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STUDY OF PARACHUTE SCALE EFFECTS

TECHNICAL DOCUMENTARY REPORT ASD-TDR-62-1023

JANUARY 1963

Flight Accessories Laboratory
Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

Project No. 6065, Task No. 606502

ASTIA

FEB 26 1963

(Prepared under Contract No. AF 33(657)-8073
by Technology Incorporated, Dayton, Ohio;
Author: William B. Walcott.)

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Aeronautical Systems Division, Dir./Aero-Mechanics, Flight Accessories Lab, Wright-Patterson AFB, Ohio.

Rpt No. ASD-TDR-62-1023. STUDY OF PARACHUTE SCALE EFFECTS. Final report, Dec 62, 92p., incl illus., tables, 158 refs.

Unclassified Report

A study was conducted to determine the effects of changing scale upon drag coefficient, falling time, peak opening force, and stability for single, unre reefed textile parachute canopies. The investigation was confined to Flat Circular, Extended Skirt, Ringslot, Ribless Guide Surface, Circular Flat Ribbon, and Conical Ribbon parachutes operating in the subsonic flow regime at altitudes below 20,000

(over)

feet. As an integral part of the study, a survey of the existing literature and test data, compilation of all pertinent data, and recommendations for future experimental investigations were made. Scaling equations with associated 95-percent confidence intervals were developed for the drag coefficient of the Flat Circular and Extended Skirt parachutes through the use of a multiple regression analysis which indicates the significant variables and their functional forms. Because the available data was poorly distributed, the equations will have to be used circumspectly to avoid misleading conclusions.

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III. Technology Inc., Dayton, Ohio

IV. Walcott, William B.

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FOREWORD

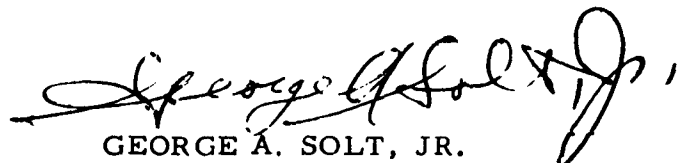
This report was prepared by Technology Incorporated, Dayton, Ohio, in compliance with United States Air Force Contract Number AF 33(657)-8073, initiated by the Retardation and Recovery Branch, Flight Accessories Laboratory, Directorate of Aeromechanics, Aeronautical Systems Division. The original Air Force Project Engineer was Mr. Clint Eckstrom; in the later phases of the program, Mr. Lawrence L. Watson assumed this position.

Technology Incorporated inaugurated the program on 15 February 1962 and completed its investigation on 15 November 1962 under the supervision of Mr. William B. Walcott, Project Engineer. Other staff members contributing significantly to the project were Mr. J. Patrick Ray, who performed the statistical analysis, and Mr. Krishan Joshi, who conducted the literature survey.

ABSTRACT

A study was conducted to determine the effects of changing scale upon drag coefficient, filling time, peak opening force, and stability for single, unreefed textile parachute canopies. The investigation was confined to Flat Circular, Extended Skirt, Ringslot, Ribless Guide Surface, Circular Flat Ribbon, and Conical Ribbon parachutes operating in the subsonic flow regime at altitudes below 20,000 feet. As an integral part of the study, a survey of the existing literature and test data, a compilation of all pertinent data, and recommendations for future experimental investigations were made. Scaling equations with associated 95-percent confidence intervals were developed for the drag coefficient of the Flat Circular and Extended Skirt parachutes through the use of a multiple regression analysis which indicates the significant variables and their functional forms. Because the available data was poorly distributed, the equations will have to be used circumspectly to avoid misleading conclusions.

Publication of this technical documentary report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.



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Chief, Aerodynamic Decelerator Branch
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LIST OF SYMBOLS

<u>Symbol</u>	<u>Concept</u>	<u>Dimensions</u>
b	Estimated Regression Coefficient	none
b'_i	Estimated Standard Partial Regression Coefficient	none
C	An Element of the Inverse Matrix	none
C_{D_o}	Drag Coefficient Based on S_o	none
C_{D_p}	Drag Coefficient Based on S_p	none
D_o	Nominal Diameter	feet
D_p	Projected Diameter	feet
$d.f.$	Degree of Freedom	none
d_o	Estimated Constant of the Regression Model	none
F	Random Variable with Snedecor's F Distribution	none
F_o	Opening Shock Force	pounds
F_r	Froude Number, $\sqrt{V^2 / q D_o}$	none
L_s	Riser Length	feet
L	Suspension Line Length	feet
M	Mach Number	none
$M.S.$	Mean Square	none
N_g	Number of Gores	none
n	Sample Size	none
q	Dynamic Pressure	pounds/feet ²
R^2	Square of the Multiple Correlation Coefficient	none
Re	Reynolds Number	none

LIST OF SYMBOLS (cont'd)

<u>Symbol</u>	<u>Concept</u>	<u>Dimensions</u>
S_o	Nominal Surface Area	feet ²
S_p	Projected Area	feet ²
S_v	Vent Area	feet ²
S.S.	Sum of Squares	none
SSE	Error Sum of Squares	none
SSR	Regression Sum of Squares	none
SST	Total Sum of Squares	none
s^2	Estimated Variance	none
t	Random Variable with Student's "t" Distribution	none
t_f	Canopy Filling Time	seconds
V	Velocity	feet/second
W	Gross Weight	pounds
X	Independent Variable	none
Y	Actual Value of the Dependent Variable	none
$\hat{Y}$	Predicted Value of the Dependent Variable	none
α	Type I Error	none
β	Actual Regression Coefficient	none
δ	Actual Constant of the Regression Model	none
λ	Porosity at $\Delta P = 1/2$ inch of Water	feet ³ /feet ² - minute
μ	Mean of the Dependent Variable	none
σ^2	Variance	none

SECTION I

INTRODUCTION

Suitable scaling equations for textile parachutes would substantially reduce the testing necessary to define their operating characteristics. Instead of using current methods of testing and modifying full-scale parachutes until the desired results are obtained, scale models in conjunction with the scaling equations would suffice; then, if desired, a full-scale model could be employed to verify the results.

This study was intended primarily to determine whether sufficient data exists which could define appropriate scaling equations for the selected parachute types. Data voids and future test needs were to be noted. If sufficient information were available, the scaling equations were to be derived.

To determine the scaling equations, it was decided at the outset to use a multiple regression analysis, a statistical technique believed to be novel in its application to the parachute field. Several reasons dictated the use of a regression analysis rather than the more conventional engineering methods commonly applied to a study of this nature. Any other type of analysis could not handle the many variables involved. These variables were numerous because the data for determining the scaling equations were collected from many different tests; for example, if sufficient data were available over the desired canopy area range, other variables, such as different canopy loadings, and different chute porosities, would also be present. Furthermore, use of a regression analysis would enable determination of the significance of a given variable, the functional form of the variable, the goodness of fit of the equation, and the confidence limits for the final results.

SECTION II

PARACHUTE SCALE EFFECTS

A . Basic Concepts of Scale Effects

A parachute scale effect can be defined as any change in a parachute's operating or performance characteristics caused solely by a change in canopy size. Such a change is brought about because change in canopy size can alter certain geometric and aerodynamic properties of the parachute. These effects can be significant in some situations or virtually negligible in others, but are always present to some degree in any scale model testing. As in any scale

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model testing, if this effect cannot be assessed, the test results can prove to be useless. The main difficulty in parachute scaling is the impossibility of assessing this change theoretically.

The change in parachute performance characteristics as effected by scaling manifests itself as a change in parachute drag coefficient, stability, filling time, or peak opening force. If these variables are defined as the dependent variables, then the problem is to define their change in terms of variations of the independent variables caused by a change in parachute size (scale). The most obvious independent scaling variable is parachute canopy area; however, there are several other independent variables which reflect changes in size that may be significant. Reynolds number and Froude number are such independent variables since by their definitions they vary with a change in size. Other independent variables which can be effected by a change in size are the number of gores and the ratio of their number to the canopy diameter. It is obvious that one or both of these changes will occur with a change in parachute size.

However, a variance in gore number does not necessarily constitute a scaling variable. There are three questions which must be satisfied before a variable can be considered a scaling variable. These questions can be enumerated as follows:

- 1) Does the variable change with a change in scale?
- 2) Does the variable affect the performance of the parachute?
- 3) Is the only way to assess the effect of the variable to consider it simultaneously with a change in canopy size (scale)?

Due to the manner in which the number of gores in a parachute vary with a change in canopy size, the answers to all three questions must be in the affirmative, and for question 3 this is reasonable when it is considered that a 1-foot nominal diameter scale model of a 50-foot nominal diameter chute cannot possibly have the same gore arrangement as the model. The 50-foot nominal diameter chute will have approximately 50 gores while for practical reasons the 1-foot diameter model would probably be constructed with 10 to 20 gores. To ascertain the effect of the change in gore arrangement it is necessary to consider it in conjunction with the change in scale since the scale model will not be constructed with either the same number of gores or the same ratio of number of gores to nominal diameter as the full scale chute. At the same time the effect of this change in gore arrangement cannot be assessed independently since scale model chutes and large diameter chutes will probably never be constructed with the same gore arrangement due to the practicalities of construction.

Other variables which affect parachute performance but are not scaling variables since they do not satisfy question 3—since their effects can be

assessed independently—are:

- a) porosity
- b) suspension line length/nominal diameter
- c) number of vertical ribbons
- d) number of horizontal ribbons
- e) space between vertical tapes/gore width at base
- f) open spacing/ribbon width
- g) canopy loading
- h) riser length/nominal diameter
- i) vent area/nominal surface area
- j) velocity
- k) dynamic pressure

Even though these above listed variables cannot be considered as scaling variables, they still may be present in the scaling equations due to their presence in an interaction term.

A special class of independent variables, of which Reynolds number and Froude number are examples, is defined as an interaction term. If a term is differentiated with respect to the variable denoting canopy size and other variables are still present, the term is defined as an interaction term. For example,

$$Re = \frac{\rho V D_0}{\mu}$$

which upon partial differentiation with respect to D_0 becomes

$$\frac{\partial Re}{\partial D_0} = \frac{\rho V}{\mu}$$

From this rather simple example it can be seen that, if Reynolds number is significant for scaling, the variables ρ , μ , and V are also significant. Therefore, even though these variables are held constant from the full scale to the scale model tests, the value of the variable will determine the amount of change in the parachute's operating characteristics due to scaling. From the preceding discussion it can be concluded that almost any variable, for example, velocity, might possibly play an important role for scaling if it appears in a significant interaction term. An interaction term which was found to be significant for the definition of the scaling effects on filling time and opening shock was $\frac{\rho D_0}{V^{.9}}$. It is possible that interaction terms involving other variables may also be significant even though none were found.

In summary then, the aerodynamic and geometric parameters,

- a) nominal surface area,
- b) number of gores,
- c) number of gores/nominal diameter,

- d) Reynolds number, and
- e) Froude number

can be assumed to be scaling variables and the other parameters, itemized previously, will enter into the scaling equations only if they are present in interaction terms.

B. Discussion of the Literature Surveyed

Literature was surveyed extensively to determine whether sufficient test data were available to permit an analysis leading to the definition of the appropriate scaling equations. The data collected during this survey is summarized and presented in Appendix II. The survey was limited to Solid Flat Circular, Extended Skirt, Ringslot, Ribless Guide Surface, Flat and Conical Ribbon parachutes operating at indicated airspeeds below 300 knots and altitudes less than 20,000 feet.

Since the data were collected from a great many different reports, there were many variables present which could affect the different performance characteristics of the parachutes and yet not be true scaling variables. Since this was the case, it was necessary to consider several more independent variables than would normally be required to arrive at the scaling equations. The independent variables whose values were considered necessary were S_o , l_s/D_o , N_g/D_o , l_r/D_o , S_v/S_o , λ , W/S_o , V , q , Re , M , and Fr . For this reason, a data point would be discarded unless a reasonable and logical assumption could be made of the value of the missing variable or variables. A more complete discussion of the literature survey is included in Appendix II with the data summary.

It was felt that sufficient data was available to determine the regression equations for drag coefficient for the Solid Flat Circular, Extended Skirt, Flat Ribbon, Ringslot, and Ribless Guide Surface parachutes. Also, there appeared to be sufficient data for filling time and peak opening force for both the Flat Circular and Extended Skirt parachutes. However, for reasons which will be explained later, the only attempts to derive scaling equations which yielded reasonable results were for the Flat Circular and Extended Skirt parachutes for drag coefficient.

Other than the data for the above mentioned parachutes, the available data were either insufficient or nonexistent. Data for any of the performance characteristics for the Conical Ribbon parachute were so meager that any attempt to summarize and present them would serve no useful purpose. Since no common description or definition of stability has been developed in the parachute realm, the available data in the literature could not be utilized. For full-scale parachutes, the period of oscillation or amount of oscillation was acquired. For scale model wind tunnel tests, however, pitching moment and the stable angle of attack were obtained. Because of this and the fact

that much of the stability data appeared to have been observed rather than measured, any attempt to define the scaling equations or to present the data in a systematic form was abandoned.

C. Utilization of Regression Analysis

Because of the scatter of data caused by the many variables in the collected data, a multiple regression analysis was selected as the technique most capable of defining the desired scaling equations. Figure 1, for example, shows the wide scatter of drag coefficient values for various nominal surface areas for the Circular Flat parachute. This figure shows that there are other variables in addition to canopy size which influence the value of the drag coefficient, for, without these other variables, the scatter for any nominal surface area would be appreciably less. Therefore, it was necessary to try not only to extract the scaling effects from the data but also to eliminate the variations due to nonscaling variables, such as suspension line length and velocity.

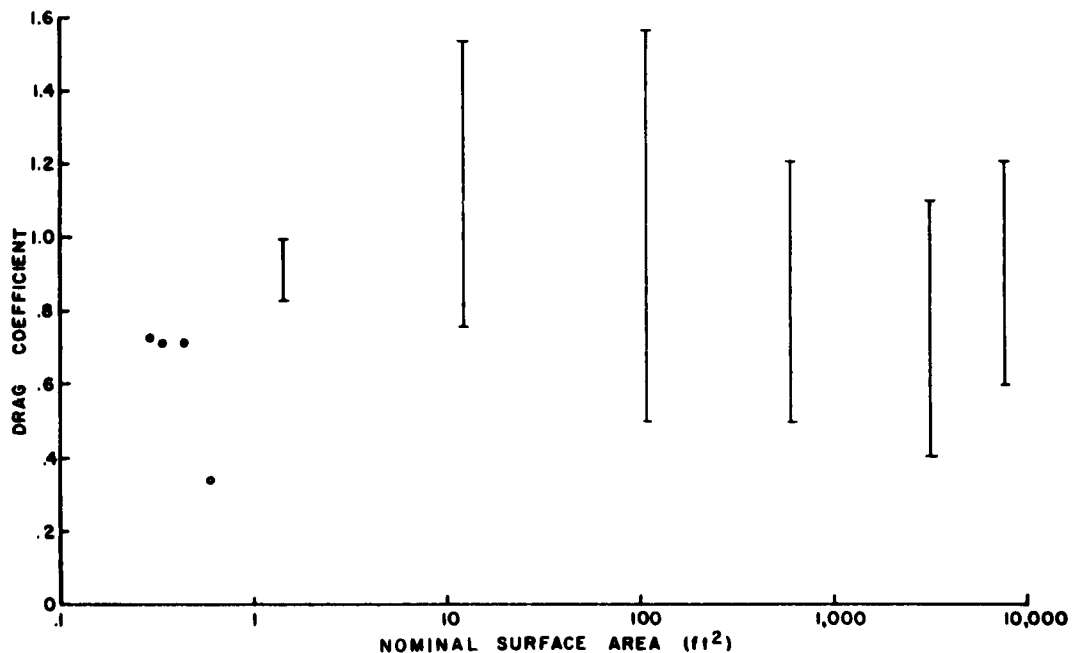


Figure 1. Circular Flat Parachute Drag Coefficient Variation

As an example, assume that a regression equation has been developed for the prediction of drag coefficient which involves only two terms--one term is a scaling variable ($\ln S_0$) and the other term is not ($\ln V$). This equation can then be used to extract from the observed data points the variation contributed due to velocity and thus allow the utilization of many more data points than if all the observed data points had to be at the same velocity. Therefore, it can be seen that the regression equation defines the variation due to scaling ($\ln S_0$) and also makes possible the utilization of data in which nonscaling variables affecting performance are also varied.

The multiple regression analysis, the theory of which is outlined in Appendix I, offers several attractive features for an analysis of this type. If the data to be analyzed by a regression technique are reasonably well distributed over the ranges of interest for the independent variables, it is possible to determine the following:

- a) how closely the developed regression equation is describing the variations for the observed data points,
- b) the significance of any given independent variable by using appropriate statistical techniques,
- c) the functional form of a significant independent variable, and
- d) the confidence limits for the predicted dependent variable.

Two methods are generally employed in choosing the regression model to represent the functional relation between the dependent and independent variables. One is to plot the sample data as 2-dimensional scatter diagrams of the dependent variable versus each of the independent variables with the other independent variables held constant to give some indication of what the individual terms of the model should be. The second method is to base the functional form of the regression model on prior knowledge and analytical considerations of the factors involved.

The first method was not adaptable for utilization in the present study since this study is based on data gathered from various sources and collected under radically different experimental conditions. It was impossible to find enough data collected under similarly controlled experimental conditions to yield meaningful 2-dimensional plots. The second method was only partially feasible since a thorough review of the pertinent literature yielded very little information applicable to the combined effects of the independent variables considered in this study.

