

ADA 032804

[Handwritten signature]

[Handwritten circled number 2]

AD _____

USAARL REPORT NO. 69-9

EVALUATION OF THE HUMAN BODY AS AN AIRFOIL

By

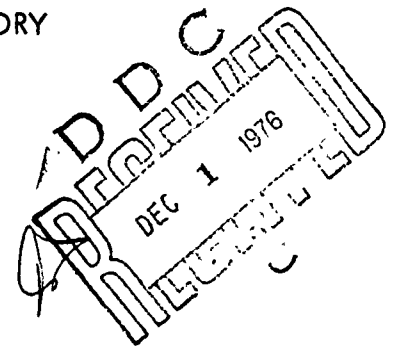
William P. Schane, LTC, MC
U. S. Army Aeromedical Research Laboratory

and

Dean C. Borgman, Research Scientist
U. S. Army Aeronautical Research Laboratory
Moffett Field, California

MAY 1969

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY
Fort Rucker, Alabama



Approved for public release;
Distribution Unlimited

NOTICE

Qualified requesters may obtain copies from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia. Orders will be expedited if placed through the librarian or other person designated to request documents from DDC (formerly ASTIA).

Change of Address

Organizations receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

Distribution Statement

Distribution of this document is unlimited.

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

AD _____

USAARL REPORT NO. 69-9

EVALUATION OF THE HUMAN BODY AS AN AIRFOIL

By

William P. Schane, LTC, MC
U. S. Army Aeromedical Research Laboratory

and

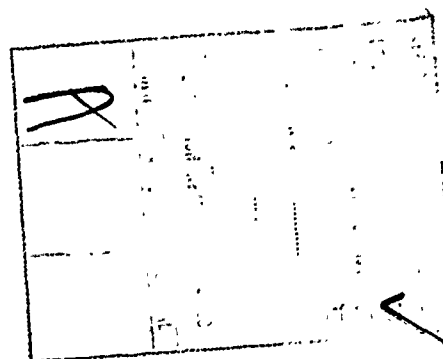
Dean C. Borgman, Research Scientist
U. S. Army Aeronautical Research Laboratory
Moffett Field, California

MAY 1969

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY
Fort Rucker, Alabama

U. S. Army Medical Research and Development Command

Distribution Statement. Distribution of this document is unlimited.



ACKNOWLEDGEMENTS

The authors wish to thank the members of the U. S. Army Parachute Team who acted as subjects for this study.

NOTATION

C_D	Drag coefficient, $\frac{D}{1/2 \rho V^2 S}$
C_L	Lift coefficient, $\frac{L}{1/2 \rho V^2 S}$
L/D	Coefficient of lift to coefficient of drag ratio.
D	Drag, Pounds
L	Lift, Pounds
S	Aerodynamic reference area, feet ²
q	Dynamic pressure, pounds per foot ²
V	Test section velocity, feet per second
W	Weight
α_{act}	Actual angle of attack, measured between model reference line and test section velocity vector, degrees.
α_{nom}	Nominal angle of attack, measured between cradle reference line and test section velocity vector, degrees.
ρ	Air density, slugs per foot ³
γ	Glide path angle with respect to horizontal

$\bar{x}$	Sample mean, $\frac{\sum_{i=1}^n X_i}{n}$
-----------	---

s

Standard deviation,

$$\sqrt{\frac{n \sum_{i=1}^n X_i^2 - (\sum_{i=1}^n X_i)^2}{n(n-1)}}$$

r

Correlation coefficient

d

Honestly significant difference

ABSTRACT

Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag.

1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43).
2. Changes in parachute pack configuration significantly changed L/D , C_L , and C_D . Subjects appeared to be homogeneous.
3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration.
4. Man is not an ideal subject to test as an airfoil in the wind tunnel.

APPROVED:


ROBERT W. BAILEY
COL, MSC
Commanding

EVALUATION OF THE HUMAN BODY AS AN AIRFOIL

INTRODUCTION

The maximum tracking attitude, as shown in Figure 1, is the body position parachutists have empirically found gives them maximum horizontal travel during free-fall (i.e., maximum lift to drag ratio). Some claim to have achieved a glide path angle as low as 55° .¹ Qualitative observations indicate that the rate of descent of the free-fall parachutist in this maximum tracking attitude is lower than the rate of descent of a free-fall parachutist in stable spread attitude (Figure 2). This is contrary to the usual situation observed in free-fall, i.e. rate of descent is inversely related to the square root of body surface area exposed to the relative wind. These qualitative observations imply that some degree of lift must be imparted to the body when it is in a tracking posture, to yield both travel and slowing of descent. Work by Straumann⁵ on ski jumpers indicates that when the ski jumper is in the typical jumping position, with the body leaning forward into the relative wind, C_L for the ski jumper and his skis is 0.43. Straumann's concepts were confirmed by Tani and Miishi.⁶ Oehlert and Higdon, as recently as January 1967⁴, show a C_L of an anthropomorphic dummy in a "track" attitude (test configurations 31 and 32) to be about 0.30 at angles of attack where lift to drag ratios (L/D) were maximal.

Figure 3 indicates how these items integrate in a tracking parachutist. Subjective estimates indicate that the jumper is about 40° head down from the horizontal, and this would make the body chord at 15° to the relative wind, an appropriate angle of attack for a high lift configuration for most high lift airfoils. Lift and drag are imparted to the body respectively perpendicular to and parallel to its relative wind. Because of the steep glide slope the words "lift" and "drag" must be viewed purely in their aerodynamic context since, in fact, "drag" contributes more force to resist gravity than does "lift".

It appears, therefore, that lift is developed by the human body provided that the body is properly posed.

The purpose of this study was to determine the lift and drag characteristics of free-fall parachutists in a tracking attitude wearing various parachute

pack configurations, using humans as test subjects. The test was conducted in the U. S. Army Aeronautical Research Laboratory 7 x 10 Foot Wind Tunnel.

MODEL DESCRIPTION

Five subjects were used in the test. All were experienced parachutists with known proficiency in tracking as demonstrated in actual free-fall. All were similarly attired in helmet, goggles, conventional jump coveralls, and boots. The subjects were tested with eight parachute pack configurations as well as with no parachute pack. The physical characteristics of the subjects are presented in Table I. The total surface area of each subject was determined from a height-weight-area nomogram.³ The aerodynamic reference area of each subject was taken as 40% of the subject's total surface area.

Figure 4 shows the conventional B-4 main parachute back pack and reserve chest pack used by most free-fall parachutists. Due to the physical interference between the strut and the reserve chest pack, the conventional reserve chest pack could not be used in test. A simulated chest pack was fabricated which conformed in shape and volume with the chest pack reserve, but did not interfere with the strut. This simulation was used in place of the chest pack during all tests.

Figures 5 through 12 illustrate the parachute pack configurations that were tested. Table II correlates the pack configuration numbers and figure numbers, and gives a brief description of each pack configuration tested.

OPERATING PROCEDURES

The subjects were mounted in the wind tunnel on a single strut which was fitted with a specially designed cradle assembly (Figure 13) to hold the subjects. A typical installation of a subject mounted in the wind tunnel is shown in Figure 14.

The tests were conducted at a nominal dynamic pressure of 40 pounds per square foot, which corresponds to 125 mph standard day conditions. This velocity is approximately the equilibrium velocity of a freely falling parachutist near sea level conditions. In general, one run consisted of an angle of attack sweep from zero to twenty degrees or from twenty-five to fifty degrees. Measurements were taken at 5° increments. During a run, the angle of attack was remotely controlled through a pitch link mechanism. The subjects were not tested at higher angles of attack for two reasons:

1. At fifty degrees, the subject's feet were close to the tunnel floor.

2. At the higher angles of attack the subjects had a tendency to slip back in the cradle assembly. This problem would have been accentuated at higher angles of attack.

Except for a special series of runs, the subjects attempted to hold a relatively constant configuration throughout the test. During the periods when data were recorded, the subjects would bring themselves to the maximum tracking posture. This maximum tracking configuration also closely approximates the configuration which Oehlert and Higdon found to be optimum for maximum L/D and stable trim conditions.⁴ Figure 14 is typical of a subject in the maximum tracking position.

Due to physical limitations, the subjects were able to hold a maximum tracking configuration for only a limited time and were allowed to relax between datum points. As a result, the subject's limb positions varied to some degree throughout each run causing a slight configuration change from datum point to datum point which could not be avoided. In addition, it was found that the subjects could not attain the same configuration in a wind-off condition as they had attained in a wind-on condition. Therefore, it was not possible to make static runs in the usual manner for pitching moment data and it was decided that the effect of shifting the model's center of gravity would be calculated rather than measured.

At each datum point six component forces and moments were measured by the wind tunnel balance system. Still photographs and movies were taken at each datum point to provide a record of the subject's positions for later analysis.

For data reduction purposes, the cradle assembly in which the subjects were mounted was considered to be part of the subject. During the early portions of the tests, a fairing protected the strut and no tares were taken from the data. For later runs, the fairing was removed and tares were removed from the data.

RESULTS OF TEST

The results of the tests are presented in Figures 15 through 26. Figures 15 through 23 present data plots of C_L , C_D , and L/D versus angle of attack for each subject and parachute pack configuration tested. The scatter in the C_L and C_D data is considerable, and this scatter is amplified when the lift-to-drag ratio is taken.

The primary reason for the data scatter is believed to be due to the unavoidable configuration changes which occurred from datum point to datum point throughout the runs. From post-test film analysis it was discovered that the subject's limb positions could change by 20° from datum point to datum point. Surprisingly, this movement was indiscernible during testing. In addition, during the time that data was recorded at a point, it was found that the subject's limb positions (particularly the arms) would oscillate at least $\pm 10^\circ$. This created oscillatory loads on the balance which were not anticipated and, therefore, not accurately measured, producing the resultant data scatter.

In an attempt to smooth the data, data from selected runs were plotted against actual angle of attack rather than nominal angle of attack, after the actual angle of attack was determined from film analysis. The difference between the two angles was due to the subject lifting out of the cradle, creating a slight difference in angle of attack between the cradle and the subject. The results of accounting for this angle difference are shown in Figure 17, and it can be seen that this technique did not have any appreciable smoothing effect on the data. Consequently, it was not carried out on the remaining data.

The C_L and C_D data were finally put into bands as shown in Figures 15 through 26. A median curve was then faired through the mid-points of the data bands and from these curves the L/D ratio was calculated. These calculated points are represented by the faired curve on each of the L/D data plots.

Figure 24 presents the final data as a function of nominal angle of attack and subject number for each of the parachute pack configurations tested. Figure 25 presents the final data as a function of nominal angle of attack and pack configuration for each subject.

For comparative purposes, a short series of runs using live subjects was made in an attempt to reproduce the data obtained from an anthropomorphic dummy.⁴ These data, and the configurations tested, are shown in Figure 26. Parachute pack configuration "1" was used for this series of runs since it corresponds to the pack configuration tested on the dummy. The live subjects attempted to assume the same limb positions as those at which the dummy was tested. The position assumed for the run shown in Figure 26a was the most natural position for the live subjects to take, and therefore, the easiest for them to maintain. Consequently, this data comes closest to matching the data presented in Reference 4. The remaining two configurations were not easily maintained by the subjects and their limbs oscillated more in these positions. This is the probable cause for the wider discrepancies between this data and the data of Oelherth and

Higdon. In addition, the problem of returning the limbs to the same position from datum point to datum point still existed, adding to the discrepancies between the data.

At the outset it was assumed that pitching moment data would also be obtained at each datum point. However, the problem of data scatter was even more severe with the pitching moment data than with the lift and drag data, and it was decided that there was no smoothing technique which could produce anything reliable from data which was so widely scattered. Therefore, no statement concerning the longitudinal stability of any of the configurations tested can be made.

Admitting these difficulties it still is possible to derive much useful information regarding the influence that parachute pack configuration has upon effective lift generated by the man-parachute pack aggregate.

In Table III, numerical information derived from the faired curves for each subject and pack configuration is tabulated. To develop this table a maximum L/D was selected from the faired curve, and the angle of attack at that L/D recorded. Then, the C_L and C_D at that angle of attack were recorded from their respective curves. Mean values for each of the parameters were computed for each configuration.

In Table IV, these mean values for each parachute configuration are tabulated. Means and standard deviations of these means were computed.

Observations of these data show a number of interesting comparisons with previously observed data and empirical observations.

1. The $\overline{C_L}$ of our unencumbered subjects (0.374) corresponds to the C_L attributed to Straumann's ski-jumper (0.43). The slightly lower $\overline{C_L}$ in our data may be because our subjects wore no skis.

2. Our maximum $\overline{L/D}$'s of 0.632, 0.676, and 0.700 in those parachute pack configurations most often actually jumped in free-fall (1, 3, and 5 respectively) corresponds well to the empirical estimates of glide path angle of 55° , since $\cot 55^\circ = 0.700 = L/D$.

3. The angle of attack of 15° , as estimated in the diagram, corresponds well with the angles of attack measured in the three above mentioned parachute pack configurations most often actually employed in free-fall of 13.8° , 23.9° , and 19.9° (mean = 19.2°).

4. Comparison of Oehlert and Higdon's configuration 32 (which appears to have the closest resemblance to the maximum tracking posture assumed by our subjects), with our own information with parachute pack configuration "1", shows reasonable agreement when both sets of data are derived from their respective curves using the same method.

	Max L/D	$\bar{\alpha}$ nom	$\bar{C}_L$	$\bar{C}_D$
Mean data for parachute pack configuration 1	0.632	13.8	0.33	0.52
Oehlert & Higdon's configuration 32	0.68	12°	0.28	0.40

Statistical evaluation of the parachute pack configurations 0 to 5, all of which were tested by each of our five subjects, was conducted using a randomized complete block design. Table V shows the summary tables for the analyses of variances for L/D , $\bar{\alpha}_{nom}$, $\bar{C}_L$ and $\bar{C}_D$. Parachute pack configurations are significantly different to the 0.01 level for L/D , $\bar{C}_L$ and $\bar{C}_D$. Table VI shows the means for these parameters which proved to be significantly different to the 0.05 level using Tukey's test for honestly significant differences as described by Winer."

In each case, test of packs 6, 7, and 8 was performed using only one subject. Since our analysis of variance tells us that subjects are homogeneous, it should not matter that each pack was tested by a different subject. However, since the assumption of homogeneity of variance is violated, these data were not subjected to statistical evaluation. However, the maximum L/D of pack configuration 6 is identical to that of pack configuration 5, and the maximum L/D of pack configuration 7 is identical to that of pack configuration 2. It appears by observation, therefore, that these packs offer no advantage in L/D over pack configurations 1, 2, 3, and 5. Pack 8, however, is strikingly different from all the other packs tested. The maximum L/D of 1.37 is beyond two standard deviations from the mean maximum L/D of 0.8213.

10 x 10 correlation matrices were computed comparing height, weight total body surface area, weight: body surface area ratio, and L/D ratios, $\bar{C}_L$, and $\bar{C}_D$ for pack configurations 0 to 5. These data are presented in Table VII.

$$r_{(.10)} = 0.805 \quad r_{(.05)} = 0.878 \quad r_{(.01)} = 0.959 \quad r_{(.001)} = 0.991$$

DISCUSSION

Conduct of the test permitted several subjective conclusions to be drawn.

1. It was determined that man is less than an ideal subject to test as an airfoil in a wind tunnel because:

- a. He moves during tests.
- b. He cannot reliably reproduce a desired attitude for repeated testing.
- c. He fatigues.

2. Qualitative appraisal by successful "trackers" indicates that maintaining the posture necessary for an efficient "track" is very tiring. We were able to confirm this in the wind tunnel. The subjects, although in good physical condition, were not able to hold the necessary position against a dynamic pressure of 40 psf for more than 10 seconds at a time. They felt that this time was unusually short because of the uncomfortable cradle support and the unusual wind tunnel conditions, but agreed that in free-fall, one could not hold a tracking posture for more than one minute under ordinary circumstances.

Statistical evaluation of our data indicates that the best L/D is achieved by tracking with no parachute. Despite the desirable glide slopes, we do not advise the use of this configuration. The only L/D of a currently available parachute pack-tray assembly tested which approached the no-pack condition was that of a flat-packed Navy NB-6 assembly with no reserve. There was no significant difference between L/D 's between these two configurations, but both had L/D 's which were significantly higher than parachute pack configuration 1, 3, and 5; and in addition, "no pack" had an L/D significantly higher than parachute pack configuration 2. In the case of the NB-6, both C_L and C_D were increased over "no pack" figures, and the optimal angle of attack was the highest we measured for any pack configurations, 34° . In all other parachute configurations the C_L was not significantly different from the C_L for the no-pack condition, but C_D 's were uniformly higher and, in the case of pack 3, 4, and 5, to beyond the 0.05 significance level. This increased drag caused the observed lower L/D 's.

Inspection of the data collected upon parachute pack configurations 6 and 7 suggests that a similar mechanism applied to these configurations, i.e., a disproportionate rise in C_D with no significant increase in C_L .

The design for pack 8 was developed from theoretical information before the wind tunnel testing and refined during test. Its main features include:

1. Correct shaping to:
 - a. Form fit to the back.
 - b. Extend from shoulders to buttocks.
 - c. Smoothly increase the camber of the man-pack to peak at about the level of the nipples, and then smoothly decrease camber to the buttocks.
2. Correct coupling to:
 - a. Prevent peeling of the parachute leading edge from the shoulders.
 - b. Prevent air passage between pack tray and man.
3. A rigid or semi-rigid dorsal surface to prevent flutter of the upper surface of the pack tray.

The test conducted upon a simulation of this pack showed a striking increase in L/D , to more than 2 standard deviations above the $\overline{L/D}$ of all configurations tested. This was produced by an increase in C_L with no increase in C_D . This indicates that a jumper's ability to achieve horizontal travel could be markedly improved by using a properly designed pack tray and harness. Further testing in actual free-fall certainly seems advisable using a functioning harness and parachute-filled pack-tray designed to these specifications.

Several interesting extensions of the wind tunnel data collected upon this experimental configuration (8) are:

1. If such an L/D is achievable in actual free-fall, a glide slope of 36° would be anticipated.

$$\cot \gamma = L/D = 1.37, \text{ then } \gamma = 36^\circ 7'$$

2. Using the C_L developed by this experimental pack tray, it is possible to calculate the velocity necessary to keep a 170 pound man with

30 pounds of parachute equipment in straight and level flight at 2500' MSL.

$$v = \sqrt{\frac{W}{C_L \times \frac{\rho}{2} \times S}}$$

$$v = \sqrt{\frac{200 \text{ lbs}}{0.52 \times \frac{0.002209 \text{ slugs/cu ft}}{2} \times 8.08 \text{ sq ft}}}$$

$$\begin{aligned} v &= 207.6 \text{ ft/sec} \\ &= 122.9 \text{ kts} \\ &= 141.6 \text{ mph} \end{aligned}$$

It is clearly possible to achieve such velocities, and means may soon become available to maintain velocities of this level for a number of minutes. It is also known that man can tolerate velocities of this level for short periods with a minimum of protective clothing. Our tests, however, do cast some doubt upon whether man can maintain a tracking posture for such a period, and the question of aerodynamic stability during such a flight is still open.

3. In the free-fall environment parasitic drag is not uniformly undesirable. Because of the steep glide slope, the vector usually described as "drag" in airfoil diagrams is, in fact, opposing gravity for the parachutist. Any "lift" vector which exists moves him horizontally across the ground. In this context, parasitic drag reduces equilibrium velocity. On the other hand, if one wishes to flatten out the glide slope, i.e., to improve "track" or increase the L/D, then parasitic drag must be kept to a minimum. To accomplish this tight clothing are desirable, flapping of clothing and equipment must be prevented, and peeling of the pack tray away from the jumper's back must be avoided. In the wind tunnel it became obvious that when the pack tray was secure against the jumper's back, it tended to increase camber, and thereby increase lift. When peeling occurred, however, the pack tray acted as a spoiler and decreased lift and markedly increased parasitic drag.

Examination of the correlation matrices indicates the following:

1. Height relates directly to L/D's of parachute pack configurations 0 and 5.
2. Weight, total body surface area, and weight: body surface area ratio relate directly with the L/D of parachute pack configuration 3 and inversely with the L/D of pack configuration 2.
3. Comparisons of the L/D's of parachute pack configurations 1 and 3, 1 and 4, 2 and 4, and 4 and 5 relate directly.
4. Comparisons of the L/D's of parachute pack configurations 0 and 1, and 0 and 4 relate inversely.

This indicates that for any individual, it may be possible to improve his L/D by the correct selection of a currently available parachute pack tray and harness configuration, with selection based upon his height, weight, total body surface area, and weight: body surface area ratio. For example, it appears that the tall individual would track best with parachute pack configuration 5 (assuming that he'd prefer to jump with a parachute), whereas the short, heavy individual would track best with parachute pack configuration 3. It also suggests that if one can successfully track with parachute pack configuration 1, he can also probably track well with parachute pack configurations 3 and 4; and if he can successfully track with parachute pack configuration 2, he can also probably track well with parachute pack configuration 4. If he then successfully tracks with parachute pack configuration 4, he probably will be able to track well with parachute pack configuration 5. Conversely, if one tracks poorly unencumbered (and assuming he survives impact), he may best improve his L/D by using parachute configurations 1 or 4.

SUMMARY

Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag.

1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43).

2. Changes in parachute pack configuration significantly changed L/D , C_L , and C_D . Subjects appeared to be homogeneous.

3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration.

4. Man is not an ideal subject to test as an airfoil in the wind tunnel.

TABLE I

SUBJECT'S PHYSICAL CHARACTERISTICS

Subject	Height Inches	Weight Lbs	Total Surface Area, Ft ² *	Aerodynamic Reference Area, Ft ²
1	71	140	18.18	7.27
2	70	175	20.30	8.12
3	72	170	20.20	8.08
4	69	165	19.35	7.74
5	67	130	17.10	6.84
$\bar{x}$	69.8	156.0	19.026	7.610
s	1.9	19.8	1.372	0.549

* Based on nomogram from Reference 3.

TABLE II

PARACHUTE PACK CONFIGURATIONS

Pack Configuration Number	Figure Number	Description
0	None	No pack
1	4	Conventional B-4 assembly back pack, simulated chest reserve pack
2	5	Conventional B-4 assembly back pack, no reserve
3	6	Back pack with piggy-back reserve (A)
4	7	NB-6 assembly back pack, no reserve
5	8	Back pack with piggy-back reserve (B)
6	9	NB-6 assembly back pack with simulated seat pack reserve
7	10	NB-6 assembly back pack with simulated piggy-back reserve
8	11	Simulated back pack-reserve pack combination, rigid

TABLE III

Subject	Max L/D	α_{nom}	C_L	C_D
Pack configuration: (0) no pack				
1	1.15	15.0°	0.37	0.32
2	1.00	17.0°	0.35	0.35
3	0.90	10.5°	0.32	0.36
4	0.93	20.0°	0.41	0.44
5	0.81	23.0°	0.42	0.52
ΣX	4.79	85.5°	1.87	1.99
$\bar{X}$	0.958	17.10	0.374	0.398
s	0.127	4.77	0.041	0.081
Pack configuration: (1) B-12 with chest reserve				
1	0.50	11.0°	0.25	0.50
2	0.64	13.5°	0.29	0.45
3	0.71	21.0°	0.36	0.51
4	0.63	11.0°	0.32	0.51
5	0.68	12.5°	0.43	0.63
ΣX	3.16	69.0°	1.65	2.60
$\bar{X}$	0.632	13.80	0.330	0.520
s	0.080	4.16	0.068	0.066
Pack configuration: (2) B-12 no reserve				
1	0.75	14.5°	0.33	0.44
2	0.67	19.0°	0.36	0.54
3	0.78	18.5°	0.39	0.50
4	0.70	13.5°	0.31	0.44
5	0.80	21.0°	0.39	0.49
ΣX	3.70	86.5°	1.78	2.41
$\bar{X}$	0.740	17.30	0.356	0.482
s	0.054	3.17	0.036	0.042

TABLE III (continued)

Subject	Max L/D	α_{nom}	C_L	C_D
Pack configuration: (3) Pioneer Piggy back				
1	0.59	20.0°	0.29	0.49
2	0.66	11.5°	0.35	0.53
3	0.77	50.0°	0.49	0.64
4	0.73	19.0°	0.35	0.48
5	0.63	19.0°	0.39	0.62
ΣX	3.38	119.5°	1.87	2.76
$\bar{X}$	0.676	23.90	0.374	0.552
s	0.073	14.98	0.074	0.073
Pack configuration: (4) NB-6 main, no reserve				
1	0.79	30.0°	0.44	0.56
2	0.91	50.0°	0.51	0.56
3	0.95	13.5°	0.41	0.43
4	0.71	50.0°	0.45	0.63
5	1.02	26.5°	0.53	0.52
ΣX	4.38	170.0°	2.34	2.70
$\bar{X}$	0.876	34.00	0.468	0.540
s	0.125	15.85	0.050	0.073
Pack configuration: (5) Security Piggy-back				
1	0.72	23.5°	0.44	0.61
2	0.74	17.0°	0.35	0.47
3	0.80	20.0°	0.39	0.49
4	0.55	19.0°	0.31	0.56
5	0.69	20.0°	0.45	0.65
ΣX	3.50	99.5°	1.94	2.78
$\bar{X}$	0.700	19.90	0.388	0.556
s	0.093	2.36	0.059	0.077

TABLE III (continued)

Subject	Max L/D	α_{nom}	C_L	C_D
Pack configuration: (6) NB-6 with seat reserve				
1	0.70	30.0°	0.38	0.54
2				
3				
4				
5				
Pack configuration: (7) NB-6 with piggy-back reserve				
1	0.74	15.5°	0.44	0.59
2				
3				
4				
5				
Pack configuration: (8) Experimental design				
1	1.37	7.5°	0.52	0.38
2				
3				
4				
5				

TABLE IV

Pack Configuration	Max L/D From Curve	$\bar{\alpha}_{nom}$	$\bar{C}_L$	$\bar{C}_D$	n
(0)	0.958	17.10	0.374	0.398	5
(1)	0.632	13.80	0.330	0.520	5
(2)	0.740	17.30	0.356	0.482	5
(3)	0.676	23.90	0.374	0.552	5
(4)	0.876	34.00	0.468	0.540	5
(5)	0.700	19.90	0.388	0.556	5
(6)	0.70	30	0.38	0.54	1
(7)	0.74	15.5	0.44	0.59	1
(8)	1.37	7.5	0.52	0.38	1
$\bar{X}$	0.8213	19.889	0.4033	0.5063	
s	0.2295	8.229	0.0605	0.0729	

TABLE V

SUMMARY TABLE ANALYSIS OF VARIANCE

	For L/D			
	SS	DF	MS	F
Between Individuals	0.0646	4	0.0161	2.0641
Between Pack Configuration	0.3999	5	0.0799	10.2435**
Error	0.1546	20	0.0078	
Total	0.6209	29		

	For α_{nom}			
	SS	DF	MS	F
Between Individuals	43.7499	4	10.9375	0.1076
Between Pack Configuration	1345.5499	5	269.1099	2.6472
Error	2033.2000	20	101.6600	
Total	3422.5000	29		

TABLE V (continued)

	For C_L			
	SS	DF	MS	F
Between Individuals	0.0270	4	0.0068	2.6986
Between Pack Configuration	0.0547	5	0.0109	4.3682
Error	0.0501	20	0.0025	
Total	0.1318	29		

	For C_D			
	SS	DF	MS	F
Between Individuals	0.0332	4	0.0083	1.9485
Between Pack Configuration	0.0920	5	0.018	4.3146**
Error	0.0853	20	0.0043	
Total	0.2106	29		

TABLE VI

Pack Configuration	C_L					
	0	1	2	3	4	5
	0.374	0.330	0.356	0.374	0.468	0.388
0	0	0.044	0.018	0	0.094	0.014
1		0	0.026	0.044	0.138*	0.058
2			0	0.018	0.112*	0.032
3				0	0.094	0.014
4					0	0.080
5						0

$d = 0.0996$ at 0.05 level

Pack Configuration	C_D					
	0	1	2	3	4	5
	0.397	0.520	0.482	0.552	0.540	0.556
0	0	0.123	0.085	0.155*	0.143*	0.159*
1		0	0.038	0.032	0.020	0.036
2			0	0.070	0.058	0.074
3				0	0.012	0.004
4					0	0.016
5						0

$d = 0.1300$ at 0.05 level

Pack Configuration	C_L/C_D					
	0	1	2	3	4	5
	0.9580	0.6320	0.7400	0.6760	0.8760	0.700
0	0	0.326*	0.218*	0.282*	0.082	0.258*
1		0	0.108	0.044	0.244*	0.068
2			0	0.064	0.136	0.040
3				0	0.200*	0.024
4					0	0.176*
5						0

