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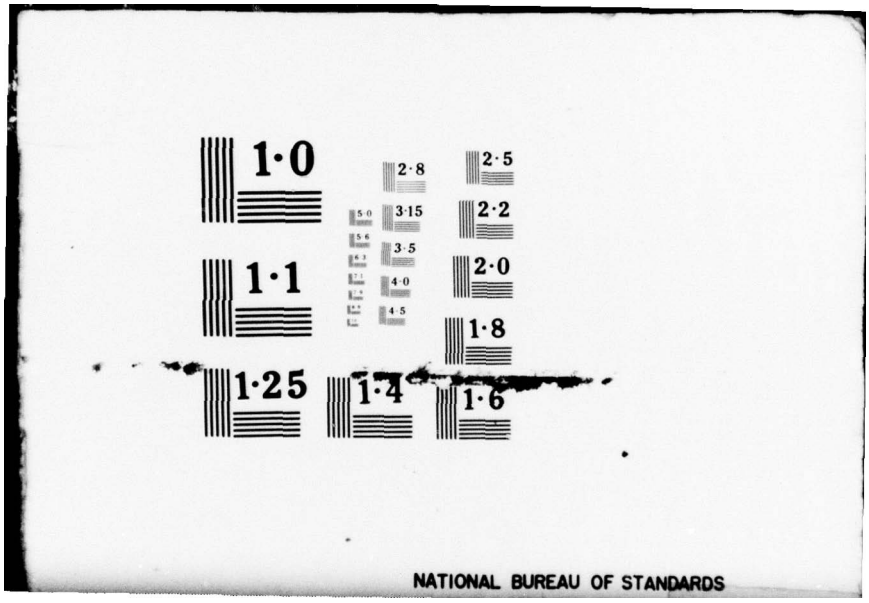
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(11) NOVEMBER 1978

DCIEM-Technical Report No. 78X37

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PRELIMINARY INVESTIGATION OF THE SEATED HEIGHT LIMIT FOR SAFE THROUGH-THE-CANOPY EJECTION FROM THE CT 114 AIRCRAFT

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H. MacDonald

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ABSTRACT

In a number of ejections from the CT 114 aircraft, the canopies have failed to jettison. The potential for head or neck injuries exists if the helmet were to contact the canopy ahead of the canopy breaker. A study was conducted to determine the seated height limit for safe through-the-canopy ejections, and the number of pilots whose seated height exceeds the safe seated height. The study involved correlating the seated heights of a number of subjects with static measurements, taken in a CT 114 ejection seat, of the vertical distance between the top of their helmets and the canopy breaker. The safe seated height was found to be 88.0 cm. for dual visor helmets, and 90.6 cm. for the helmet shell alone. These limits would cut off about 75% and 45% of the pilots respectively. It is recommended that further studies be conducted to determine what effect the actual shape of the canopy may have on the safe seated height, and what effect the ejection forces have on pilot's seated height during the first moments of ejection.

INTRODUCTION

In a number of ejections from the CT 114 aircraft, the canopies have failed to jettison. The potential for head or neck injuries exists if the helmet were to contact the canopy ahead of the canopy breaker. DCIEM was asked to investigate the extent of this problem, namely to determine the the seated height limit for CT 114 pilots which will ensure safe "through-the-canopy" ejections, and the number of pilots whose seated height exceeds the safe seated height. It was assumed, for purposes of this study, that all pilots whose helmets protrude above the canopy breaker when seated in a CT 114 ejection seat would be exposed to danger from helmet/canopy impact if they were to eject through the canopy. Of course, the actual shape of the canopy (ie., the lateral and longitudinal contours) and the angle at which the seat is ejected could affect the amount of effective head clearance at the point of canopy/breaker impact. For simplicity, however, it was assumed that if the horizontal plane defined by the highest point of the helmet was above the horizontal plane defined by the highest point of the centre of the canopy breaker, the helmet would contact the canopy before the breaker upon ejection. This assumption could lead to a conservative limit for the safe seated height because it does not take into account the shape of the canopy. There are other reasons why the safe seated height might be somewhat conservative. For example, dynamic factors, such as submarining, tend to reduce helmet height during ejection, but little else is known about them. Finally, a certain amount of spinal compression and helmet deformation could occur without necessarily causing injury to the pilot.

Because helmet height is a function of sitting posture and the type of helmet worn, it was not possible simply to apply standard anthropometric data to this problem. Therefore, it was necessary to determine the differences in height between helmet height of pilots sitting in this particular seat and their standard anthropometric seated height. This information is needed to convert the safe helmet height to a seated height limit to which the standard anthropometric percentile tables could be applied.