Another source of information indicative of the independent variables and cross-products of independent variables (interactions) which are significantly affecting the dependent variable is a statistical computation procedure known as analysis of variance, a technique for analyzing the results of a designed experiment. A designed experiment is one planned in advance with the levels and combinations of levels of the independent variables chosen so that the maximum desired information on the factors may be elicited. The analysis of variance method is based on a partitioning of the variance of the observations on the dependent variable, each part measuring the variability attributed to some specific source. The method provides the quantities necessary for testing the significance of this variability. Obviously, this technique was not applicable in the present study due to the poorly distributed data on the independent variables.

It was decided to use a multiple regression technique in building a regression model by a process of trial and elimination. Application of this technique to the parachute field is believed to be unique. (Appendix I discusses the utilization of the IBM 7090 in the development of this model.) The data for this development were gathered and processed in the form of four dependent variables and approximately 12 independent variables considered to have the greatest effect on the former. A regression model for drag coefficient involving linear terms of the independent variables was first fitted but rather unsuccessfully. Other functional relations—such as models composed of the squares, reciprocals, or natural logarithms of the independent variables—were all fitted with varying degrees of success. One functional relation would fit reasonably well for one type of parachute but would not fit at all for some other type of parachute.

With the possible exception of differences in the coefficients, approximately the same functional form for a given dependent variable should fit all different types of parachutes. For each respective dependent variable, the approach employed to obtain similar functional relations for all types of parachutes was the following: Various transformations on the independent variables—transformations such as squaring, computing the reciprocal, squaring the reciprocal, extracting the square root, computing the natural logarithm, squaring the natural logarithm, and computing the reciprocal of the natural logarithm of "1" plus the variable—were performed; furthermore, cross-product terms—such as the number of gores divided by the nominal diameter and dynamic pressure times nominal surface area—were computed. Each of these terms was considered to be an "independent" variable. The correlation coefficients for all possible pairs of these "independent" variables were calculated, and the highly correlated terms were removed. Iterative multiple regression analyses were run on the remaining terms until all those not statistically significant had been deleted. The resulting functional relations are presented in Tables 1 and 2.

Table 1 presents the drag coefficient prediction equations for the five types of parachutes which had sufficient data to attempt a regression analysis. Performing the transformations on the independent variables presented in the table and then combining all terms results in a predicted drag coefficient. The degree of fit (R^2) of the tabulated (observed) values in Appendix II for the prediction equations is indicated in the parentheses. The same procedure follows for Table 2 which presents peak opening shock and filling time prediction equations for the Circular Flat and Extended Skirt parachutes. For a given dependent variable, dissimilarities in these functional relations for the various types of parachutes must be attributed to differences in the availability of data for the various parachutes.

In an effort to explain as much of the data variation as possible, several interaction terms which appear in various theoretical parachute analyses were tried in the regression models. Except for Reynolds number and Froude

Table 1
Prediction Equations for Drag Coefficient

Ribless Guide Surface ($R^2 = .9253$)	Extended Skirt ($R^2 = .8833$)	Circular Flat ($R^2 = .8635$)	Ringslot ($R^2 = .8391$)	Ribbon ($R^2 = .6351$)
2.7367	8.5738	14.8010	-161.0286	17.1465
$-.7895 \ln S_0$	$+.2676 \ln S_0$	$+.1316 \ln S_0$	$-.0760 S_0$	$+3.7779 \ln S_0$
$+.0271 S_0$	$+.7067 \ln F_r$	$-11.2727 \sqrt{F_r}$	$-.1024 W/S_0$	$+.0553 S_0$
$-.0251 F_r$	$+.3985 F_r$	$+5.6058 \ln F_r$	$+.3796 \ln W/S_0$	$-1.8017 \sqrt{S_0}$
$-.5919 1/(W/S_0)$	$-.1312 1/F_r$	$+.7340 F_r$	$+.0007 1/(W/S_0)^2$	$+9.8516 1/S_0$
$+.0417 1/(W/S_0)^2$	$-.2195 N_g/D_0$	$+1.1263 (\ln F_r)^2$	$-.7492 \ln V$	$-.0305 1/(W/S_0)$
$-.0008 W/S_0$	$+.8292 \ln W/S_0$	$-.6929 1/(W/S_0)$	$+.0015 V$	$+.4858 \ln V$
$+1.6853 1/V$	$-.5600 \ln V$	$+.1852 (\ln W/S_0)^2$	$+6.1886 N_g$	$-4.265 \ln R_0$
$+.0022 V$	$-2.6168 \ln V$	$+.0831 1/(W/S_0)^2$	$+1183.7375 1/N_g$	$-.1601 \lambda$
$-.0285 1/q^2$		$-1.1010 \ln V$		$52.5409 1/\lambda$
$-25.5945 (10^5) 1/R_0$		$-.0556 q$		$12.2819 \ln \lambda$
$+82.6427 (10^{10}) 1/R_0^2$		$+.2306 1/q$		$+5.6517 \sqrt{\lambda}$
$-.3235 1/(\ln D_0)^2$		$-.0245 1/q^2$		$+.0089 1/M$
				$-.8069 (10^{-5}) 1/M^2$

Table 2
Prediction Equations for Filling Time and Opening Shock

Filling Time		Opening Shock	
Circular Flat ($R^2 = .5121$)	Extended Skirt ($R^2 = .4137$)	Circular Flat ($R^2 = .5564$)	Extended Skirt ($R^2 = .8695$)
$-.8279$	-5664.0513	$210.7387 (10^2)$	$-1213.9166 (10^2)$
$+3142.5799 \rho D_0/V^3$	$+.3910 1/\rho$	$-4757.9144 (10^3) \rho$	$+9771.1968 (10) \ln N_g$
$-1881.1376 (10^2) \rho^2$	$+1573.1123 (10^7) 1/Re$	$+9780.2371 (10^3) \rho D_0/V^3$	$+2861.5800 1/M$
$+.0029 V$	$+474.2279 \ln Re$	$-366.7599 (10^2) 1/\ln(1+q)$	$-2520.9976 (10) \ln S_0$
$-.0010 1/\rho$	$+467.0649 \ln \rho$	$-7.3409 S_0$	$+1081.3135 (10^3) 1/N_g$
$+.0041 \lambda$	$-.3352 (10^{-4}) 1/\rho^2$	$+3.9308 (10^{-5}) Re$	$-51.8082 1/M^2$
$+303.8672 S_0/V S_0$	$-5664.4910 (10^{13}) 1/Re^2$	-8.1269λ	$+1238.1923 (10) \ln M$
$+.3037 (10^{-6}) 1/\rho^2$	$-1694.6732 (10^2) \rho$		$-947.1344 N_g$
$+35.3660 1/\lambda$	$-3889 (10^{-5}) Re$		$+4.7390 S_0$
	$-.7334 q$		$-4028.1048 (10) N_g/D_0$
	$+1136.0969 (10^4) \rho^2$		$-4051.9106 (10^6) 1/S_0^2$
	$+17.4472 \ln q$		$-138.1699 1/(W/S_0)^2$
	$+.0015 q^2$		
	$-3783.4468 (10) \rho D_0/V^3$		
	$+3.8789 Fr$		
	$+16.5306 \ln S_0$		
	$+114.3176 1/Fr$		

number, however, the only interaction term found to be significant was $\frac{\rho D_0}{V \cdot g}$

which was for filling time. This does not necessarily indicate that these other variables may not be significant; for this could have resulted from the observed data used in the regression analyses. It is of interest to note the b

value (coefficient) for $\frac{\rho D_0}{V \cdot g}$ for the Circular Flat parachute listed in

Table 2. This value with its associated 95-percent confidence limits will encompass the constant, $\frac{8}{\rho_0}$ ($\rho_0 = .002378$), which is given in the "USAF Parachute Handbook" (reference 30).

It was initially anticipated that the same variables with similar functional forms and possibly just slightly different coefficients would be significant for all the parachute types. That the regression models did not substantiate this anticipation was apparently due to the poor distribution of the available data. Nevertheless, it is believed that adequate data will prove the hypothesis. At least it should be noted that the scaling variables ($\ln S_0, Fr, \ln Fr, Fr, [\ln Fr]^2$) for the Circular Flat parachute drag coefficient are similar to the scaling variables ($\ln S_0, \ln Fr, Fr, 1/Fr$) for the Extended Skirt parachute drag coefficient. Furthermore, these two regression models were obtained from larger amounts of data than were available for the other types of parachutes.

D. Scaling Equation Theory

If the prediction equations as presented in Tables 1 and 2 are used, the scaling equations can be derived as follows: The only variables of interest in these prediction equations are the scaling variables; therefore, for practical purposes the other variables are disregarded. The reasoning that substantiates this statement is that a scale effect is interpreted as a change in the dependent variable (drag coefficient, etc.) due to a change in only the independent scaling variables. As a change denotes an increment, the non-scaling variables can be eliminated since they don't vary through this interval. Assuming the prediction equation to have five terms of which the first two and the last are scaling variables ($b_1 X_{1j}, b_2 X_{2j}$ and $b_5 X_{5j}$),

$$\hat{Y}_j = d_0 + b_1 X_{1j} + b_2 X_{2j} + b_3 X_{3j} + b_4 X_{4j} + b_5 X_{5j},$$

then, the incremental change in the dependent variable, as predicted by the regression equation, is

$$\hat{Y}_2 - \hat{Y}_1 = b_1 (X_{12} - X_{11}) + b_2 (X_{22} - X_{21}) + b_5 (X_{52} - X_{51}) = b_1 K_1 + b_2 K_2 + b_5 K_5$$

Thus, $(\hat{Y}_2 - \hat{Y}_1)$ is the incremental change in drag coefficient, filling time, or opening shock caused by a change in scale and this derived equation is then the scaling equation.

With the change in the dependent variable known, it is also desirable to

determine the confidence limits for this change. To predict confidence limits, the variance of the predicted change must be estimated.

To estimate the variance of the difference between two predicted mean values of the dependent variable when one or more of the independent variables remains constant, let it again be assumed for purposes of illustration that the fitted regression equation has five terms:

$$\hat{Y} = d_0 + b_1 X_{1j} + b_2 X_{2j} + b_3 X_{3j} + b_4 X_{4j} + b_5 X_{5j}$$

The estimate of the variance of $(\hat{Y}_2 - \hat{Y}_1)$ is desired when, for example, X_3 and X_4 remain constant, i. e., $X_{31} = X_{32}$ and $X_{41} = X_{42}$.

Now,

$$\text{Var } (\hat{Y}_2 - \hat{Y}_1) = E \left[(\hat{Y}_2 - \hat{Y}_1)^2 \right] - \left[E(\hat{Y}_2 - \hat{Y}_1) \right]^2,$$

$$\text{and } \hat{Y}_2 - \hat{Y}_1 = b_1 (X_{12} - X_{11}) + b_2 (X_{22} - X_{21}) + b_5 (X_{52} - X_{51}) = b_1 K_1 + b_2 K_2 + b_5 K_5$$

Thus,

$$\text{Var } (\hat{Y}_2 - \hat{Y}_1) = E \left[(b_1 K_1 + b_2 K_2 + b_5 K_5)^2 \right] - \left[E(b_1 K_1 + b_2 K_2 + b_5 K_5) \right]^2$$

Considering these two terms separately,

$$\begin{aligned} E \left[(b_1 K_1 + b_2 K_2 + b_5 K_5)^2 \right] &= E \left[b_1^2 K_1^2 + b_2^2 K_2^2 + b_5^2 K_5^2 + 2 b_1 b_2 K_1 K_2 + 2 b_1 b_5 K_1 K_5 + 2 b_2 b_5 K_2 K_5 \right] \\ &= K_1^2 \left[\sigma_1^2 + \beta_1^2 \right] + K_2^2 \left[\sigma_2^2 + \beta_2^2 \right] + K_5^2 \left[\sigma_5^2 + \beta_5^2 \right] \\ &\quad + 2 K_1 K_2 \left[\sigma_{12} + \beta_1 \beta_2 \right] + 2 K_1 K_5 \left[\sigma_{15} + \beta_1 \beta_5 \right] + 2 K_2 K_5 \left[\sigma_{25} + \beta_2 \beta_5 \right] \end{aligned}$$

and

$$\begin{aligned} \left[E(b_1 K_1 + b_2 K_2 + b_5 K_5) \right]^2 &= \left[K_1 \beta_1 + K_2 \beta_2 + K_5 \beta_5 \right]^2 = K_1^2 \beta_1^2 + K_2^2 \beta_2^2 + K_5^2 \beta_5^2 \\ &\quad + 2 K_1 K_2 \beta_1 \beta_2 + 2 K_1 K_5 \beta_1 \beta_5 + 2 K_2 K_5 \beta_2 \beta_5. \end{aligned}$$

Taking the difference of these two expressions yields

$$\text{Var } (\hat{Y}_2 - \hat{Y}_1) = K_1^2 \sigma_1^2 + K_2^2 \sigma_2^2 + K_5^2 \sigma_5^2 + 2 K_1 K_2 \sigma_{12} + 2 K_1 K_5 \sigma_{15} + 2 K_2 K_5 \sigma_{25},$$

where $\sigma_i^2 = \text{Var}(b_i)$ and $\sigma_{ij} = \text{Cov}(b_i, b_j)$

would be estimated by

$$S^2_{\hat{Y}_2 - \hat{Y}_1} = S^2_E \left[K_1^2 C_{11} + K_2^2 C_{22} + K_5^2 C_{55} + 2 K_1 K_2 C_{12} + 2 K_1 K_5 C_{15} + 2 K_2 K_5 C_{25} \right]$$

where c_{ii} and c_{ij} are defined, as before, to be elements of the inverse matrix C .

The predicted change due to scaling with associated 95-percent confidence limits is then,

$$(\hat{Y}_2 - \hat{Y}_1) \pm 1.96 S_{\hat{Y}_2 - \hat{Y}_1}$$

E. Limitations of Regression Models for Development of Scaling Equations

There are several reasons why the regression equations, other than the equations for the Circular Flat and Extended Skirt parachutes, were not used to develop scaling equations. Presented in Table 3 are the ranges of the independent variables of the observed data. If the regression equations are used for prediction purposes for values of the independent variables outside these ranges, a correct result would be purely accidental. However, not only is it necessary to consider the range, but also the distribution of the observed data with respect to the independent variables in this range. Of primary importance for this investigation is the distribution with respect to canopy nominal surface area. These distributions for surface area are presented in Figures 2 through 8 and are typical of the distributions for the other independent variables. As can be seen, the ranges for the independent variable presented in Table 3 can be quite misleading since only extreme values are indicated. It is, therefore, necessary to consider the distribution of observed data points for every scaling variable before the scaling equations can be developed and used.

Table 3
Ranges of Independent Variables

Parachute Type	Dependent Variables	S_o (ft. ²)	l_a/D_o	N_g/D_o	l_x/D_o	S_v/S_o	λ at $\Delta P = 1/2 \rho V^2$ (ft. ³ /ft. ² -min)	W/S_o (per)	V (ft./sec)	q (per)	$Re \times 10^{-6}$	M	Fr
Flat Circular	C_D	0.196 to 17,671.5	0.816 to 1.810	1.00 to 20.70	0.0 to 1.3	0.0 to 0.25	0 to 426	0.188 to 51.60	10.4 to 235.8	0.12 to 60.0	0.1383 to 28.650	.0094 to .2445	.229 to 31.1
	t_f and F_o	452.0 to 804.0	0.700 to 0.850	• •	0 0	0.0 to .01	60 to 260	0.256 to 0.499	168.0 to 467.6	27.7 to 204.4	20.7 to 70.07	.1114 to .4236	5.45 to 15.58
Extended Skirt	C_D	1.910 to 5319.73	0.600 to 1.400	0.5007 to 17.96	0.0 to 0.1	0.0 to 0.1	10 to 275	0.119 to 10.33	9.8 to 111.7	0.108 to 12.55	0.129 to 18.053	0.0088 to 0.100	.374 to 15.75
	t_f and F_o	715.6 to 5230.0	0.699 to 1.000	0.500 to 0.9376	0.0 to 0.09	0.0 to 0.008	30 to 135	0.226 to 0.736	150.0 to 504.1	24.9 to 194.8	30.58 to 280.0	0.1340 to 0.4681	4.274 to 15.05
Ribbon	C_D	3.66 to 129.2	1.000 to 1.400	1.345 to 7.412	0 to 1.430	0 to 0.010	• to 30.0	0.078 to 70.53	9.9 to 514.0	0.108 to 295.0	0.747 to 35.40	0.0087 to 0.4627	0.511 to 30.93
Ring Slot	C_D	48.0 to 920.8	1.0 to 1.535	.3346 to 1.964	No Value	0.0 to 0.008	• to 17.80	0.10 to 48.20	9.8 to 584.0	0.111 to 364.0	0.727 to 25.55	.0088 to 0.518	0.503 to 36.83
Guide Surface (Ribless)	C_D	0.611 to 48.10	1.0 to 1.72	1.278 to 13.14	• to 13.2	0 to 0.002	40 to 275	0.161 to 47.00	10.8 to 516.0	0.119 to 304.0	0.469 to 19.90	0.009 to 0.471	0.629 to 45.0