$d = 0.1722$ at 0.05 level

CORRELATION MATRIX FOR COEFFICIENT OF LIFT

	1	2	3	4	5	6	7	8	9	10
1 Height	1.00	0.53	0.66	0.37	-0.88*	-0.57	-0.04	0.22	-0.80	-0.10
2 Weight		1.00	0.99	0.98	-0.60	-0.31	-0.11	0.32	-0.33	-0.81
3 Surface area			1.00	0.93	-0.72	-0.37	-0.06	0.34	-0.41	-0.71
4 Weight/Surface area ratio				1.00	-0.43	-0.24	-0.18	0.28	-0.24	-0.90*
5 Pack 0					1.00	0.34	-0.31	-0.43	0.53	0.06
6 Pack 1						1.00	0.69	0.64	0.38	0.27
7 Pack 2							1.00	0.72	0.26	0.50
8 Pack 3								1.00	-0.26	-0.01
9 Pack 4									1.00	0.17
10 Pack 5										1.00

n = 5

$r(.10) = 0.805$
 $r(.05) = 0.878$
 $r(.01) = 0.959$
 $r(.001) = 0.991$

CORRELATION MATRIX FOR COEFFICIENT OF DRAG

	1	2	3	4	5	6	7	8	9	10
1 Height	1.00	0.53	0.66	0.37	-0.90*	-0.70	0.04	-0.02	-0.40	-0.61
2 Weight		1.00	0.99	0.98	-0.46	-0.77	0.43	-0.09	-0.02	-0.95*
3 Surface area			1.00	0.93	-0.58	-0.81	0.43	-0.06	-0.12	-0.97**
4 Weight/Surface area ratio				1.00	-0.30	-0.70	0.37	-0.15	0.11	-0.88*
5 Pack 0					1.00	0.84	-0.07	0.30	0.15	0.57
6 Pack 1						1.00	-0.18	0.51	-0.19	0.78
7 Pack 2							1.00	0.51	-0.44	-0.59
8 Pack 3								1.00	-0.88*	-0.04
9 Pack 4									1.00	0.23
10 Pack 5										1.00

n = 5

$r(.10) = 0.805$

$r(.05) = 0.878$

$r(.01) = 0.959$

$r(.001) = 0.991$

CORRELATION MATRIX FOR COEFFICIENT OF LIFT TO COEFFICIENT OF DRAG RATIO

	1	2	3	4	5	6	7	8	9	10
1 Height	1.00	0.53	0.66	0.37	0.56	-0.18	-0.11	0.33	-0.20	0.56
2 Weight		1.00	0.99**	0.98**	0.05	0.33	-0.65	0.70	-0.21	0.10
3 Surface area			1.00	0.93*	0.14	0.27	-0.59	0.67	-0.18	0.24
4 Weight/Surface area ratio				1.00	-0.04	0.37	-0.70	0.72	-0.27	-0.07
5 Pack 0					1.00	-0.88*	-0.39	-0.45	-0.56	0.11
6 Pack 1						1.00	0.24	0.69	0.61	0.18
7 Pack 2							1.00	-0.05	0.55	0.34
8 Pack 3								1.00	-0.04	-0.01
9 Pack 4									1.00	0.66
10 Pack 5										1.00

n = 5

$r(.10) = 0.805$
 $r(.05) = 0.878$
 $r(.01) = 0.959$
 $r(.001) = 0.991$

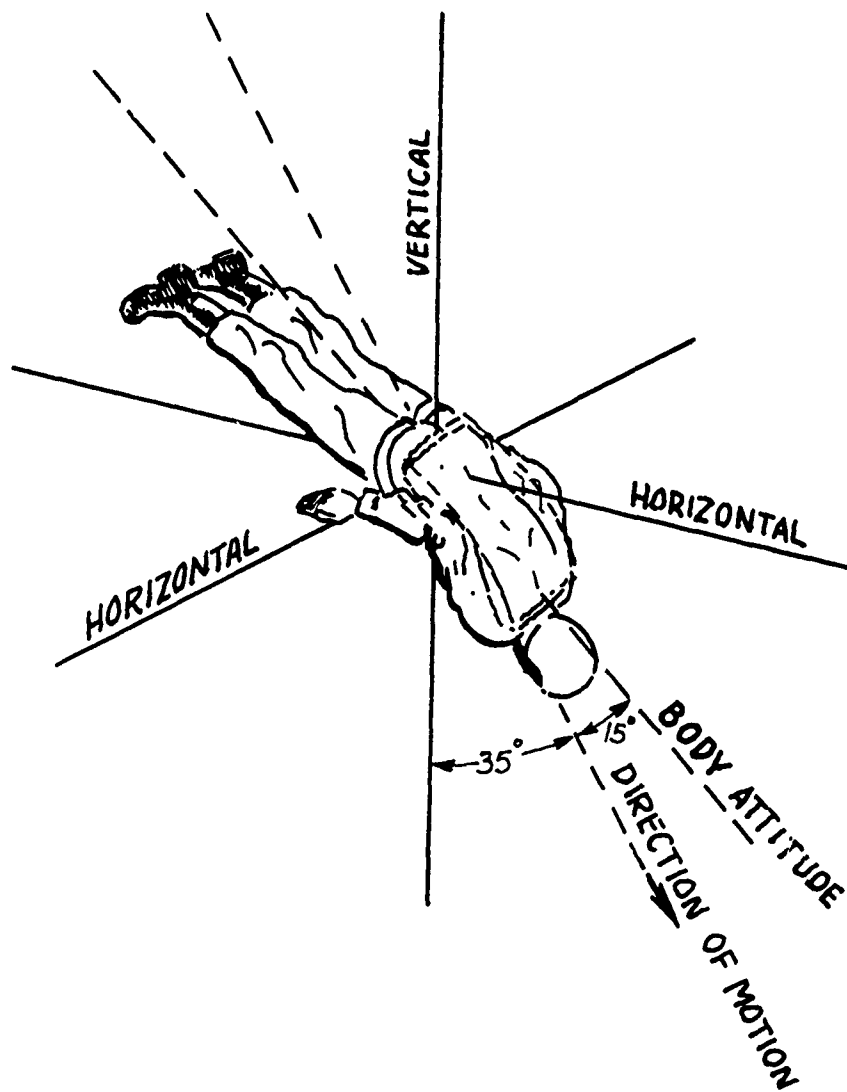


Figure 1

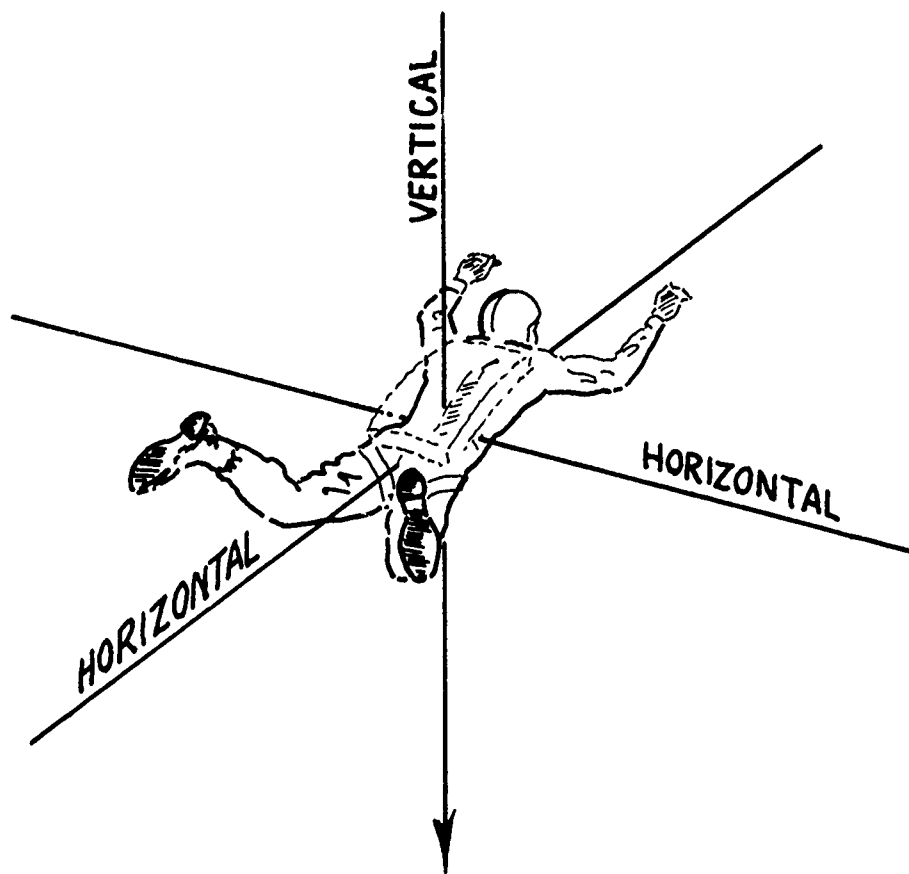


Figure 2

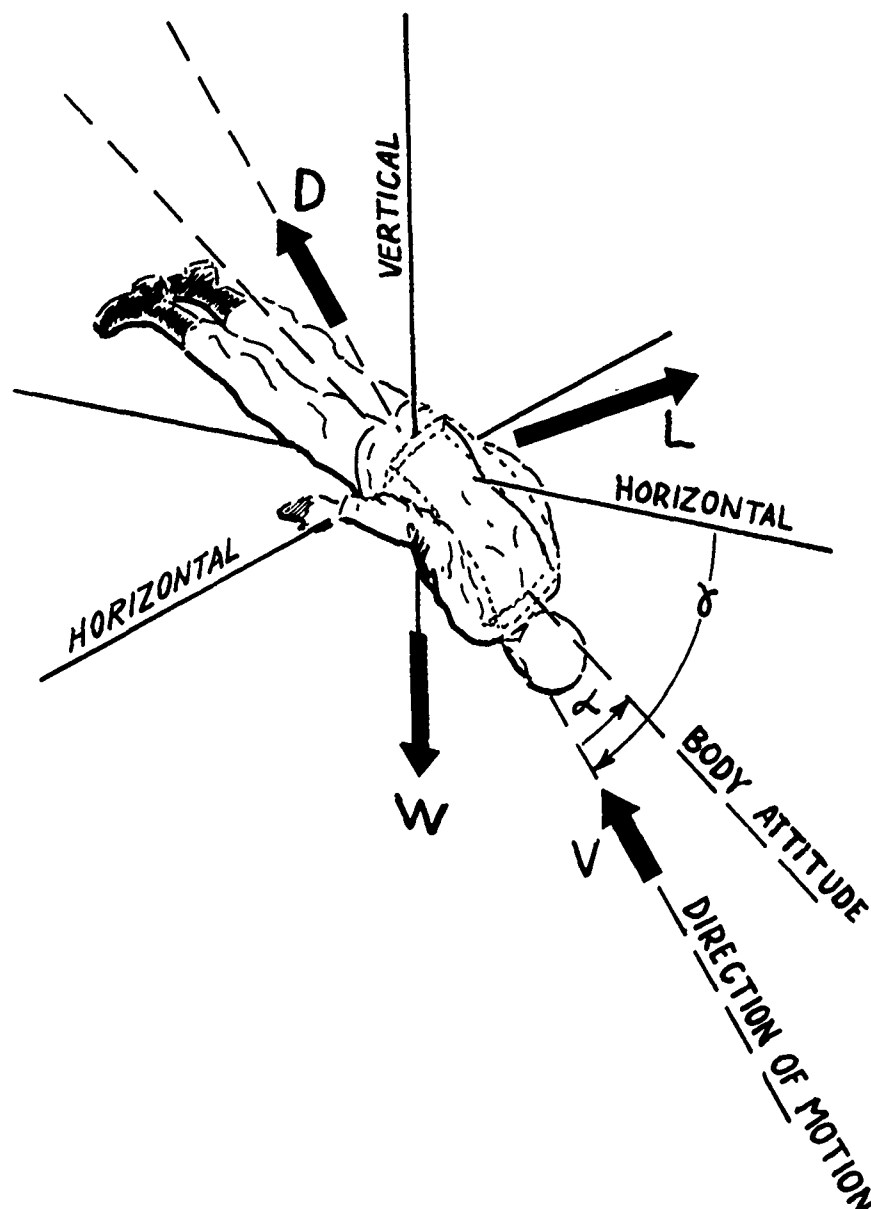


Figure 3



Figure 4. Conventional Main Parachute Back Pack and
Reserve Chest Pack Configuration -
Subject No. 1



Figure 4. Concluded

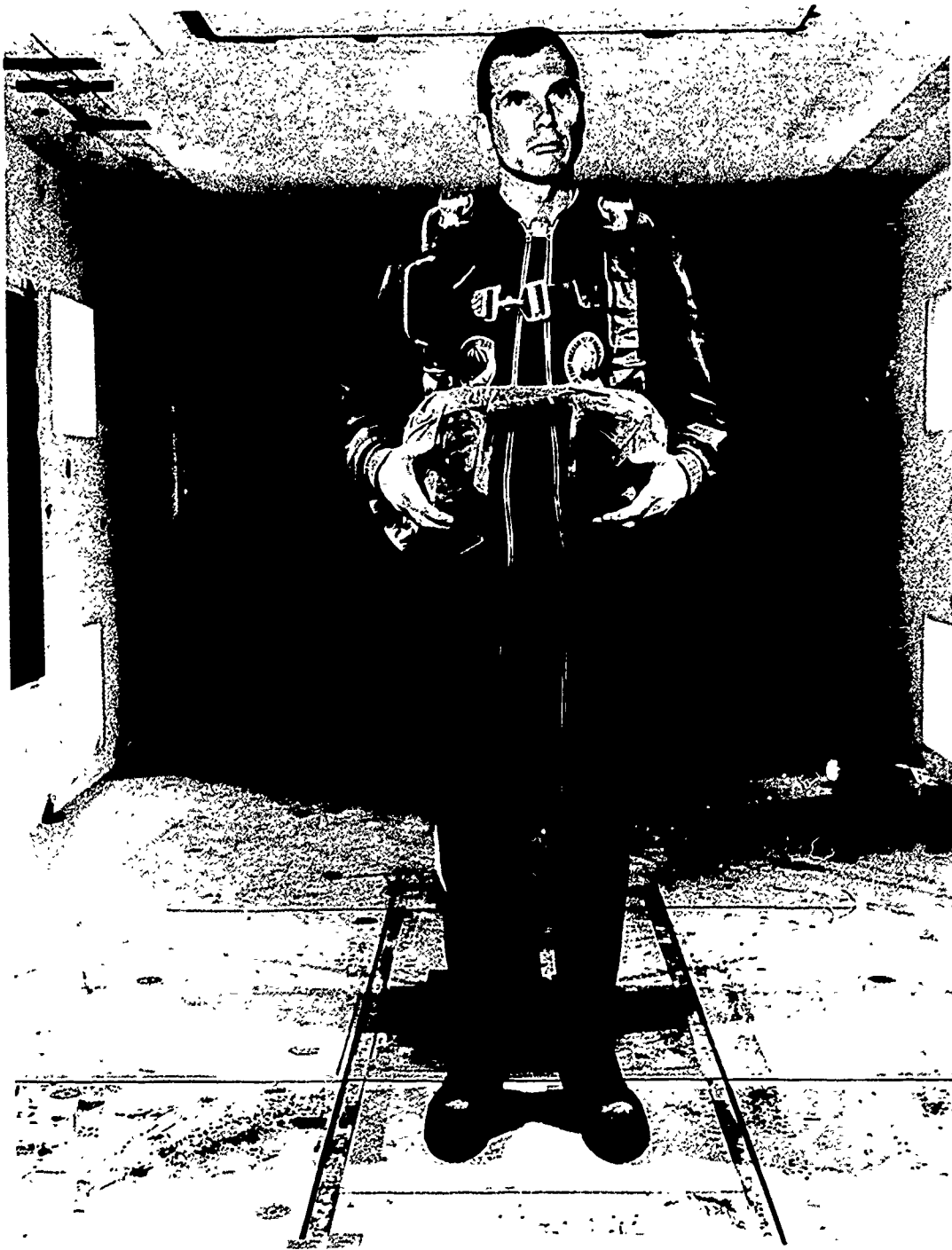


Figure 5. Parachute Pack Configuration Number 1 -
Subject No. 1

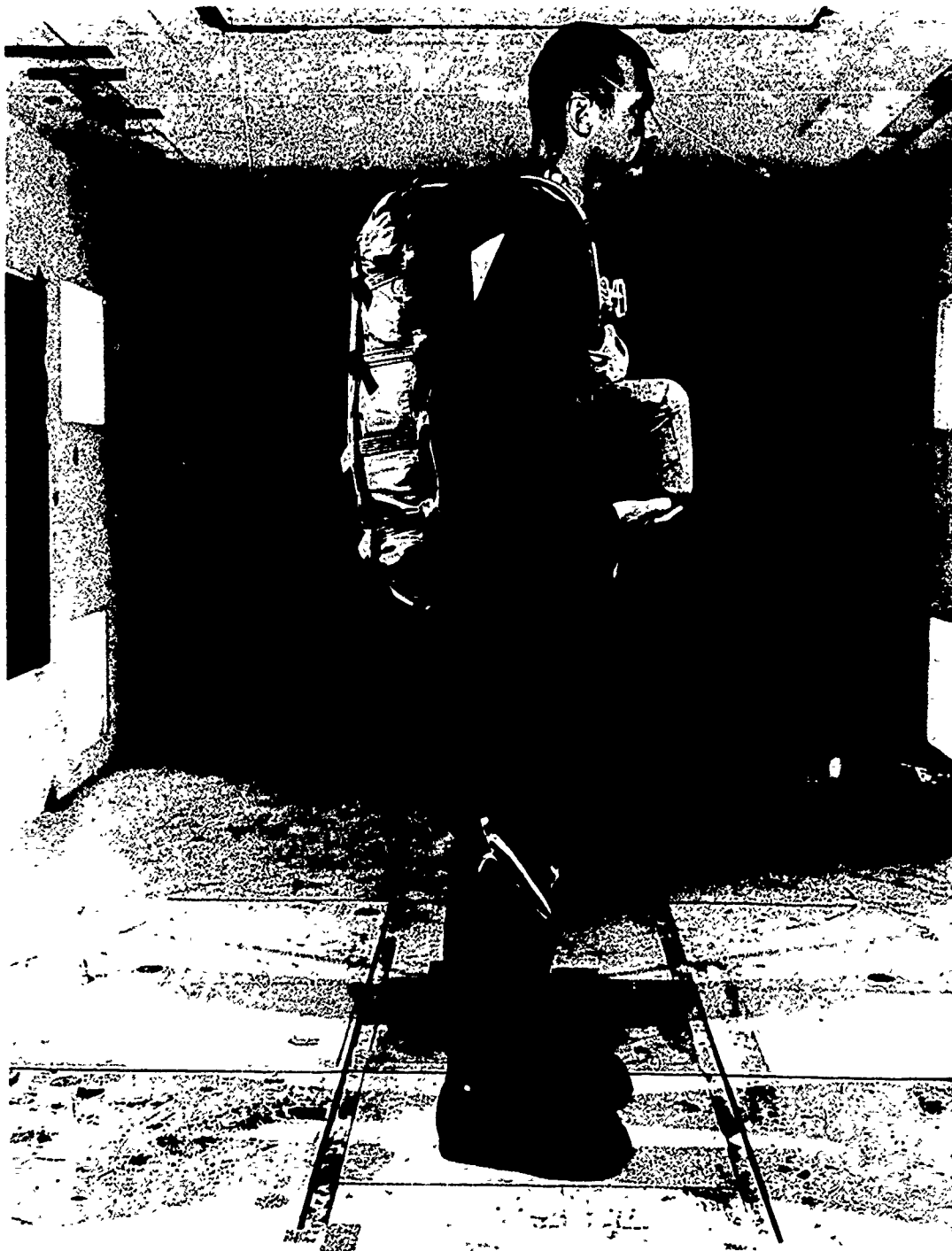


Figure 5. Concluded



Figure 6. Parachute Pack Configuration Number 2 -
Subject No. 1



Figure 6. Concluded



Figure 7. Parachute Pack Configuration Number 3 -
Subject No. 3



Figure 7. Concluded



Figure 8. Parachute Pack Configuration Number 4 -
Subject No. 2



Figure 8. Concluded



Figure 9. Parachute Pack Configuration Number 5 -
Subject No. 4



Figure 9. Concluded



Figure 10. Parachute Pack Configuration Number 6 -
Subject No. 2



Figure 10. Concluded



Figure 11. Parachute Pack Configuration Number 7 -
Subject No. 5



Figure 11. Concluded



Figure 12. Parachute Pack Configuration Number 8 -
Subject No. 1



Figure 12. Concluded

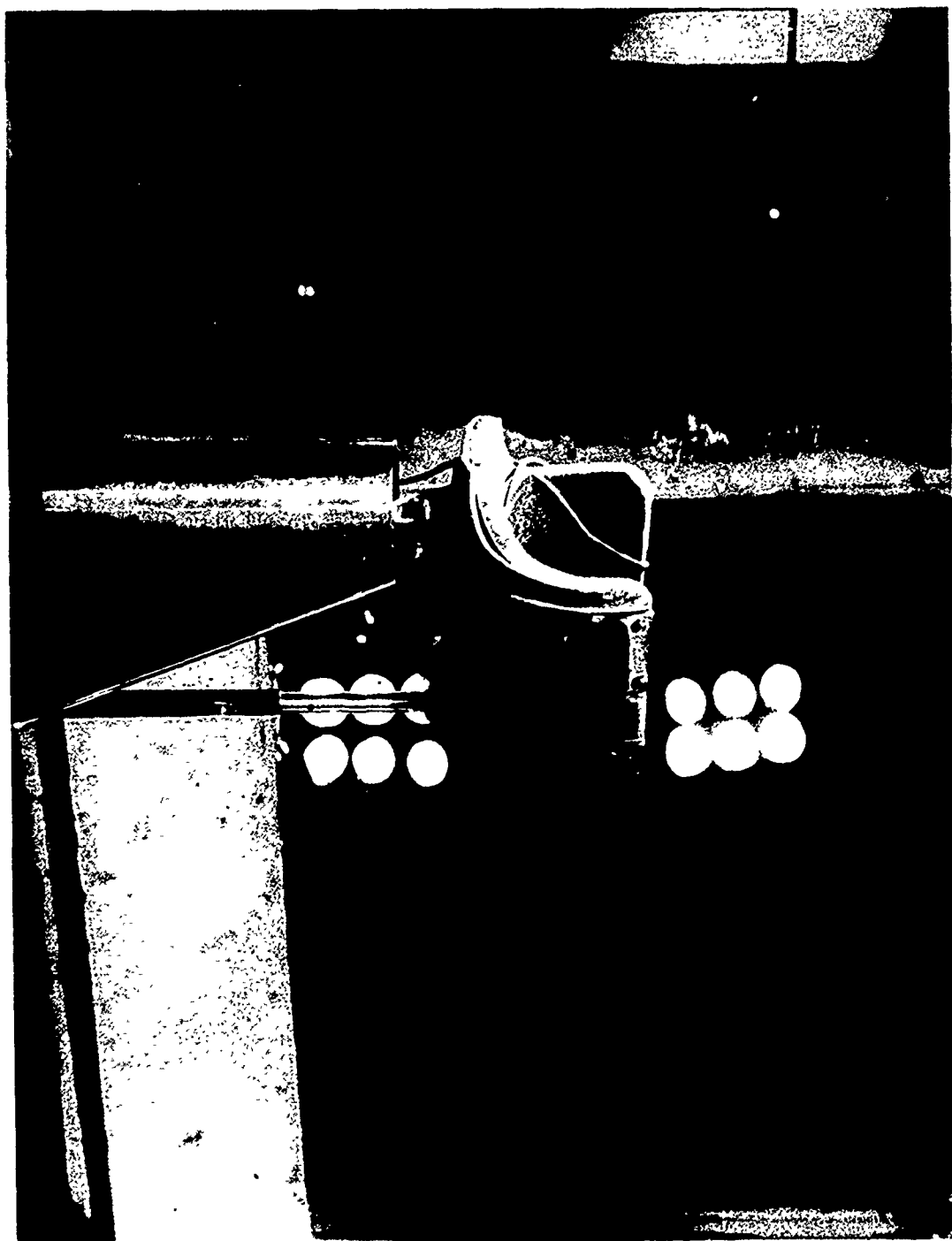
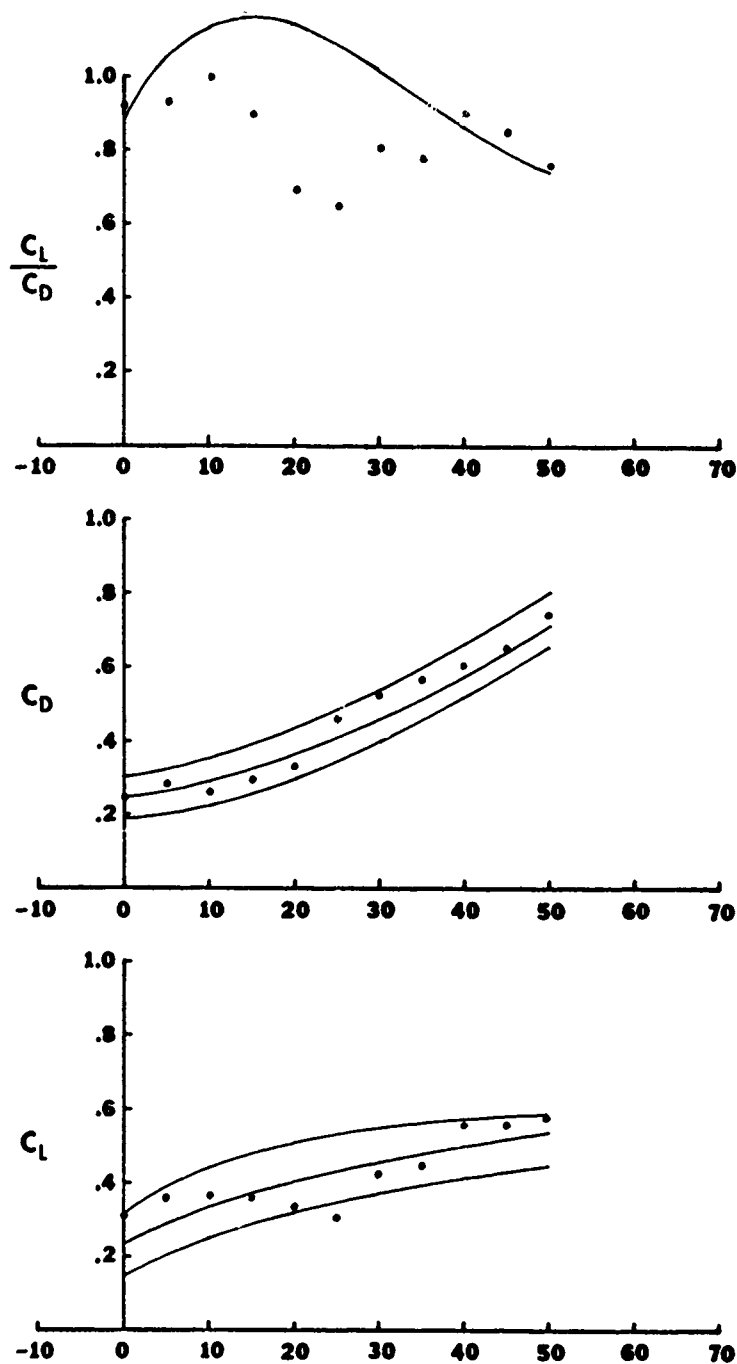


Figure 13. Cradle and Strut Assembly



Figure 14. Subject Mounted in Wind Tunnel



α DEGREES
 PARACHUTE PACK CONFIGURATION NO. 0
 SUBJECT NO. 1

Figure 15 (a)