PROCEDURE

A study was undertaken to investigate the relationship between the standard anthropometric seated height of subjects and the vertical distance between the top of their helmet when seated in a CT 114 ejection seat to the midpoint of the canopy breaker. The safe seated height was defined as the standard anthropometric seated height which corresponds to a zero difference in height between the helmet and canopy breaker.

A number of measurements of each subject were taken in the following order. First, the standard seated height was measured using standardized techniques (see Annex A). Subjects were then fitted with a dual visor, 41-2, helmet and the seated helmet height was measured. The subjects then strapped into the CT 114 ejection seat using a properly fitted parachute pack and assumed the proper pre-ejection posture. Qualified members of the Medical Life Support Division of this Institute were present to supervise the fitting of helmets and strapping-in of subjects to ensure these were properly done. The vertical distance between the uppermost portion of the helmet and the mid-point of the canopy breaker was measured. If a helmet were below the mid-point of the breaker, this measurement was assigned a negative value. Finally, the distance from the uppermost portion of the helmet outer shell to the mid-point of the canopy breaker was measured to provide information on the effect on helmet height of the dual visor.

Thirty subjects were used in this study. They were military and civilian employees at DCIEM. The range of seated height was 86.8 cm. to 99.3 cm., with a mean seated height of 91.7 cm. This sample represents a range of 15th to 99th percentile of the Canadian Forces population (ref. 1), and a 2nd to 97th percentile range for USAF aircrew (ref. 2). All subjects were within the CFP 154 seated height limits of 86.4 cm. to 100.3 cm.

RESULTS

The results appear in the Table below.

Table 1: SEATED HEIGHT AND CORRESPONDING DISTANCES TO BREAKER

SUBJECT NO.	SEATED HT. (CM.)	SEATED HELMET HT. (CM.)	VISOR TO BREAKER DISTANCE (CM.)	SHELL TO BREAKER DISTANCE (CM.)
2	92.8	98.1	+3.8	+2.2
3	99.3	102.5	+9.3	+7.0
4	96.9	102.3	+9.2	+7.6
5	95.4	100.2	+6.5	+5.0
6	92.8	98.1	+2.6	-0.4
7	88.9	93.7	+2.9	-0.6
8	92.6	98.3	+6.1	+4.0
9	94.5	97.9	+5.1	+3.5
10	90.0	94.2	+2.3	+1.6
11	90.1	95.1	+2.1	-0.8
12	90.3	92.5	+2.7	-0.1
13	88.8	91.7	+1.7	-1.2
14	92.0	97.2	+4.1	+2.4
15	90.8	94.7	+3.9	+1.8
16	87.5	90.7	-1.5	-3.4
17	88.1	91.8	-0.3	-1.6
18	88.0	92.0	-0.5	-2.8
19	95.1	99.8	+5.9	+3.5
20	88.2	92.4	-0.3	-2.4
21	90.8	95.7	+1.9	-1.4
22	91.8	97.0	+4.6	+2.6
23	91.3	95.9	+1.9	-0.9
24	90.2	95.2	+2.2	-1.2
25	93.1	97.6	+4.9	+2.8
26	86.8	90.5	-3.5	-5.0
27	96.0	100.6	+6.1	+4.0
28	92.0	96.2	+1.9	-0.7
29	93.8	98.6	+6.5	+4.4
30	89.5	93.6	+2.5	0.0

It can be seen that the current CF helmet shell adds approximateely 4 cm. to the seated height. Regression analysis showed the helmet to breaker distance and the shell to breaker distance to be very highly correlated with seated height, as expected (r=.924 and r=.909 respectively). Figure 2 presents the distance from the visor to breaker and from the shell to the breaker as a function of seated height.