*Note. N. range

** Geometric priority given in percent.

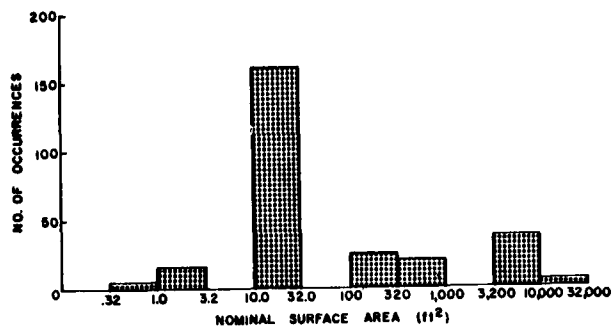


Figure 2
Circular Flat Drag Coefficient Data
Distribution

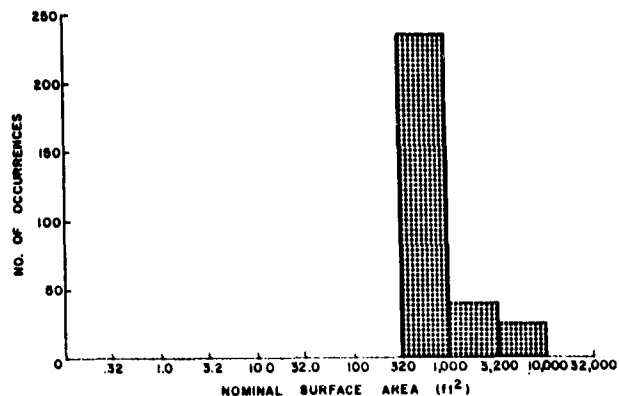


Figure 5
Extended Skirt Filling Time and
Opening Shock Data Distribution

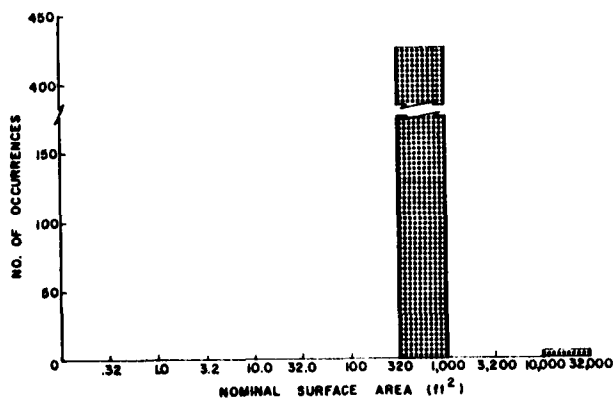


Figure 3
Circular Flat Filling Time and Opening
Shock Data Distribution

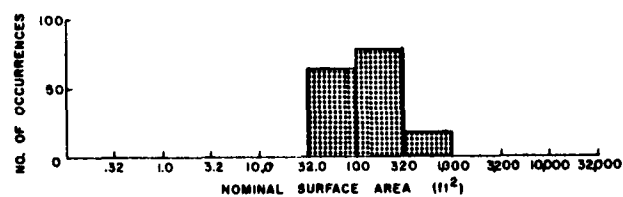


Figure 6
Ringslot Drag Coefficient Data
Distribution

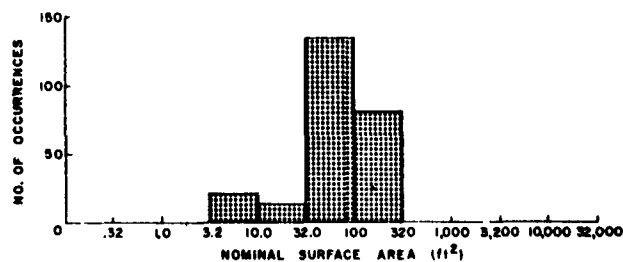


Figure 7
Ribbon Drag Coefficient Data
Distribution

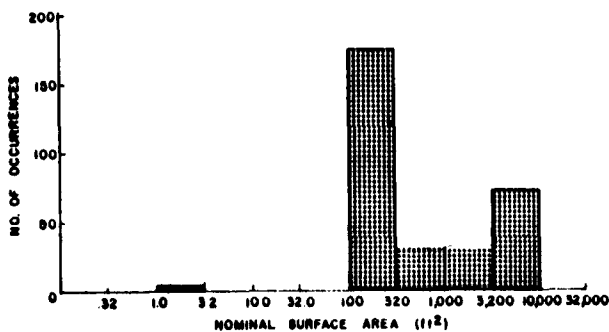


Figure 4
Extended Skirt Drag Coefficient Data
Distribution

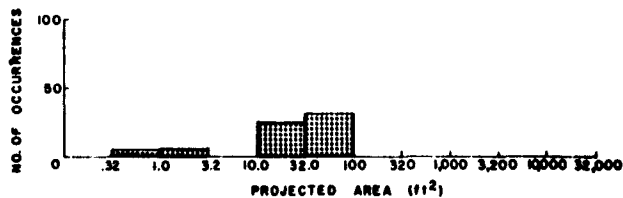


Figure 8
Ribless Guide Surface Drag
Coefficient Data Distribution

As an obvious example of why a scaling equation was not developed, virtually all of the collected data for filling time and opening shock for the Circular Flat parachute fell in one area range. Therefore, any predictions involving canopy areas outside this range would be unwarranted extrapolations. It should also be noted with reference to Figure 4 that data for the Extended Skirt parachute drag coefficient was nil for the smaller nominal surface areas. For this reason, the restriction on the use of the developed scaling equation in this canopy area range should be carefully observed. Also, reference to Appendix II will show that the distribution of the observed data for N_g/D_0 for the Extended Skirt is for practical purposes much narrower than indicated in Table 3.

The most subtle and, consequently, most difficult reason to recognize, which prevents the development of scaling equations from most of the regression models, is the warped or unreasonable surface shape predicted by the regression models. In other words, it is very possible for the regression model to have a very high multiple correlation (R^2), but due to the poor distribution of the observed data, be capable of predicting accurately only for the observed data points.

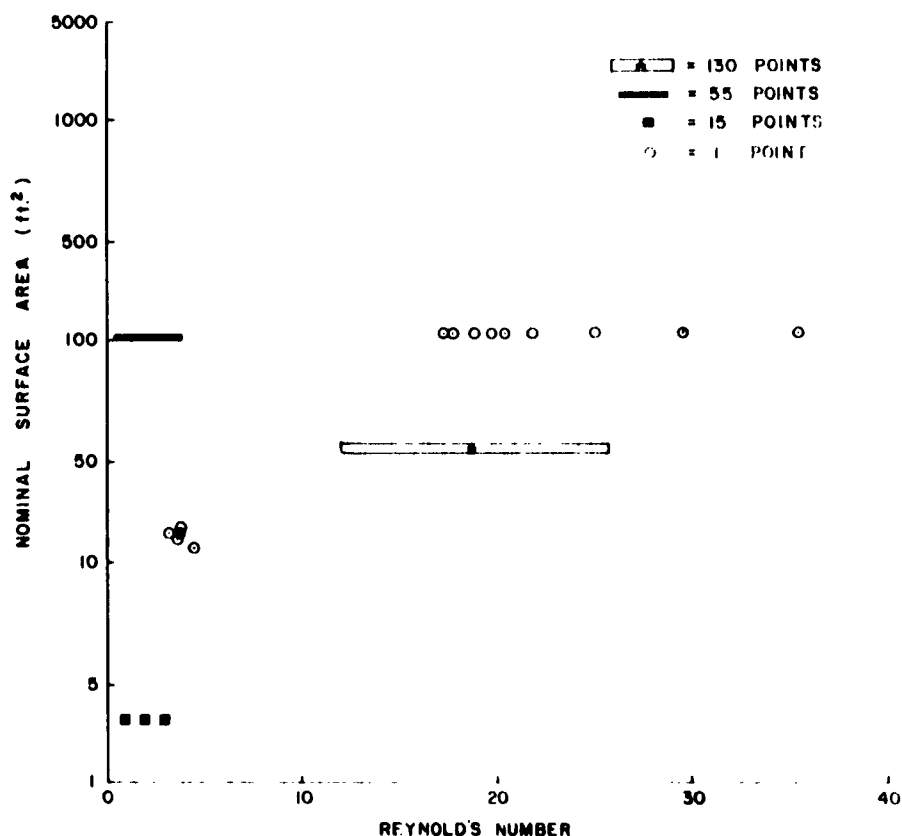


Figure 9. Ribbon Parachute Observed Data Distribution for Scaling Variables

To clarify this point, the regression model for the Circular Flat Ribbon parachute will be used as an example. Figure 9 presents the observed data

distribution for the Ribbon parachute as a function of the scaling variables, canopy surface area, and Reynolds number. These variables were chosen to demonstrate the data distribution since both were significant scaling variables as predicted by the Ribbon parachute regression model. Figure 9 shows that the observed data is very highly concentrated in three or four regions. For comparison purposes, Figure 10 presents the observed data distribution for the Circular Flat parachute for its significant scaling variables, canopy surface area, and Froude number. The Circular Flat parachute data can be seen to be much more evenly distributed as a function of its scaling variables than the Ribbon parachute data is.

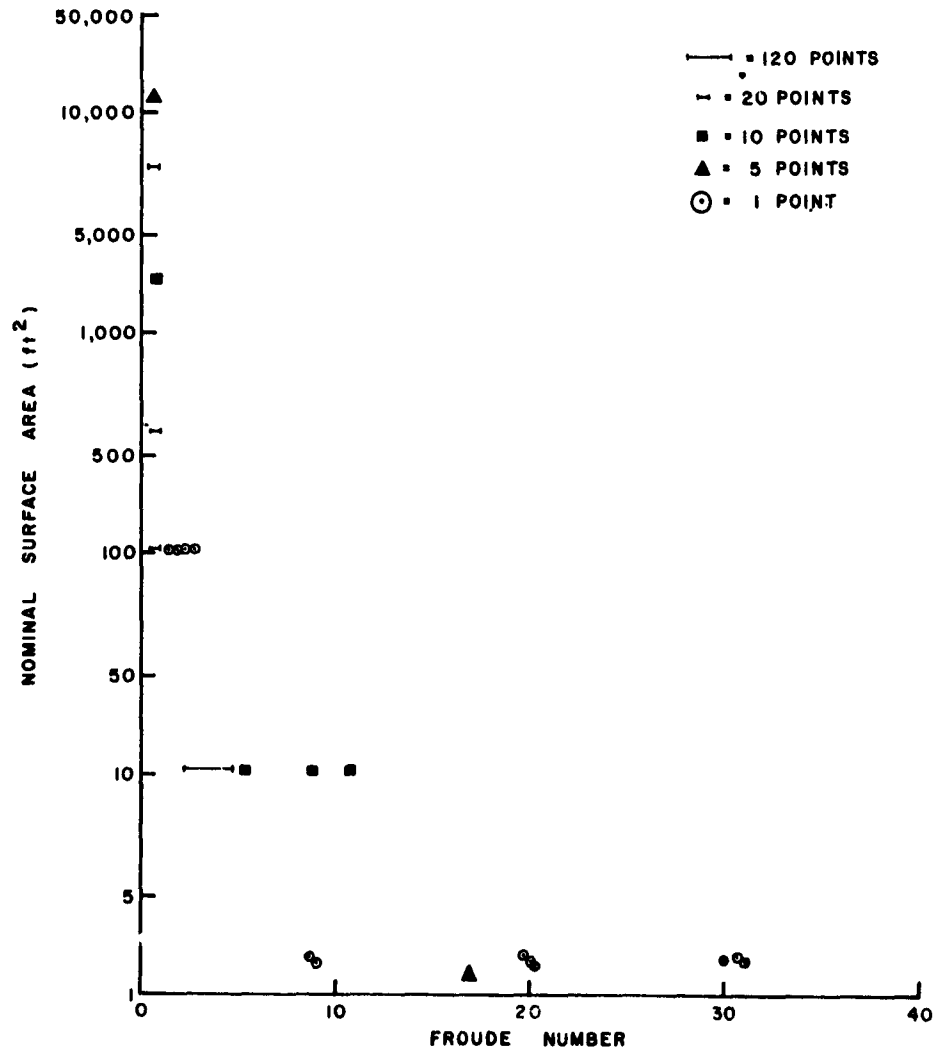


Figure 10. Circular Flat Observed Data Distribution for Scaling Variables

To demonstrate the effect that the difference in data distribution can have, assume that the drag coefficient is predicted for both types of parachutes for a 75-square foot surface area, 10^7 Reynolds number, and 1.35 Froude number (Reynolds number and Froude number are compatible so that the same condition is being investigated for both parachute types). It will be

found that the regression model for the Circular Flat parachute will predict very well and the regression model for the Ribbon parachute will predict very poorly. It can be seen by reference to Figures 9 and 10, however, that the point at which the drag coefficient prediction is being attempted falls among clusters of observed data for both parachute types. To demonstrate the cause of this apparent paradox, the Ribbon parachute regression model can be differentiated with respect to canopy surface area, which yields,

$$\frac{\partial C_D}{\partial S_0} = .0553 + \frac{3.7799}{S_0} - \frac{1.8017}{2\sqrt{S_0}} - \frac{9.8516}{S_0^2}$$

Evaluation of this differential through a canopy surface area range of 40 feet² to 120 feet² yields the slopes for the predicted surface as presented in Figure 11. Since the observed data for the Ribbon parachute is very heavily concentrated around the canopy surface areas of 55 feet² and 110 feet², it can be surmised, with reference to Figure 11, that the prediction surface is passing through the observed data at these points and dropping down to an inflection point at a canopy surface of 75 feet². This in actuality is what is occurring and this is demonstrated in the 3-dimensional sketch of the predicted surface presented in Figure 12. The observed data points are represented by the dots and the prediction by the cross in this figure. It can be seen from the sketch of this surface, how a regression equation can fit the observed data very well (high R^2) and still not be appropriate for prediction purposes at any other points. This is probably the most forceful argument that can be made for the necessity of a well designed experiment which results in a favorable distribution of observed data points.

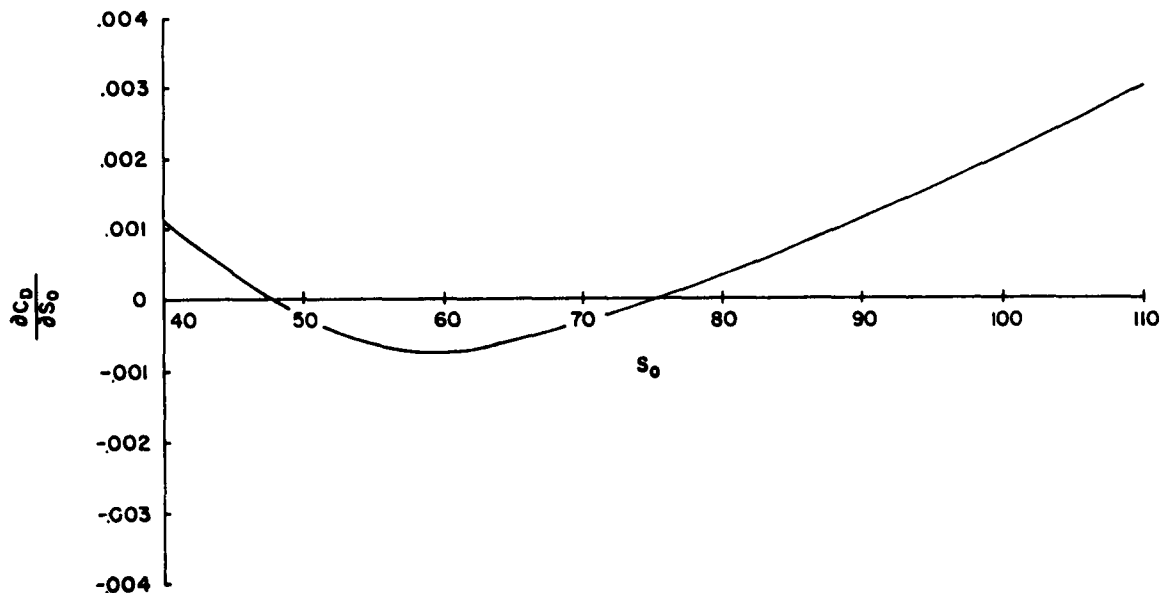


Figure 11. Slope of Drag Coefficient Surface for Ribbon Parachute

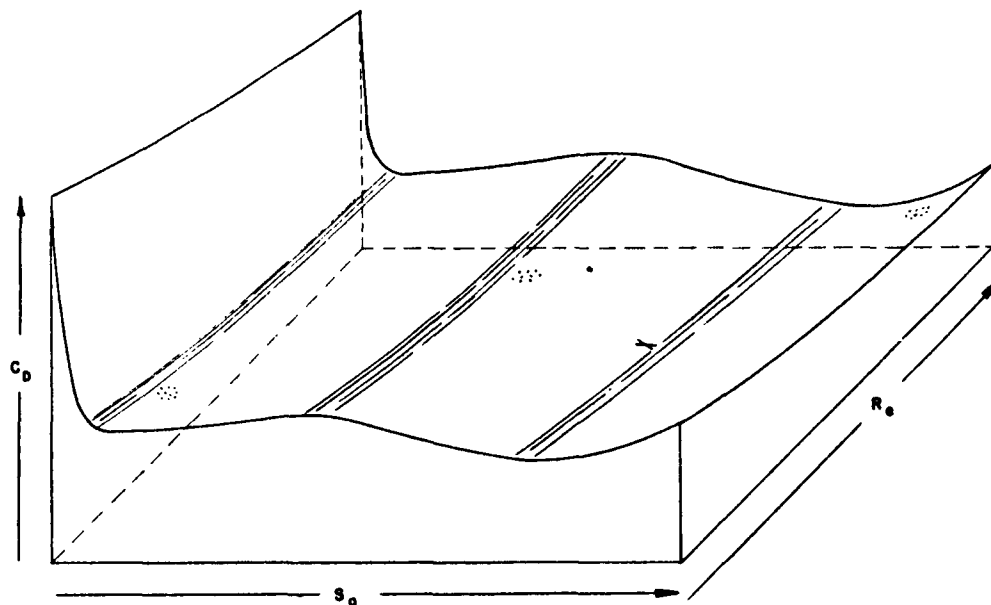


Figure 12. Drag Coefficient Surface Predicted by Regression Equation

F. Scaling Equations for Circular Flat and Extended Skirt Parachutes Drag Coefficient

This subsection presents the information necessary to derive the scaling effects and associated confidence intervals on drag coefficient for the Circular Flat and Extended Skirt parachutes and gives an example using the Circular Flat parachute. The reasons for selecting only these two regression models to develop scaling equations are as explained previously.