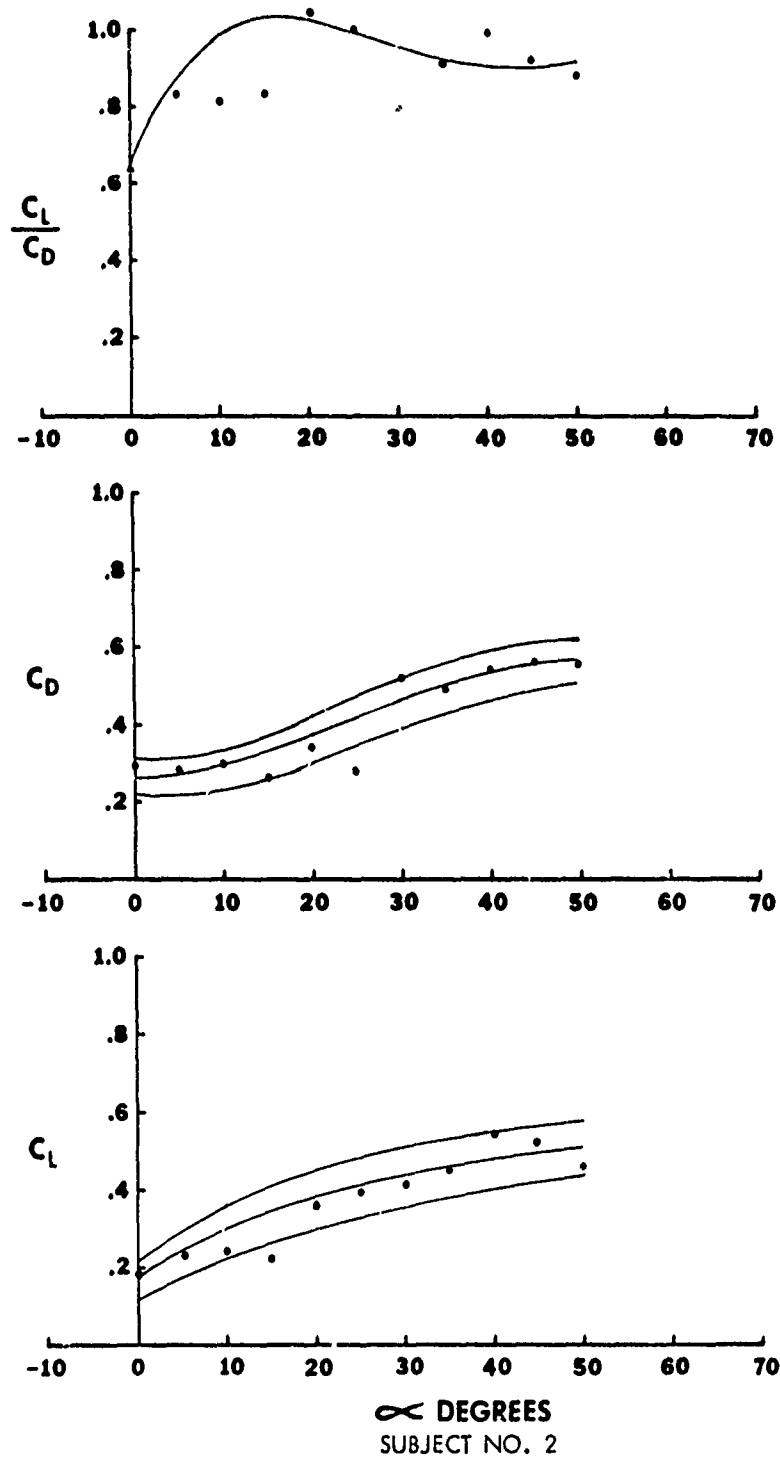
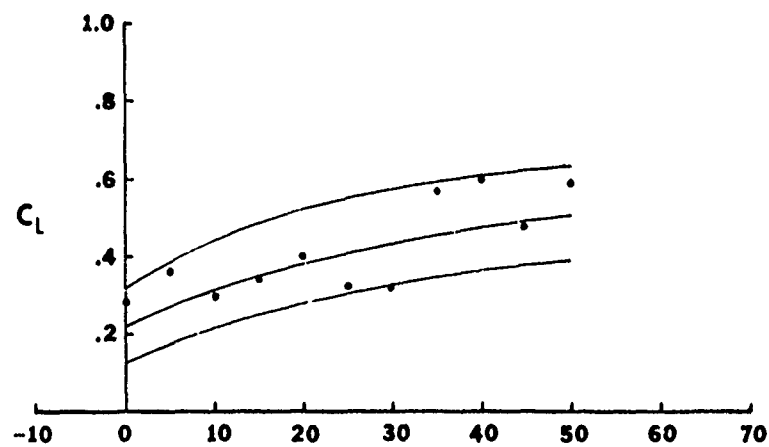
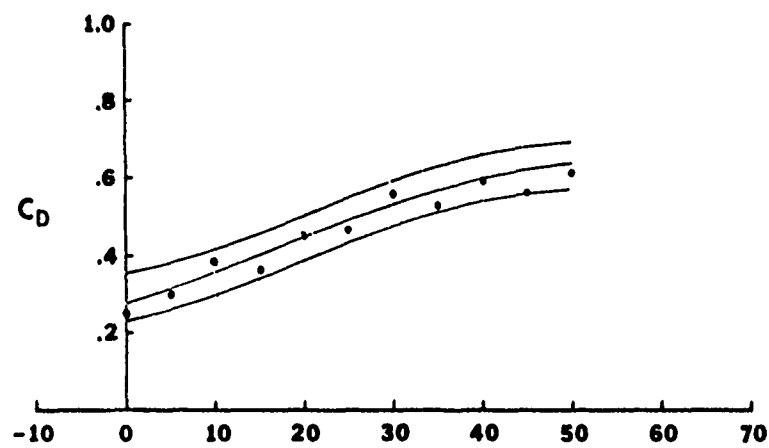
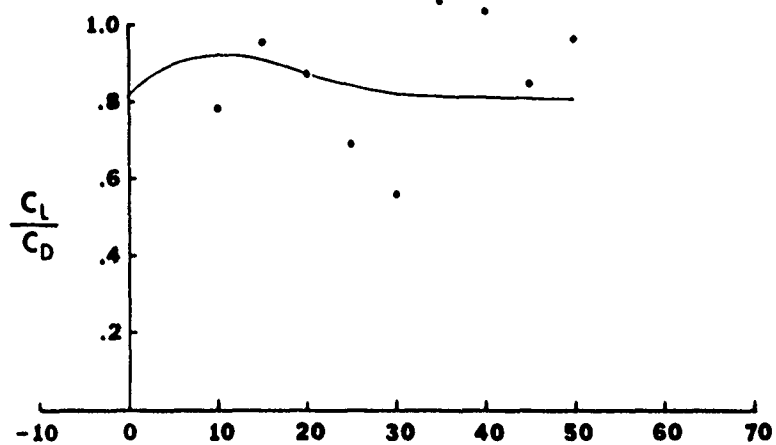
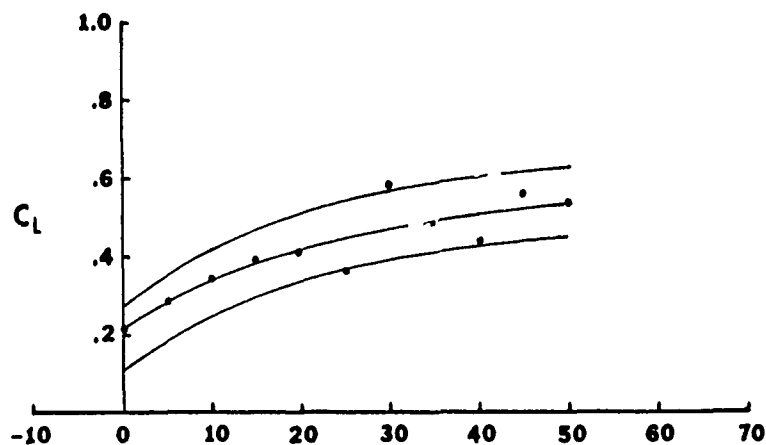
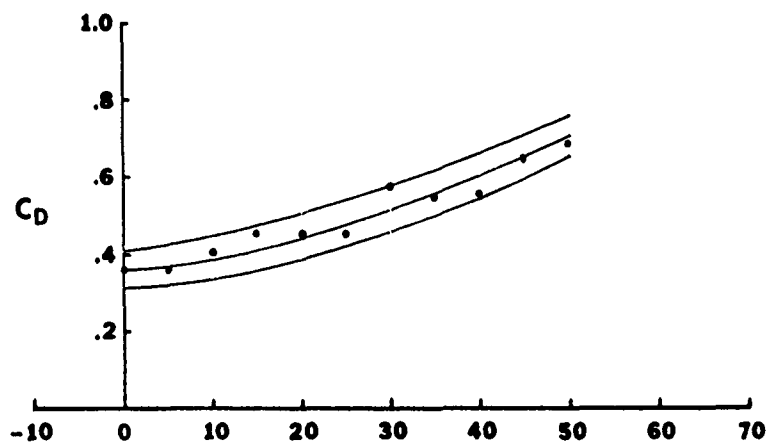
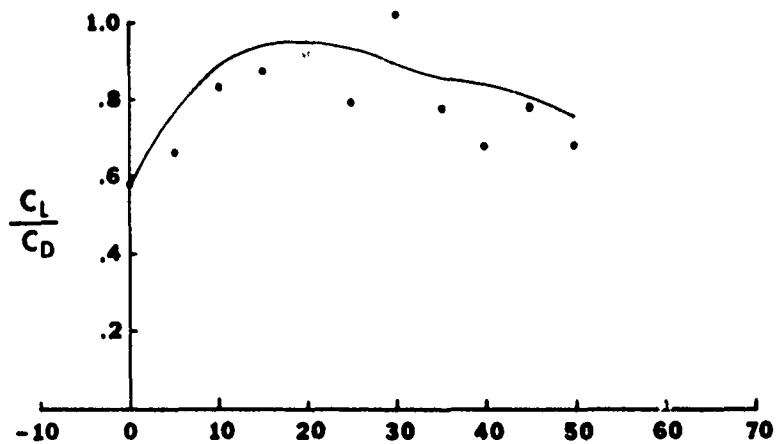


Figure 15 (b)



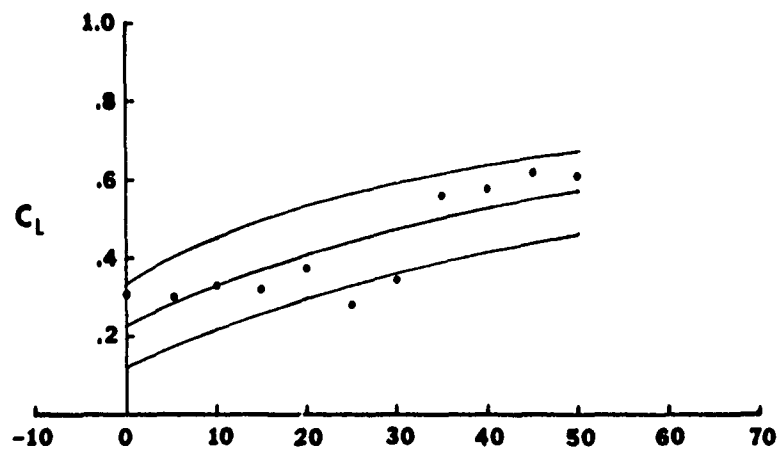
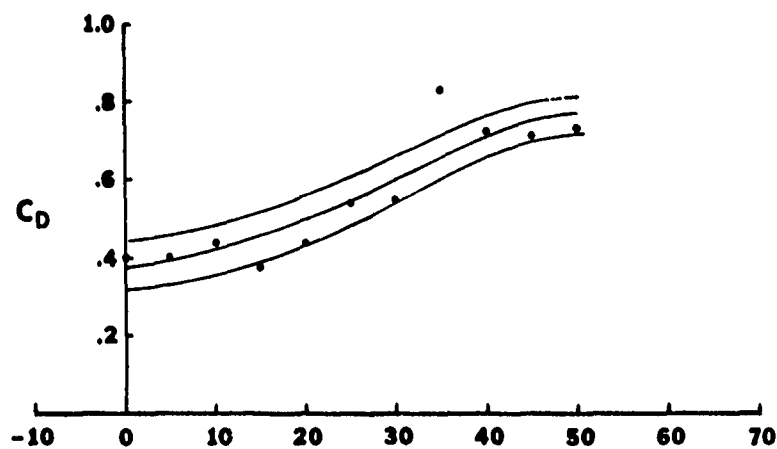
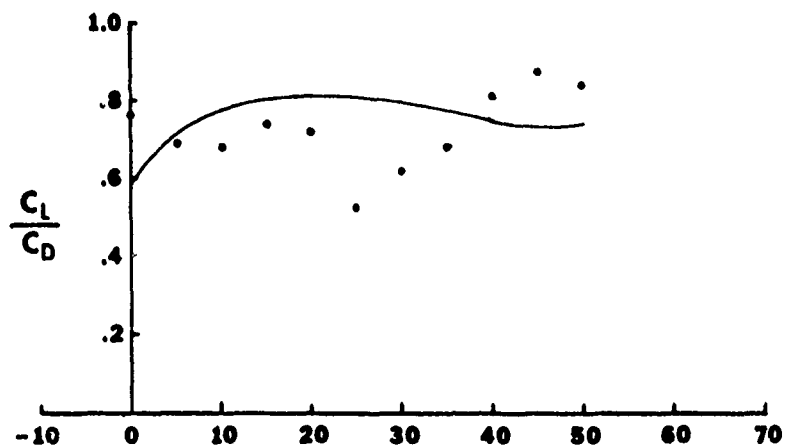
α DEGREES
SUBJECT NO. 3

Figure 15 (c)



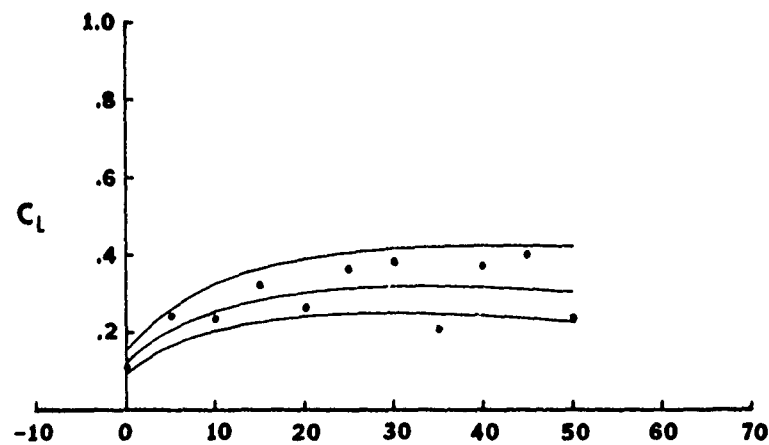
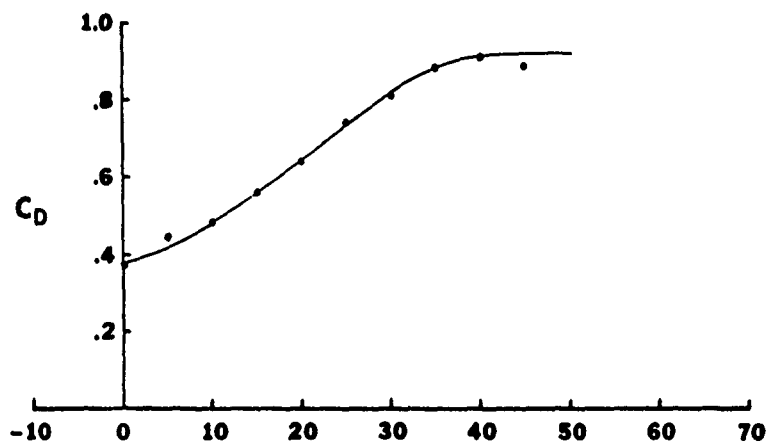
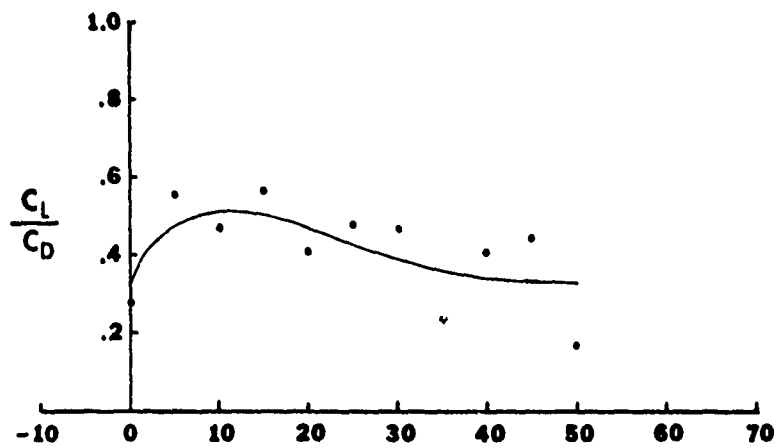
α DEGREES
SUBJECT NO. 4

Figure 15 (d)



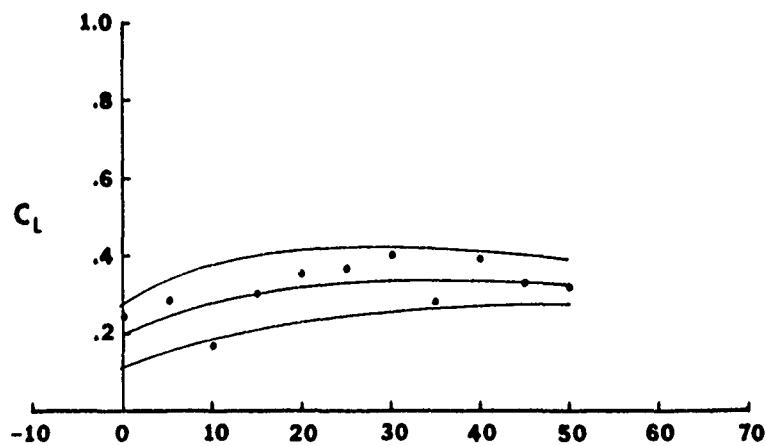
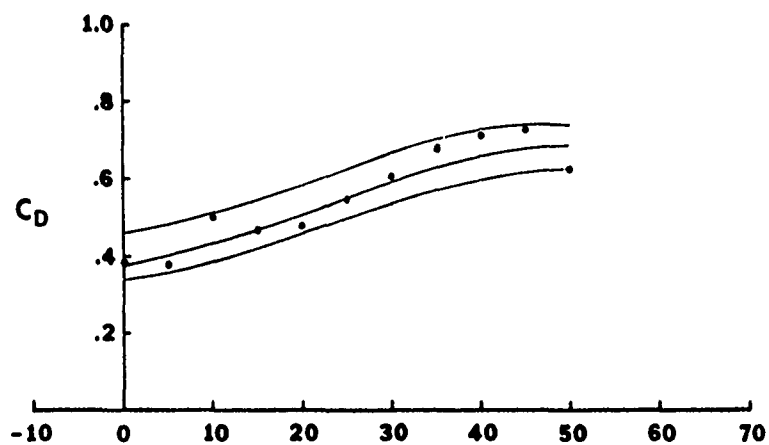
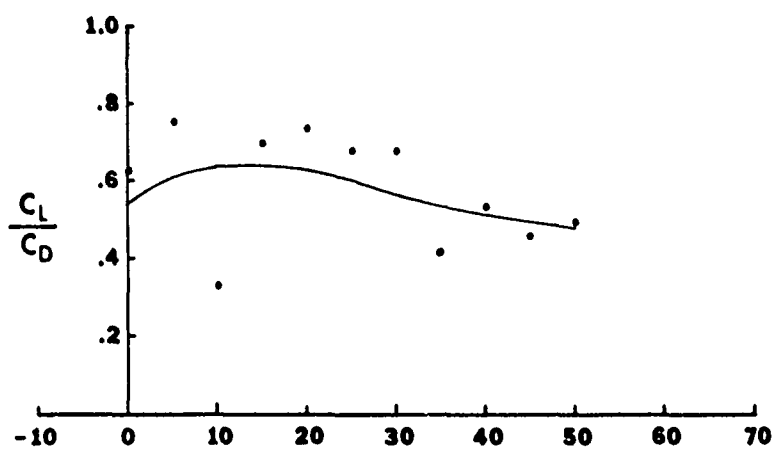
∞ DEGREES
SUBJECT NO. 5

Figure 15 (e)



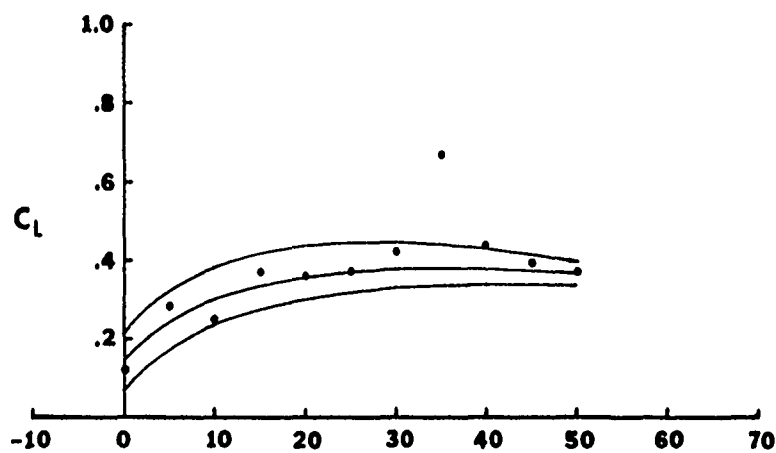
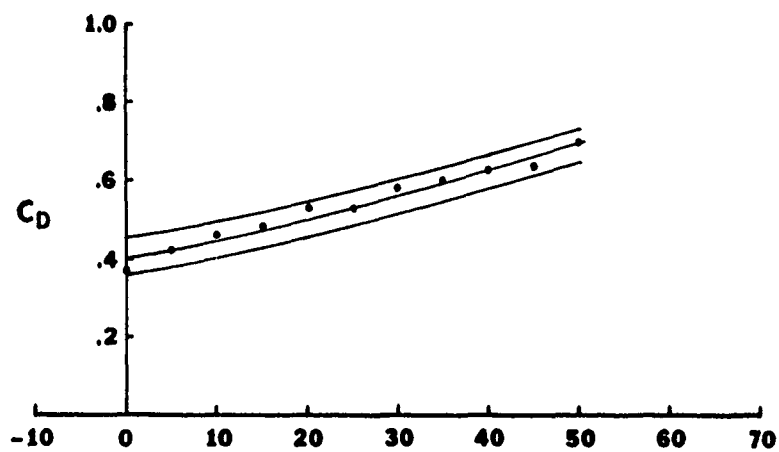
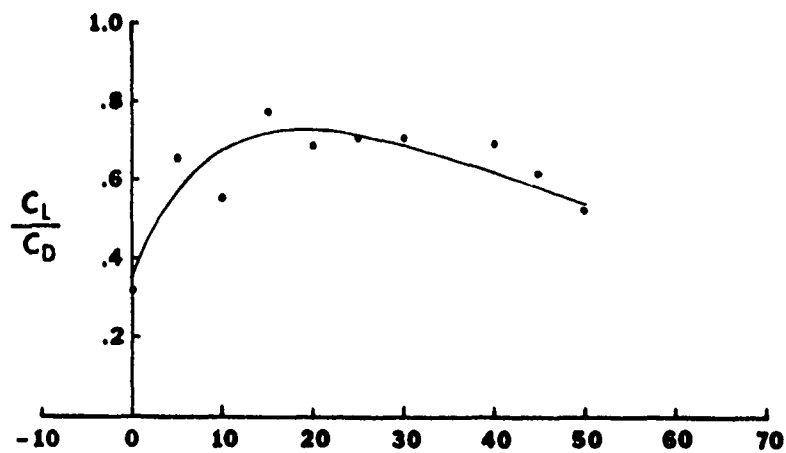
α DEGREES
 PARACHUTE PACK CONFIGURATION NO. 1
 SUBJECT NO. 1

Figure 16 (a)



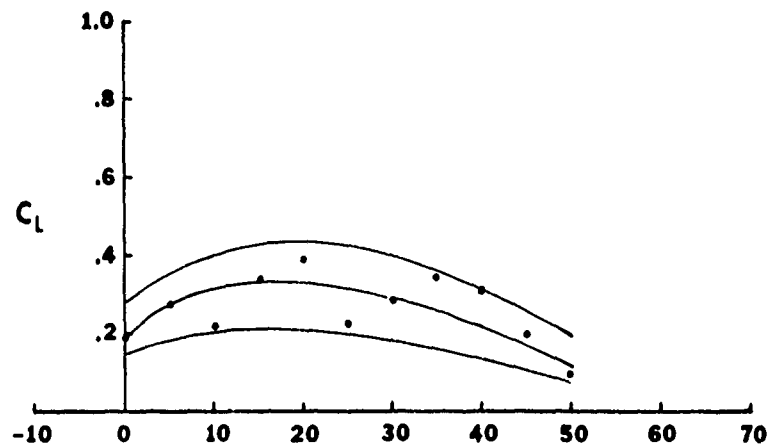
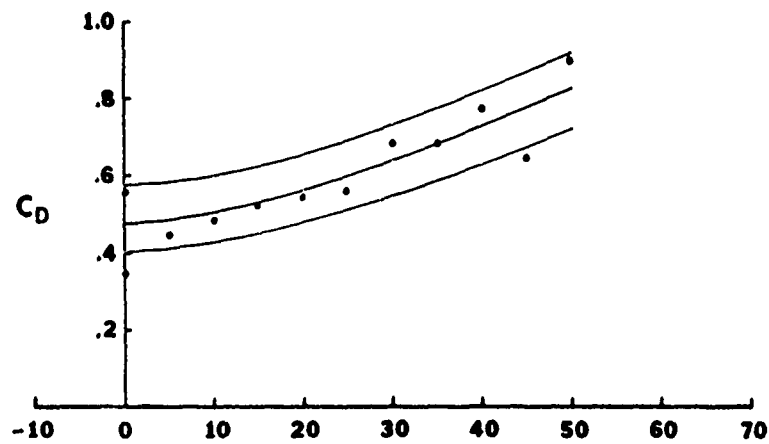
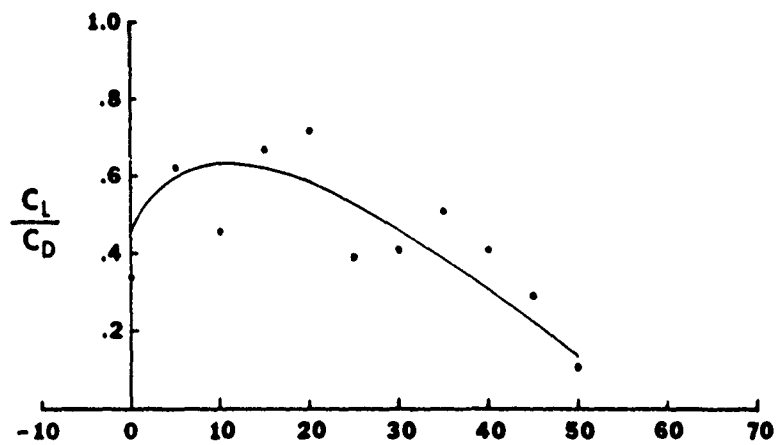
∞ DEGREES
SUBJECT NO. 2

Figure 16 (b)



∞ DEGREES
SUBJECT NO. 3

Figure 16 (c)



∞ DEGREES
SUBJECT NO. 4

Figure 16 (d)

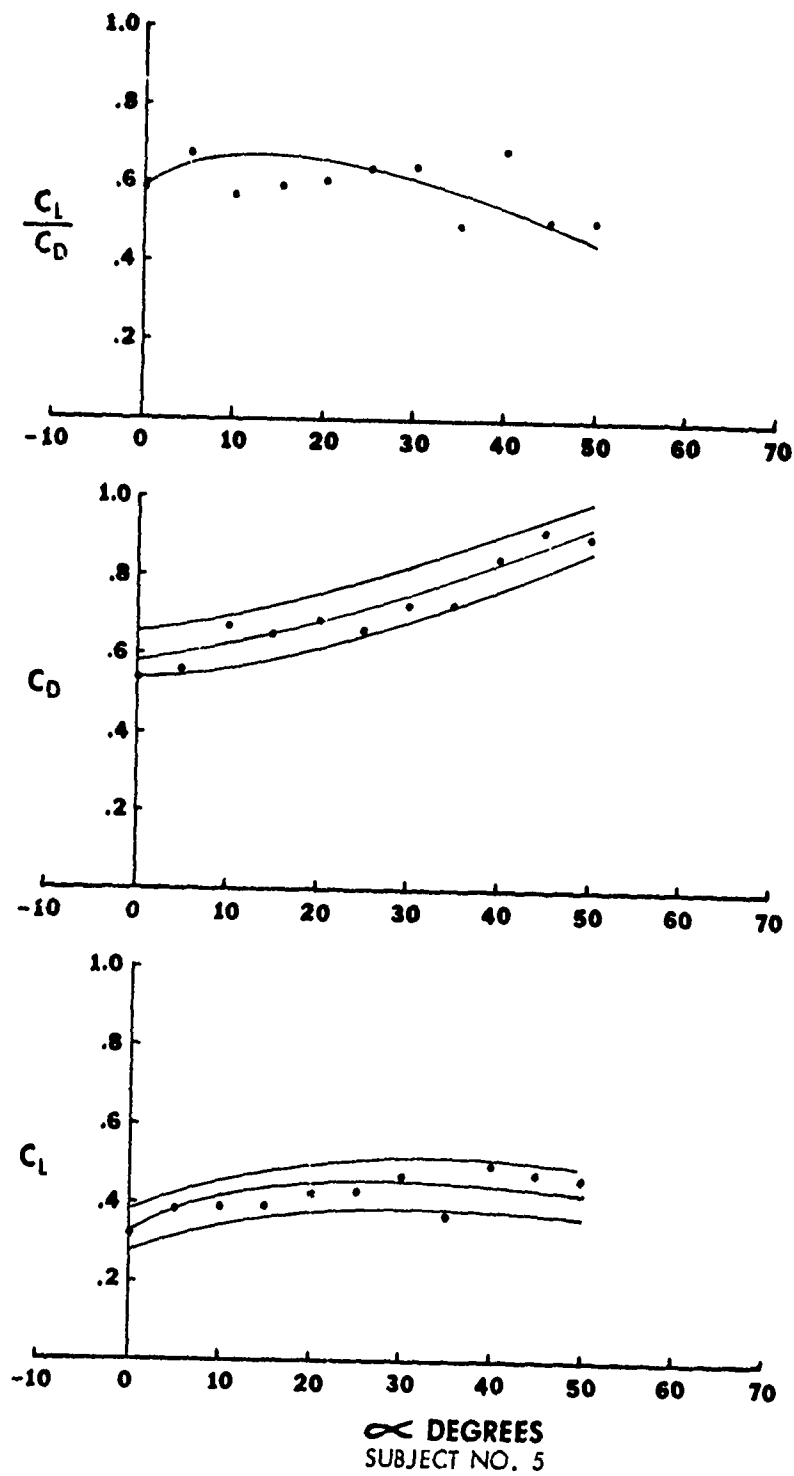
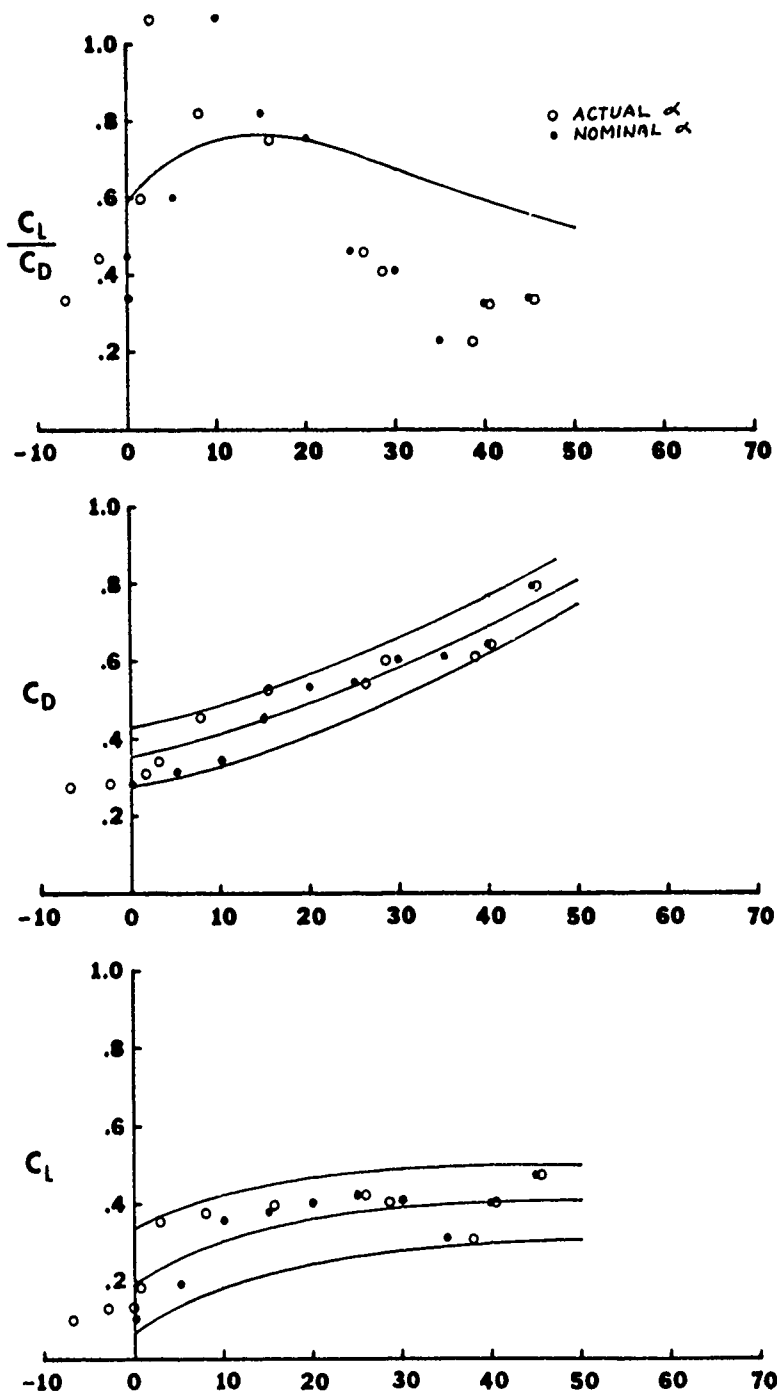