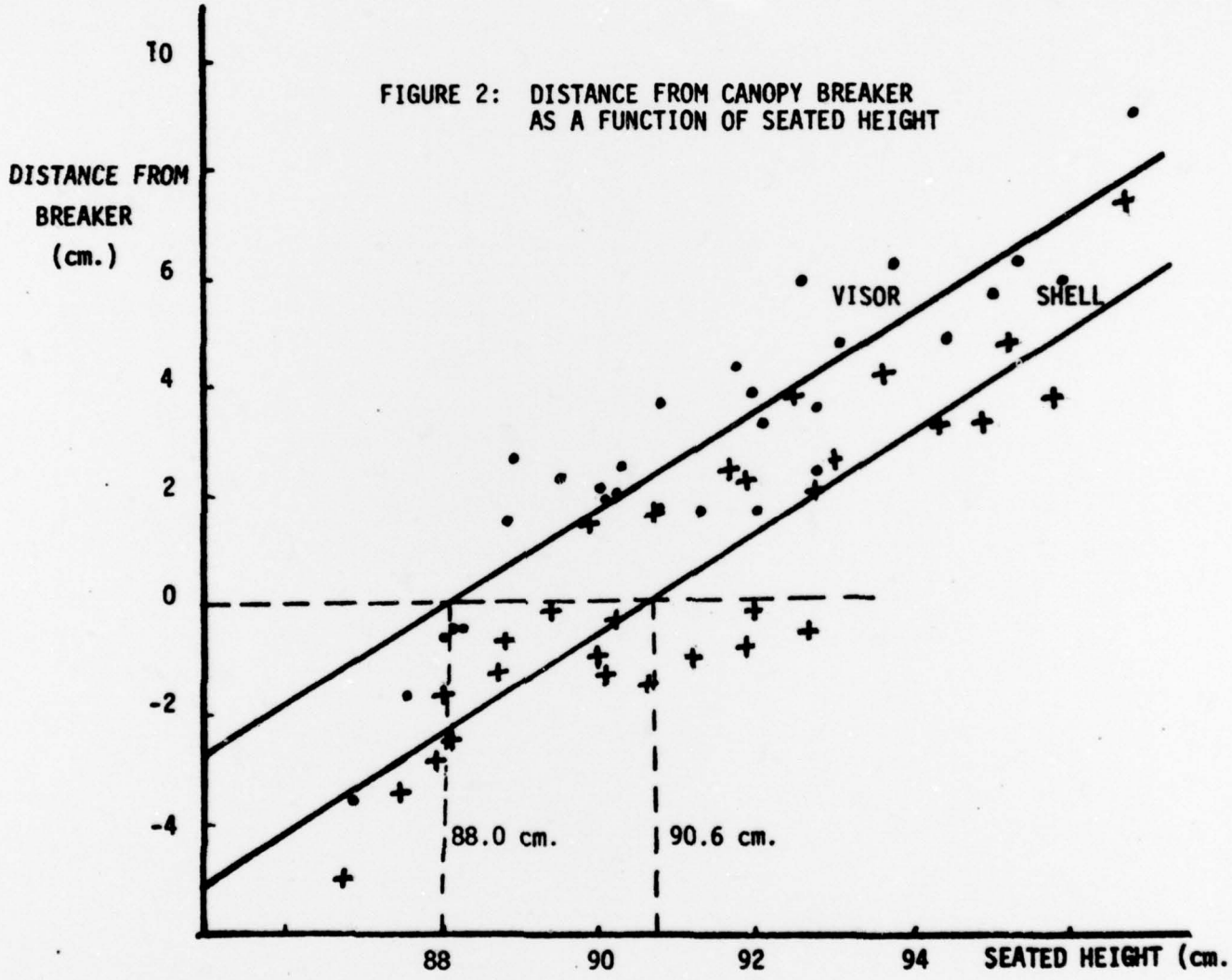

FIGURE 2: DISTANCE FROM CANOPY BREAKER AS A FUNCTION OF SEATED HEIGHT

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The safe seated heights shown in Figure 2 were obtained from the regression formulas of the curves. They were calculated to be 79.8 cm. for the dual helmet, and 90.55 for the helmet shell. The visor, on the average, adds 2.6 cm. to helmet height. It should be noted, however, that four of the thirty subjects had seated heights greater than 90.6 cm. (one of them 92.8) but their helmets did not protrude above the canopy breaker. Similarly, one of the thirty had a seated height of 90.0 cm. but his helmet protruded 1.6 cm. above the canopy breaker. This variation about the cut-off limit is typical, and can be resolved in critical cases by individual fitting trials.

DISCUSSION

Annex A is a Table of sitting height data taken from a recent anthropometric survey of Canadian Forces personnel (ref. 1). This Table shows that 88 cm. is roughly equivalent to the 25th percentile sitting height. This means that about 75% of Canadian Forces personnel would sit with their visors protruding above the canopy breaker. If the visor were such that it broke easily upon impact, the safe seated height could be increased to 90.6 cm. However, 45% of Canadian Forces Personnel still exceed this limit. The table further shows that the 95th percentile sitting height is 95.6 cm. From Figure 2 it can be seen that the canopy breaker would have to be raised by more than 4 cm. in order that 95% of CF personnel could be assured a safe through-the-canopy ejection. Alternatively, the same proportion of CF aircrew would be accomodated if the curvature of the canopy were such that it was 4 cm. higher above the pilot's helmet than above the canopy breaker.