Presented in Table 4 are the scaling variables and coefficients for the Circular Flat and Extended Skirt parachutes which may vary for a change in scale if the other independent variables are held constant. Table 5 presents the associated c_{ij} and c_{ji} values.

Table 4
Scaling Variables and Coefficients

Flat Circular		Extended Skirt*	
Variable	b_i	Variable	b_i
$\ln S_0$	0.1316	$\ln S_0$	0.2676
$\sqrt{F_r}$	-11.2727	$\ln F_r$	0.7067
$\ln F_r$	5.6058	F_r	0.3985
F_r	0.7340	$1/F_r$	-0.1312
$(\ln F_r)^2$	1.1263	N_0/D_0	-0.2195

*Information to be used only in the nominal surface canopy area range of 100 feet² to 5300 feet².

Table 5
Inverse Matrix, C, Values

Flat Circular		Extended Skirt	
$C_{11} = 0.2257$	$C_{25} = -14.9632$	$C_{11} = 1.6231$	$C_{25} = 1.6305$
$C_{12} = -2.8230$	$C_{33} = 41.9722$	$C_{12} = 6.9017$	$C_{33} = 1.0708$
$C_{13} = 2.1354$	$C_{34} = 5.0599$	$C_{13} = -0.2483$	$C_{34} = -0.9737$
$C_{14} = 0.1666$	$C_{35} = 7.9017$	$C_{14} = 0.1911$	$C_{35} = -0.6395$
$C_{15} = 0.3342$	$C_{44} = 0.7060$	$C_{15} = 0.1528$	$C_{44} = 1.1988$
$C_{22} = 148.9704$	$C_{45} = 0.9812$	$C_{22} = 32.6942$	$C_{45} = 0.5544$
$C_{23} = -76.4048$	$C_{55} = 1.5620$	$C_{23} = -2.7609$	$C_{55} = 0.3892$
$C_{24} = -10.0956$		$C_{24} = 2.7680$	
$S^2_E = 0.006508$		$S^2_E = 0.003025$	

To predict the change in drag coefficient for the Circular Flat parachute for a change in size from a nominal diameter of two feet to a nominal diameter of fifty feet, assuming velocity equal to 32.2 feet/second, the procedure is as follows:

First, with $D_0 = 50$ and $D_0 = 2$, the variables listed in Table 4 would yield the following values:

D	50	2
$\ln S_0$	7.58248	1.14473
$\sqrt{F_r}$	.89586	2.00312
$\ln F_r$	-.21995	1.38941
F_r	.80256	4.01249
$(\ln F_r)^2$	.04838	1.93046

where $F_r = \sqrt{\frac{V^2}{gD_0}}$. Now,

$$\Delta C_D = \hat{Y}_1 - \hat{Y}_2 = b_1 K_1 + b_2 K_2 + b_3 K_3 + b_4 K_4 + b_5 K_5$$

$$K_1 = (X_{12} - X_{11})$$

$$\text{where } X_{12} = 7.58248$$

$$\text{and } X_{11} = 1.14473$$

$$K_4 = (X_{42} - X_{41})$$

$$\text{where } X_{42} = .80256$$

$$\text{and } X_{41} = 4.01249$$

$$K_2 = (X_{22} - X_{21})$$

$$\text{where } X_{22} = .89586$$

$$\text{and } X_{21} = 2.00312$$

$$K_5 = (X_{52} - X_{51})$$

$$\text{where } X_{52} = .04838$$

$$\text{and } X_{51} = 1.93046$$

$$K_3 = (X_{32} - X_{31})$$

$$\text{where } X_{32} = -.21995$$

$$\text{and } X_{31} = 1.38941$$

$$\begin{aligned} \Delta C_D = & 0.1316 (7.58248 - 1.14473) - 11.2727 (0.89586 - 2.00312) \\ & + 5.6058 (-0.21995 - 1.38941) + 0.7340 (0.80256 - 4.01249) \\ & + 1.1263 (0.04838 - 1.93046) \end{aligned}$$

$$\Delta C_D = .84721 + 12.48181 - 9.02175 - 2.35609 - 2.11979$$

$$\Delta C_D = -.1686$$

which is then the change in drag coefficient for a change in nominal diameter from two feet to fifty feet.

To estimate the variance of this change,

$$S_{\hat{Y}_2 - \hat{Y}_1}^2 = S_E^2 \left[K_1^2 c_{11} + K_2^2 c_{22} + K_3^2 c_{33} + K_4^2 c_{44} + K_5^2 c_{55} + 2 K_1 K_2 c_{12} + 2 K_1 K_3 c_{13} \right. \\ \left. + 2 K_1 K_4 c_{14} + 2 K_1 K_5 c_{15} + 2 K_2 K_3 c_{23} + 2 K_2 K_4 c_{24} + 2 K_2 K_5 c_{25} + 2 K_3 K_4 c_{34} \right. \\ \left. + 2 K_3 K_5 c_{35} + 2 K_4 K_5 c_{45} \right]$$

$$S_{\hat{Y}_2 - \hat{Y}_1}^2 = .006508 \left[(6.43775)^2 (0.2257) + (-1.10726)^2 (148.9704) \right. \\ \left. + (-1.60936)^2 (41.9722) + (-3.20993)^2 (0.7060) + (-1.88208)^2 (1.5620) \right. \\ \left. + 2(6.43775)(-1.10726)(-.28230) + 2(6.43775)(-1.60936)(2.1354) \right. \\ \left. + 2(6.43775)(-3.20993)(0.1666) + 2(6.43775)(-1.88208)(0.3342) \right. \\ \left. + 2(-1.10726)(-1.60936)(-.764048) + 2(-1.10726)(-3.20993)(-.100956) \right. \\ \left. + 2(-1.10726)(-1.88208)(-.149632) + 2(-1.60936)(-3.20993)(5.0599) \right. \\ \left. + 2(-1.60936)(-1.88208)(7.9017) + 2(-3.20993)(-1.88208)(0.9812) \right]$$

$$S_{\hat{Y}_2 - \hat{Y}_1}^2 = .006508 [.094675]$$

$$S_{\hat{Y}_2 - \hat{Y}_1}^2 = .000616$$

The standard deviation is then $\sqrt{.000616}$ which is equal to 0.02482 and the expected change in drag coefficient with associated 95-percent confidence limits is $-.1686 \pm 1.96 (0.02482)$ or $-.1686 \pm 0.04869$. This is shown in Figure 13 as the squares and circle along with the expected change in drag coefficient and 95-percent confidence limits for any change in nominal diameter between two feet and one hundred feet.

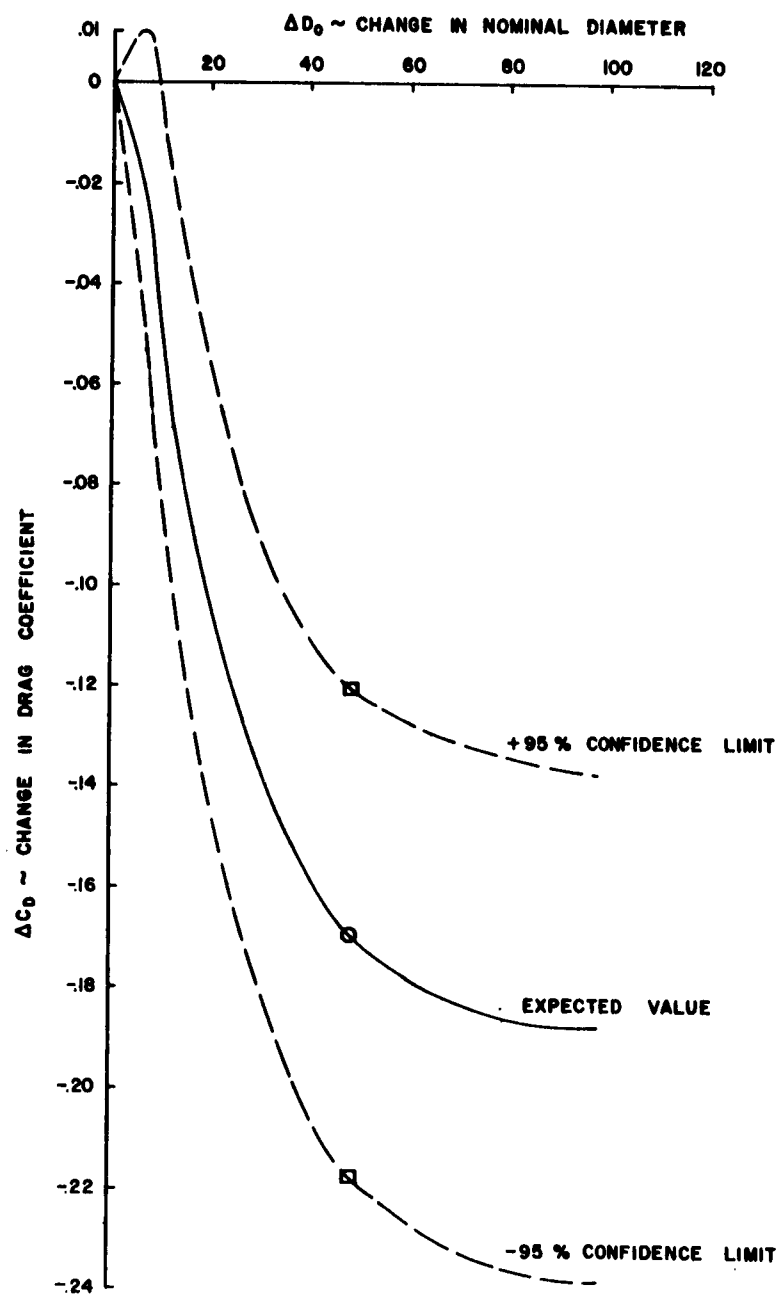


Figure 13. Incremental Change in Drag Coefficient Due to Scaling

SECTION III

CONCLUSIONS

1. The development of scaling equations by statistical techniques is feasible.
2. Scaling equations were developed for drag coefficient for the Circular Flat and Extended Skirt parachute types which apparently yield reasonable predictions although the Extended Skirt scaling equation is rather limited in range of application.
3. The distribution of the observed data is probably the most significant single factor influencing the development of accurate scaling equations.
4. A high multiple correlation (R^2) for the regression model cannot be relied upon as a satisfactory condition for permitting the development of accurate scaling equations.
5. Variables, such as suspension line length, porosity, etc., which are known to affect parachute performance, did not necessarily appear statistically significant for the regression analysis due to the poor distribution of available data.
6. The collection of data from many varied sources led to less accurate equations than data gathered from one set of tests.

SECTION IV

RECOMMENDATIONS

As noted previously, many areas in this investigation have insufficient or questionable data. The developed scaling equations, therefore, can be considered only as preliminary media in the development of basic equations. Scrutiny of the developed equations and data distribution charts and tables in Section II and the data summary tables in Appendix II reveals the lack of data in several areas. There is practically no usable information defining any parachute's stability; only the Solid Flat Circular and Extended Skirt types of parachutes have usable peak opening shock and filling time data. The Conical Ribbon parachute data are virtually nonexistent. Since all types of parachutes need additional information to some degree, the following recommendations are made.

1. Future testing should be directed toward filling the existing voids in the available data. The less the variation of parameters other than the scaling variables, the more desirable this testing will be.

2. Initial concentration toward defining the scaling equations for only one type of parachute would be desirable, since it is felt that the scaling equations for all common types of parachutes will be similar.

3. All future testing should be conducted according to a specific statistical design of experiment in order to yield maximum use of the resultant test data.

4. A consistent method should be established for the definition of parachute stability. At present, it is impossible to correlate the period and the amplitude of parachute oscillation (also gliding and coning) under free-fall conditions with wind tunnel tests which define pitching moment at angle of attack. Therefore, until this problem is solved, pitching moment at angle of attack will probably mean very little except in the general sense that the parachute is stable or unstable over a given range. For an analysis of parachute scaling effects for stability, this consistent definition is almost mandatory.

Looking further into the future, the following recommendations are made:

1. The range of applicability of the scaling equations should be extended to include a much broader operating regime (altitude and velocity).

2. The effects of variables other than scaling variables—for example, ribbon spacing—should be investigated so that a scale model test can be used to evaluate parachute performance without requiring unnecessarily complicated fabrication procedures.

3. The effects of different types of testing—such as free-fall, wind tunnel, and rocket sled—should be evaluated.

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This bibliography is a comprehensive listing of the references pertinent to the subject of this report. All available literature relating to the parachute research program was reviewed before the preparation of the bibliography.

The references have been separated into two sections: Part I lists the references which provided data used in the program analysis, and Part II presents the references which did not offer usable data.

The items are arranged either alphabetically by author or sequentially by reference number when anonymous. As many of the publications are in the general or special collections of ASTIA, they are identified accordingly.

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APPENDIX I

REGRESSION ANALYSIS AND COMPUTER PROGRAM

A. General Least Squares Multiple Regression

A general least squares multiple regression analysis with k fixed variates postulates that some variable or characteristic, Y , is related to or depends on certain other variables or characteristics, $X_1, X_2, \dots, X_k$, by means of the general linear relation (regression model)

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k,$$

where $X_i (i=1, 2, \dots, k)$ may take any functional form of the independent variable; e.g., natural log, inverse, etc. Obtaining estimates of the regression coefficients by the method of least squares consists of obtaining an expression

$$\hat{Y} = d_0 + b_1 X_1 + b_2 X_2 + \dots + b_k X_k$$

such that the error sum of squares, i.e., the sum of the deviations squared of the observed Y from the predicted or fitted $\hat{Y}$, $SSE = \sum_{j=1}^n (Y_j - \hat{Y}_j)^2$, be a minimum, where there are n observations or data points ($n \geq k+1$).

In order that tests of hypotheses involving the β 's and the overall regression may be made and confidence intervals for the β 's and predicted Y values computed, the following assumptions concerning the measured variables must be made:

(i) the X 's are measured with negligible error and, therefore, are regarded as fixed constants which may be chosen at the discretion of the experimenter;

(ii) for a given set of X 's, the possible Y values are normally and independently distributed with mean, $\mu_Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k$, and variance, σ_E^2 ;

(iii) the variance of Y for all sets of X 's is identically σ_E^2

It must be emphasized that this postulated relationship between Y and the X 's is not necessarily a causal one, but is rather a relationship which may be used for predictive or analytic purposes.

B. The Method of Least Squares

To minimize the error sum of squares, the following procedure is employed. Write

$$SSE = \sum (Y - \hat{Y})^2 = \sum (Y - d_0 - b_1 X_1 - b_2 X_2 - \dots - b_k X_k)^2,$$

where the index of summation has been omitted for simplicity of notation. Partially differentiate SSE with respect to each of the parameters to be estimated and equate these partial derivatives to zero:

$$\begin{aligned}\frac{\partial SSE}{\partial d_0} &= 2 \sum (Y - d_0 - b_1 X_1 - b_2 X_2 - \dots - b_k X_k)(-1) = 0 \\ \frac{\partial SSE}{\partial b_1} &= 2 \sum (Y - d_0 - b_1 X_1 - b_2 X_2 - \dots - b_k X_k)(-X_1) = 0 \\ \frac{\partial SSE}{\partial b_2} &= 2 \sum (Y - d_0 - b_1 X_1 - b_2 X_2 - \dots - b_k X_k)(-X_2) = 0 \\ &\vdots \\ \frac{\partial SSE}{\partial b_k} &= 2 \sum (Y - d_0 - b_1 X_1 - b_2 X_2 - \dots - b_k X_k)(-X_k) = 0\end{aligned}$$

Multiply the first equation by 1/2, perform the indicated summations term by term, and solve for d_0 :

$$d_0 = \bar{Y} - b_1 \bar{X}_1 - b_2 \bar{X}_2 - \dots - b_k \bar{X}_k ,$$

where $\bar{Y}, \bar{X}_1, \bar{X}_2, \dots, \bar{X}_k$ are the arithmetic means. Multiply the remaining equations by 1/2, perform the indicated summations term by term, and transfer the first sum in each equation to the right side:

$$\begin{aligned}d_0 \sum X_1 + b_1 \sum X_1^2 + b_2 \sum X_1 X_2 + \dots + b_k \sum X_1 X_k &= \sum X_1 Y \\ d_0 \sum X_2 + b_1 \sum X_2 X_1 + b_2 \sum X_2^2 + \dots + b_k \sum X_2 X_k &= \sum X_2 Y \\ &\vdots \\ d_0 \sum X_k + b_1 \sum X_k X_1 + b_2 \sum X_k X_2 + \dots + b_k \sum X_k^2 &= \sum X_k Y\end{aligned}$$

Substitute the expression for d_0 in each of these equations and group similar terms:

$$\begin{aligned}b_1(\sum X_1^2 - \bar{X}_1 \sum X_1) + b_2(\sum X_1 X_2 - \bar{X}_2 \sum X_1) + \dots + b_k(\sum X_1 X_k - \bar{X}_k \sum X_1) &= (\sum X_1 Y - \bar{Y} \sum X_1) \\ b_1(\sum X_2 X_1 - \bar{X}_1 \sum X_2) + b_2(\sum X_2^2 - \bar{X}_2 \sum X_2) + \dots + b_k(\sum X_2 X_k - \bar{X}_k \sum X_2) &= (\sum X_2 Y - \bar{Y} \sum X_2) \\ &\vdots \\ b_1(\sum X_k X_1 - \bar{X}_1 \sum X_k) + b_2(\sum X_k X_2 - \bar{X}_2 \sum X_k) + \dots + b_k(\sum X_k^2 - \bar{X}_k \sum X_k) &= (\sum X_k Y - \bar{Y} \sum X_k)\end{aligned}$$

These equations thusly obtained by the method of least squares are commonly known as the normal equations.