Figure 16 (e)



α DEGREES
PARACHUTE PACK CONFIGURATION NO. 2
SUBJECT NO. 1

Figure 17 (a)

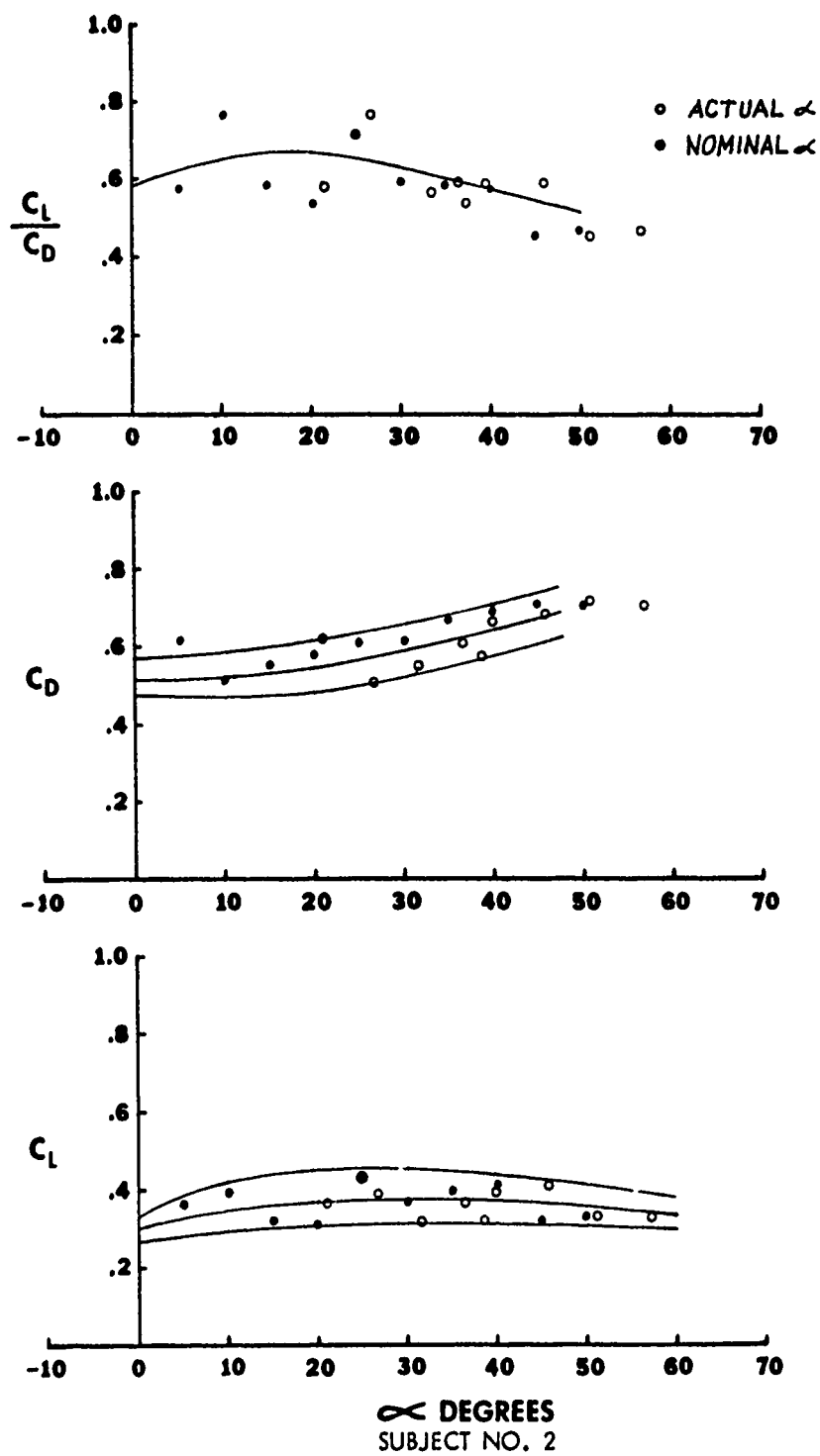
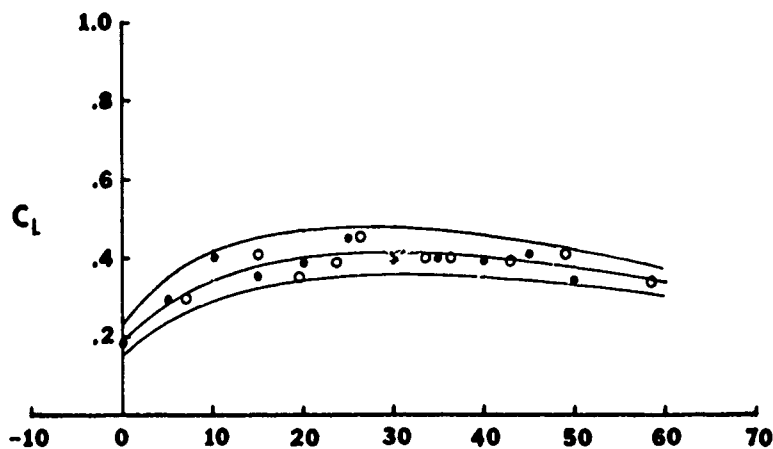
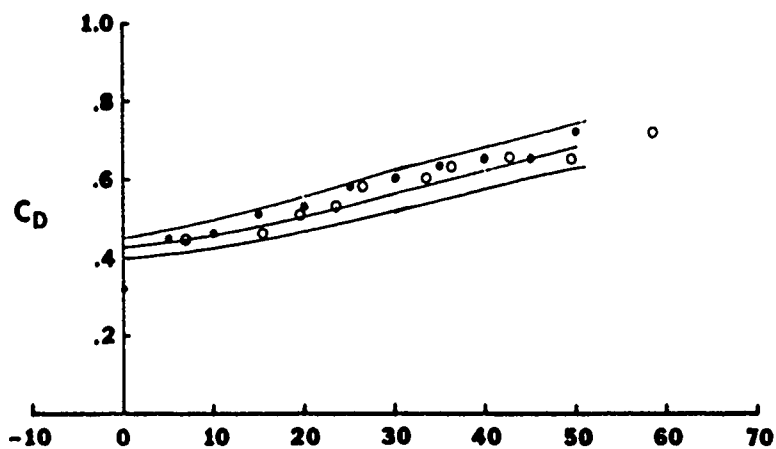
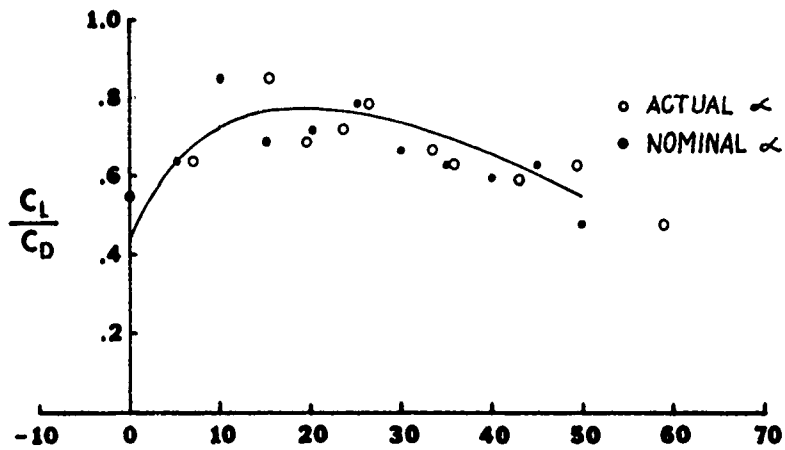
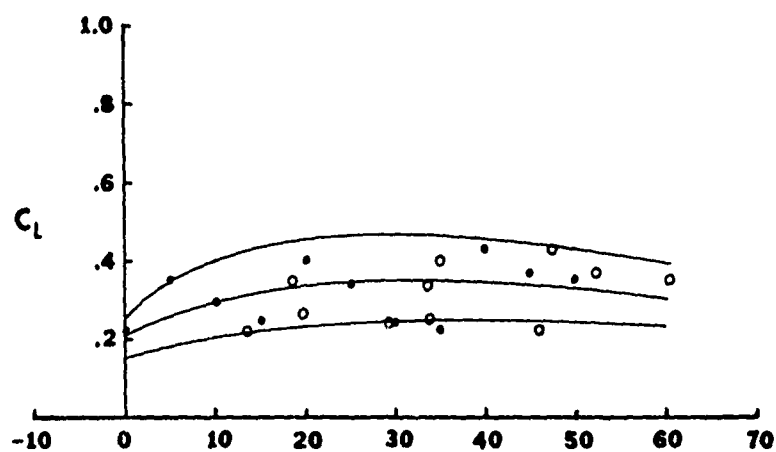
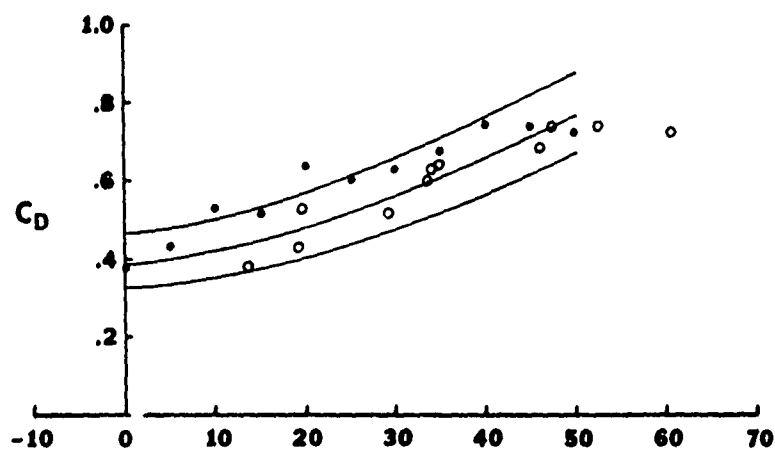
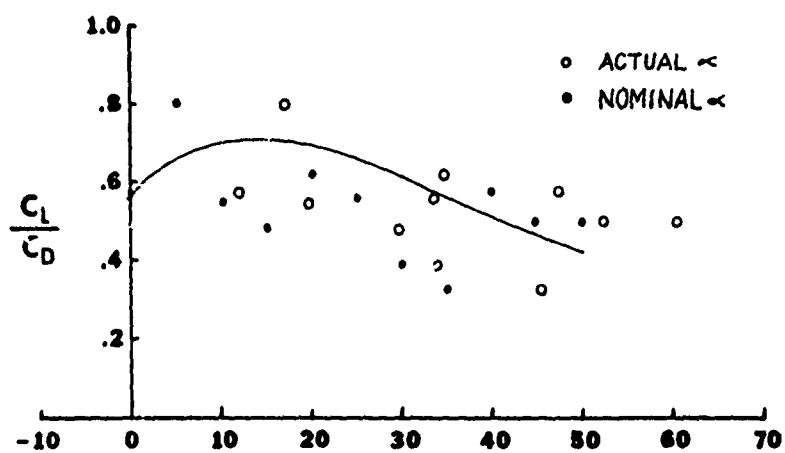


Figure 17 (b)



α DEGREES
SUBJECT NO. 3

Figure 17 (c)



α DEGREES
SUBJECT NO. 4

Figure 17 (d)

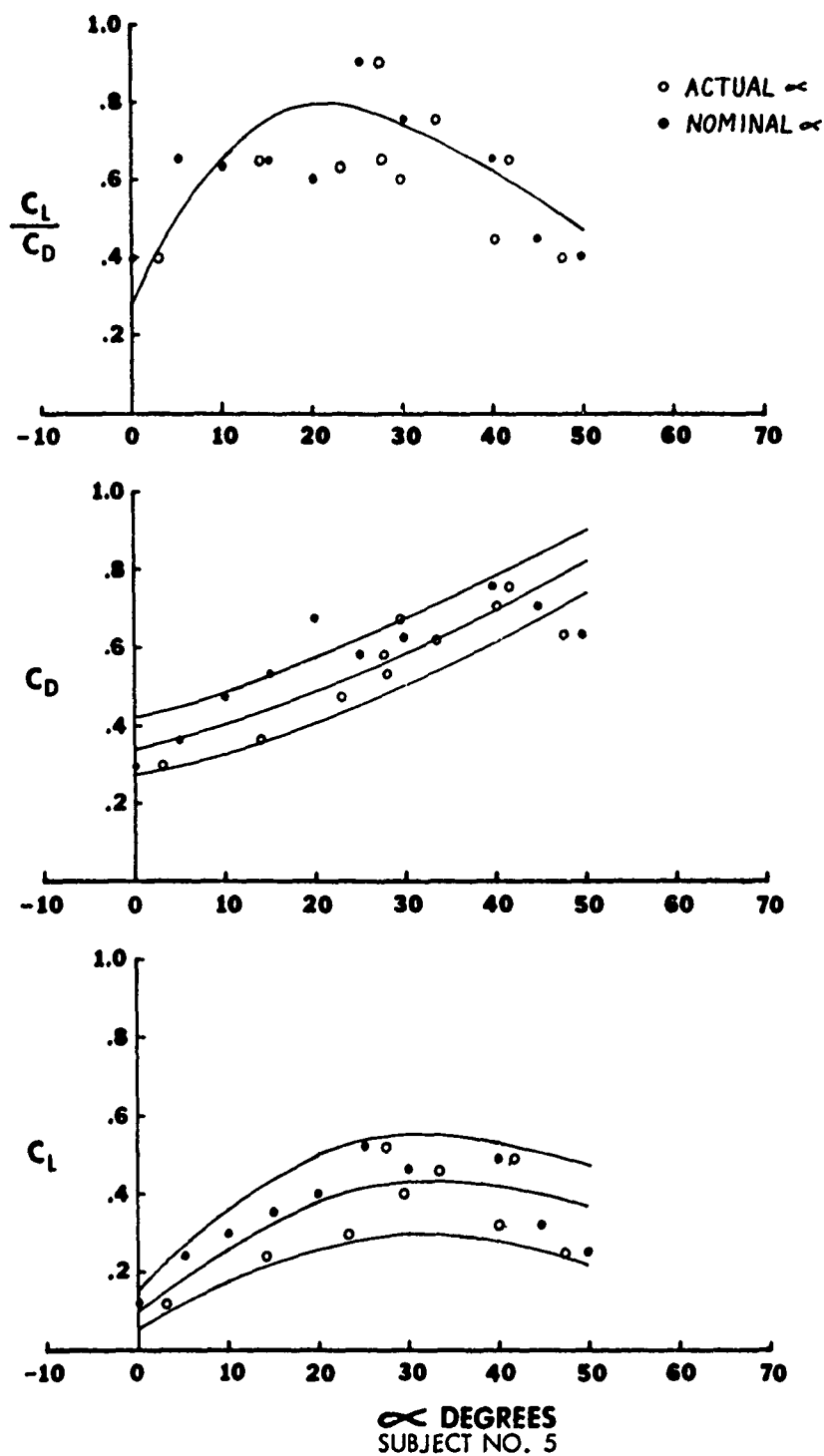
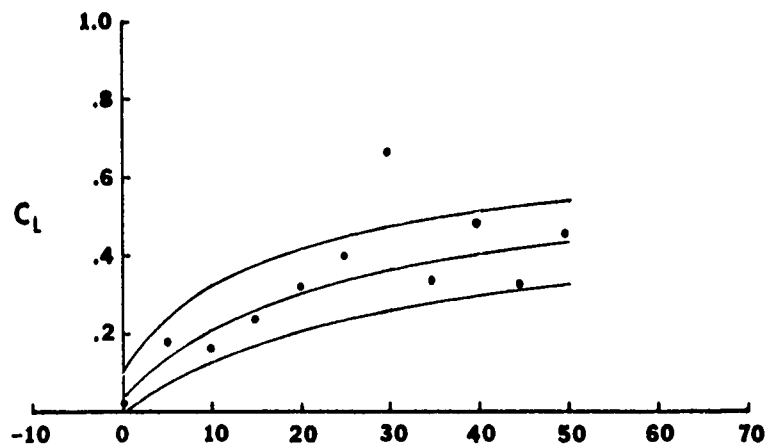
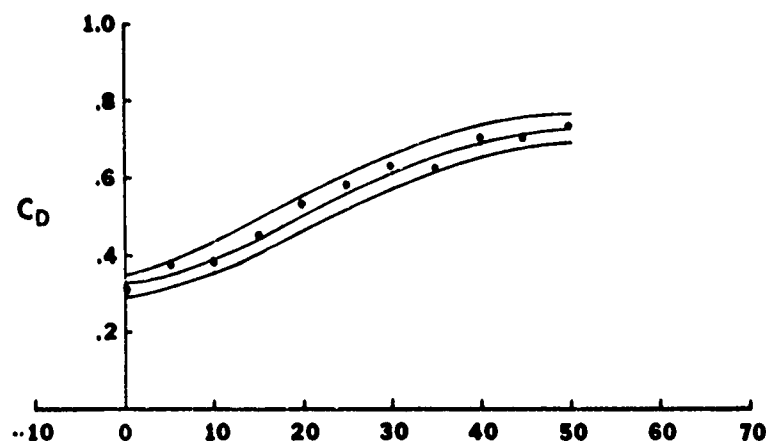
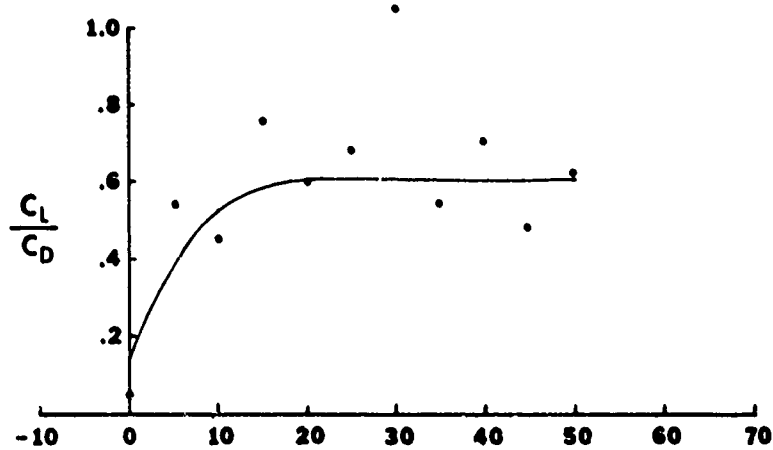
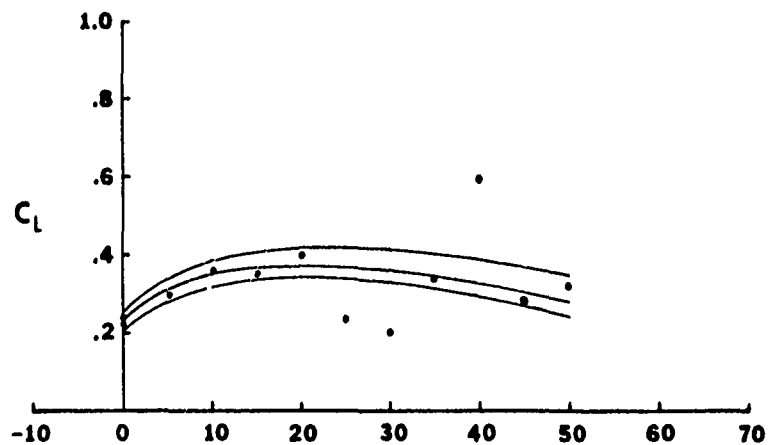
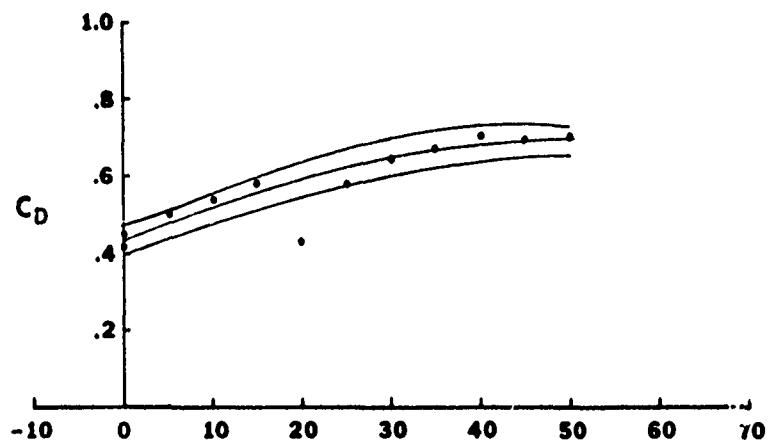
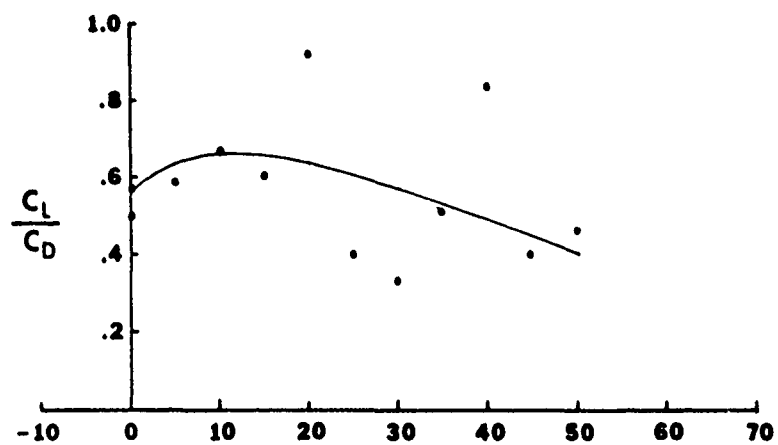


Figure 17 (e)



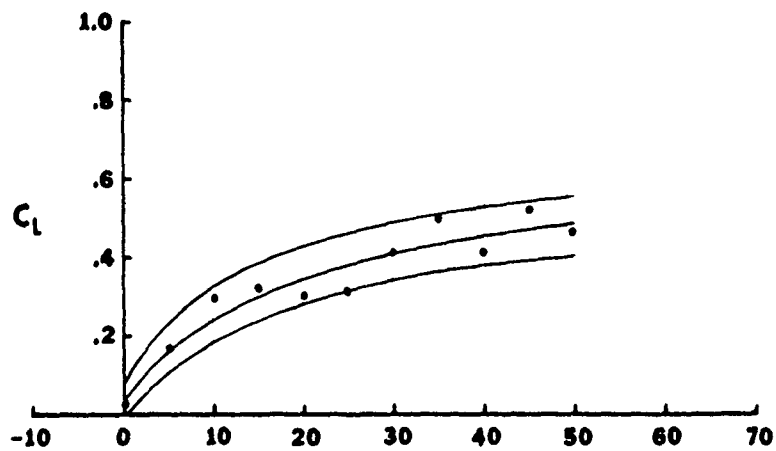
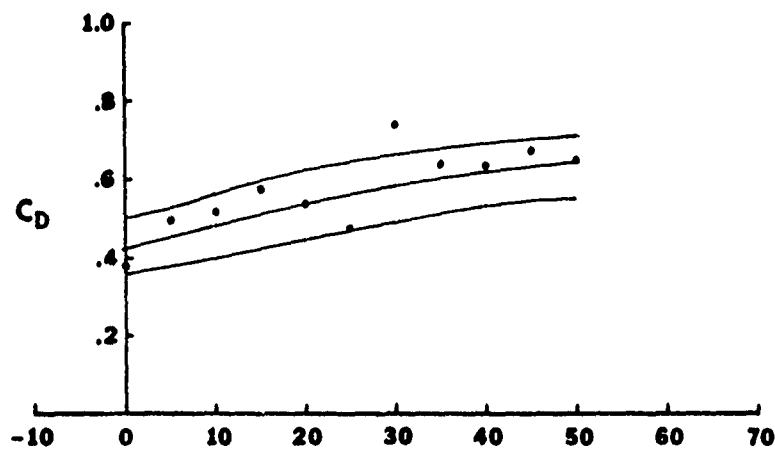
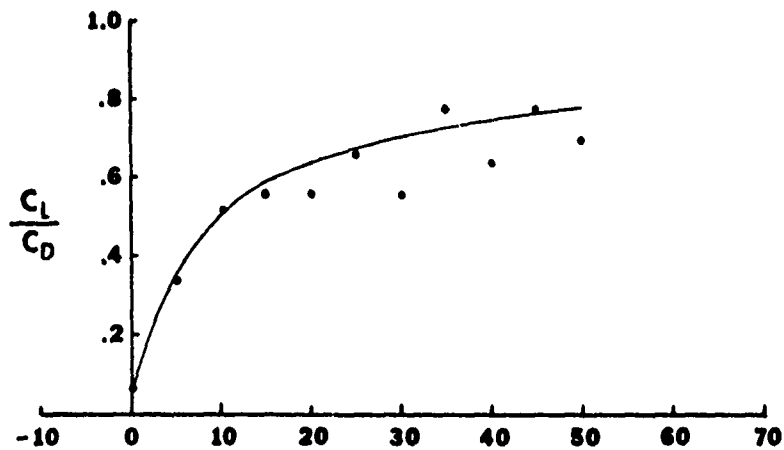
α DEGREES
 PARACHUTE PACK CONFIGURATION NO. 3
 SUBJECT NO. 1

Figure 18 (a)



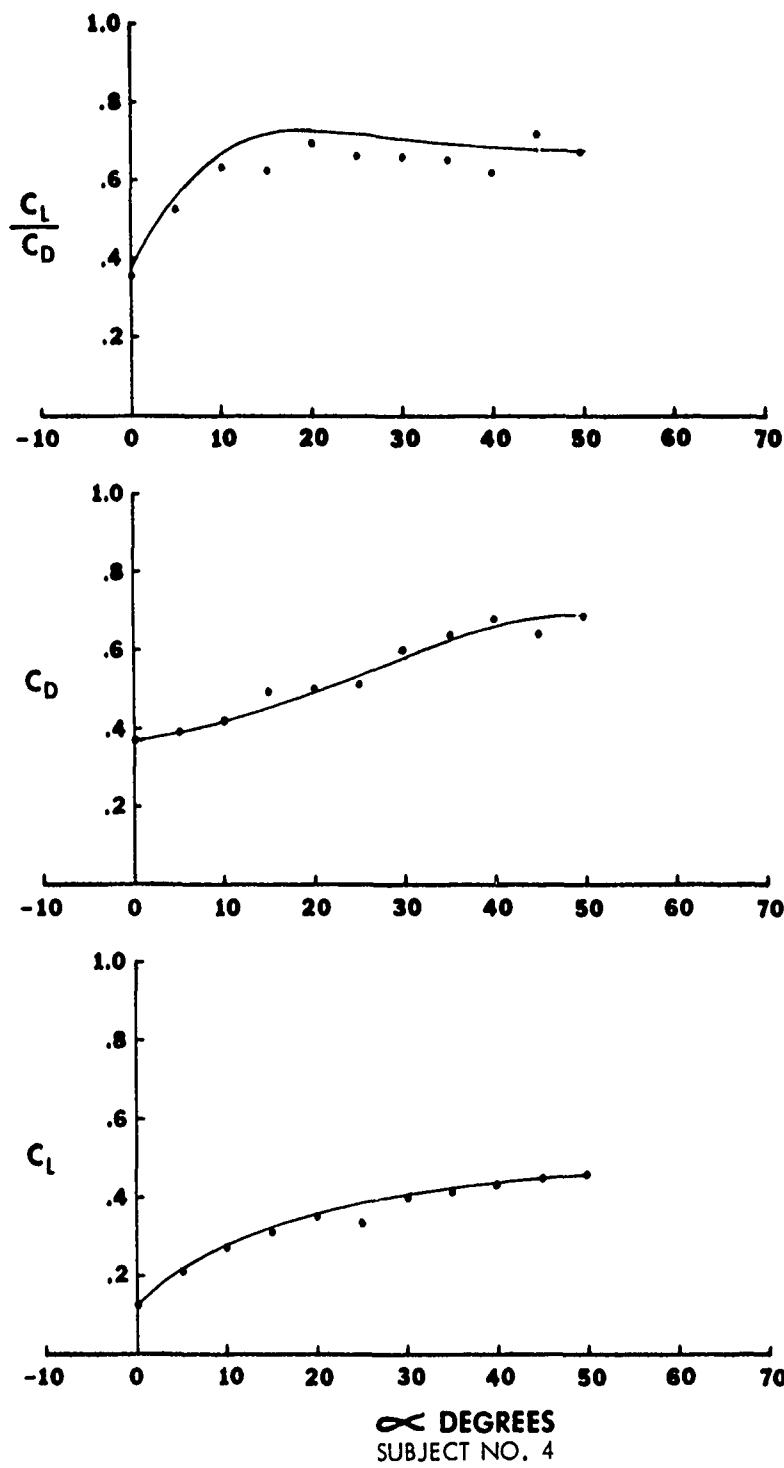
∞ DEGREES
SUBJECT NO. 2

Figure 18 (b)