Comparison of the data for the pilot sub-group with the other trades represented in the 1974 anthropometric survey indicated that the CF pilot population tends to be somewhat taller than the general CF population, thereby increasing the severity of the problem. This comparison is extremely tenuous due to the small sample size (n=31) of the pilot sub-group; however, the trend is consistant with findings of other surveys. In fact, it is suspected that the CF pilot population would be closer to USAF pilot population than to the general CF population. USAF aircrew sitting height percentiles, (ref. 2) are given in Table 3, beside the CF data.

Table 3: COMPARISON OF USAF AND CF SITTING HEIGHT

%ILE	CF	USAF
1	82.4	86.2
3	84.0	87.4
5	84.8	88.1
10	86.0	89.2
15	86.7	89.9
25	87.9	91.0
50	90.0	93.1
75	92.7	95.3
85	94.0	96.5
90	94.7	97.4
95	95.6	98.6
97	96.3	99.3
99	97.9	100.6

CONCLUSIONS

The results of these trials give rise to serious concerns for pilot safety in the CT 114 aircraft. Based on the assumption that any pilot whose helmet protrudes above the canopy breaker is at risk during a through-the-canopy ejection, the seated height limits were found to be 88.0 cm. using the dual visor helmet and 90.6 cm. using only the shell of the helmet. About half of CF pilots appear to exceed even the latter, more liberal seated height limit for safe through-the-canopy ejections from the CT 114 aircraft. If possible, the canopy breaker should be raised by about 4 cm. in order to ensure that 95% of CF pilots would sit with their helmets below the canopy breaker. Further work is recommended, however, to study whether the actual shape of the canopy provides for greater head clearance than assumed, and to determine what effect the ejection forces have on pilot's seated height during the first moments of ejection.

REFERENCES

1. McCann C., et al., 1974 Anthropometric Survey of Canadian Forces Personnel, DCIEM Report No. 75-R-1114, 1975.

2. The AMRL Anthropometric Data Bank Library: ASCC Holdings, Draft ASCC Advisory Publication, ASCC Working Party 61/105.

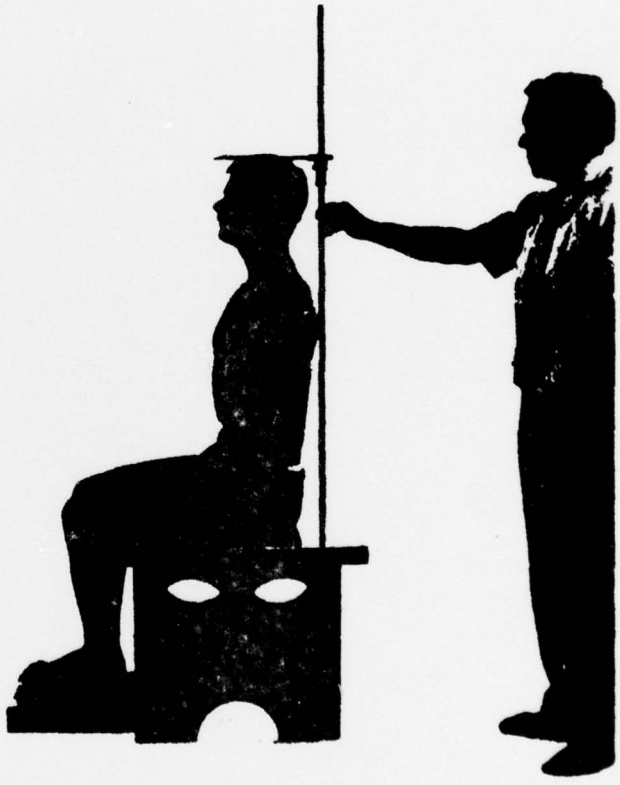
ANNEX A

SITTING HEIGHT

Subject sits erect, head in Frankfort plane, upper arms hanging relaxed, forearms and hands extended forward horizontally. With the anthropometric arm compressing the hair and touching the scalp firmly, the vertical distance from sitting surface to top of head is measured.

PERCENTILE TABLE

MM	%ILE	INCH
824	1	32.45
835	2	32.89
840	3	33.07
848	5	33.37
860	10	33.86
867	15	34.13
874	20	34.41
879	25	34.62
884	30	34.80
890	35	35.04
894	40	35.20
897	45	35.31
900	50	35.43
906	55	35.67
910	60	35.83
914	65	35.98
920	70	36.22
927	75	36.49
933	80	36.73
940	85	37.01
947	90	37.28
956	95	37.63
963	97	37.92
968	98	38.10
979	99	38.55



SUMMARY STATISTICS

MEAN	902.550	(35.53")	SKEWNESS (G1)	0.007
S.D.	33.710	(1.33")	KURTOSIS (g2)	0.645

NO. OF SUBJECTS 565