Particular note should be made of the quantities in parentheses. These quantities are the corrected sums of squares or sums of products, i.e.,

$$(\sum x_i x_j - \bar{x}_i \sum x_j) = (\sum x_i x_j - \frac{\sum x_i \sum x_j}{n}) = \sum (x_i - \bar{x}_i)(x_j - \bar{x}_j) = (\sum x_j x_i - \bar{x}_j \sum x_i),$$

(i, j = 1, 2, \dots, k)

and

$$(\sum x_i y - \bar{y} \sum x_i) = (\sum x_i y - \frac{\sum y \sum x_i}{n}) = \sum (x_i - \bar{x})(y - \bar{y}), (i = 1, 2, \dots, k).$$

Denoting the corrected sums of squares and sums of products of the X 's and Y 's by a_{ij} and a_{iy} , respectively, the normal equations take the form

$$\begin{aligned} a_{11} b_1 + a_{12} b_2 + \dots + a_{1k} b_k &= a_{1y} \\ a_{21} b_1 + a_{22} b_2 + \dots + a_{2k} b_k &= a_{2y} \\ &\vdots \\ a_{k1} b_1 + a_{k2} b_2 + \dots + a_{kk} b_k &= a_{ky} \end{aligned}$$

where, as indicated above, $a_{ij} = a_{ji}$, (i, j = 1, 2, \dots, k).

To obtain the least squares estimates $b_1, b_2, \dots, b_k$ of the regression coefficients $\beta_1, \beta_2, \dots, \beta_k$, it is required to solve the system of normal equations for $b_1, b_2, \dots, b_k$, and then substitute these values into the expression for d_0 to obtain the complete prediction equation $\hat{Y}$.

C. Estimation of the Regression Coefficients and Tests of Significance

Expressing the normal equations in matrix notation where

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1k} \\ a_{21} & a_{22} & \dots & a_{2k} \\ \vdots & \vdots & & \vdots \\ a_{k1} & a_{k2} & \dots & a_{kk} \end{bmatrix}, \quad \underline{b} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_k \end{bmatrix}, \quad \text{and} \quad \underline{G} = \begin{bmatrix} a_{1y} \\ a_{2y} \\ \vdots \\ a_{ky} \end{bmatrix}$$

yields $A \underline{b} = \underline{G}$.

Multiplication by A^{-1} produces

$$\begin{aligned} A^{-1} A \underline{b} &= A^{-1} \underline{G} \\ I \underline{b} &= A^{-1} \underline{G} \\ \underline{b} &= A^{-1} \underline{G}, \end{aligned}$$

where A^{-1} is the inverse of the A matrix and I denotes the identity matrix.

Denoting the elements of the inverse of the A matrix as

$$C = A^{-1} = \begin{bmatrix} C_{11} & C_{12} & \cdots & C_{1k} \\ C_{21} & C_{22} & \cdots & C_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ C_{k1} & C_{k2} & \cdots & C_{kk} \end{bmatrix},$$

the estimates of the regression coefficients are found by:

$$\begin{aligned} b_1 &= C_{11} a_{1y} + C_{12} a_{2y} + \cdots + C_{1k} a_{ky} \\ b_2 &= C_{21} a_{1y} + C_{22} a_{2y} + \cdots + C_{2k} a_{ky} \\ &\vdots \\ b_k &= C_{k1} a_{1y} + C_{k2} a_{2y} + \cdots + C_{kk} a_{ky} \end{aligned}$$

and then

$$d_0 = \bar{Y} - b_1 \bar{X}_1 - b_2 \bar{X}_2 - \cdots - b_k \bar{X}_k.$$

It can be demonstrated¹ that

$$\begin{aligned} SSE &= \sum_{j=1}^n (Y_j - \hat{Y}_j)^2 = \sum_{j=1}^n \left[Y_j - \bar{Y} - \sum_{i=1}^k b_i (X_{ij} - \bar{X}_i) \right]^2 \\ &= \sum_{j=1}^n (Y_j - \bar{Y})^2 - \sum_{i=1}^k b_i \sum_{j=1}^n (X_{ij} - \bar{X}_i)(X_j - \bar{Y}) = \sum_{j=1}^n (Y_j - \bar{Y})^2 - \sum_{i=1}^k b_i a_{iy} \end{aligned}$$

which is another way of stating that the corrected total sum of squares for the dependent variable, Y , can be partitioned into a sum of squares attributable to the regression of Y on the X 's and a sum of squares not explained by the regression and which is presumably due to the experimental error, i. e.,

$$SST = SSR + SSE.$$

It is, therefore, possible, under the assumptions of (i), (ii), and (iii), to set up the following analysis of variance table to test the hypothesis pertaining to the significance of the overall regression.

1. Anderson, R. L., and Bancroft, T. A., Statistical Theory in Research, McGraw-Hill Book Company, Inc., 1952, p. 171.

ANALYSIS OF VARIANCE TABLE

Source of Variation	d.f.	S.S.	M.S.	F
Regression	k	$\sum_i b_i a_{iy} = SSR$	$\sum_i b_i a_{iy} / (k) = S_R^2$	S_R^2 / S_E^2
Error	n-k-1	$\sum_j (Y_j - \hat{Y}_j)^2 = SSE$	$\sum_j (Y_j - \hat{Y}_j)^2 / (n-k-1) = S_E^2$	
Total	n	$\sum_j (Y_j - \bar{Y})^2 = SST$		

The computed F ratio may be compared with the tabular F value for (k) and $(n-k-1)$ degrees of freedom (at the desired level of significance) to test the null hypothesis that all the β_i 's ($i=1,2,\dots,k$) are equal to zero.

Another useful statistic to be computed is the square of the multiple correlation coefficient,

$$R^2 = SSR / SST,$$

which indicates what proportion of the variation in the Y 's, expressed as a sum of squares of deviations from the mean, is explained by the regression of Y on the X 's.

Under the assumption of normality, it follows¹ that each of the b_i 's ($i=1,2,\dots,k$) is normally distributed with mean, β_i , and variance, $C_{ii} \sigma_E^2$, where C_{ii} is the i^{th} diagonal element of the inverse of matrix A . Therefore, to test the null hypothesis that one of the individual regression coefficients is zero, $H_0 : \beta_i = 0$, ($i=1,2,\dots,k$), compute

$$t = b_i / \sqrt{C_{ii} S_E^2}$$

and compare with the tabular t value for $(n-k-1)$ degrees of freedom (at the desired level of significance). To test the null hypothesis that a particular β_i , ($i=1,2,\dots,k$) is equal to some specified value, $H_0 : \beta_i = \beta$, compute

$$t = (b_i - \beta) / \sqrt{C_{ii} S_E^2}$$

and again compare with the tabular t value for $(n-k-1)$ degrees of freedom (at the desired level of significance). One other possible test of hypothesis

1. Anderson, R. L., and Bancroft, T. A., Statistical Theory in Research McGraw-Hill Book Company, Inc., 1952, p. 177.

which may be of interest is the null hypothesis that two of the regression coefficients are equal, $H_0: \beta_i = \beta_j (i, j = 1, 2, \dots, k; i \neq j)$. Testing this hypothesis requires the computation of

$$t = (b_i - b_j) / \sqrt{(C_{ii} + C_{jj} - 2C_{ij}) S_E^2}$$

to also be compared with the tabular t value for $(n-k-1)$ degrees of freedom (at the desired level of significance).

The β_i 's are known as partial regression coefficients since β_i indicates the amount Y would vary per unit change in X_i if the remaining X 's were held fixed and b_i is the sample estimate of this change. It is impossible to determine the relative importance of the various independent variables as they contribute to (or explain) the variation of the dependent variable simply by examination of the magnitudes of the b_i 's, since the contribution to the overall regression depends on the product of b_i times X_i . However, the standard partial regression coefficients

$$b_i' = b_i \sqrt{\sum_j (X_{ij} - \bar{X}_i)^2 / \sum_j (Y_j - \bar{Y})^2}, (i = 1, 2, \dots, k)$$

offer a proper comparison when ranked in descending order of their absolute values, since they are all expressed in the same units.

The upper and lower confidence bounds for $\beta_i (i = 1, 2, \dots, k)$ would be computed by

$$b_i \pm t_{(n-k-1)} \alpha \sqrt{C_{ii} S_E^2}$$

and similarly for the difference between two regression coefficients,

$$\beta_i - \beta_j, (i, j = 1, 2, \dots, k; i \neq j), (b_i - b_j) \pm t_{(n-k-1)} \alpha \sqrt{(C_{ii} + C_{jj} - 2C_{ij}) S_E^2},$$

where $t_{(n-k-1)} \alpha$ is the tabular t value for $(n-k-1)$ degrees of freedom (at the α level of significance).

To place confidence bounds around the average $Y, \hat{Y}_0$, for a specified set of X values, $X_{01}, X_{02}, \dots, X_{0k}$, the quantities

$$\hat{Y}_0 \pm t_{(n-k-1)} \alpha \sqrt{S_E^2 \left[\frac{1}{n} + \sum_{i,j=1}^k C_{ij} (X_{0i} - \bar{X}_i)(X_{0j} - \bar{X}_j) \right]}$$

are computed, where n is the number of observations or data points included in the regression study, $\hat{Y}_0 = d_0 + \sum_{i=1}^k b_i X_{0i}$, and the other quantities are defined as above. To compute confidence bounds for an individual predicted

Y value given a specified set of X_i 's, an additional factor of 1 is added within the square brackets of the above expression to give

$$\hat{Y}_0 \pm t_{(n-k-1)} \alpha \sqrt{s_E^2 \left[1 + \frac{1}{n} + \sum_{i,j=1}^k c_{ij} (x_{0i} - \bar{x}_i)(x_{0j} - \bar{x}_j) \right]}$$

The interpretation concerning the "desired level of significance," α , to be associated with a test of hypothesis or with a confidence interval is the following: If the null hypothesis is rejected at the α level of significance (α is commonly taken to be .05 or .01, but may be any value, depending on the problem at hand and the use which is to be made of the results), this says that a value of the test statistic (computed from the sample data) at least as large as the critical (tabular) value of the test statistic would be expected to occur by chance alone approximately $100 \cdot \alpha$ times out of each 100 repeated samples, assuming the null hypothesis were true. This is, in effect, stating that the null hypothesis would be incorrectly rejected $100 \cdot \alpha$ percent of the time. The same basic idea holds with respect to confidence intervals. An $100(1 - \alpha)$ per cent confidence interval (computed from the sample data) for a given parameter is interpreted to mean that, if repeated samples were taken and the corresponding confidence intervals computed, approximately $100(1 - \alpha)$ times out of each 100 repeated samples, the range of the confidence interval would encompass the parameter.

By application of the above computational techniques, it is possible to assess the overall significance of a regression model, rank the independent variables according to their relative contribution to the total regression, test the individual terms in the model for significance, and on these bases determine if the model should be reduced. After a model involving only significant terms has been obtained, confidence intervals for the regression coefficients and predicted Y values may be computed.

D. Computer Program for Multiple Regression Analysis

An IBM 704 FORTRAN II program, identified as TV-MRCA MULTIPLE REGRESSION-COMPREHENSIVE ANALYSIS, was obtained from the SHARE Library in Building 57, Area B, Wright-Patterson Air Force Base, as the most applicable computer program available. Various modifications and additions to this program were deemed necessary.

Modifications were required to render this program compatible with IBM 7090 FORTRAN II and the accompanying procedures in effect at the ASD computer installation in Building 57, Area B, Wright-Patterson Air Force Base.

Originally, this routine provided the least squares fit of a multiple regression model containing a maximum of 23 independent variables for a maximum of 500 observations (data points). It was limited to the consideration of one dependent variable per set of data. The output included the

estimates of the regression coefficients and their corresponding standard deviations; the Total, Regression, and Error sums of squares; the averages of all the variables; and predictions and residual errors for each observation used in the study.

Two optional features were also available. A list of synthetic data points (containing no value for the dependent variable) could be added to the input data for which the predicted values and standard deviations of the dependent variable would be computed. Any number or combination of the independent variables could be excluded from the regression model and the analysis rerun on this basis producing the same output, excepting that the computation of the predicted values and residual errors for the observations would be deleted.

The above computer program was rewritten in the form of a subroutine and its capacity increased to provide for the consideration of a regression model containing a maximum of 49 independent variables. Modifications and allowances were made so that the program now contains the following features and supplements to its output.

Since the regression program is now in the form of a subroutine, a main program can be written to read in the input data, perform any desired transformations on the variables, store them on tape, and call the regression routine. Any of the variables could then be designated the dependent variable and a least squares multiple regression analysis be run considering any number (less than 50) or combination of the other variables as dependent variables. Thus, the number of dependent and independent variables per set of data as well as the rerun option has been greatly extended. The output of the program now includes the correlation coefficients between all pairs of the independent variables, the correlation coefficients between each independent variable and the dependent variable, the A matrix (corrected sums of squares and sums of products), the C matrix (the inverse of the A matrix), an Analysis of Variance table, the actual and predicted values of the $\underline{G}$ vector (the corrected sums of products of the X 's and the Y), the t tests for testing $H_0: \beta_i = 0, (i=1, 2, \dots, k)$, the standard partial regression coefficients, and as before, the averages of the X 's and the Y , the estimated regression coefficients and their corresponding standard deviations, and the predicted value and residual error for each observation (data point). Values of the independent variables may be included in the input data for which predicted values of the dependent variable and the corresponding standard deviations will be computed.

APPENDIX II

LITERATURE REVIEW AND DATA PRESENTATION

A. Literature Review

As the statistical development of textile parachute similarity laws was based on the design and performance data of varying sizes of parachutes, all pertinent literature was reviewed to gather the maximum amount of useful information. The review was restricted to the following types of parachutes operating at indicated airspeeds up to 300 knots and altitudes up to 20,000 feet: (1) Circular Flat Solid cloth type parachute canopy, (2) Extended Skirt Solid cloth type parachute canopy, (3) Ringslot type parachute canopy, (4) Ribbon (Flat Circular and Conical) type parachute canopy, and (5) Guide Surface (ribless) type parachute canopy. Furthermore, the collection of data was limited to the dependent variables most indicative of parachute performance—filling time, opening shock, drag coefficient, and stability—and those independent variables considered functionally related to the former. The independent variables chosen are as follows: S_0 , l_s/D_0 , N_0/D_0 , l_r/D_0 , S_v/S_0 , λ , W/S_0 , V , q , Re , M , and Fr .

Only about a third of the more than 150 sources reviewed provided valid and useful information. Many bore deceptive titles since they contained insignificant data. Some had incomplete or unreliable data; for example, one source stated values of 0.4 and 0.5 for the drag coefficient for Extended Skirt parachutes. Others could also not be used since either most of the independent variables were unknown or none of the dependent variables were given. As the stability data in these sources is primarily of an observational nature and a statistical analysis requires definitive experimental information, no useful data of this type could be extracted. All sources had to be considered judiciously. Although similar conditions prevailed in some sources, their data varied appreciably.

Some of the data and terms required modification to suit the purposes of the statistical development. In some cases where atmospheric conditions were not given, reasonable values were assumed to calculate dynamic pressure, Reynolds number, Mach number, etc. The canopy loading definition was changed from gross weight/drag area to gross weight/surface area to provide a term more appropriate to the statistical analysis.

B. Data Presentation

All data are summarized in Tables 6 through 10 for reference; these data may lead to additional evaluations in future studies. These data are pertinent to five types of parachutes operating at indicated airspeeds up to 300 knots and altitudes up to 20,000 feet.