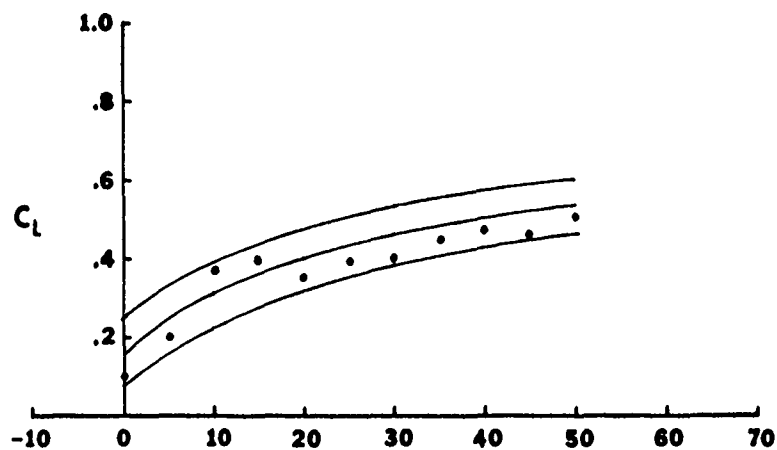
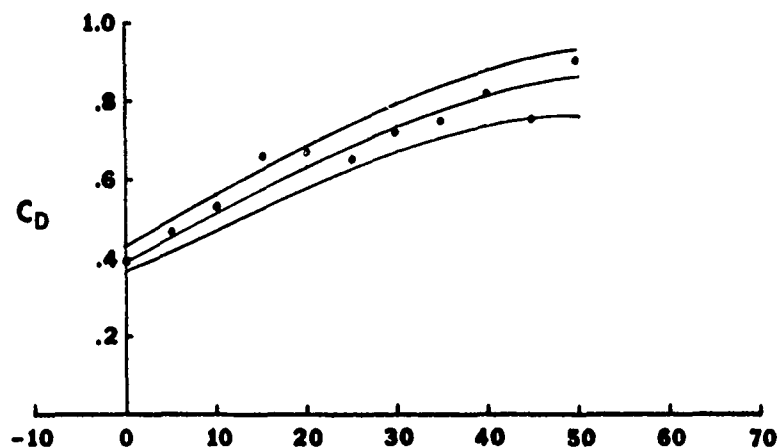
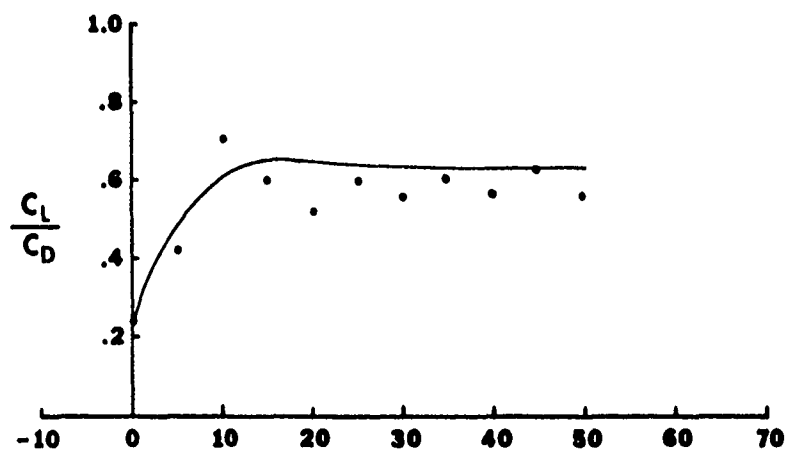
∞ DEGREES
SUBJECT NO. 3

Figure 18 (c)



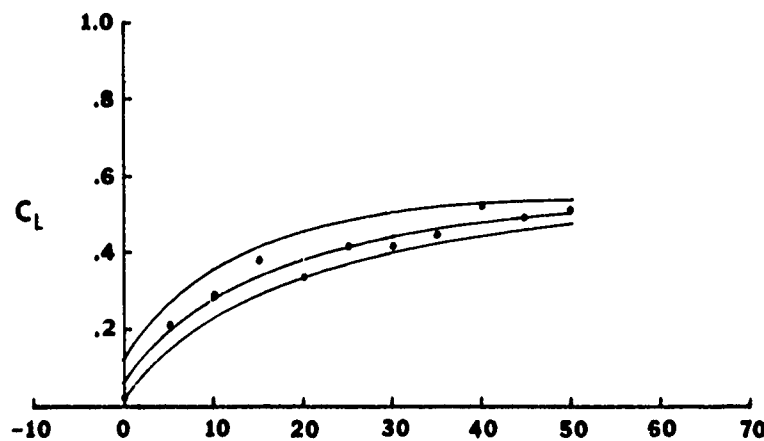
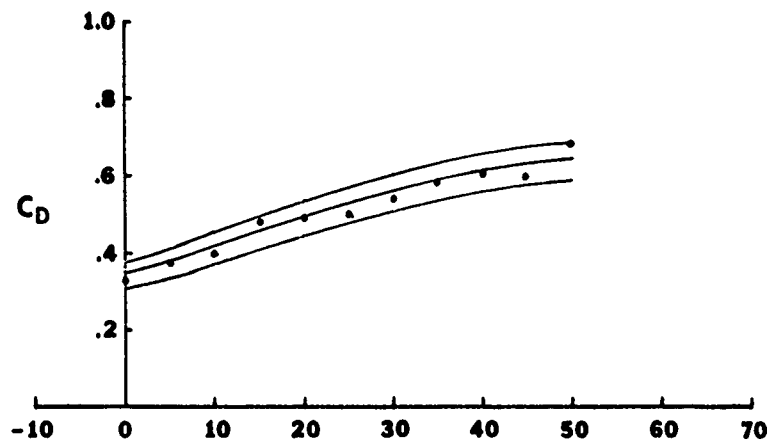
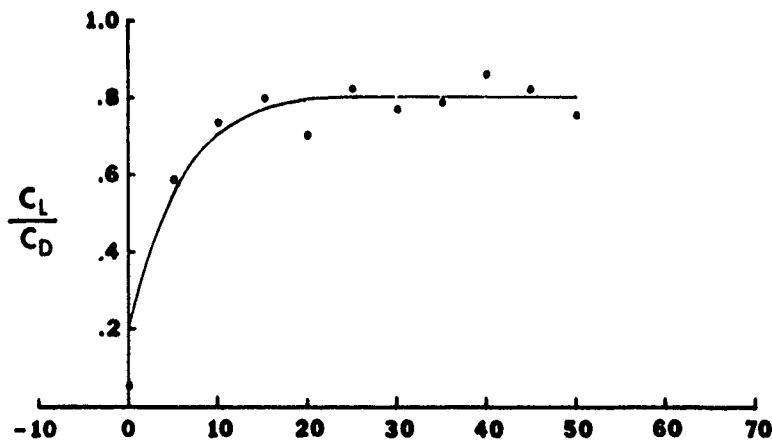
α DEGREES
SUBJECT NO. 4

Figure 18 (d)



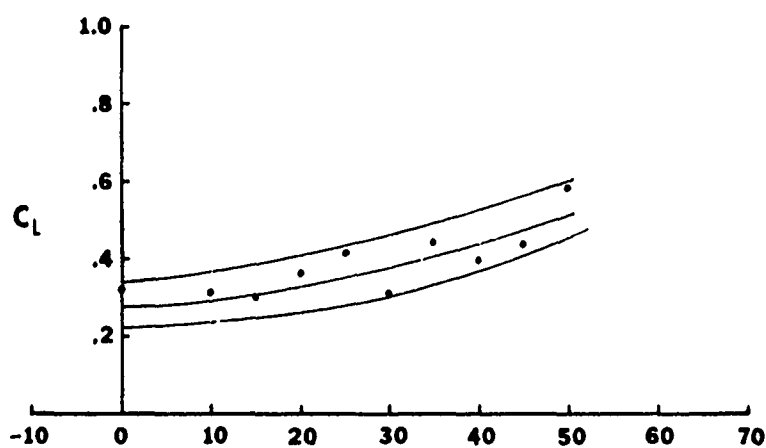
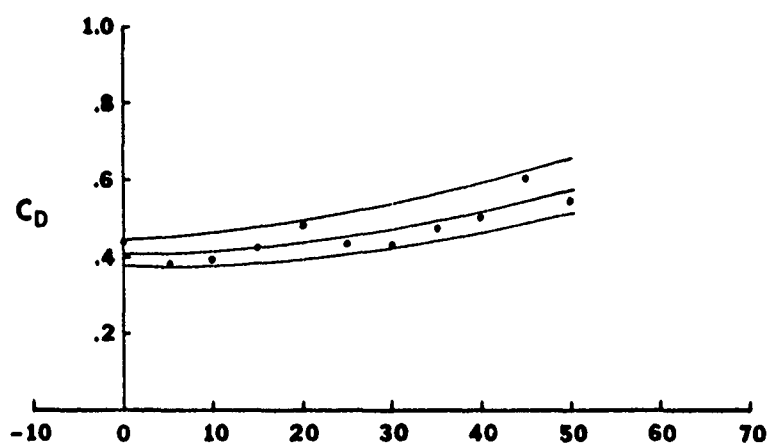
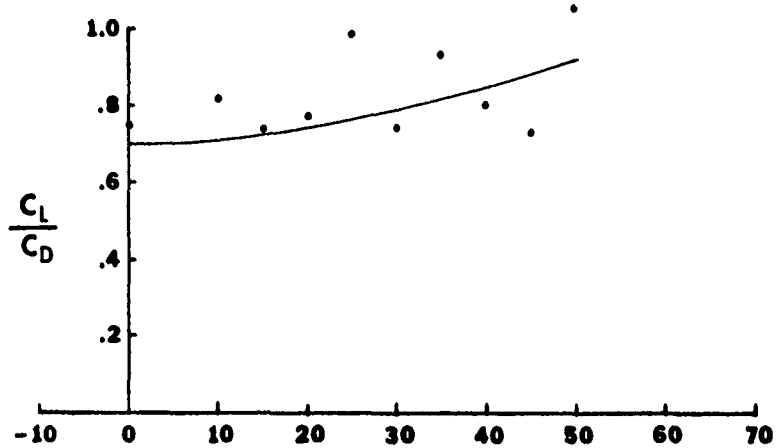
∞ DEGREES
SUBJECT NO. 5

Figure 18 (e)



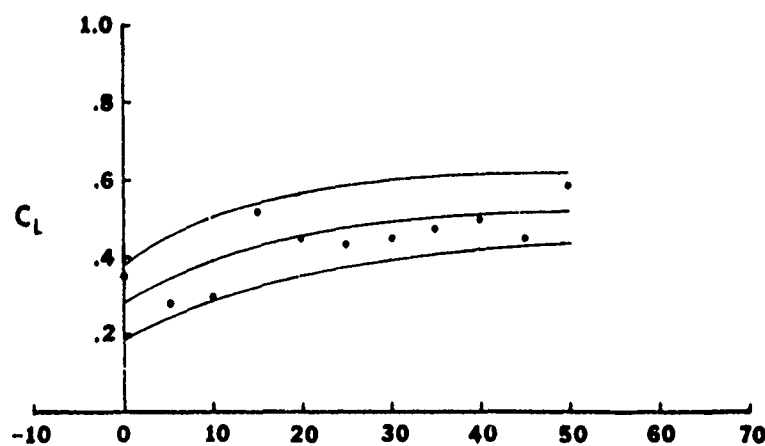
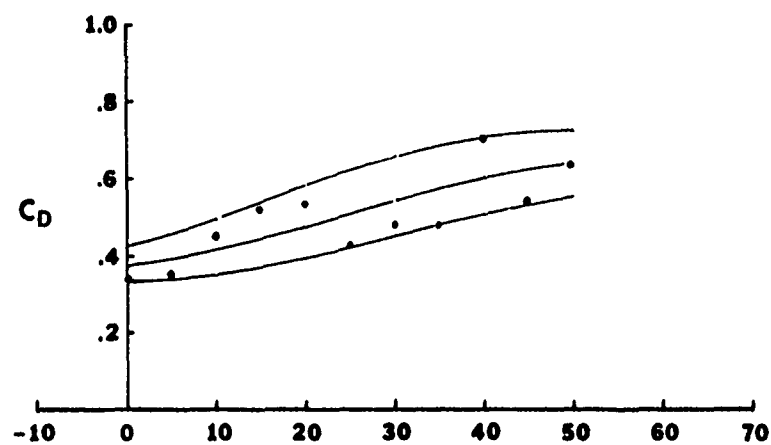
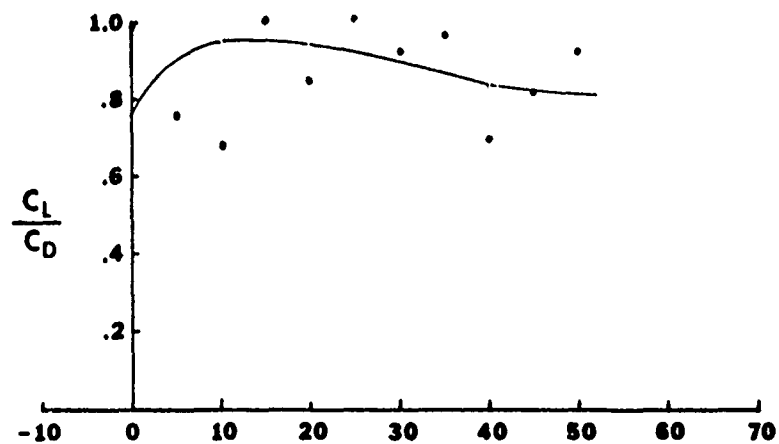
∞ DEGREES
 PARACHUTE PACK CONFIGURATION NO. 4
 SUBJECT NO. 1

Figure 19 (a)



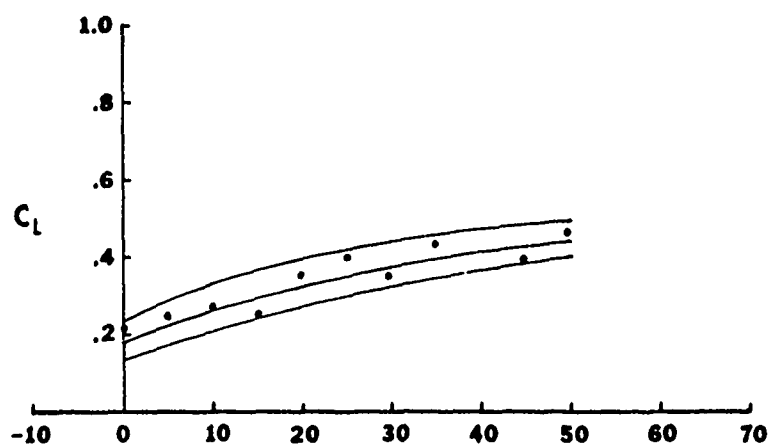
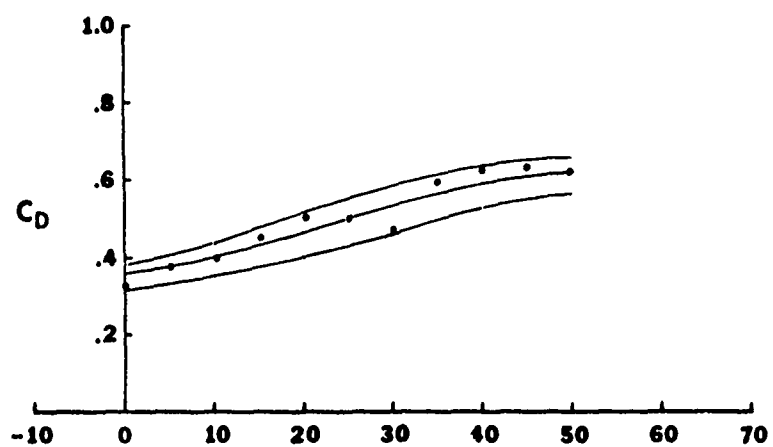
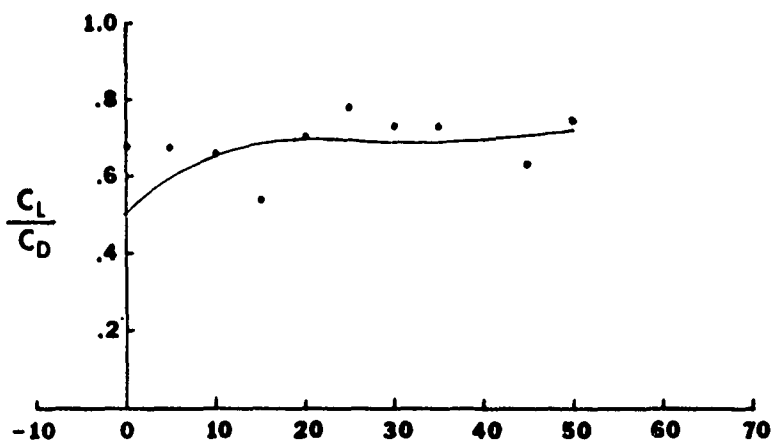
∞ DEGREES
SUBJECT NO. 2

Figure 19 (b)



∞ DEGREES
SUBJECT NO. 3

Figure 19 (c)



∞ DEGREES
SUBJECT NO. 4

Figure 19 (d)

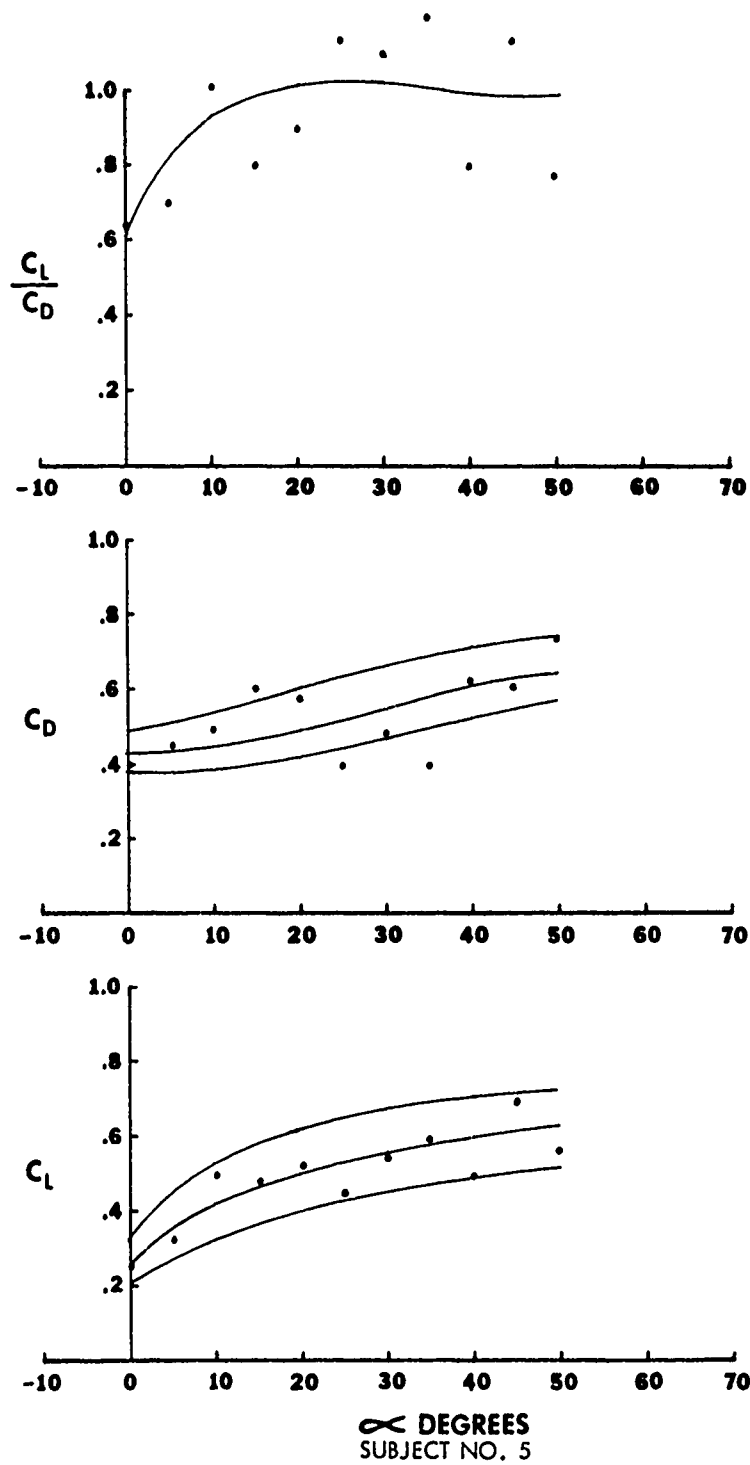
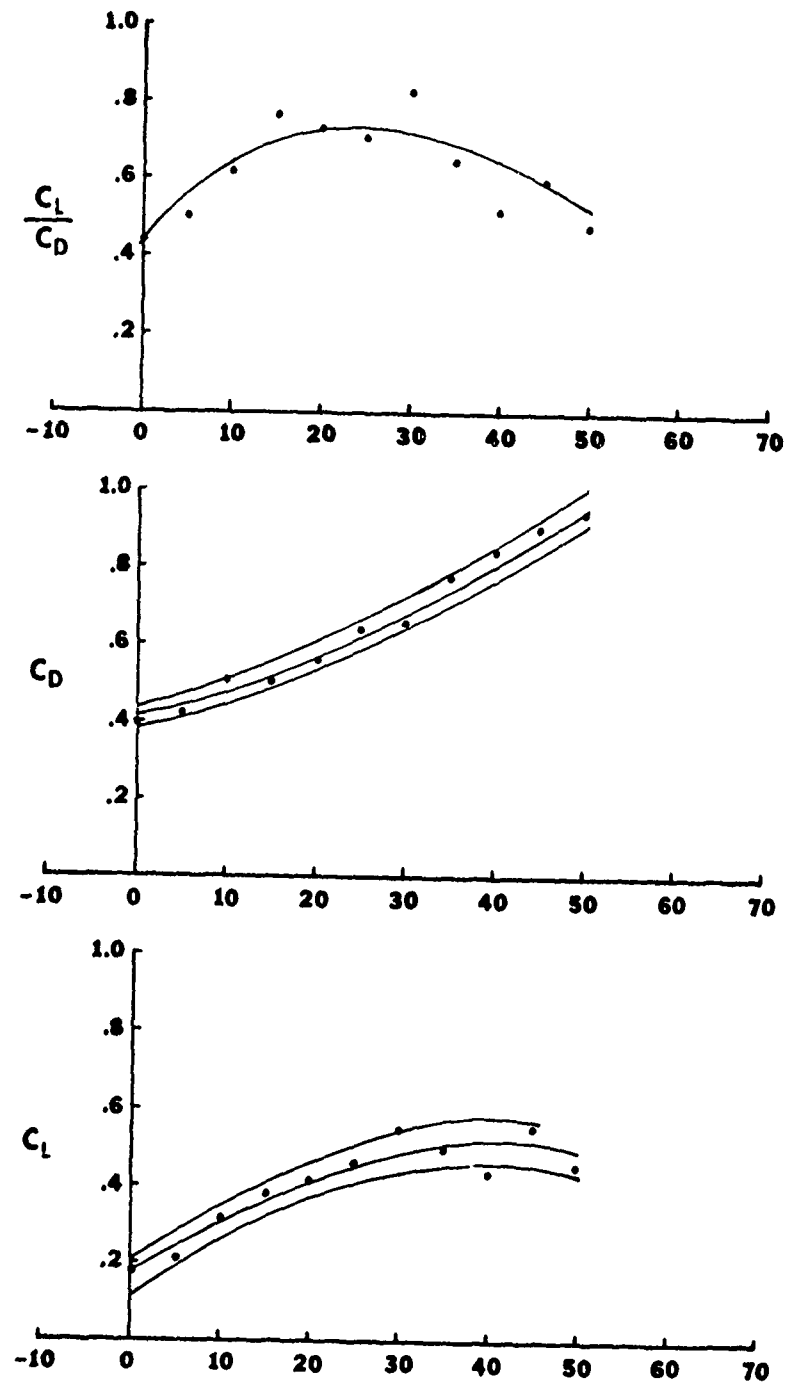
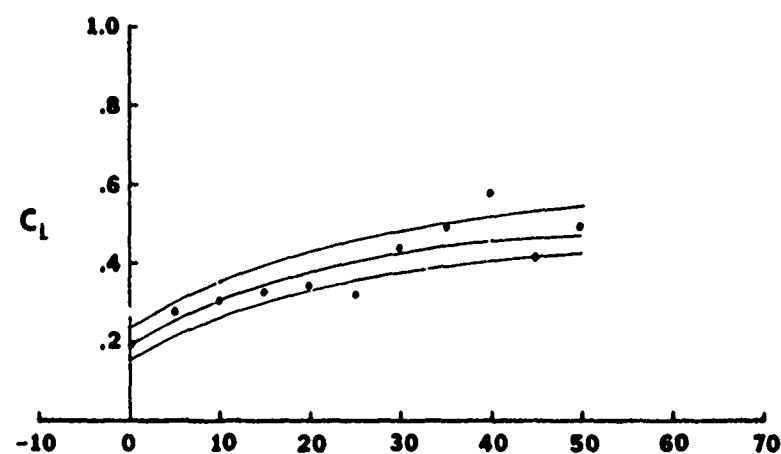
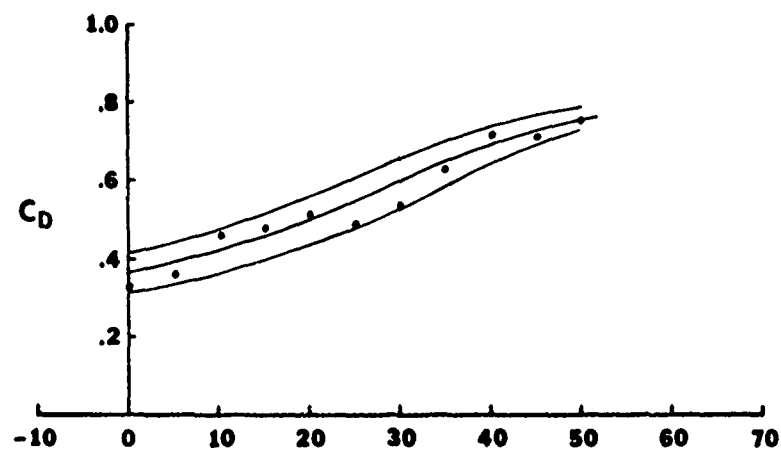
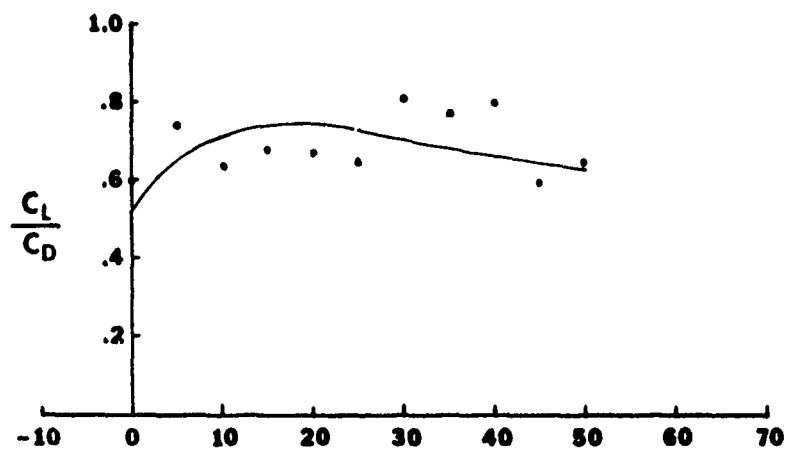


Figure 19 (e)



