum and Minimum Allowance

neck	maximum	minimum
32	1.5	.4
34	1.6	.5
36	1.7	.5
38	1.8	.5
40	1.9	.6
42	2.0	.6
44	2.1	.6
46	2.2	.6

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MATRIX OF SIZES AND DEMAND FOR RECOMMENDED SHIRT

COLLAR	SHIRT SLEEVE LENGTH IN CM										Total
	74	77	80	83.5	87	91	95	99	104	108	
31	5	2	3	1	1	0					1
32	25	8	1	3	3	0					40
33	47	11	5	1	3	0					67
34	45	31	20	7	0	0					103
35	81	104	89	36	9	1					240
36	178	240	258	185	33	4					668
37	291	492	542	333	103	12					1773
38	358	702	888	569	218	34					2767
39	394	811	1167	831	335	70					3608
40	335	745	1170	975	425	74					3777
41	239	599	1016	885	375	71					3165
42	148	395	697	656	315	59					2270
43.5	91	261	494	508	276	71					1791
45.0	47	118	223	281	146	42					857
46.5	8	28	55	79	32	11					213

heavy outline indicates 43 recommended sizes to fit 20231 men, that is, 93% of all subjects.

ANNEX D

STATISTICS OF SHIRT-RELATED VARIABLES

TAKEN FROM IR IS DATA

	<u>mean, cm</u>	<u>standard deviation, cm.</u>	<u>number</u>
collar	38.8	2.42	21785
chest	97.7	7.18	21794
waist	84.24	8.59	21803
seat	96.61	6.23	21777
wrist	17.57	0.896	21794
sleeve	80.24	4.09	21681
body length (cervical height minus inside leg)	70.02	3.51	21440

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CORRELATION MATRIX

collar	chest	waist	seat	body	sleeve	wrist
	.677	.669	.610	.422	.246	.509
chest		.812	.781	.467	.296	.525
waist			.816	.396	.238	.477
seat				.525	.301	.527
body					.351	.406
sleeve						.379

---

**ANNEX E**

FOR BIRTH OF ...  
 A. L. ...

Size (Neck and Sleeve Sizes)	LONG and short sleeve										short sleeve	
	Length of collar from eye of buttonhole to centre of button	Girth at base of armhole when buttoned	Girth at waist when buttoned	Girth around the shirt at side vent	Length of back and front from top of shirt at side of collar	Sleeve length from centre back to bottom edge of cuff	Cuff from eye of button- hole to centre of button	Sleeve vent opening from back to bottom of cuff	Back width at yoke	Length from centre of arm- hole to turn- up	Length of sleeve at turn- up	
31 - 74	32	96	80	96	78	74	21	21	36	21	15.5	
32 - 76	33	98	82	98	78	76	21	21	37	21	16	
33 - 79	34	100	84	100	80	79	23	21	38	21	16.5	
34 - 81	35	102	86	102	80	81	23	21	39	21	17	
35 - 81	36	104	88	104	82	81	23	21	40	22	17.5	
36 - 81	37	106	92	108	82	81	23	21	41	22	18	
37 - 79 81	38	112	96	112	84	79 81	25	22	42	22	18.5	
38 - 81 84 86	39	116	100	116	84	81 84 86	25	22	43	22	19	
39 - 79 81 84 86 89	40	120	104	120	84	79 81 84 86 89	25	22	44	22	19.5	
40 - 79 81 84 86 89	41	124	108	124	84	79 81 84 86 89	25	22	45	24	20	

ANNEX E (continued)

Size (Neck and Sleeve Sizes)	LONG AND SHORT SLEEVES										SHORT SLEEVES	
	Length of collar from eye of buttonhole to centre of button	Girth at base of armhole when buttoned	Girth at waist when buttoned	Girth around the shirt at side vent	Length of back and front from top of shirt at side of collar	Sleeve length from centre back to bottom edge of cuff	Cuff from eye of button- hole to centre of button	Sleeve vent opening from back to bottom of cuff	Back width at yoke	Length from centre crown to turn-up	Width of sleeve at turn-up	
41 - 81 84 86 89	42	128	112	128	86	81 84 86 89	26	22	46	24	20.5	
42 - 81 84 86 89	43	132	116	132	86	81 84 86 89	26	22	47	24	21	
43 - 84 86 89	44	136	120	136	86	84 86 89	27	23	48	25	21.5	
44 - 84 86 89	45	140	124	140	86	84 86 89	27	23	49	25	22	
45 - 86 89	46	144	128	144	88	86 89	28	23	50	25	22.5	
46 - 89	47	148	132	145	88	89	28	23	51	25	23	

**ANNEX P**

SIZE	Collar	Chest	Waist	Seat	Length	Sleeve	Cuff	Vent
34-36	35	100	87	100	75	77	23	19
36-38	36	104	92	104	75	74	23	19
38-40	36	104	92	104	75	77	23	19
40-42	36	104	92	104	75	80	23	19
42-44	36	104	92	104	75	83.5	23	19
44-46	36	104	92	104	75	87	23	19
46-48	37	108	97	108	75	74	24	19
48-50	37	108	97	108	75	77	24	19
50-52	37	108	97	108	75	80	24	19
52-54	37	108	97	108	75	83.5	24	19
54-56	37	108	97	108	75	87	24	19
56-58	38	112	102	112	75	74	25	19
58-60	38	112	102	112	75	77	25	19
60-62	38	112	102	112	75	80	25	19
62-64	38	112	102	112	75	83.5	25	19
64-66	38	112	102	112	75	87	25	19
66-68	39	116	107	116	75	74	25	19
68-70	39	116	107	116	75	77	25	19
70-72	39	116	107	116	75	80	25	19
72-74	39	116	107	116	75	83.5	25	19
74-76	39	116	107	116	75	87	25	19
76-78	40	120	112	120	75	74	25	19
78-80	40	120	112	120	75	77	25	19
80-82	40	120	112	120	75	80	25	19
82-84	40	120	112	120	75	83.5	25	19
84-86	40	120	112	120	75	87	25	19
86-88	41	120	112	120	75	74	25	19
88-90	41	120	112	120	75	77	25	19
90-92	41	120	112	120	75	80	25	19
92-94	41	120	112	120	75	83.5	25	19
94-96	41	120	112	120	75	87	25	19
96-98	42	120	112	120	75	74	25	19
98-100	42	120	112	120	75	77	25	19
100-102	42	120	112	120	75	80	25	19
102-104	42	120	112	120	75	83.5	25	19
104-106	42	120	112	120	75	87	25	19
106-108	43.5	120	112	120	80	77	25	19
108-110	43.5	120	112	120	80	80	25	19
110-112	43.5	120	112	120	80	83.5	25	19
112-114	43.5	120	112	120	80	87	25	19
114-116	45	120	112	120	80	77	25	19
116-118	45	120	112	120	80	80	25	19
118-120	45	120	112	120	80	83.5	25	19
120-122	45	120	112	120	80	87	25	19

**LME**  
**— 8**