Table 6. a
Summary of Data - Circular Flat Parachute

C_D	t_f (sec)	F_0 (lbs)	S_0 (ft ²)	L_s/D_0	H_p/D_0 (ft)	L_r/D_0	S_v/S_0	λ at $\Delta P = 1/2 \rho H_0^2$ (ft ³ /ft ² min.)	W/S_0 (psf)	V (ft/sec)	q (psf)	$Re \times 10^{-6}$	M	Pr	Type of Test	Ref.										
1.558			108.50	1.020	1.362		.01	98.0	.188	10.4	.121	.776	.0094	.535	Free Fall	28										
1.368									.188	11.1	.137	.828	.0100	.571												
1.445									.188	10.8	.130	.805	.0097	.555												
1.036									.326	16.8	.315	1.250	.0151	.864												
1.115									.326	16.2	.293	1.210	.0146	.833												
.934									.326	17.7	.349	1.320	.0154	.910												
1.029									.741	25.4	.719	1.890	.0229	1.310												
.925									.741	26.8	.801	1.990	.0241	1.380												
1.022									.741	25.5	.725	1.900	.0230	1.310												
1.003									1.862	39.8	1.851	2.970	.0359	2.050												
.957									1.889	41.1	1.976	3.060	.0370	2.110												
.979									.188	40.6	1.929	3.030	.0366	2.090												
1.136									.188	12.1	.146	.902	.0109	.622												
1.215									.188	11.7	.155	.873	.0105	.566												
1.326									.326	11.2	.142	.835	.0101	.576												
1.249									.326	15.2	.261	1.130	.0137	.781												
1.318									.326	14.8	.248	1.100	.0133	.761												
1.233									.741	15.1	.265	1.140	.0138	.787												
.913									.741	26.8	.812	1.990	.0241	1.380												
.886									.741	27.2	.836	2.030	.0245	1.390												
1.025									1.650	25.3	.723	1.840	.0228	1.300												
.974									1.650	38.5	1.697	2.870	.0347	1.980												
.492									1.650	54.2	3.364	4.040	.0488	2.790												
1.200			12.57	1.100	6.00	0	0	120.0	.636	16.5	.580	.473	.0238	2.337	Infinite Mass	28										
1.200									.636																	
1.190									.636																	
1.190									.636																	
1.170									.636																	
1.160									.636																	
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1.070									.636																	
1.050									.636																	
1.030									.636																	
.990									.636																	
1.160							.010	120.0	.766	27.5	.660	.517	.0247	2.422												
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1.200			.010	120.0	.636	16.5	.580	.473		.0238	2.337	Infinite Mass	28													
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.990					.636																					
1.160			.010	120.0	.766	27.5	.660	.517	.0247	2.422																
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.990					.766																					
.780			.25		120.0								.766	27.5	.660	.517	.0247	2.422								
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Table 6.b
Summary of Data - Circular Flat Parachute

C_D	t_T (sec)	F_0 (lbs)	S_0 (ft ²)	L_0/D_0	H_0/D_0 (ft)	L_T/D_0	S_V/S_0	$\Delta P = 1/2 \rho V^2$ (ft ³ /ft ² min.)	W/S_0 (lb/ft ²)	V (ft/sec)	q (lb/ft ²)	$Re \times 10^{-6}$	M	Fr	Type of Test	Ref.	
1.110			12.566	1.000	2.00	0	0	333.0	13.210	100.0	11.900	2.540	.0900	8.826		14	
1.120								333.0	19.150	120.0	17.100	3.050	.1070	10.591			
1.180								343.0	5.504	60.0	4.300	1.520	.0540	5.296			
1.170								343.0	13.920	100.0	11.900	2.540	.0900	8.826			
1.100								366.0	4.730	60.0	4.300	1.520	.0540	5.296			
1.050								366.0	12.500	100.0	11.900	2.540	.0900	8.826			
1.040								366.0	17.780	120.0	17.100	3.050	.1070	10.591			
1.100								403.0	4.730	60.0	4.300	1.520	.0540	5.296			
1.060								403.0	12.610	100.0	11.900	2.540	.0900	8.826			
1.040								403.0	17.780	120.0	17.100	3.050	.1070	10.591			
1.150								420.0	4.945	60.0	4.300	1.520	.0540	5.296			
1.070								420.0	12.730	100.0	11.900	2.540	.0900	8.826			
1.070								420.0	18.300	120.0	17.100	3.050	.1070	10.591			
1.070								426.0	4.601	60.0	4.300	1.520	.0540	5.296			
1.020								426.0	12.140	100.0	11.900	2.540	.0900	8.826			
.980			2.640	1.11	8.70	0	.0113	91.6	14.500	151.0	25.000	1.570	.1320	19.670		22	
.620			2.600	1.13	8.70			.0115	171.5	15.500	151.0	25.000	1.560	.1320			19.740
.750			2.410	1.13	9.15			.0083	108.0	3.750	67.5	5.000	.604	.0580			8.980
.730			2.410	1.13	9.15			.0083	108.0	18.25	151.0	25.000	1.502	.1320			20.100
.770			2.410	1.13	9.15			.0083	108.0	46.200	233.8	60.000	2.325	.2040			31.100
.920						0	.09	2.190	53.1		.968		.0476	4.683	Infinite Mass	24	
.910								2.166	53.1	2.380	.968			4.683			
.880								2.094	53.1		.968			4.683			
.860								2.047	53.1		.968			4.683			
.910								.573									
.910								.573									
.910								.573									
.910								.573									
.900								.567									
.890								.561									
.880								.554									
.870								.957									
.870								.957									
.860								.946									
.850								.935									
.850								.935									
.840								.924									
.830								.913									
.840								1.991									
.840								1.991									
.840								1.991									
.830								1.967									
.820								1.943									
.810								1.920									
.790			12.57	1.100	6.00	0	.1200	1.872								26	
.840			.529														
.850			.530														
.830			.517														
.820			.517														
.810			.510														
.800			.504														
.790			.490														
.820			.918														
.820			.918														
.810			.407														
.800			.896														
.790			.884														
.780			.874														
.760			.851														
.940			2.352														
.940			2.294														
1.110			.678														
1.130			.678														
1.120			.672														
1.110			.666														
1.100			.660														
1.070			.642														
1.040			.624														
1.070			1.134														
1.070			1.134														

Table 6. c
Summary of Data - Circular Flat Parachute

C_D	t_r (sec)	F_0 (lbf)	S_0 (ft ²)	l_a/u_0	N_1/u_0 (/ft)	l_r/u_0	S_v/S_0	$\Delta P = 1/2 \rho u_0^2$ (ft lbf/ft ² min.)	α/β (per)	V (ft/sec)	Q (lbf)	$h \times 10^{-3}$	M	K_F	Type of Test	Ref.	
1.060									.921	25.0	1.000	.055		3.086			
1.050									.919	25.0	1.000	.055		3.086			
1.020									1.001	25.0	1.000	.055	.0314	3.086			
1.000									1.000	25.0	1.000	.055		3.086			
.920									.917	25.0	1.000	.055		3.086			
.990							.0400		.985								
.990									.985								
.980									.975								
.970									.965	22.4	.975	.075	.0808	4.558			
.960									.965								
.960									.965								
.920									.917								
1.050									.915								
1.040									.910								
1.030			12.57	1.100	0.0			120.0	.905							26	
1.020									.900	25.0	.900	.080	.0292	4.537			
.990									.895								
.960									.890								
.910									.885								
.990							.0000		.880								
.990									.875								
.970									.870	25.0	.861	.098	.0320	4.539			
.960									.865								
.960									.865								
.910									.860								
.910									.860								
.930									.855								
.920									.850								
.850			1.450		20.60				.845	111.7	12.550	.600	.1000	16.897			
.830			1.428		20.70				.840	111.7	12.550	.600	.1000	16.898			
.850			1.438		20.60				.830	111.7	12.550	.600	.1000	16.923		12	
.904			1.450		20.60				.825	111.7	12.550	.600	.1000	16.897			
.989			1.421		20.70				.820	111.7	12.550	.600	.1000	16.974			
1.490									.817	6.507	8.000	1.520	.0540	5.296			
1.430									.817	17.017	10.000	1.500	.0500	8.826			
1.420									.817	24.080	17.100	1.050	.1070	10.591			
1.510									.817	6.577	6.000	1.520	.0540	5.296			
1.410									.817	16.775	11.000	1.500	.0530	8.826			
1.420									.817	24.080	17.100	1.050	.1070	10.591			
1.510									.817	6.577	6.000	1.520	.0540	5.296			
1.380			12.566		2.0				.817	16.577	10.000	1.500	.0500	8.826			
1.350									.817	21.085	12.000	1.050	.1070	10.591			
1.370									.817	5.871	6.000	1.520	.0540	5.296			
1.260									.817	19.784	11.000	1.500	.0500	8.826		14	
1.240									.817	21.209	12.000	1.050	.1070	10.591			
1.280									.817	5.506	6.000	1.520	.0540	5.296			
1.210									.817	11.700	10.000	1.500	.0500	8.826			
1.170									.817	5.506	6.000	1.520	.0540	5.296			
.610			2.690	1.11				.0014	.817	1.050	6.75	5.000	.070	.0500	8.790		
.720			2.410	1.11				.0008	.817	3.629	6.75	5.000	.068	.0580	8.980		
.615			2.600	1.11				.0017	.817	1.080	6.75	5.000	.068	.0580	8.830		
.715			2.410	1.11				.0008	.817	17.000	15.10	2.000	1.500	.1370	20.100		22
.860			2.690	1.11				.0011	.817	21.000	21.000	2.000	1.500	.1370	20.200		
.760			2.410	1.11				.0010	.817	9.000	21.000	2.000	1.500	.1370	20.100		
.700			2.600	1.11				.0012	.817	42.000	21.000	2.000	1.500	.1370	20.500		
.641			.614	1.15	9.08			.000	.817	2.721	42.00	2.000	1.500	.1370	20.500		
.709			.692	1.15	11.13			.000	.817	1.000	34.3	1.000	1.000	.0907	6.983		24
.706			.693	1.15	11.00			.000	.817	1.276	34.3	1.000	1.000	.0907	8.177		
.726			.616	1.15	10.00			.000	.817	1.007	34.3	1.000	1.000	.0907	10.070		
.828			17.071.5	.90				.000	.817	2.000	21.000	2.000	1.500	.1370	20.500		
.802			17.071.5	.90				.000	.817	2.000	21.000	2.000	1.500	.1370	20.500		
.897			17.071.5	.90				.000	.817	2.000	21.000	2.000	1.500	.1370	20.500		
.906			17.071.5	.90				.000	.817	2.000	21.000	2.000	1.500	.1370	20.500		
.838								130.0	.817	2.000	21.000	2.000	1.500	.1370	20.500		
.621									.817	2.000	21.000	2.000	1.500	.1370	20.500		
.810									.817	2.000	21.000	2.000	1.500	.1370	20.500		
.801									.817	2.000	21.000	2.000	1.500	.1370	20.500		
.670									.817	2.000	21.000	2.000	1.500	.1370	20.500		
.699									.817	2.000	21.000	2.000	1.500	.1370	20.500		

Table 6.d
Summary of Data - Circular Flat Parachute

C _D	t _r (sec)	V ₀ (ft/s)	S ₀ (ft ²)	1 ₃ /D ₀	N _r /D ₀ (/ft)	1 _r /D ₀	S _v /S ₀	at ΔP=1/2 ρV ² (ft ³ /ft ² min.)	w/S ₀ (ft/sec)	V (ft/sec)	q (lb/ft ²)	H ₀ x 10 ⁻¹⁰	M	Pr	Type of Test	Ref.						
0.850			7853.98	.750	1.20		.005	130.0	.421	20.7	.496	12.910	.0189	.262		13						
0.737									.389	21.4	.527	13.340	.0192	.377								
0.923									.478	21.5	.518	13.080	.0194	.370								
0.816										21.0	.508	13.070	.0189	.370								
0.961										19.4	.431	12.010	.0174	.342								
0.710									.517	22.6	.584	14.030	.0203	.398								
1.190										17.7	.448	10.950	.0159	.312								
0.970										19.3	.427	11.970	.0173	.340								
1.140										17.8	.464	11.050	.0160	.334								
0.752										.661	27.8	.879	17.112	.0250			.490					
0.899			3216.99	1.810	1.00	.001	125.0	.478	21.4	.532	8.574	.0192	.472									
0.974								.653	24.0	.671	9.623	.0215	.529									
1.080								.503	20.0	.464	8.007	.0179	.441									
1.090								.503	20.0	.463	7.997	.0179	.441									
0.675								.653	28.9	.967	11.550	.0259	.637									
0.626								.684	31.0	1.033	12.220	.0279	.683									
0.405									.932	45.0	2.303	17.730	.0405			.992						
0.488									.932	41.0	1.912	16.160	.0369			.904						
0.433									.935	43.5	2.152	17.140	.0393			.959						
-0.651								.708	30.9	1.068	12.190	.0278	.681									
0.706			7853.98	.950	1.20	.005	130.0	.906	34.1	1.284	20.510	.0308	.601									
0.780								.887	32.1	1.138	19.300	.0290	.566									
0.756								.887	32.6	1.174	19.600	.0294	.574									
0.683								.887	34.3	1.279	20.630	.0309	.605									
0.730									33.2	1.217	19.960	.0300	.585									
0.692									34.1	1.284	20.510	.0308	.601									
0.811								.883	31.5	1.096	18.940	.0284	.555									
0.594									36.8	1.496	22.130	.0332	.648									
0.794									31.7	1.118	19.170	.0286	.559									
0.795									31.8	1.117	19.120	.0287	.560									
0.836			615.0	.750		.000	100.0	.950	19.2	.418	3.330	.0172	.650	Free Fall	29							
1.200									17.6	.342	3.050	.0158	.596									
0.680									21.6	.515	3.740	.0194	.731									
0.896									18.8	.390	3.260	.0169	.637									
0.507									25.0	.690	4.340	.0224	.847									
1.200									16.2	.290	2.810	.0145	.550									
0.522									24.6	.670	4.260	.0221	.834									
0.790									20.0	.442	3.470	.0180	.677									
0.660									19.5	.510	3.380	.0175	.660									
0.697									20.3	.494	3.610	.0223	.677									
0.948				.816	1.00	.003	120.0	.944	17.4	.361	3.090	.0191	.580	2								
0.837									18.5	.411	3.290	.0202	.616									
0.754									19.5	.456	3.460	.0214	.650									
0.748									20.0	.460	3.560	.0224	.667									
0.743									20.1	.463	3.570	.0242	.668									
0.595									22.4	.579	3.980	.0250	.756									
0.664									20.8	.518	3.700	.0225	.674									
0.724									19.9	.475	3.540	.0215	.664									
	1400.0							706.0	.850		.001	110.0	.200			175.0	36.35	33.300	.1570	5.620	20	
	1500.0															175.0	36.35	33.300	.1570	5.620		
	1800.0															219.0	54.70	41.700	.1960	7.050		
	1650.0			219.0	54.70	41.700	.1960						7.050									
	1000.0		804.0	.845		.002	110.0	.200	206.0	77.70	48.700	.2290	8.240									
	2200.0								204.0	102.60	55.200	.2630	9.450									
	1050.0								175.0	36.35	35.600	.1570	5.450									
	1000.0								175.0	36.35	35.600	.1570	5.450									
	1900.0		615.8	.815		.000	110.0	.947	219.0	54.70	44.500	.1960	6.830		7							
	1700.0								219.0	54.70	44.500	.1960	6.830									
	2100.0								204.0	77.70	52.000	.2290	7.990									
	3300.0								204.0	102.60	52.700	.2630	9.170									
	1000.0									204.0	77.70	52.000	.2290	7.990								
	3590.0									173.9	149.20	56.010	.1380	12.460								
	3975.0									173.9	149.20	56.010	.1380	12.460								
	2900.0									173.9	149.20	56.010	.1380	12.460								
	3375.0									100.1	147.10	59.650	.1571	11.130								
	3350.0									407.0	106.10	61.080	.1654	11.580								
	1850.0									411.1	146.20	61.120	.1709	11.780								
										173.9	149.20	56.010	.1380	12.460								

Table 6. e
Summary of Data - Circular Flat Parachute

C_D	t_T (sec)	F_0 (lbs)	S_0 (ft ²)	l_3/D_0	N_P/D_0 (/ft)	l_r/D_0	S_v/S_0	$\Delta t = 1/2 \lambda_{H_2O}$ (ft ³ /ft ² min.)	W/S_0 (lb)	V (ft/sec)	q (lb/ft ²)	$Re \times 10^{-5}$	M	Fr	Type of Test	Ref.
	.52	2640.0								199.7	28.30	25.93	1806	6.650		
	.58	2325.0								201.9	29.50	25.30	1809	6.730		
		2040.0								201.9	29.50	25.30	1804	6.730		
		4500.0								201.9	29.50	25.30	1804	6.730		
		2400.0								208.1	31.30	26.08	1900	6.930		
		2250.0								208.1	31.30	26.08	1900	6.930		
		1860.0								208.1	31.30	26.08	1900	6.930		
		3600.0								239.5	41.60	39.01	2149	7.980		
		2000.0								239.5	41.60	39.01	2149	7.980		
		4100.0								241.6	42.30	40.27	2206	8.050		
		2750.0								241.6	42.30	40.27	2206	8.050		
		2140.0								241.6	42.30	40.27	2206	8.050		
		3700.0								243.7	43.00	40.54	2226	8.120		
		1825.0								243.7	43.00	40.54	2226	8.120		
		4240.0								243.7	43.00	40.54	2226	8.120		
		3975.0								302.4	67.70	87.89	2762	10.080		
		2640.0								304.5	68.80	88.15	2814	10.150		
	.59	3525.0								304.5	68.80	88.15	2814	10.150		
	.82	3000.0								304.5	68.80	88.15	2814	10.150		
	.95	2150.0								304.5	68.80	88.15	2814	10.150		
		3450.0								306.7	69.10	88.43	2822	10.220		
		5250.0								306.7	69.10	88.43	2822	10.220		
		3210.0								308.6	72.40	88.67	2887	10.280		
	.73	2425.0						130.0	.947	308.6	72.40	88.67	2887	10.280		
	.50	4000.0								308.6	72.40	88.67	2887	10.280		
	.63	4300.0								308.6	72.40	88.67	2887	10.280		
	.77	4160.0								374.4	96.40	96.92	3454	12.470		
	.76	4570.0								374.4	96.40	96.92	3454	12.470		
	.76	4700.0								374.4	96.40	96.92	3454	12.470		
	.70	2650.0								226.5	40.73	24.17	2127	7.547		
	.20	3400.0								226.5	40.73	24.17	2127	7.547		
	.52	2640.0								227.5	41.00	24.28	2136	7.580		
	.52	2700.0								227.5	41.00	24.28	2136	7.580		
	.40	3270.0	615.8	.815	1.00	.000.0	.000			229.9	41.66	24.54	2153	7.660		
		3750.0								241.4	45.08	25.76	2267	8.043		
		3260.0								241.4	45.08	25.76	2267	8.043		
		3650.0								246.1	46.50	26.26	2317	8.200		
		2865.0								246.1	46.50	26.26	2317	8.200		
		4775.0								246.1	46.50	26.26	2317	8.200		
	.57	4000.0								302.5	69.22	88.29	2851	10.080		
	.47	4150.0								302.5	69.22	88.29	2851	10.080		
	.45	4250.0								307.1	70.9	88.78	2884	10.210		
	.41	5700.0								307.1	70.9	88.78	2884	10.210		
	.54	5250.0								307.1	70.9	88.78	2884	10.210		
	.53	4700.0								307.1	70.9	88.78	2884	10.210		
	.94									307.1	70.9	88.78	2884	10.210		
	.94	1850.0								373.9	125.38	96.03	3421	12.460		
	.74	2950.0								363.9	96.40	96.92	3332	12.170		
		4050.0								370.2	99.80	96.39	3390	12.310		
	1.18	3500.0								384.9	111.9	98.22	3590	12.820		
	2.50	4600.0								407.4	120.6	91.12	3779	13.590		
	.52	3300.0								232.2	43.50	24.78	2220	7.737		
	.49	2675.0								232.2	43.50	24.78	2220	7.737		
	.62	1160.0								234.5	44.10	25.03	2242	7.811		
	.41	4000.0								251.6	48.50	26.85	2380	8.383		
	.41	3575.0								251.6	48.50	26.85	2380	8.383		
	.25	3815.0								251.6	48.50	26.85	2380	8.383		
	.53	4325.0								261.6	52.10	28.86	2486	8.783		
	.59	4100.0								261.6	52.10	28.86	2486	8.783		
	.46	4650.0								277.1	57.80	31.79	2705	9.326		
	.42	4225.0								277.1	57.80	31.79	2705	9.326		
	.42	4025.0								277.1	57.80	31.79	2705	9.326		
	.38	4700.0								303.8	60.70	32.80	2916	10.290		
		4740.0								303.8	60.70	32.80	2916	10.290		
		4845.0								303.8	60.70	32.80	2916	10.290		
	.45	4850.0								303.8	60.70	32.80	2916	10.290		
	.42	5160.0								303.8	60.70	32.80	2916	10.290		
	.72	3815.0								303.8	60.70	32.80	2916	10.290		
	.44	2480.0								303.8	60.70	32.80	2916	10.290		
	.66	3650.0								303.8	60.70	32.80	2916	10.290		