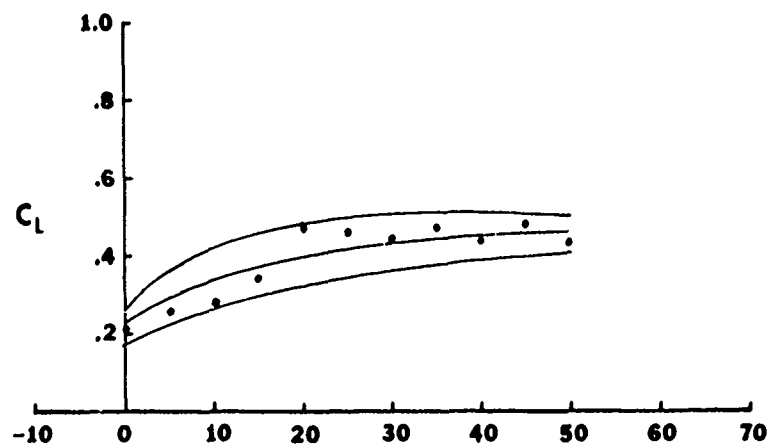
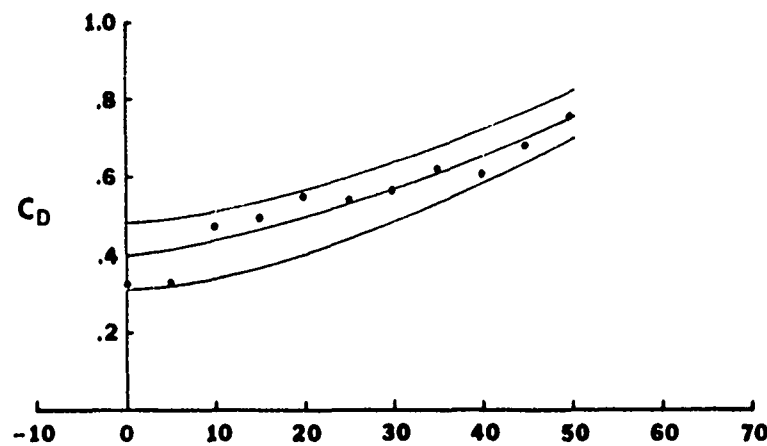
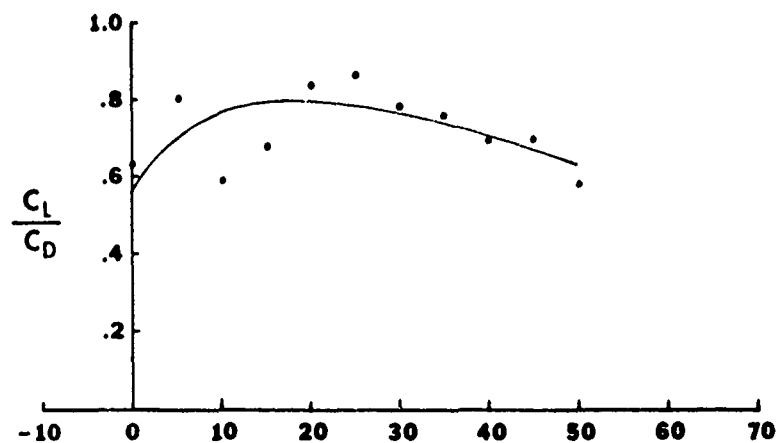
∞ DEGREES
PARACHUTE PACK CONFIGURATION NO. 5
SUBJECT NO. 1

Figure 20 (a)



∞ DEGREES
SUBJECT NO. 2

Figure 20 (b)



∞ DEGREES
SUBJECT NO. 3

Figure 20 (c)

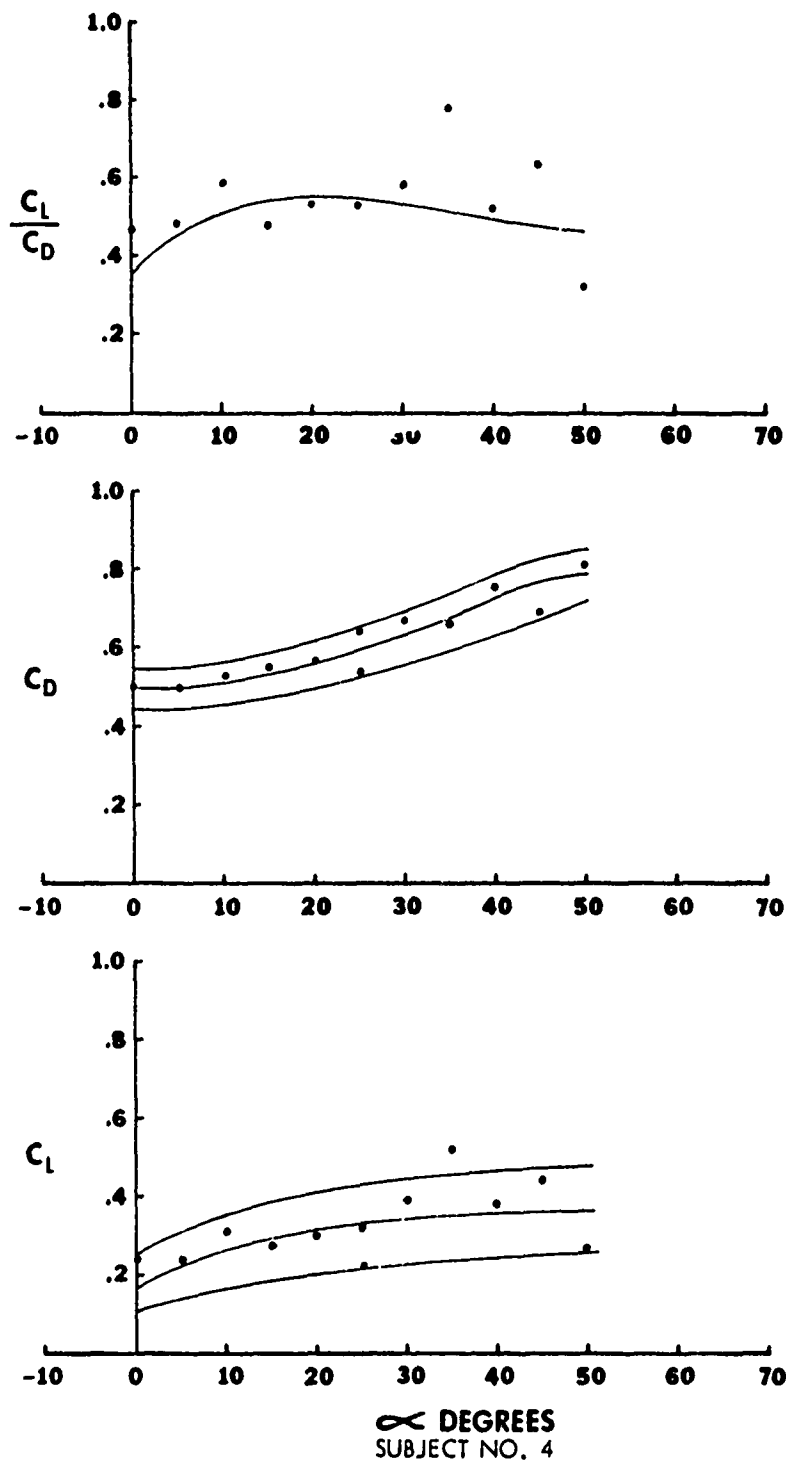


Figure 20 (d)

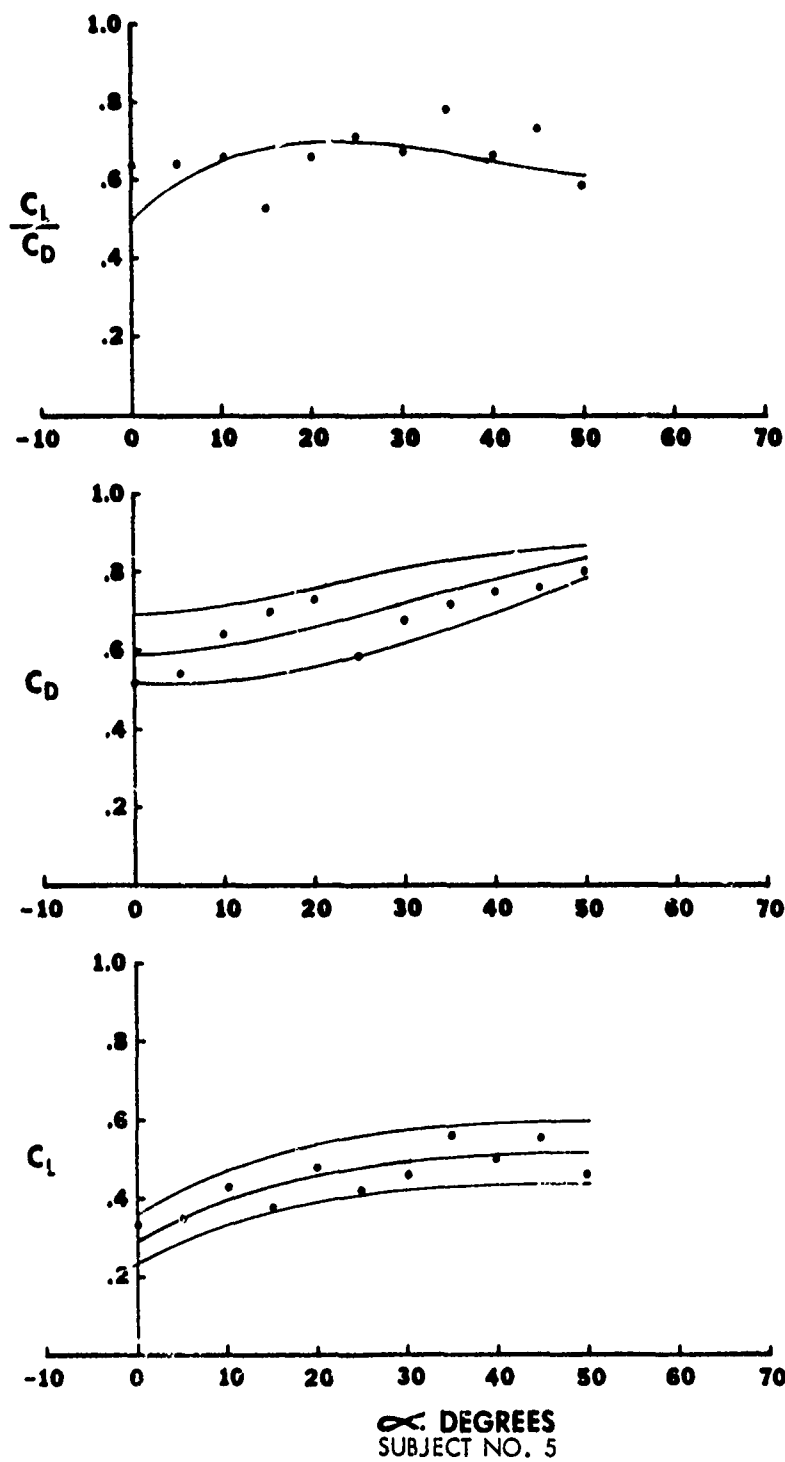


Figure 20 (e)

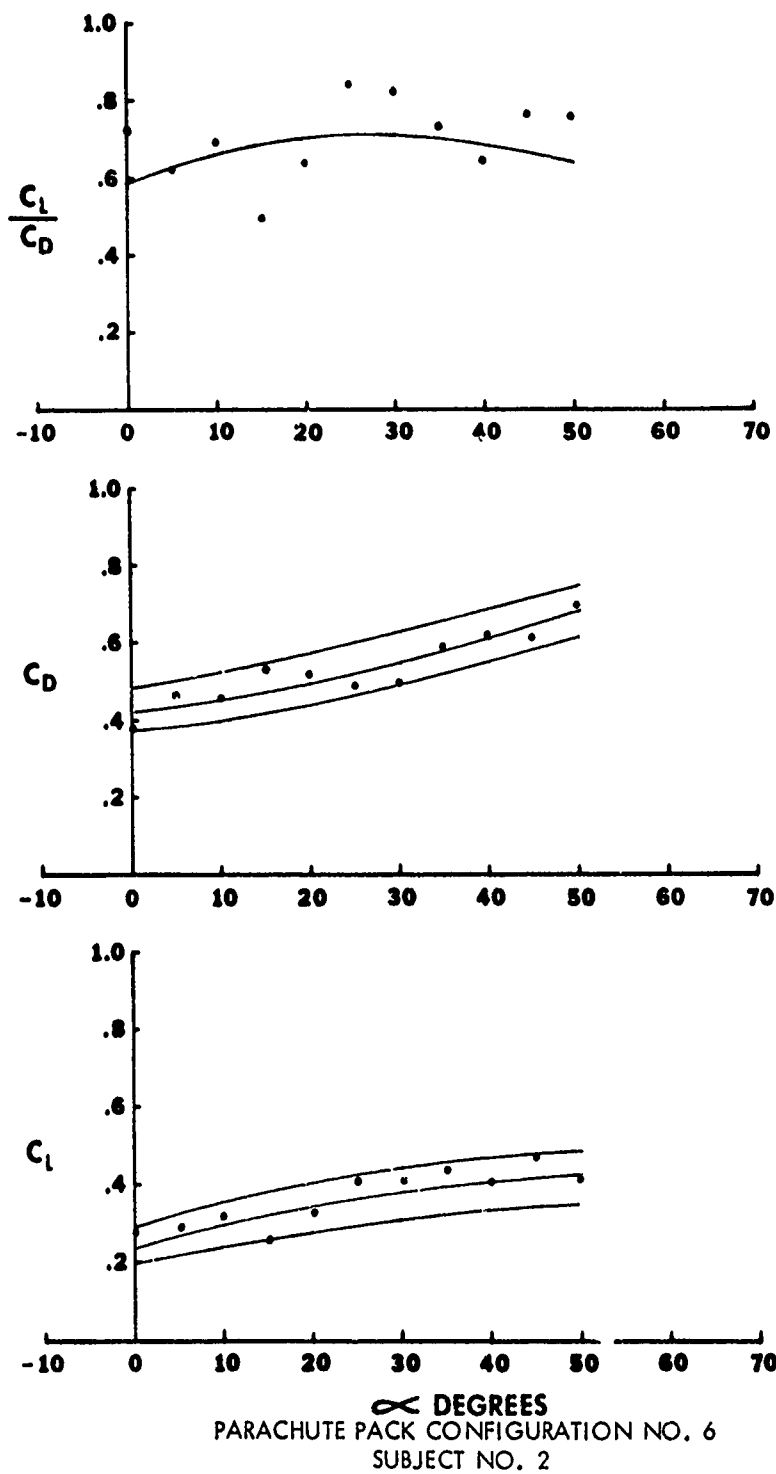


Figure 21

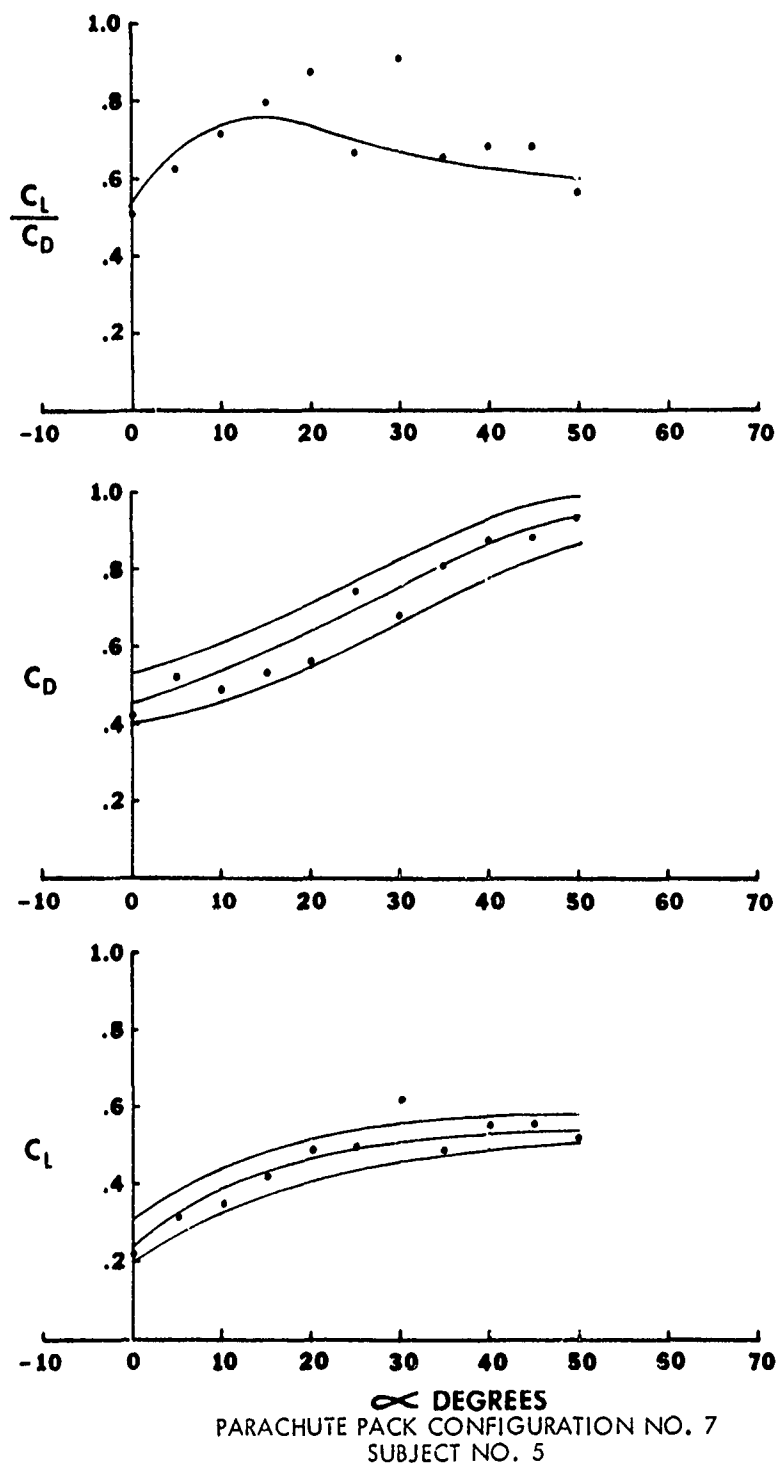
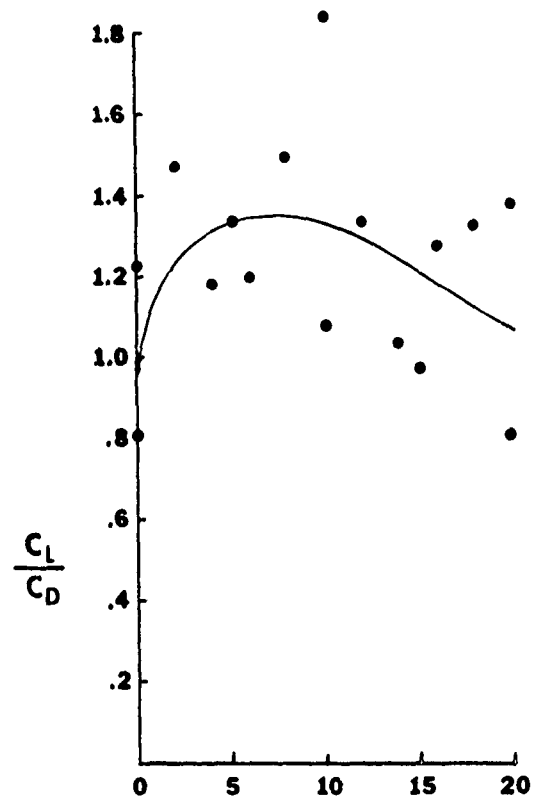
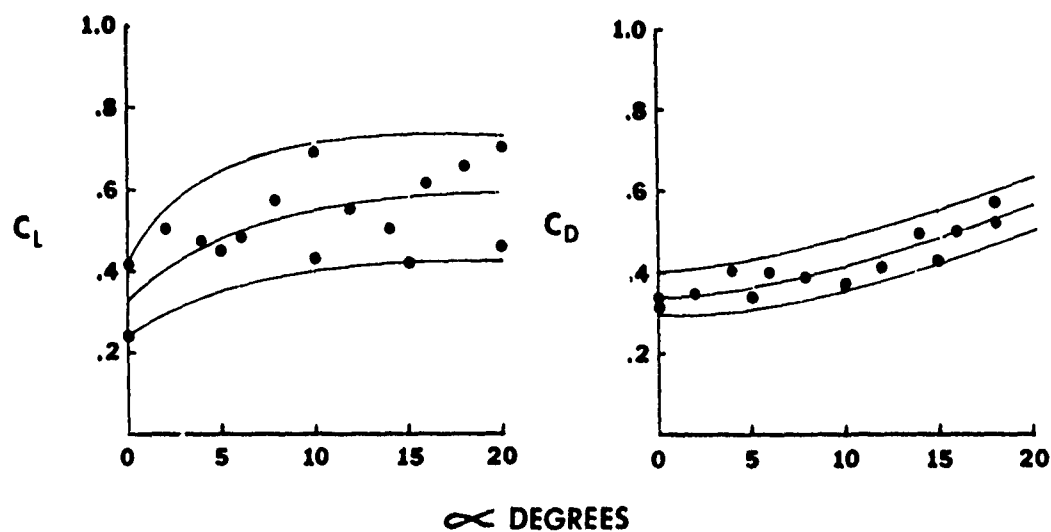
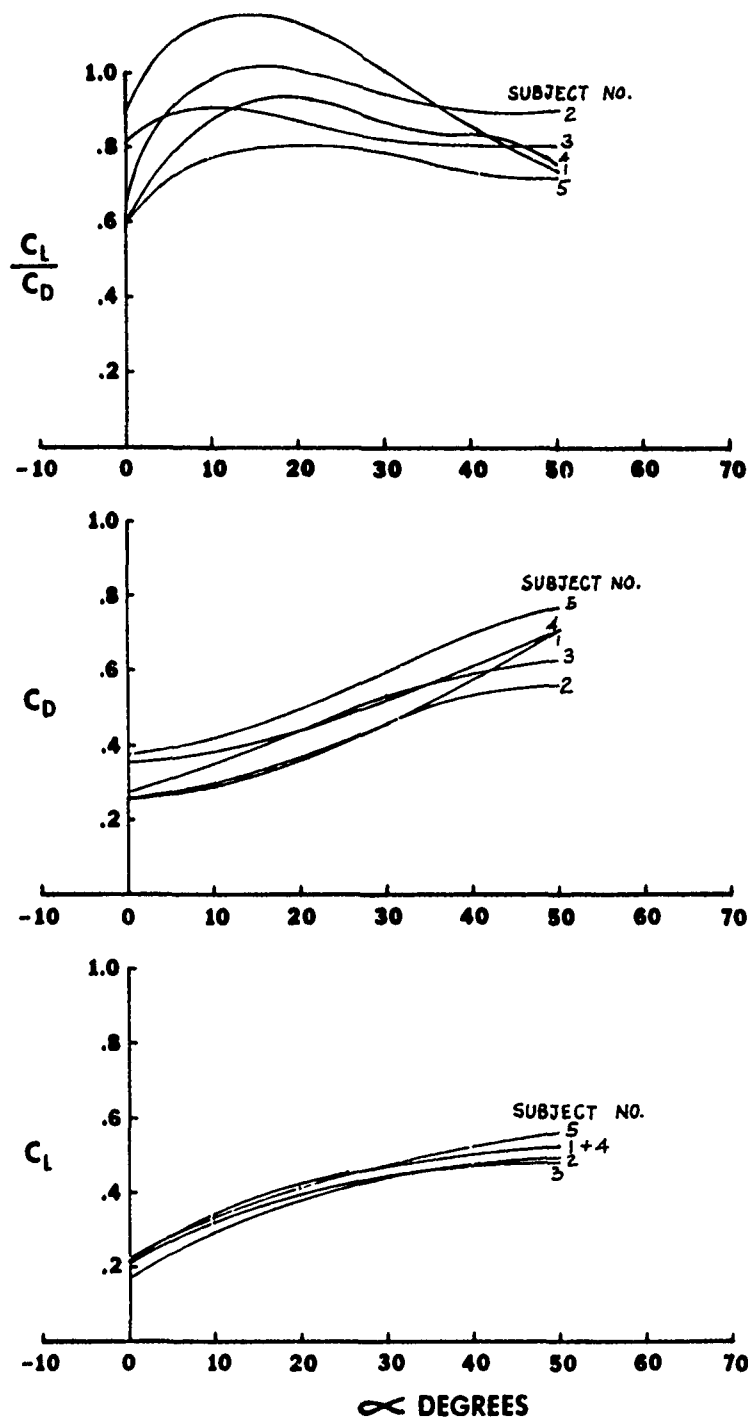


Figure 22



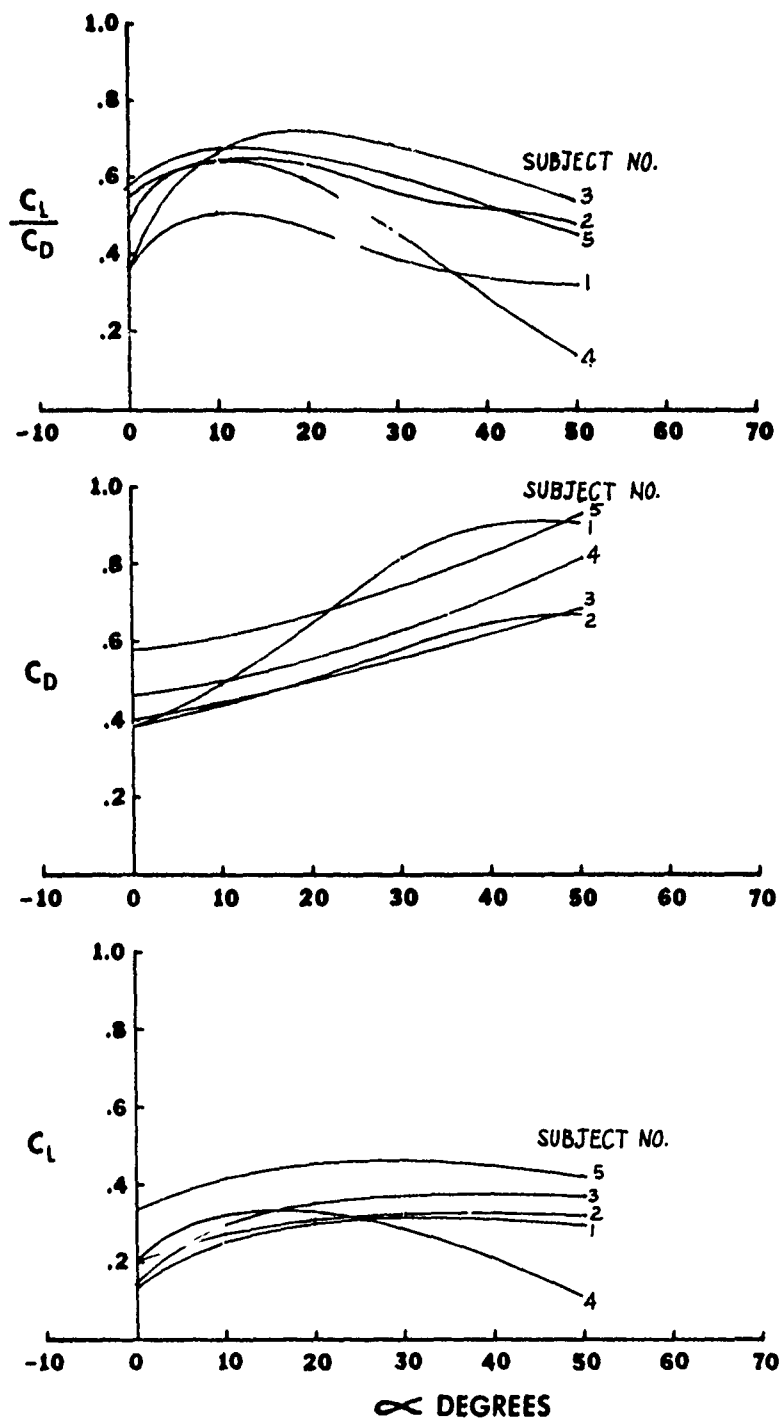
PARACHUTE PACK CONFIGURATION NO. 8
SUBJECT NO. 1

Figure 23



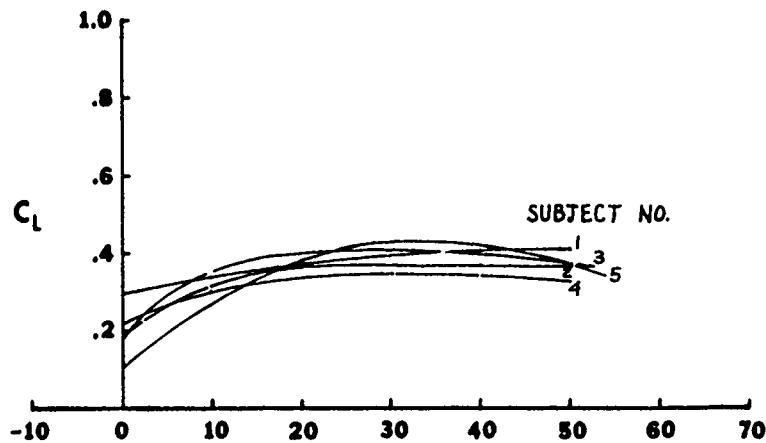
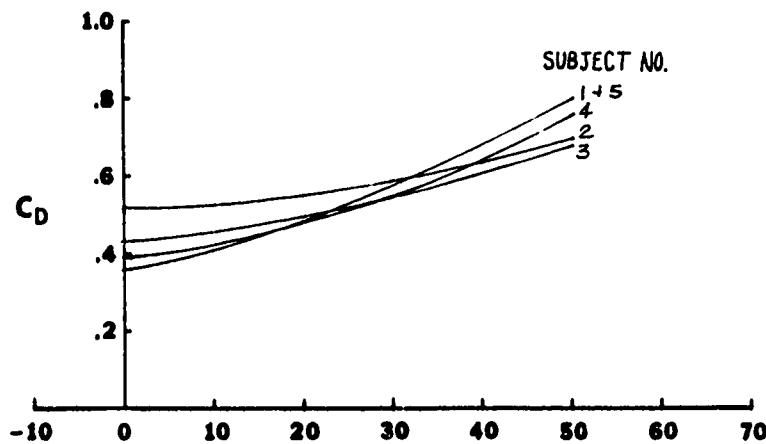
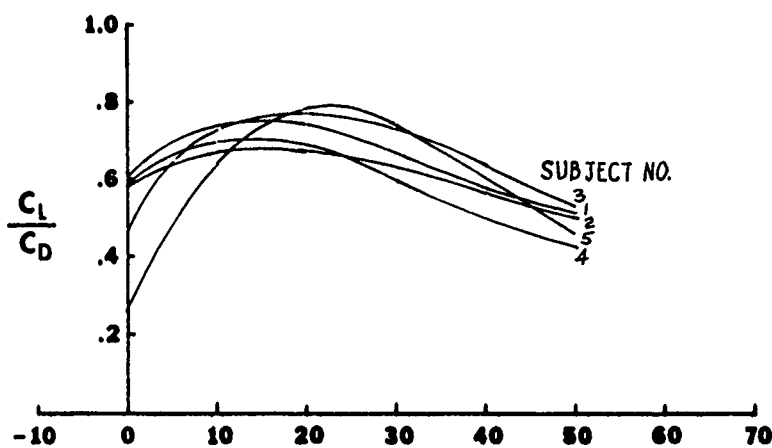
PARACHUTE PACK CONFIGURATION NO. 0

Figure 24 (a)



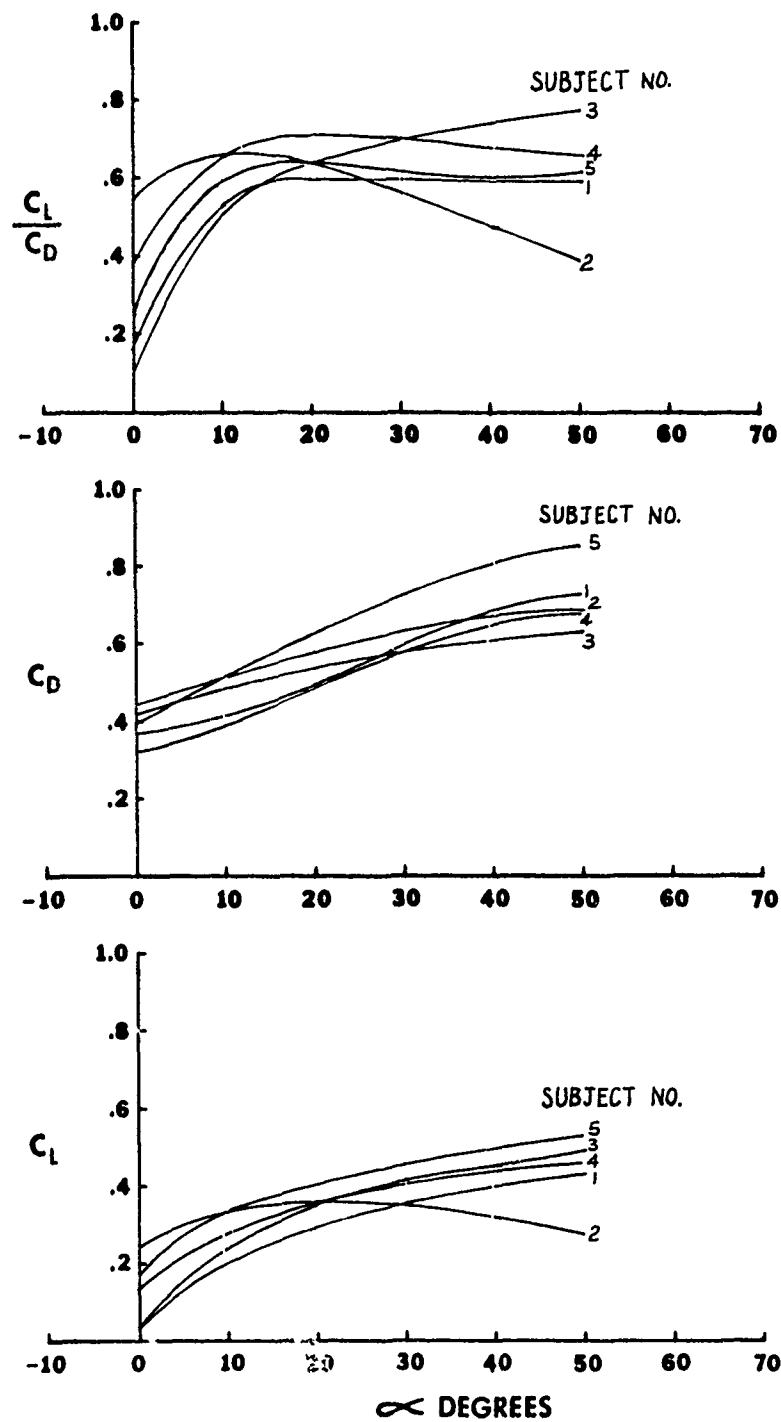
PARACHUTE PACK CONFIGURATION NO. 1

Figure 24 (b)



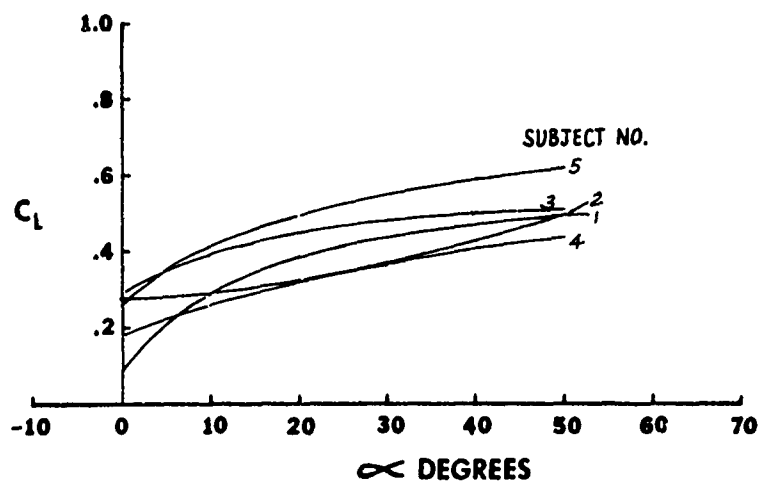
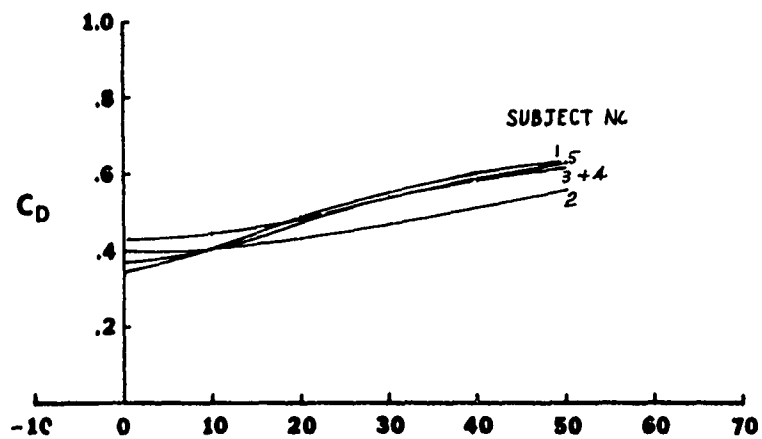
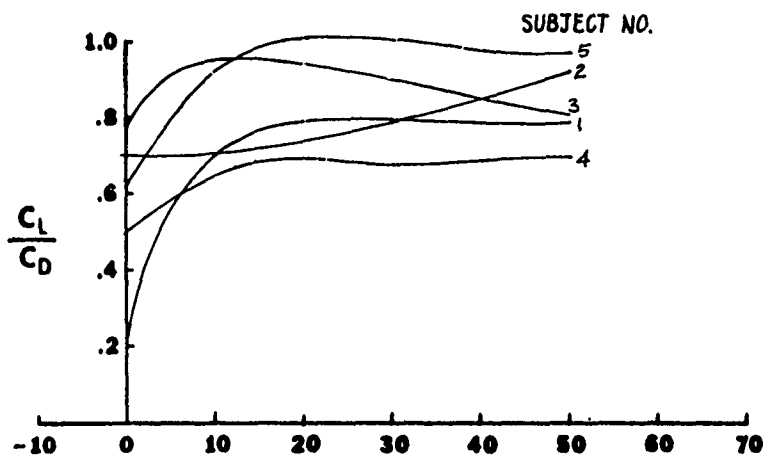
PARACHUTE PACK CONFIGURATION NO. 2

Figure 24 (c)



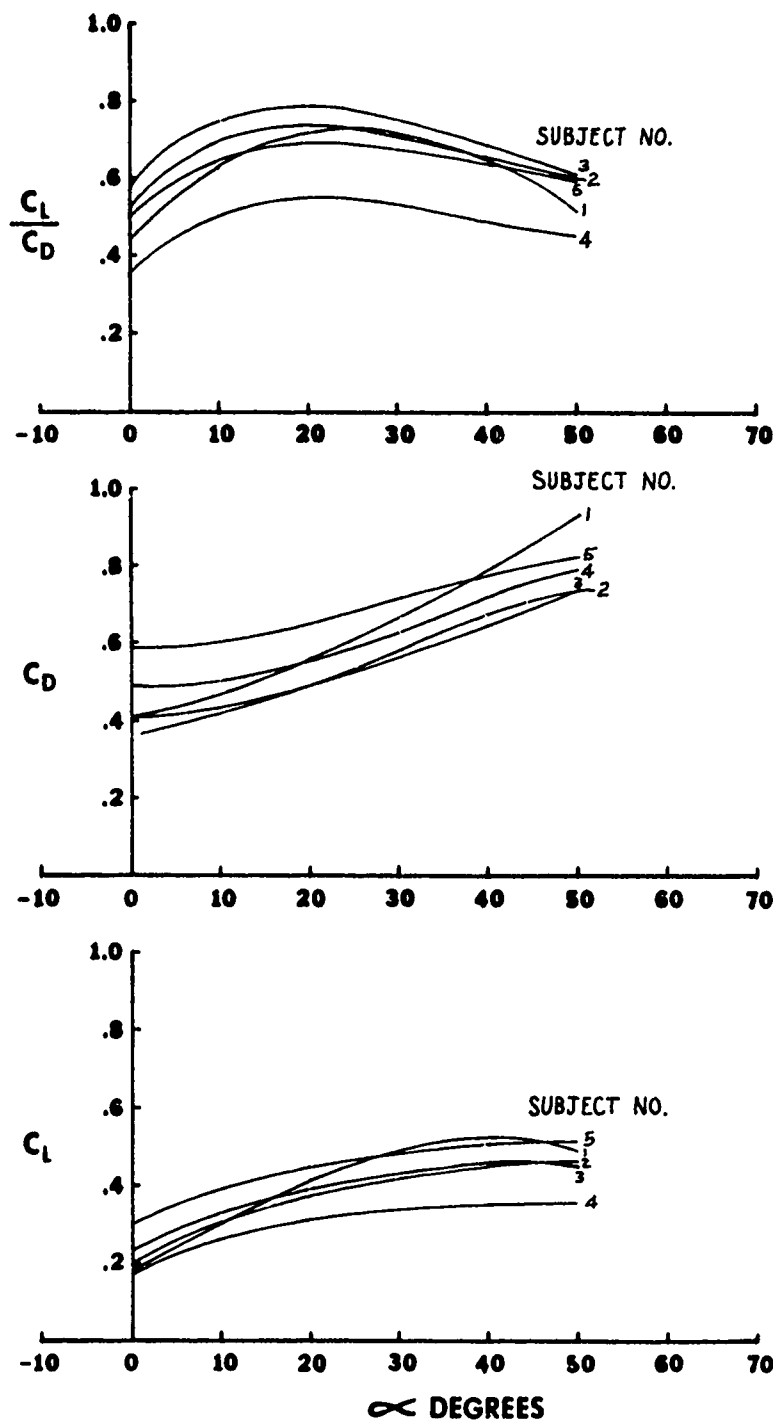
PARACHUTE PACK CONFIGURATION NO. 3

Figure 24 (d)



PARACHUTE PACK CONFIGURATION NO. 4

Figure 24 (e)



PARACHUTE PACK CONFIGURATION NO. 5

Figure 24 (f)

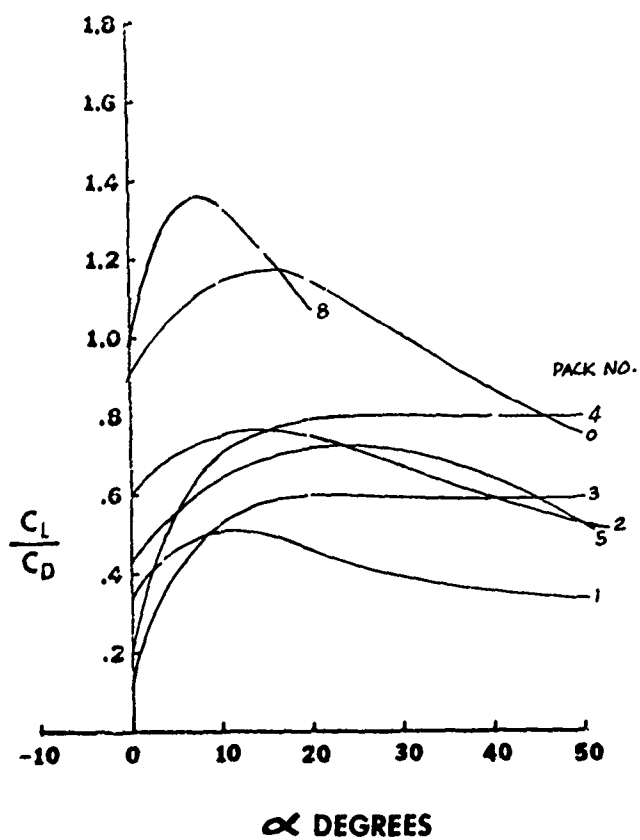
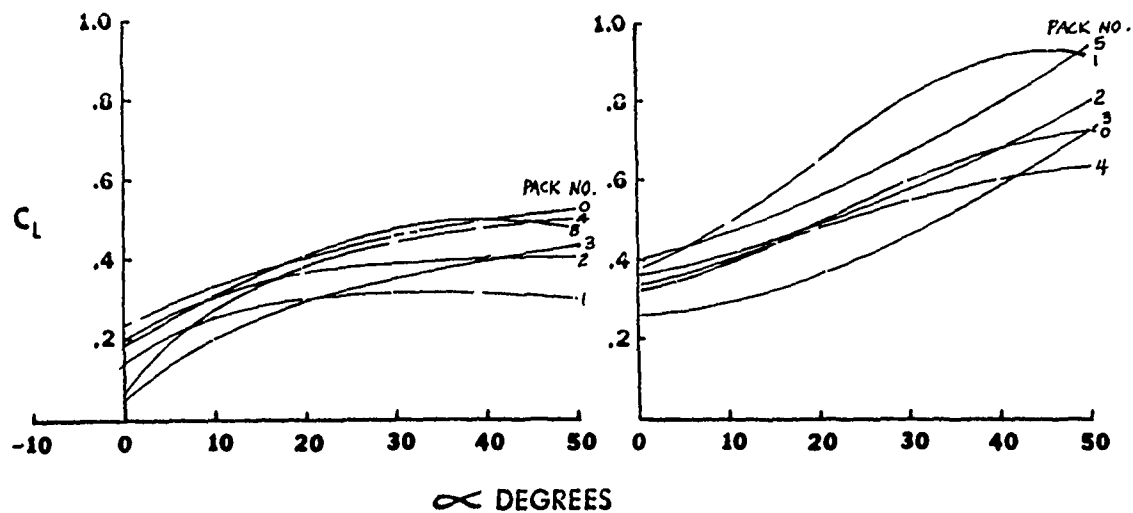