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Summary of Data - Circular Flat Parachute

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Table 6. g

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Table 6. h
Summary of Data - Circular Flat Parachute

C_D	t_f (sec)	F_0 (lbs)	S_0 (ft ²)	l_s/D_0	H_0/D_0 (/ft)	l_r/D_0	S_v/S_0	λ $\Delta P = 1/2 \rho H_0^2$ (ft ³ /ft ² min.)	H/S_0 (ft)	V (ft/sec)	Q (ft ³)	$H_0 \times 10^{-6}$	M	Pr	Type of Test	Ref.
		1750.0								206.0	32.4	22.12	.1932	7.420		
	.36	6350.0								206.0	32.4	22.12	.1932	7.420		
		2475.0								206.0	32.4	22.12	.1932	7.420		
		3075.0								206.0	32.4	22.12	.1932	7.420		
	.54	2725.0								206.0	31.2	22.12	.1897	7.420		
	.51	2200.0								208.1	31.8	22.15	.1916	7.490		
	.56									208.1	31.8	22.15	.1916	7.490		
	.76	3925.0								212.3	34.4	22.80	.1992	7.640		
	.67	2600.0								214.4	33.8	23.03	.2011	7.720		
	.53	2425.0								250.0	45.9	26.85	.2302	8.999		
		4400.0								250.0	45.9	26.85	.2302	8.999		
	.60	2750.0								250.0	45.9	26.85	.2302	8.999		
	.59	3200.0								250.0	45.9	26.85	.2302	8.999		
	.62	3450.0								287.7	61.4	30.848	.2659	10.360		
	.69	3350.0								298.2	65.9	32.027	.2756	10.730		
	.55	3550.0								298.2	65.9	32.027	.2756	10.730		
	.75	3780.0								300.2	65.2	33.220	.2723	10.810		
	.98	2350.0								300.2	65.2	33.220	.2723	10.810		
	.58	4600.0								300.2	65.2	33.220	.2723	10.810		
		3550.0								304.5	68.8	32.700	.2814	10.960		
	.65	4000.0								306.7	69.7	32.920	.2835	11.040		
		4750.0								376.5	108.2	40.440	.3532	13.550		
	.63	6250.0								376.5	108.2	40.440	.3532	13.550		
	.59	5200.0								376.5	108.2	40.440	.3532	13.550		
	.68	4600.0								376.5	108.2	40.440	.3532	13.550		
	.76	5125.0								384.7	112.9	42.390	.3608	14.210		
	.77	5350.0								384.7	112.9	42.390	.3608	14.210		
		3000.0								226.5	30.7	20.720	.2129	8.150		
		3150.0								227.5	31.0	20.810	.2138	8.189		
		3250.0								227.5	31.0	20.810	.2138	8.189		
		2775.0								227.5	31.0	20.810	.2138	8.189		
	.88	2050.0								227.9	30.9	21.030	.2134	8.276		
	.72	1650.0								227.9	30.9	21.030	.2134	8.276		
		4700.0	452.0	.701	1.0	0	0	110	.4000	258.6	39.2	23.660	.2426	9.309	Free Fall	7
		2800.0								258.6	39.2	23.660	.2426	9.309		
		5050.0								258.6	39.2	23.660	.2426	9.309		
		3050.0								258.6	39.2	23.660	.2426	9.309		
		3000.0								258.6	39.2	23.660	.2426	9.309		
		4900.0								304.8	54.4	27.880	.2810	10.970		
	.62	4300.0								304.8	54.4	27.880	.2810	10.970		
		5450.0								307.1	55.7	28.090	.2881	11.050		
		3600.0								307.1	55.7	28.090	.2881	11.050		
	.34	3750.0								307.1	55.7	28.090	.2881	11.050		
	.60	4375.0								372.8	83.0	34.100	.3497	13.420		
	.20	5400.0								372.8	83.0	34.100	.3497	13.420		
	.34	5700.0								372.8	83.0	34.100	.3497	13.420		
	.38	4750.0								386.7	89.3	35.180	.3690	13.920		
	.44	5125.0								386.7	89.3	35.180	.3690	13.920		
	.54	3650.0								389.0	91.2	35.590	.3712	14.000		
	.37	6500.0								389.0	91.2	35.590	.3712	14.000		
	.33	5850.0								392.3	94.8	35.890	.3743	14.120		
	.64	3800.0								392.3	94.8	35.890	.3743	14.120		
	.47	1950.0								392.3	94.8	35.890	.3743	14.120		
	.52	2810.0								392.3	94.8	35.890	.3743	14.120		
	.59	2410.0								392.3	94.8	35.890	.3743	14.120		
	.54	2640.0								392.3	94.8	35.890	.3743	14.120		
	.62	3325.0								392.3	94.8	35.890	.3743	14.120		
	.61	3760.0								392.3	94.8	35.890	.3743	14.120		
		4120.0								392.3	94.8	35.890	.3743	14.120		
	.46	4050.0								392.3	94.8	35.890	.3743	14.120		
	.55	4010.0								392.3	94.8	35.890	.3743	14.120		
	.40	6100.0								392.3	94.8	35.890	.3743	14.120		
	.53	4575.0								392.3	94.8	35.890	.3743	14.120		
	.53	4150.0								392.3	94.8	35.890	.3743	14.120		
	.62	4550.0								392.3	94.8	35.890	.3743	14.120		
	.55	4400.0								392.3	94.8	35.890	.3743	14.120		
		6500.0								392.3	94.8	35.890	.3743	14.120		
		6750.0								392.3	94.8	35.890	.3743	14.120		
		6775.0								392.3	94.8	35.890	.3743	14.120		
		6800.0								392.3	94.8	35.890	.3743	14.120		

Summary of Data - Circular Flat Parachute

C_D	V (m/s)	T_0 (N)	$\frac{5}{U_0}$ (1/s)	i_1/b_0	R_0/b_0 (1/s)	T_1/b_0	i_2/b_0	$\Delta T = T_1 - T_0$ (N)	$\frac{\Delta T}{T_0}$ (%)	T/T_0	V/V_0	R/R_0	P/P_0	F/F_0	Type of test	Ref.
	1.00	1000.0		1.00				100.0	10.0	1.10	1.00	1.10	1.10	1.10	Free fall	7
	1.10	1210.0		1.10				121.0	21.0	1.21	1.10	1.21	1.21	1.21		
	1.20	1440.0		1.20				144.0	44.0	1.44	1.20	1.44	1.44	1.44		
	1.30	1690.0		1.30				169.0	69.0	1.69	1.30	1.69	1.69	1.69		
	1.40	1960.0		1.40				196.0	96.0	1.96	1.40	1.96	1.96	1.96		
	1.50	2250.0		1.50				225.0	125.0	2.25	1.50	2.25	2.25	2.25		
	1.60	2560.0		1.60				256.0	156.0	2.56	1.60	2.56	2.56	2.56		
	1.70	2890.0		1.70				289.0	189.0	2.89	1.70	2.89	2.89	2.89		
	1.80	3240.0		1.80				324.0	224.0	3.24	1.80	3.24	3.24	3.24		
	1.90	3610.0		1.90				361.0	261.0	3.61	1.90	3.61	3.61	3.61		
	2.00	4000.0		2.00				400.0	300.0	4.00	2.00	4.00	4.00	4.00		
	2.10	4410.0		2.10				441.0	341.0	4.41	2.10	4.41	4.41	4.41		
	2.20	4840.0		2.20				484.0	384.0	4.84	2.20	4.84	4.84	4.84		
	2.30	5290.0		2.30				529.0	429.0	5.29	2.30	5.29	5.29	5.29		
	2.40	5760.0		2.40				576.0	476.0	5.76	2.40	5.76	5.76	5.76		
	2.50	6250.0		2.50				625.0	525.0	6.25	2.50	6.25	6.25	6.25		
	2.60	6760.0		2.60				676.0	576.0	6.76	2.60	6.76	6.76	6.76		
	2.70	7290.0		2.70				729.0	629.0	7.29	2.70	7.29	7.29	7.29		
	2.80	7840.0		2.80				784.0	684.0	7.84	2.80	7.84	7.84	7.84		
	2.90	8410.0		2.90				841.0	741.0	8.41	2.90	8.41	8.41	8.41		
	3.00	9000.0		3.00				900.0	800.0	9.00	3.00	9.00	9.00	9.00		
	3.10	9610.0		3.10				961.0	861.0	9.61	3.10	9.61	9.61	9.61		
	3.20	10240.0		3.20				1024.0	924.0	10.24	3.20	10.24	10.24	10.24		
	3.30	10890.0		3.30				1089.0	989.0	10.89	3.30	10.89	10.89	10.89		
	3.40	11560.0		3.40				1156.0	1056.0	11.56	3.40	11.56	11.56	11.56		
	3.50	12250.0		3.50				1225.0	1125.0	12.25	3.50	12.25	12.25	12.25		
	3.60	12960.0		3.60				1296.0	1196.0	12.96	3.60	12.96	12.96	12.96		
	3.70	13690.0		3.70				1369.0	1269.0	13.69	3.70	13.69	13.69	13.69		
	3.80	14440.0		3.80				1444.0	1344.0	14.44	3.80	14.44	14.44	14.44		
	3.90	15210.0		3.90				1521.0	1421.0	15.21	3.90	15.21	15.21	15.21		
	4.00	16000.0		4.00				1600.0	1600.0	16.00	4.00	16.00	16.00	16.00		
	4.10	16810.0		4.10				1681.0	1681.0	16.81	4.10	16.81	16.81	16.81		
	4.20	17640.0		4.20				1764.0	1764.0	17.64	4.20	17.64	17.64	17.64		
	4.30	18490.0		4.30				1849.0	1849.0	18.49	4.30	18.49	18.49	18.49		
	4.40	19360.0		4.40				1936.0	1936.0	19.36	4.40	19.36	19.36	19.36		
	4.50	20250.0		4.50				2025.0	2025.0	20.25	4.50	20.25	20.25	20.25		
	4.60	21160.0		4.60				2116.0	2116.0	21.16	4.60	21.16	21.16	21.16		
	4.70	22090.0		4.70				2209.0	2209.0	22.09	4.70	22.09	22.09	22.09		
	4.80	23040.0		4.80				2304.0	2304.0	23.04	4.80	23.04	23.04	23.04		
	4.90	24010.0		4.90				2401.0	2401.0	24.01	4.90	24.01	24.01	24.01		
	5.00	25000.0		5.00				2500.0	2500.0	25.00	5.00	25.00	25.00	25.00		

Summary of Data - Circular Flat Parachute

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Table 7. a
Summary of Data - Extended Skirt (10%) Parachute

C _D	t _r (sec)	F ₀ (lbs)	S ₀ (ft ²)	l _a /D ₀	H ₀ /D ₀ (/ft)	l _r /D ₀	S _v /S ₀	at ΔP=1/2 ρH ₀ ² (ft ³ /ft ² min.)	W/S ₀ (psf)	V (ft/sec)	q (psf)	Re x 10 ⁻⁶	M	Fr	Type of Test	Ref.			
10% Extension																			
.797			1.910	1.000	17.96	0	120.0	10.000	111.7	12.550	.600	.1000	15.775	Infinite Mass	12				
.822			2.120		17.04	0	10.0	10.320	111.7	12.550	.600	.1000	15.463						
.824			2.012		17.49	0	275.0	10.330	111.7	12.550	.600	.1000	15.556						
.810			2.021		17.45	0	30.0	10.390	111.7	4.180	.600	.1000	15.556						
.838				111.10	.600	.01			.139	12.1	.165	.913	.0109	.618					
.910									.139	11.6	.152	.875	.0104	.593					
.838									.139	12.1	.165	.913	.0109	.618					
.828									.274	17.1	.130	.129	.0154	.874					
.809									.274	17.3	.138	1.305	.0155	.884					
.731									.274	18.2	.174	1.373	.0163	.930					
.582									.679	32.1	1.164	2.422	.0288	1.640					
.590									.679	31.9	1.150	2.407	.0286	1.630					
.532									.679	33.6	1.276	2.535	.0302	1.717					
.979						1.400			.184	12.8	.187	.966	.0115	.654					
.979										.184	12.8	.187	.966	.0115					.654
.934										.184	13.1	.196	.989	.0118					.669
.889								.274	16.4	.108	1.238	.0148	.838						
.900								.274	16.3	.104	1.229	.0147	.833						
.911								.274	16.2	.100	1.222	.0146	.823						
.885								.679	25.9	.768	1.954	.0233	1.323						
.864								.679	26.2	.786	1.977	.0236	1.338						
.864								.679	26.2	.786	1.977	.0236	1.338						
.848								1.800	42.8	2.125	3.229	.0386	2.187						
.962								1.665	38.9	1.731	2.935	.0350	1.988						
.928								1.665	39.6	1.796	2.988	.0357	2.024						
.878				111.10	1.345	0			.184	13.5	.210	1.019	.0122	.690	Free Fall	28			
.890									.184	13.4	.206	1.011	.0121	.685					
.842									.184	13.8	.216	1.041	.0124	.705					
1.016									.274	15.3	.269	1.154	.0138	.782					
.845									.274	16.8	.125	1.268	.0151	.858					
1.016									.274	15.3	.269	1.154	.0138	.782					
.880									.679	25.9	.771	1.954	.0233	1.323					
.763									.679	27.8	.889	2.098	.0250	1.421					
.810									.679	27.0	.838	2.037	.0243	1.380					
1.172									.139	10.2	.118	.770	.0091	.521					
1.087									.139	10.6	.128	.800	.0095	.542					
1.087									.139	10.6	.128	.800	.0095	.542					
.896				1.240			.274	16.4	.126	1.238	.0146	.838							
.807								.274	17.3	.140	1.305	.0154			.884				
.896								.274	16.4	.105	1.238	.0146			.838				
.912								.679	25.6	.744	1.932	.0228			1.308				
.898								.679	25.8	.756	1.947	.0230			1.318				
.920								.679	25.5	.738	1.924	.0228			1.303				
.751								1.508	40.9	1.874	3.086	.0368			2.090				
.729								1.508	41.5	1.929	3.132	.0370			2.120				
.903								1.845	41.8	2.044	3.154	.0376			2.136				
1.210								.139	10.0	.114	.755	.0093			.511				
1.185								.139	10.1	.117	.762	.0091			.516				
1.077								.139	10.6	.126	.800	.0095			.542				
.837				111.10	1.080				.274	16.9	.127	1.275	.0152	.864					
1.062									.274	15.0	.128	1.132	.0135	.766					
.827									.274	17.0	.131	1.283	.0153	.869					
.831									.679	26.7	.816	2.015	.0241	1.364					
.877									.679	26.0	.774	1.962	.0234	1.329					
.850									.679	26.4	.798	1.992	.0238	1.349					
1.130									.139	10.3	.122	.777	.0092	.526					
1.088									.139	10.5	.127	.792	.0094	.536					
1.249									.139	9.8	.111	.740	.0088	.501					
.860									.274	16.6	.118	1.252	.0148	.848					
.966									.274	15.5	.127	1.170	.0139	.792					
.870									.274	16.5	.114	1.245	.0148	.843					
.883							.679	25.8	.769	1.947	.0231	1.318							
.843							.679	26.4	.854	1.992	.0236	1.349							
.794							.679	27.2	.131	2.052	.0244	1.390							
.536							1.508	52.7	2.410	3.977	.0471	2.693							
.728							1.508	45.0	2.000	3.396	.0401	2.300							
.863							1.845	41.0	1.120	3.044	.0366	2.095							
1.067							.139	10.6	.110	.819	.0095	.542							