Figure 25 (a), SUBJECT NO. 1

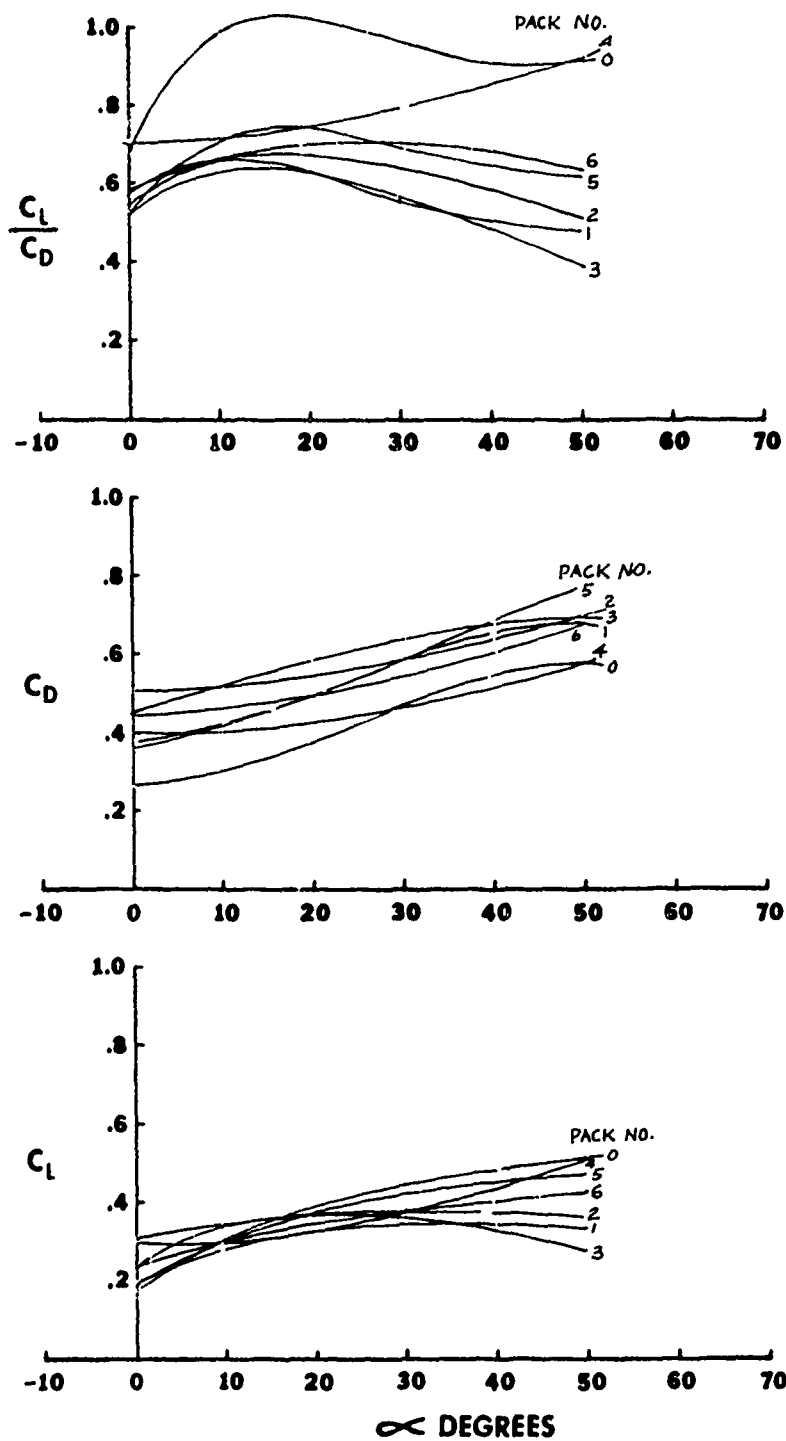


Figure 25 (b), SUBJECT NO. 2

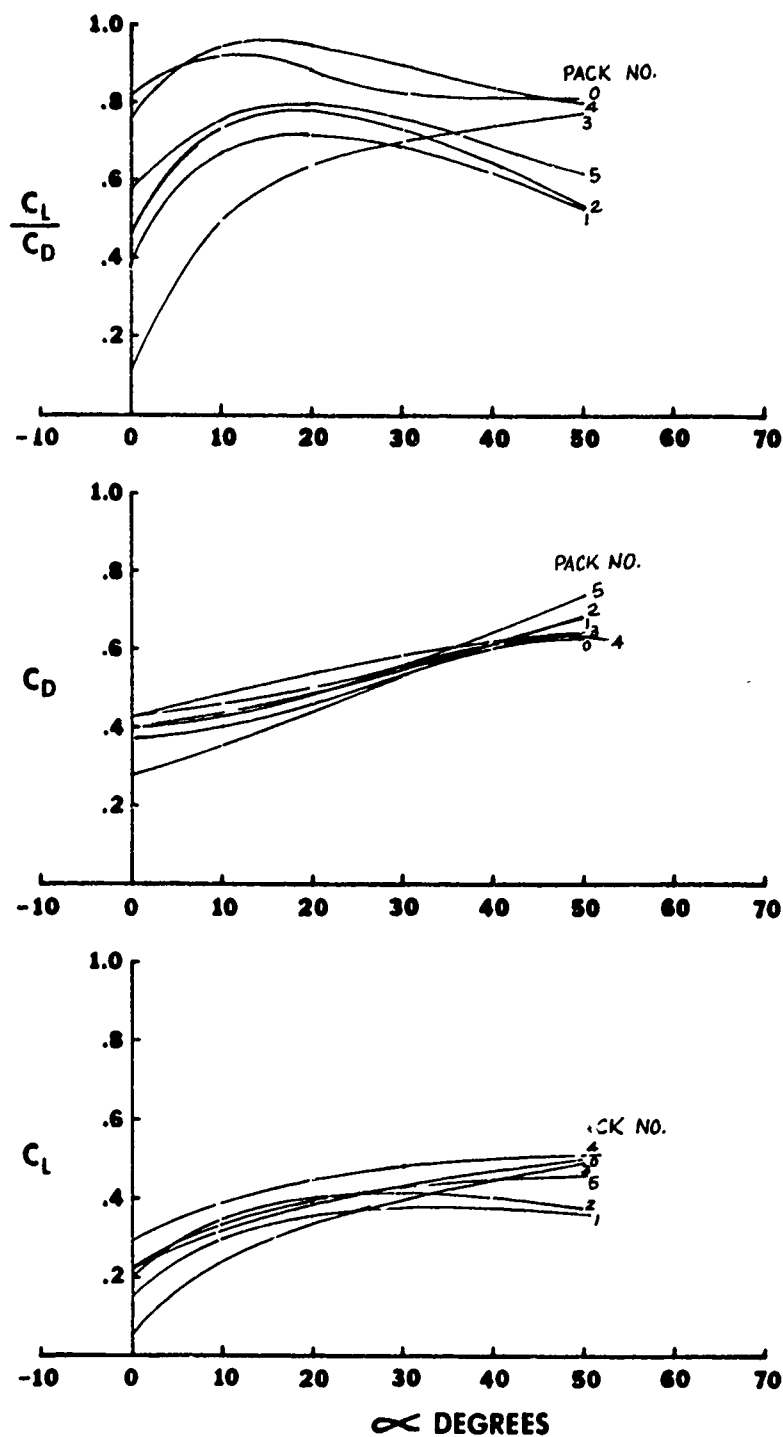


Figure 25 (c), SUBJECT NO. 3

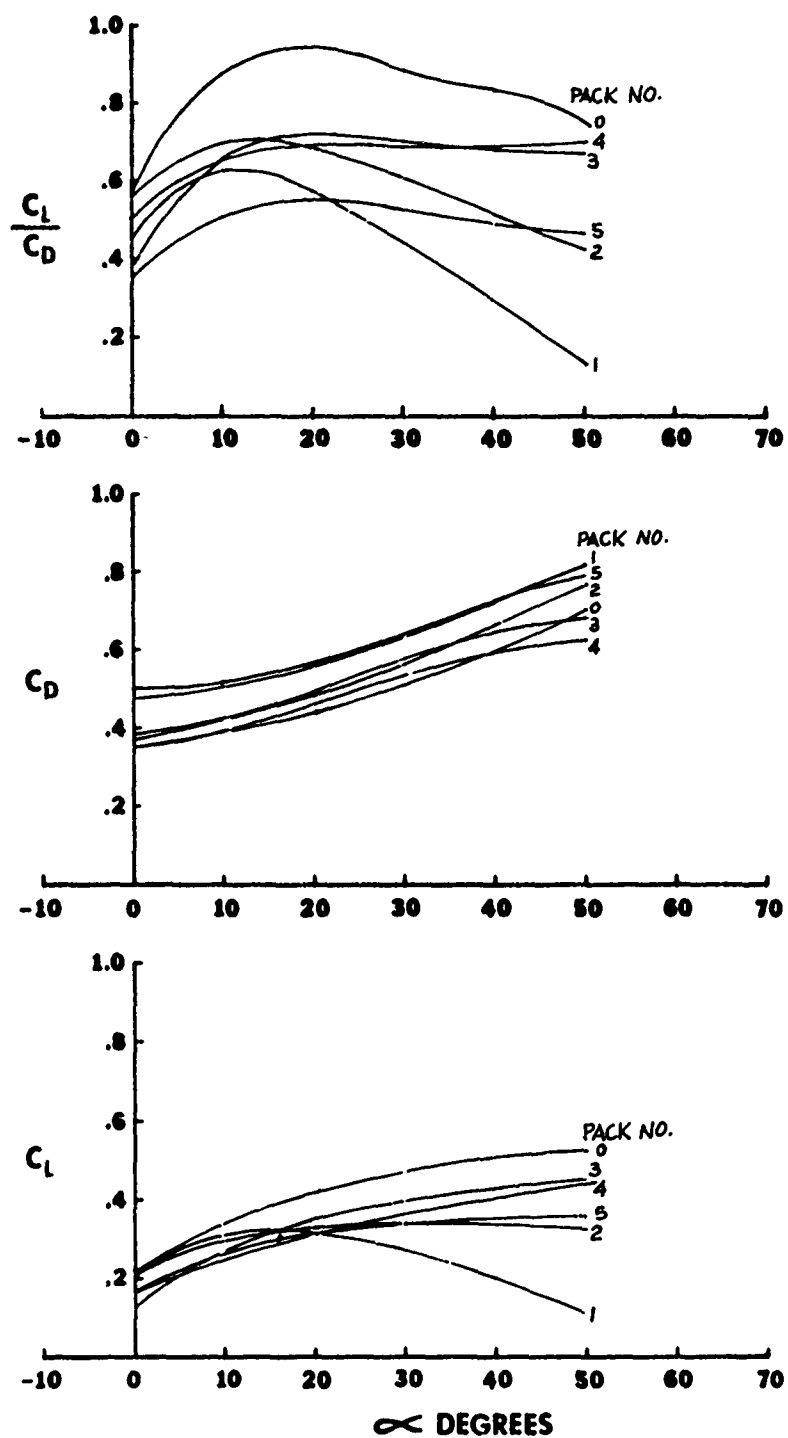


Figure 25 (d) , SUBJECT NO. 4

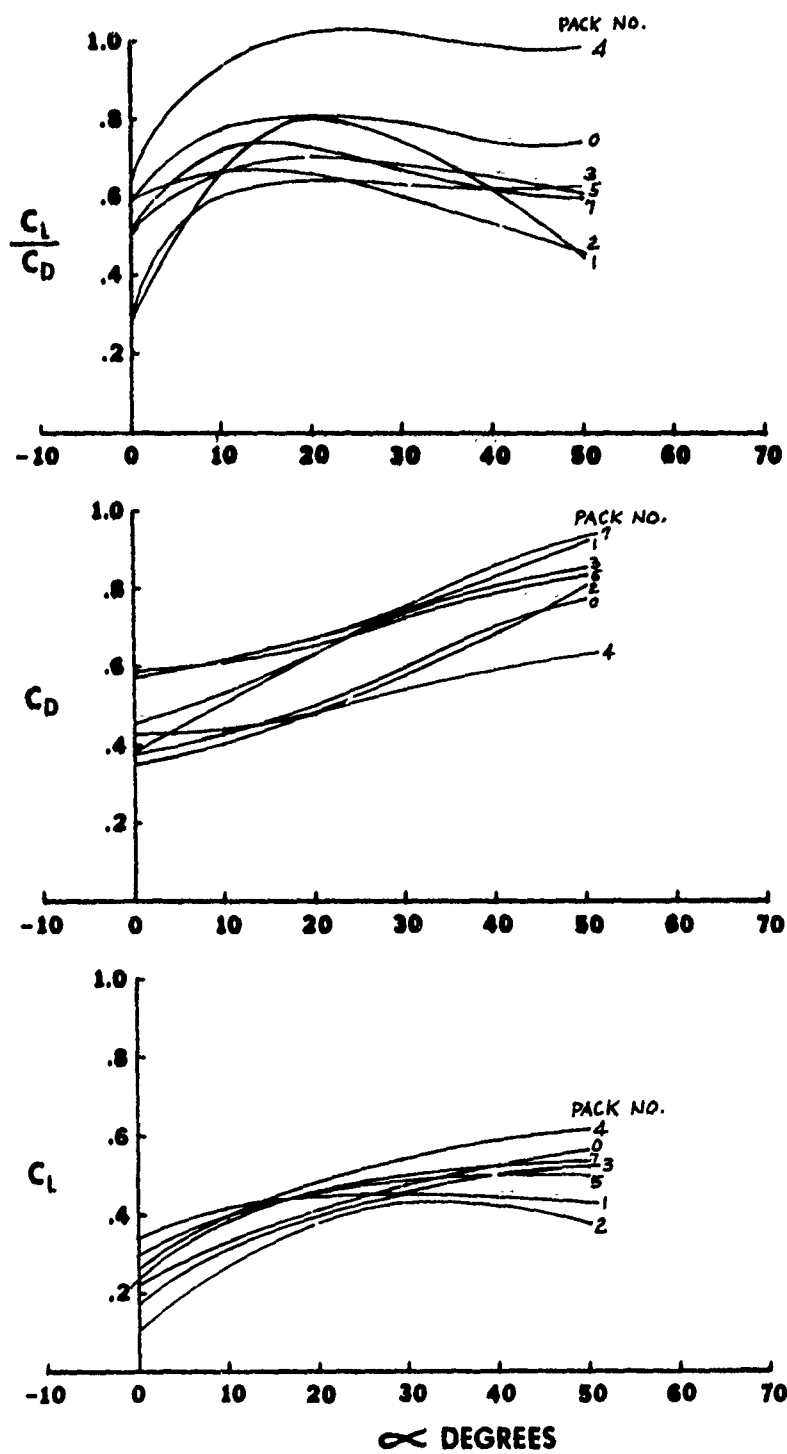


Figure 25 (e) , SUBJECT NO . 5

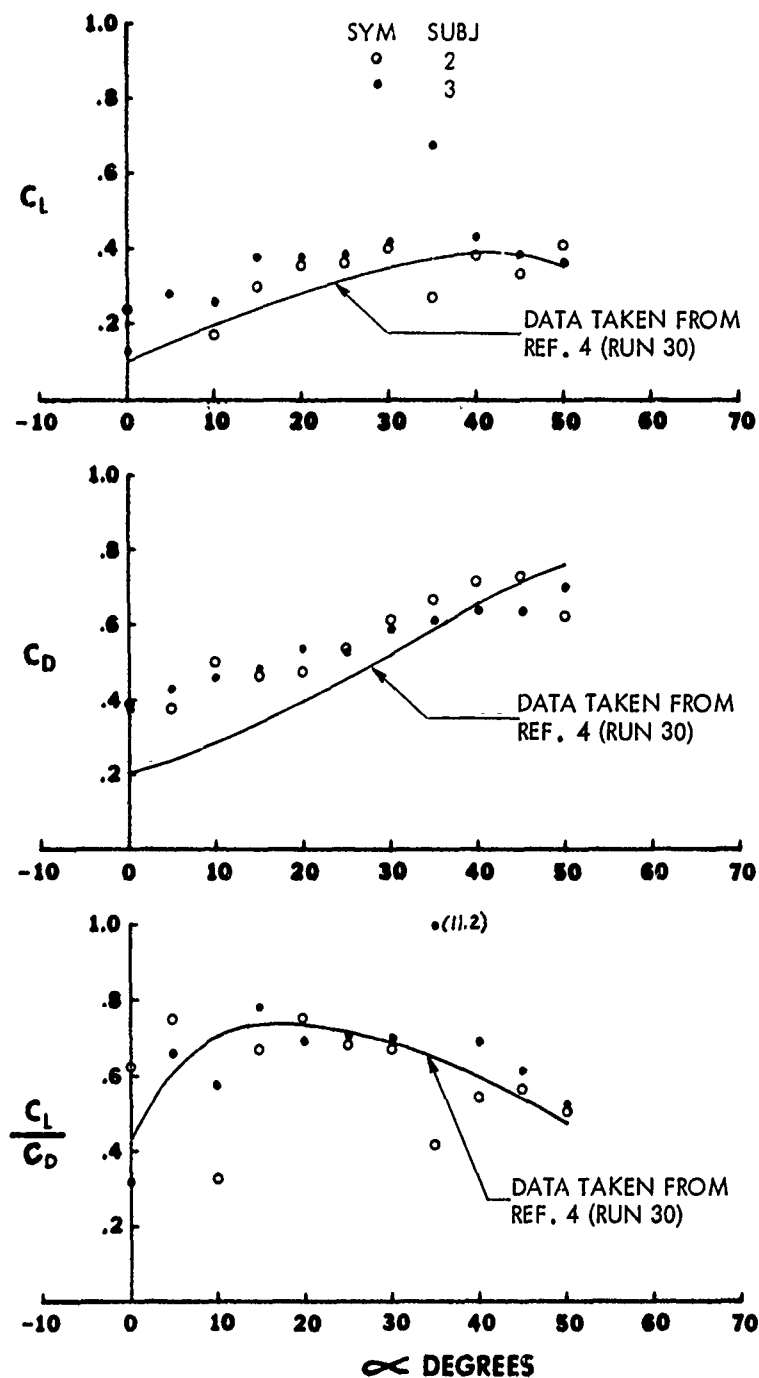


Figure 26 (a)
 COMPARISON OF DATA OBTAINED FROM
 LIVE SUBJECTS AND AN ANTHROPOMORPHIC DUMMY
 (a) BODY CONFIGURATION "A"

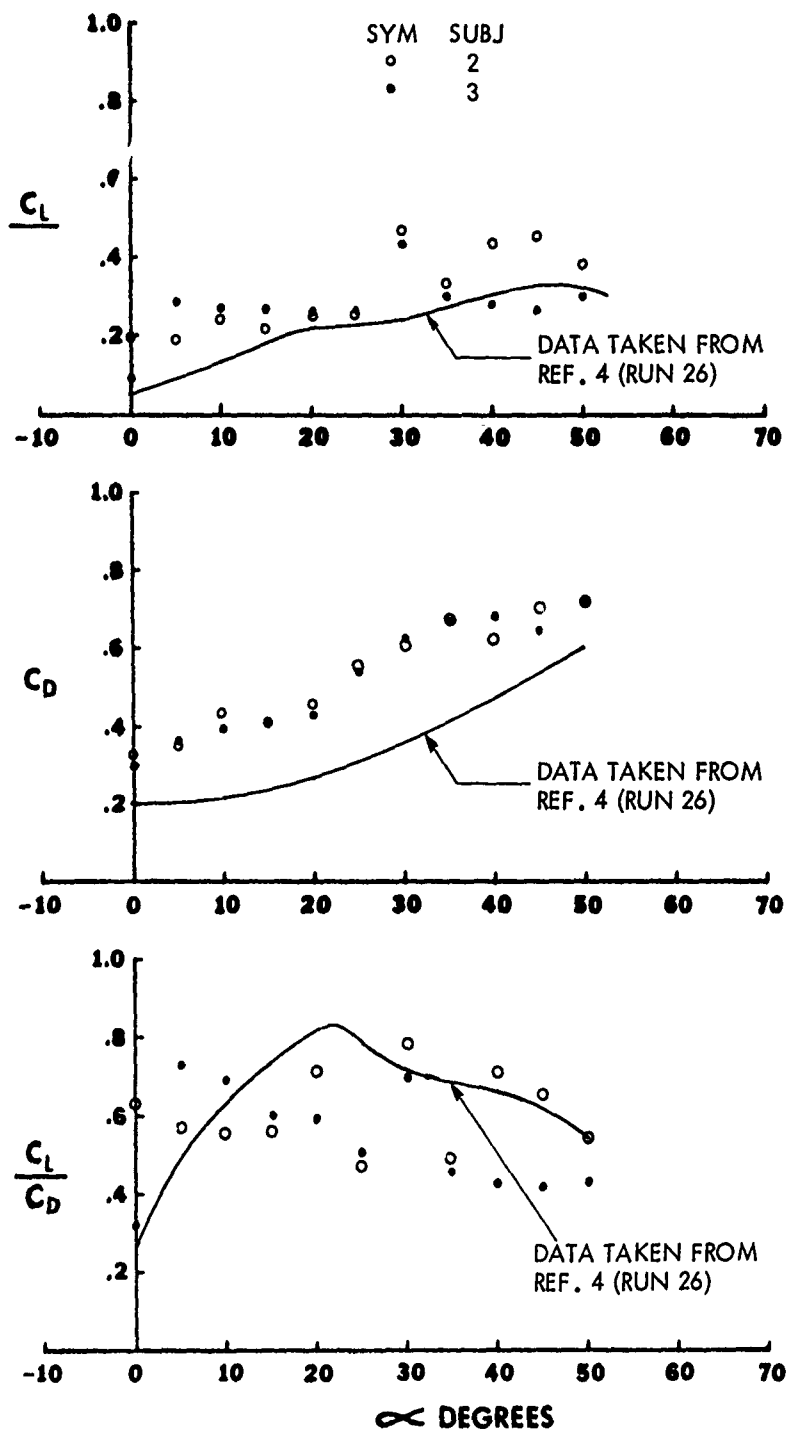


Figure 26 (b)

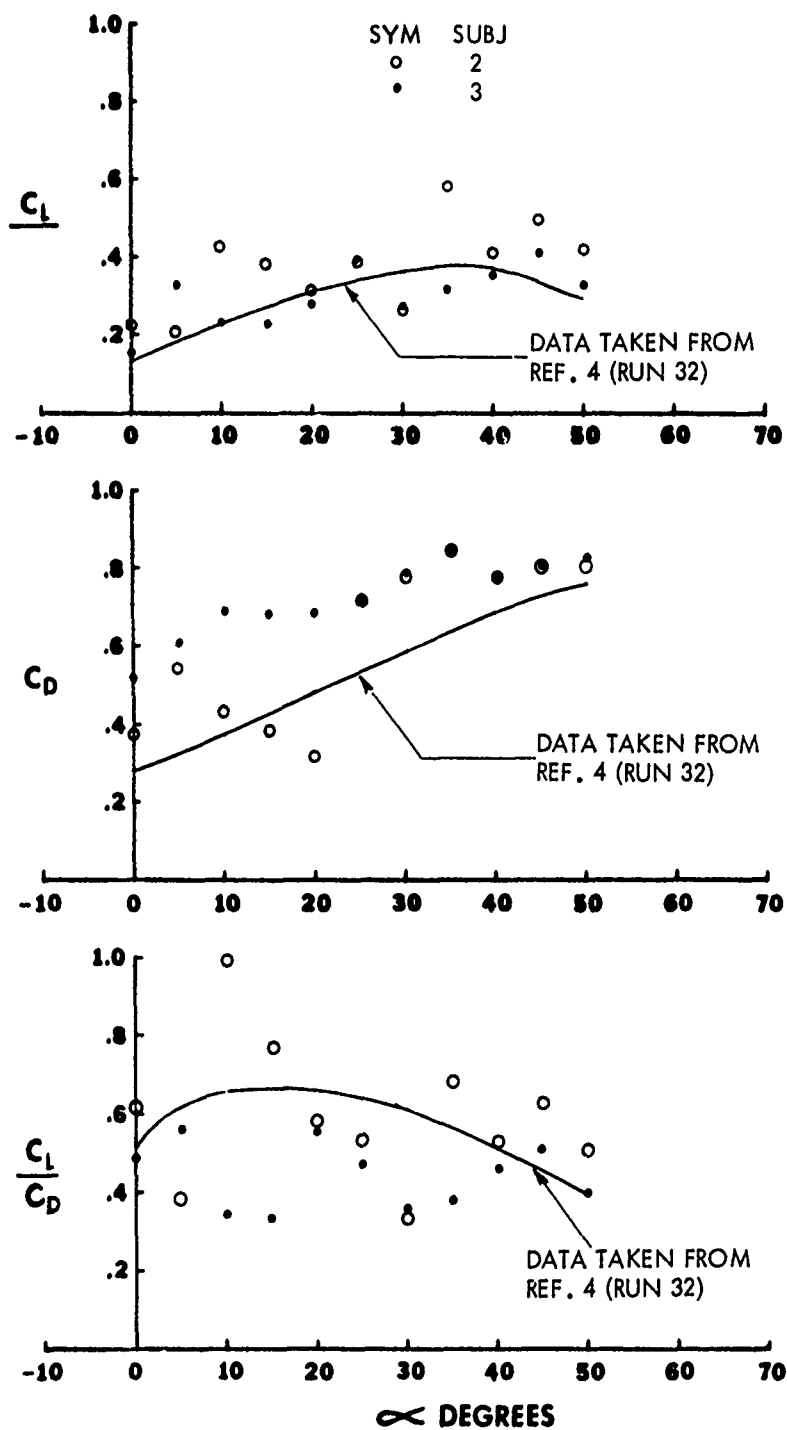


Figure 26 (c)

BIBLIOGRAPHY

1. Grabow, Richard M., "An Experimental Investigation of the Drag and Lift Forces of the Human Body at Terminal Velocities", A secondary Thesis for graduation, von Karmann Institute for Fluid Dynamics, dated 25 October 1966.
2. Hoerner, Sighard F., "Aerodynamic Drag", First Edition, Published by the Author, 1951.
3. NASA Life Science Data Book, First Edition, June 1962.
4. Oehlert, G. H. and D. T. Higdon, "Aerodynamic Trajectory Control for a Parachutist in Free Fall", AR 67-1, Aeronautical Engineering Department, Wichita State University, January 1967.
5. Straumann, von R., "Praktische Ergebnisse Aerodynamischer Messungen am Skiläufer (Practical Results of Aerodynamic Measurements in Skiers)," Helvetica Physica Acta, 14: 311-313, 1941, (in German).
6. Tani, Ichiro and Miishi, Satoru, "Aerodynamics in Ski Jumping Science", 21: 117-122, March 1951, (in Japanese).
7. Winer, B. J., Statistical Principles in Experimental Design , New York: McGraw-Hill, 1962.

DISTRIBUTION LIST OF USAARL REPORTS

Project No. 3AO 2560 1A 819 Army Aviation Medicine

No. of
Copies

DEPARTMENT OF DEFENSE

- 20 Defense Documentation Center for Scientific and Technical Information,
Cameron Station, Alexandria, Virginia 22314

U. S. ARMY

- 1 US Army Combat Developments Command, Medical Service Agency,
Fort Sam Houston, Texas 78234
- 1 PP&A Div., G-3, Hqs, USACDCEC, ATTN: Plans Officer (Psychologist)
Fort Ord, California 93941
- 1 Walter Reed Army Institute of Research, Walter Reed Army Medical Center,
Washington, D. C. 20012
- 1 U. S. Army Infantry School, ATTN: Surgeon's Office, Fort Benning,
Georgia 31905
- 1 Medical Equipment Development Laboratory, Fort Totten, Flushing, L.I.,
New York 11359
- 1 US Army Biomechanical Research Laboratory Library, Walter Reed Army
Medical Center, Forest Glen Section, Washington, D. C. 20012
- 1 US Army Medical Research Unit, Kuala Lumpur, Malaysia
- 1 US Army Medical Research Institute of Infectious Diseases, Frederick, Md. 21701
- 1 US Army Natick Laboratories, Clothing and Organic Material Division,
ATTN: AMXRE-CCE, Natick, Massachusetts 01760
- 1 US Army Medical Research Laboratory, Fort Knox, Kentucky 40121
- 1 US Army Institute of Surgical Research, Brooke Army Medical Center,
Fort Sam Houston, Texas 78234
- 1 US Army Medical Research & Nutrition Laboratory, Fitzsimons General
Hospital, Denver, Colorado 80240
- 1 US Army Medical Research Unit, Europe, APO New York, N. Y. 09180
- 1 William Beaumont General Hospital, ATTN: Librarian, El Paso, Texas
79920
- 1 US Army Medical Research Unit, APO New York, N. Y. 09180
- 1 Letterman Army Institute of Research, San Francisco, Calif. 94129

No. of
Copies

- 1 Valley Forge General Hospital, ATTN: Librarian, Phoenixville,
Pennsylvania 19460
- 1 U. S. Continental Army Command, ATTN: Surgeon, Fort Monroe,
Virginia 23351
- 1 First United States Army, ATTN: Surgeon, Fort George G. Meade,
Maryland 20755
- 1 First United States Army Medical Laboratory, 90 Church Street, New
York, New York 10007
- 1 Second United States Army, ATTN: Surgeon, Fort George G. Meade,
Maryland 20755
- 1 Human Engineering Laboratory, ATTN: Aviation Branch, Aberdeen
Proving Ground, Maryland 21005
- 1 Second United States Army Medical Laboratory, Fort George G. Meade,
Maryland 20755
- 1 Third United States Army, ATTN: Surgeon, Fort McPherson, Georgia
30330
- 1 Third United States Army Medical Laboratory, Fort McPherson, Georgia
30330
- 1 Fourth United States Army, ATTN: Surgeon, Fort Sam Houston, Texas
78234
- 1 Fourth United States Army Medical Laboratory, Brooke Army Medical
Center, Fort Sam Houston, Texas 78234
- 1 Commanding General, Fifth United States Army, ATTN: Surgeon,
Fort Sheridan, Illinois 60037
- 1 Fifth United States Army Medical Laboratory, St. Louis Area Support
Center, U. S. Army, 12th and Spruce Streets, St. Louis, Missouri 63102
- 1 Sixth United States Army, ATTN: Surgeon, Presidio of San Francisco,
California 94129
- 1 Sixth United States Army Medical Laboratory, Fort Baker, Sausalito,
California 94965
- 1 Military District of Washington, U. S. Army, ATTN: Surgeon, Building
T-B, Gravelly Point, Washington, D. C. 20315
- 1 Commanding Officer, Medical General Laboratory (406), APO San
Francisco, California 96343
- 1 Director of Medical Research, U. S. Army Chemical R&D Laboratories,
Edgewood Arsenal, Maryland 21041
- 1 USAAVNS Element Technical Library, Hunter Army Airfield, Georgia
31409

No. of
Copies

- 1 Commanding Officer, U. S. Army Research Institute of Environmental
Medicine, Quartermaster Research & Engineering Center, Natick,
Massachusetts 01760
- 1 Director, U. S. Army Institute of Dental Research, Walter Reed Army
Medical Center, Washington, D. C. 20012
- 1 Letterman General Hospital, ATTN: Librarian, Presidio of San Francisco,
California 94129
- 1 Brooke General Hospital, Brooke Army Medical Center, Medical Library,
Box 151, Fort Sam Houston, Texas 78234
- 5 Life Sciences Division, Office of the Chief of Research and Development
413B, Washington, D. C. 20310
- 1 Fitzsimons General Hospital, ATTN: Librarian, Denver, Colorado 80240
- 1 Madigan General Hospital, ATTN: Librarian, Tacoma, Washington 98431
- 1 Walter Reed General Hospital, ATTN: Librarian, Walter Reed Army
Medical Center, Washington, D. C. 20012
- 1 The Historical Unit, U. S. Army Medical Service, Forest Glen Section,
Walter Reed Army Medical Center, Washington, D. C. 20012
- 4 Commanding General, US Army Medical R&D Command, ATTN: MEDDH-RP,
Washington, D. C. 20315
- 1 United States Army, Europe, ATTN: Surgeon, APO New York, N. Y.
09403
- 1 United States Army, Alaska, ATTN: Surgeon, APO Seattle, Washington
98749
- 1 United States Army, Pacific, ATTN: Surgeon, APO San Francisco,
California 96558
- 1 Commander, US Army Southern Command, ATTN: Chief Surgeon, APO
New York 09834
- 1 Commanding Officer, US Army Environmental Health Agency, Edgewood
Arsenal, Maryland 21041
- 1 Commanding General, United States Army, Hawaii, ATTN: Surgeon,
APO San Francisco, California 96557
- 1 Commanding General, Eighth United States Army, ATTN: Surgeon,
APO San Francisco, California 96301
- 1 Commanding General, 7th Logistical Command, ATTN: Surgeon,
APO San Francisco, California 96212
- 1 US Army Medical Research Unit, Box 2011, Balboa Heights, Canal
Zone 09827
- 1 Commanding General, I Corps Group, ATTN: Surgeon, APO San
Francisco, California 96358

No. of
Copies

- 1 Commanding General, United States Army, Japan, ATTN: Surgeon, APO San Francisco, California 96343
- 1 Commanding General, United States Army, Ryukyu Islands/IX Corps, ATTN: Surgeon, APO San Francisco, California 96249
- 1 Directorate, Plans, Supply and Operations, Aviation Branch, Office of The Surgeon General, DA, Washington, D. C. 20315
- 1 US Army Behavioral Science Research Laboratory, ATTN: CRDBSRL DOL Washington, D. C. 20315
- 1 Technical Director of Research, Armed Forces Institute of Pathology, Washington, D. C. 20012
- 5 Commanding General, United States Army Aviation Center, Fort Rucker, Alabama 36360
- 1 Director of Research, United States Army Aviation Human Research Unit, Fort Rucker, Alabama 36360
- 1 Commanding Officer, United States Army Board for Aviation Accident Research, Fort Rucker, Alabama 36360
- 2 Commanding Officer, United States Army Aviation Test Board, Fort Rucker, Alabama 36360
- 1 Commanding Officer, United States Army Combat Developments Command Aviation Agency, Fort Rucker, Alabama 36360
- 1 Commanding Officer, Lyster Army Hospital, Fort Rucker, Alabama 36360

U. S. NAVY

- 2 Bureau of Medicine and Surgery, Director, Research Division, Department of the Navy, Washington, D. C. 20360
- 4 Director, Naval Aerospace Medical Institute, Pensacola NAS, Pensacola, Florida 32512
- 1 Naval Medical Research Institute, National Naval Medical Center, Technical Reference Library, Bethesda, Maryland 20014
- 1 US Naval Air Development Center, Aviation Medical Acceleration Laboratory, ATTN: Librarian, Johnsville, Pennsylvania 18974
- 1 Head, Aero-Medical Department, Naval Aviation Safety Center, Naval Air Station, Building SP-50, Norfolk, Virginia 23511
- 1 Commander, US Naval Weapons Laboratory, Dahlgren, Virginia 22448
- 1 Navy Department, Aerospace Medical Flight Safety Branch, BuMED-523, Washington, D. C. 20390

No. of
Copies

U. S. AIR FORCE
HQ AIR FORCE SYSTEMS COMMAND

- 1 Hq AFSC(SCBB), Directorate of Bioastronautics, Andrews Air Force Base, Washington, D. C. 20331
- 2 6570th Aerospace Med Rsch Labs (MRBAA), Wright-Patterson Air Force Base, Ohio 45433
- 1 6570th Aerospace Med Rsch Labs (MRA), Wright-Patterson Air Force Base, Ohio 45433
- 1 Tech Tng Cen (MSSTL/AFL 3021), Drop 114, Sheppard Air Force Base, Texas 76311
- 1 Hq USAF (AFRDDG), Directorate of Science & Technology, Washington, D. C. 20330
- 1 USAF School of Aerospace Medicine, ATTN: Aeromedical Library (SMSL), Brooks Air Force Base, Texas 78235
- 1 Life Support System Program Office, ASD (ASWL), Wright Patterson AFB, Ohio 45433

GOVERNMENTAL AGENCIES

- 2 Biomedical Program Office, NASA Flight Research Center, Edwards AFB, California 93523
- 1 Civil Aeromedical Research Institute, Federal Aviation Agency, P. O. Box 1082, Oklahoma City, Oklahoma 73101
- 1 Library of Congress, Science and Technology Division, ATTN: Dr. A. J. Jacobius, Washington, D. C. 20525
- 1 National Institute of Health, Library, ATTN: Acquisitions Section, Building 10, Room 5N118, Bethesda, Maryland 20014
- 1 National Library of Medicine, ATTN: Acquisition Section, 8600 Wisconsin Avenue, Bethesda, Maryland 20014
- 1 National Research Council, Division of Medical Sciences, Medical Records, 2101 Constitution Avenue, N. W., Washington, D. C. 20525
- 1 Federal Aviation Agency, Aviation Medical Library, MS-111, Washington, D. C. 20525

OTHER AGENCIES

- 1 Guggenheim Center for Aerospace Health and Safety, Harvard School of Public Health, 665 Huntington Avenue, Boston, Massachusetts 02115

No. of
Copies

MEDICAL COLLEGE/SCHOOL LIBRARIES AND DEPARTMENTS

- 2 George Washington University, Human Resources Research Office,
300 N. Washington Street, Alexandria, Virginia 22314
- 1 University of Alabama, Medical Center Library, 620 S. 20th Street,
Birmingham, Alabama 35233

FOREIGN

- 1 Army Headquarters, Australian Capital Territory, ATTN: Col. E. F.
Campbell, Director of Psychology, Canberra, Australia
- 1 British Navy Staff Office, Army Medical Liaison Officer, ATTN: F. P.
Ellis, Surgeon Captain, Royal Navy, Benjamin Franklin Station, P. O.
Box 165, Washington, D. C. 20044
- 1 British Army Medical Liaison Officer, British Army Staff, British Embassy,
Washington, D. C. 20008
- 10 Canadian Liaison Officer, Office of The Surgeon General, U. S. Army
ATTN: B. L. P. Brosseau, Room 1709A, Main Navy Building, Washington,
D. C. 20315
- 1 Defence Research Establishment Toronto, P. O. Box 2000, Downsview,
Ontario
- 3 Medical Liaison Officer, Royal Air Force Staff, British Embassy, Washing-
ton, D. C. 20008
- 1 Department of Aviation Medicine, Army Aviation Centre, Middle Wallop,
Stockbridge, Hants England

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)		2a. REPORT SECURITY CLASSIFICATION	
US Army Aeromedical Research Laboratory Fort Rucker, Alabama		Unclassified	
2b. GROUP			
3. REPORT TITLE			
EVALUATION OF THE HUMAN BODY AS AN AIRFOIL			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name)			
10 William P. Schane, LTC, MC Dean C. Borgman, Research Scientist			
6. REPORT DATE		7a. TOTAL NO. OF PAGES	
20 May 1969		94	
7b. NO. OF REFS		7	
8. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S)	
12 11P		USAARL Report No. 69-9	
9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)			
9. PROJECT NO.		10. DISTRIBUTION STATEMENT	
3AO 2560 1A 91C		Distribution of this document is unlimited. ~~Qualified requesters may obtain copies from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia.~~	
c. Task No. 275 (FY 69)		11. SUPPLEMENTARY NOTES	
d.		12. SPONSORING MILITARY ACTIVITY	
		US Army Medical Research and Development Command, Washington, D. C. 20315	
13. ABSTRACT			
Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag. 1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43). 2. Changes in parachute pack configuration significantly changed L/D, C_L, and C_D. Subjects appeared to be homogeneous. 3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration. 4. Man is not an ideal subject to test as an airfoil in the wind tunnel.			

DD FORM 1473

REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE

101

Unclassified
Security Classification

404578

15

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Human Body Aerodynamics Airfoil Parachuting Free-fall						

Unclassified

Security Classification

ARL 69-9
AD
U. S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama
EVALUATION OF THE HUMAN BODY AS AN AIRFOIL by LTC W. P. Schane and Dean Borgman. 94 pp, 9 tables, 26 figures. DA Project No. 3AO 2560 1A-91C, Aviation Medicine Research Division, May 1969.

Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag.

1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43).
2. Changes in parachute pack configuration significantly changed L/D , C_L , and C_D . Subjects appeared to be homogeneous.
3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration.
4. Man is not an ideal subject to test as an airfoil in the wind tunnel.

- UNCLASSIFIED
1. Human Body
 2. Aerodynamics
 3. Airfoil
 4. Parachuting
 5. Free-Fall

ARL 69-9
AD
U. S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama
EVALUATION OF THE HUMAN BODY AS AN AIRFOIL by LTC W. P. Schane and Dean Borgman. 94 pp, 9 tables, 26 figures. DA Project No. 3AO 2560 1A-91C, Aviation Medicine Research Division, May 1969.

Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag.

1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43).
2. Changes in parachute pack configuration significantly changed L/D , C_L , and C_D . Subjects appeared to be homogeneous.
3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration.
4. Man is not an ideal subject to test as an airfoil in the wind tunnel.

- UNCLASSIFIED
1. Human Body
 2. Aerodynamics
 3. Airfoil
 4. Parachuting
 5. Free-Fall

ARL 69-9
AD
U. S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama
EVALUATION OF THE HUMAN BODY AS AN AIRFOIL by LTC W. P. Schane and Dean Borgman. 94 pp, 9 tables, 26 figures. DA Project No. 3AO 2560 1A-91C, Aviation Medicine Research Division, May 1969.

Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag.

1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43).
2. Changes in parachute pack configuration significantly changed L/D , C_L , and C_D . Subjects appeared to be homogeneous.
3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration.
4. Man is not an ideal subject to test as an airfoil in the wind tunnel.

- UNCLASSIFIED
1. Human Body
 2. Aerodynamics
 3. Airfoil
 4. Parachuting
 5. Free-Fall

ARL 69-9
AD
U. S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama
EVALUATION OF THE HUMAN BODY AS AN AIRFOIL by LTC W. P. Schane and Dean Borgman. 94 pp, 9 tables, 26 figures. DA Project No. 3AO 2560 1A-91C, Aviation Medicine Research Division, May 1969.

Five subjects were used to determine the lift and drag characteristics of the human body held in a tracking attitude. The effects of eight different parachute pack configurations were tested to evaluate the influence of the pack upon lift and drag.

1. The mean C_L of our unencumbered subjects (0.374) corresponded to the C_L attributed to Straumann's ski-jumpers (0.43).
2. Changes in parachute pack configuration significantly changed L/D , C_L , and C_D . Subjects appeared to be homogeneous.
3. Design of a pack tray is described which, by test, had a significantly higher L/D than any currently available parachute pack tray configuration.
4. Man is not an ideal subject to test as an airfoil in the wind tunnel.

- UNCLASSIFIED
1. Human Body
 2. Aerodynamics
 3. Airfoil
 4. Parachuting
 5. Free-Fall