Table 7.b
Summary of Data - Extended Skirt (10%) Parachute

C_D	L_T (sec)	r (ft)	S_D (ft ²)	$1/v_{T0}$	R/v_{T0} (/ft)	$1/r/v_{T0}$	C_D/C_{D0}	λ at $\Delta P = 1/2 \rho v_{T0}^2$ (ft ² /ft ² min.)	w/v_{T0} (ft/sec)	z (ft/sec)	q (lb/ft ²)	$R \times 10^{-3}$	μ	FR	Type of Fall	Ref.
.700				.600					1.638	45.2	2.115	1.411	.0199	2.112	Free Fall	28
.710									1.13	10.8	.135	.815	.0097	.557		
.72									1.13	11.4	.136	.860	.0102	.583		
1.018									2.79	15.1	.261	1.119	.0135	.772		
.743				1.080					2.79	17.8	.305	1.301	.0159	.910		
1.023									2.79	15.2	.267	1.147	.0136	.777		
.818									2.79	26.8	.310	2.022	.0240	1.369		
.768									2.79	27.1	.361	2.060	.0244	1.395		
.876									2.79	27.9	.375	1.954	.0232	1.323		
.719				.600					1.638	45.2	2.278	1.365	.0193	2.279		
1.048									1.12	10.7	.132	.807	.0096	.547		
1.048									1.12	10.7	.132	.807	.0096	.547		
1.130									1.12	10.1	.123	.777	.0093	.526		
.915									2.99	16.1	.249	1.215	.0145	.823		
.870									1.19	16.5	.134	1.245	.0148	.843		
.820									1.11	17.0	.133	1.283	.0153	.869		
.810									.817	27.1	.317	2.045	.0244	1.385		
.902									2.79	25.7	.353	1.939	.0231	1.313		
.817				.920					.811	27.0	.311	2.037	.0243	1.380		
.908									1.998	41.5	1.998	3.132	.0367	2.121		
.812									2.185	43.4	2.185	3.275	.0384	2.218		
.850									2.089	41.9	2.089	3.162	.0368	2.141		
1.168									1.19	10.2	.119	.770	.0092	.521		
.858									1.61	11.9	.161	.898	.0171	.608		
1.022									1.15	10.9	.115	.823	.0098	.557		
.905									2.79	16.1	.101	1.230	.0147	.833		
.915									2.79	16.2	.229	1.222	.0146	.827		
.950									2.79	15.9	.288	1.120	.0143	.812		
.860									.679	26.7	.788	1.984	.0237	1.343		
.723			111.10						.679	28.7	.934	2.166	.0238	1.466		
.765									.679	27.9	.887	2.105	.0251	1.426		
.621				.600	1.354		.01	.91	1.638	48.0	2.638	3.660	.0423	2.452		
1.011									1.13	10.9	.137	.822	.0098	.557		
.895									1.19	11.6	.155	.875	.0140	.608		
.810									1.13	12.2	.171	.921	.0109	.623		
.777									2.79	17.5	.352	1.321	.0157	.894		
.930									2.79	16.0	.239	1.207	.0143	.818		
.751									2.79	17.8	.364	1.343	.0160	.910		
.727									.679	28.5	.944	2.151	.0256	1.456		
.797									.679	27.2	.951	2.052	.0244	1.390		
.711									.679	28.8	.954	2.173	.0258	1.472		
.744									1.820	45.1	2.442	3.438	.0398	2.315		
.718									1.830	46.2	2.452	3.486	.0406	2.361		
.831				.760					1.810	43.5	2.540	3.282	.0382	2.273		
.810									1.19	12.2	.171	.921	.0109	.623		
.979									1.19	11.1	.142	.838	.0100	.567		
.845									1.19	11.3	.147	.853	.0103	.577		
.844									2.79	16.8	.324	1.268	.0151	.858		
.813									2.79	17.1	.336	1.290	.0153	.874		
.844									2.79	16.8	.324	1.268	.0151	.858		
.768									.679	27.8	.889	2.098	.0249	1.421		
.742									.679	28.4	.921	2.135	.0254	1.446		
.753									.679	28.1	.908	2.120	.0252	1.436		
.845									1.19	11.9	.142	.838	.0107	.608		
.903									1.19	11.5	.153	.860	.0101	.588		
.858									1.19	11.8	.162	.890	.0106	.602		
.770									2.79	17.5	.355	1.321	.0157	.894		
.766				.600					2.79	17.7	.357	1.336	.0159	.904		
.725									2.79	18.2	.378	1.373	.0163	.910		
.686									.679	29.2	.983	2.291	.0262	1.497		
.694									.679	29.5	.977	2.278	.0264	1.502		
.701									.679	29.2	.981	2.291	.0258	1.492		
.950								100.0	.685	24.6	.632	10.133	.0221	.529	5	
.900								107.0	.679	24.1	.631	9.801	.0217	.518		
.920								115.0	.679	24.9	.685	10.060	.0225	.536		
.780			3546.74	1.000	.8111		.0125	115.8	.681	25.6	.715	10.460	.0231	.550		
.780								107.5	.686	25.2	.712	10.300	.0227	.542		
.750								117.0	.689	25.5	.729	10.420	.0230	.548		
.880								120.2	.691	21.9	.538	8.952	.0197	.473		
.950								100.0	.680	21.2	.504	8.666	.0191	.456		

Summary of Data - Extended Skirt (10%) Parachute

C_D	t_f (sec)	F_0 (lbs)	S_0 (ft ²)	$1_s/D_0$	N_s/D_0 (/ft)	$1_r/D_0$	S_v/S_0	λ at $\Delta P = 1/2 \rho V^2$ (ft ³ /ft ² min.)	W/S_0 (psf)	V (ft/sec)	q (psf)	P in 10^{-3}	M	Fr	Type of Test	Ref.
1.100			3546.74	1.000	.8333		.0025	127.8	.590	19.8	.440	8.073	.0178	.476		5
.990			3546.74	1.000	.8333		.0025	113.4	.498	20.2	.480	8.461	.0186	.445		5
.610									.651	31.5	1.100	10.920	.0275	.743		
1.163									.366	17.3	.412	5.298	.0152	.480		
.686									.611	29.7	.979	10.299	.0261	.700		
.778			2456.00	1.010	.5007	0	.004		.806	23.0	.496	7.217	.0183	.495		19
.985									.489	22.0	.516	7.831	.0198	.533		
.594									.651	31.8	1.110	11.020	.0260	.750		
.807									.651	27.3	.812	9.460	.0240	.644		
.637									.283	19.1	.443	4.800	.0171	.535		
.845									.277	16.6	.323	4.147	.0147	.465		
.713			1231.63	.810	.8586	.10	.003		.277	18.1	.384	4.522	.0160	.507		16
.606									.271	19.2	.452	4.825	.0173	.538		
.620									.280	19.1	.447	4.800	.0172	.535		
.673									.276	18.3	.444	4.533	.0164	.513		
.690									.733	31.2	1.081	12.070	.0270	.688		
.480									.716	36.6	1.240	14.200	.0317	.807		
.857			3217.00	.740	.5312	.09		130.0	.713	27.3	.841	10.690	.0238	.602		10
.625									.306	21.2	.506	5.273	.0185	.468		
.540									.707	31.7	1.309	13.840	.0297	.743		
.786									.306	18.8	.394	7.232	.0163	.413		
.689									.670	25.6	.780	6.174	.0223	.733		
.961									.672	24.1	.691	5.812	.0210	.690		
.891									.672	25.0	.743	6.023	.0218	.716		
.870			1133.54	1.000	.9476				.670	25.3	.762	6.101	.0220	.724		
.940									.671	24.9	.708	5.909	.0212	.699		
.888									.672	25.1	.770	6.073	.0218	.719		
.691									.683	28.7	.979	6.921	.0250	.804		
.918									.681	24.3	.702	6.005	.0216	.713		
.754									.685	27.5	.909	6.632	.0242	.787		
.720									.686	28.2	.946	6.801	.0248	.807		
.743									.749	29.3	1.007	6.371	.0253	.877		
.927									.749	28.0	.804	5.633	.0225	.784		
.751										23.1	1.091	6.371	.0252	.877		15
.729										23.3	1.075	6.253	.0250	.890	Free Fall	
.674										30.7	1.123	6.722	.0268	.926		
.834										27.0	.920	6.087	.0241	.838		
.700										33.3	1.376	6.590	.0266	.908		
.834										27.5	.962	6.243	.0244	.832		
1.081			934.35		1.044			100.0		24.2	.815	5.233	.0210	.730		
.656										31.7	1.070	6.331	.0272	.941		
.889										26.7	.890	5.696	.0232	.805		
.740										29.3	1.055	6.245	.0255	.883		
.834										27.6	.907	6.043	.0252	.832		
.674										30.7	1.121	6.722	.0274	.926		
.775										28.3	.853	6.196	.0252	.851		
.702										28.5	.866	6.240	.0252	.859		
.854										26.0	.846	5.720	.0240	.850		
1.020										16.3	.388	3.900	.0165	.535		
1.100										17.6	.460	4.300	.0178	.562		
1.220										16.7	.329	3.160	.0150	.492		
.640										21.0	.612	4.136	.0207	.747		
.624										21.9	.636	4.300	.0211	.760		
1.060			715.60	.750	.9276		.003			18.5	.376	3.660	.0160	.600		29
.634										22.2	.670	4.136	.0200	.720		
.745										19.0	.510	3.540	.0170	.617		
.641										20.6	.606	3.853	.0180	.666		
.572										21.8	.625	4.005	.0190	.707		
.510										25.0	.735	4.605	.0232	.837		
.702										17.7	.320	3.160	.0150	.493		
1.000										19.3	.433	3.720	.0155	.5274		
1.220										22.6	.610	4.136	.0207	.740		
1.220										23.3	.636	4.300	.0211	.760		
1.220										22.2	.670	4.136	.0200	.720		
1.600	3500.0		3217.00	.740	.5312	.09	.003	130.0	.713	27.3	.841	10.690	.0238	.602		10
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.2	.670	4.136	.0200	.720		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0									23.3	.636	4.300	.0211	.760		
1.220	3500.0									22.6	.610	4.136	.0207	.740		
1.220	3500.0															

Table 7. d
Summary of Data - Extended Skirt (10%) Parachute

C_D	t_r (sec)	F_0 (lbf)	S_0 (ft ²)	$1g/U_0$	N_r/D_0 (/ft)	$1r/U_0$	S_v/U_0	λ at $P=1/2 \rho U_0^2$ (ft ³ /ft ² min.)	W/A_{10} (lbf)	V (ft/sec)	q (lbf/ft ²)	$10x \times 10^{-4}$	M	Pr	Type of Test	Ref.
		6370.0	3217.00	.740	.5112	.07	.003	110.0	.713	221.9	57.15	87.849	.1962	5.001		10
		4.80 5320.0							.716	226.5	57.36	87.850	.1961	4.992		
		4.20							.714	232.1	57.32	86.610	.1990	5.116		
		5.10 6270.0							.714	225.3	57.28	88.190	.1964	4.996		
									.707	226.1	57.10	88.020	.1964	4.983		
		4.70							.701	222.3	57.29	88.880	.1966	4.913		
		5.00							.706	226.1	57.28	88.020	.1964	4.983		
		1.20							.706	228.5	57.33	87.520	.1965	5.036		
		1.35 980.0							.704	217.0	57.460	.1668	5.506			
		1.34 1420.0							.704	217.0	57.460	.1668	5.506			
		1.34 1040.0							.704	217.0	57.460	.1668	5.506			
		1.32 1430.0							.701	216.1	57.510	.1719	5.673			
		1.52 1250.0							.701	216.1	57.510	.1719	5.673			
		1650.0							.704	216.1	57.510	.1719	5.673			
		2100.0							.704	216.1	57.510	.1719	5.673			
		2240.0							.704	216.1	57.510	.1719	5.673			
		1700.0							.704	216.1	57.510	.1719	5.673			
		2160.0							.704	216.1	57.510	.1719	5.673			
		1.49 1475.0							.704	216.1	57.510	.1719	5.673			
		1175.0							.704	216.1	57.510	.1719	5.673			
		1275.0							.704	216.1	57.510	.1719	5.673			
		1375.0							.704	216.1	57.510	.1719	5.673			
		900.0							.704	216.1	57.510	.1719	5.673			
		2250.0							.704	216.1	57.510	.1719	5.673			
		1560.0							.704	216.1	57.510	.1719	5.673			
		1525.0							.704	216.1	57.510	.1719	5.673			
		1490.0							.704	216.1	57.510	.1719	5.673			
		1700.0							.704	216.1	57.510	.1719	5.673			
		1600.0							.704	216.1	57.510	.1719	5.673			
		1300.0							.704	216.1	57.510	.1719	5.673			
		1575.0							.704	216.1	57.510	.1719	5.673			
		2050.0							.704	216.1	57.510	.1719	5.673			
		1.21 2225.0							.704	216.1	57.510	.1719	5.673			
		2140.0							.704	216.1	57.510	.1719	5.673			
		1.26 2340.0							.704	216.1	57.510	.1719	5.673			
		1.10 2800.0							.704	216.1	57.510	.1719	5.673			
		2900.0							.704	216.1	57.510	.1719	5.673			
		1.21 2650.0							.704	216.1	57.510	.1719	5.673			
		2480.0							.704	216.1	57.510	.1719	5.673			
		3060.0							.704	216.1	57.510	.1719	5.673			
		1.17 3450.0							.704	216.1	57.510	.1719	5.673			
		1.20 3050.0							.704	216.1	57.510	.1719	5.673			
		1.08 3575.0							.704	216.1	57.510	.1719	5.673			
		1.06 3800.0							.704	216.1	57.510	.1719	5.673			
		1.48 3200.0							.704	216.1	57.510	.1719	5.673			
		1.26 2500.0							.704	216.1	57.510	.1719	5.673			
		1.68 3175.0							.704	216.1	57.510	.1719	5.673			
		1.61 4000.0							.704	216.1	57.510	.1719	5.673			
		1.42 3775.0							.704	216.1	57.510	.1719	5.673			
		1.36 3550.0							.704	216.1	57.510	.1719	5.673			
		.92 4575.0							.704	216.1	57.510	.1719	5.673			
		1.00 1690.0							.704	216.1	57.510	.1719	5.673			
		.87 2100.0							.704	216.1	57.510	.1719	5.673			
		.89 1550.0							.704	216.1	57.510	.1719	5.673			
		1.02 3525.0							.704	216.1	57.510	.1719	5.673			
		.89 1445.0							.704	216.1	57.510	.1719	5.673			
		.68 1950.0							.704	216.1	57.510	.1719	5.673			
		.66 2100.0							.704	216.1	57.510	.1719	5.673			
		.97 1925.0							.704	216.1	57.510	.1719	5.673			
		1.11 1936.0							.704	216.1	57.510	.1719	5.673			
		1.10 1810.0							.704	216.1	57.510	.1719	5.673			
		1.02 1900.0							.704	216.1	57.510	.1719	5.673			
		.75 1860.0							.704	216.1	57.510	.1719	5.673			
		.67 2242.0							.704	216.1	57.510	.1719	5.673			
		1.02 2140.0							.704	216.1	57.510	.1719	5.673			
		2900.0							.704	216.1	57.510	.1719	5.673			
		2650.0							.704	216.1	57.510	.1719	5.673			
		1.28 2650.0							.704	216.1	57.510	.1719	5.673			
		2450.0							.704	216.1	57.510	.1719	5.673			
		2450.0							.704	216.1	57.510	.1719	5.673			
		2450.0							.704	216.1	57.510	.1719	5.673			

Table 7. e

Summary of Data - Extended Skirt (10%) Parachute

C _D	t _T (sec)	F ₀ (lbf)	S _u (ft ²)	l _s /D ₀	N _p /U ₀ (/ft)	l _p /U ₀	S _v /U ₀ ^λ at ΔP=1/2 ρU ₀ ² (ft ³ /ft ² min.)	W/S _u (lbf)	V (ft/sec)	q (lbf)	R _u x 10 ⁻³	M	Fr	Type of Test	Ref.									
		3400.0	804.30	1.000	.6250	0	.004	135.0	.424	173.0	41.50	38.600	1.670	6.010		6								
		2600.0							.424	224.0	57.70	44.100	1.980	6.290										
		2275.0							.448	195.0	43.70	38.400	1.740	6.090										
		7450.0							.541	224.0	57.00	44.100	1.990	6.290										
		3400.0							.671	224.0	57.10	44.100	1.950	6.290										
		4200.0							.671	262.0	78.70	51.800	2.100	8.180										
	3.40	5845.0	2463.01	.699	.5714				.676	262.0	76.24	51.400	2.070	6.192		4								
		4675.0							.676	262.1	76.29	51.220	2.060	6.180										
	3.50	6515.0							.679	262.1	76.26	51.220	2.060	6.180										
	4.70	4130.0							.394	261.4	76.27	52.400	2.260	6.159										
	11.00	2155.0							.394	227.4	57.10	40.890	1.970	5.367										
	4.90	4150.0							.396	227.7	57.89	40.920	1.980	5.365										
	4.50	2760.0							.396	228.8	57.81	41.120	1.970	5.391										
	7.20								.391	226.6	57.77	40.510	1.970	5.339										
	5.00								.391	227.4	57.11	40.820	1.960	5.358										
	8.10								.391	226.7	57.29	40.570	1.960	5.341										
	3.90								.391	225.2	57.10	40.040	1.960	5.306										
	1.54	1300.0	956.60	.731	.8596	0	0	30.0	.226	186.4	33.00	34.810	1.670	5.563	Free Fall	7								
	1.77	975.0								186.4	33.00	34.810	1.670	5.563										
	1.63	1460.0								186.4	33.00	34.810	1.670	5.563										
	1.65	1500.0								186.4	33.00	34.810	1.670	5.563										
	1.68	1175.0								186.4	33.00	34.810	1.670	5.563										
	1.68	1550.0								186.4	33.00	34.810	1.670	5.563										
	1.62	1785.0								186.4	33.00	34.810	1.670	5.563										
	1.52	1750.0								186.4	33.00	34.810	1.670	5.563										
	1.64	1720.0								186.4	33.00	34.810	1.670	5.563										
	1.80	1725.0								186.4	33.00	34.810	1.670	5.563										
	1.12	1950.0								186.4	33.00	34.810	1.670	5.563										
	1.10	2300.0								186.4	33.00	34.810	1.670	5.563										
	1.24	2310.0								186.4	33.00	34.810	1.670	5.563										
	1.17	2135.0								186.4	33.00	34.810	1.670	5.563										
	1.06	2250.0								186.4	33.00	34.810	1.670	5.563										
		2200.0								186.4	33.00	34.810	1.670	5.563										
	1.27	2540.0								186.4	33.00	34.810	1.670	5.563										
	1.42	2450.0								186.4	33.00	34.810	1.670	5.563										
	1.31	1840.0								186.4	33.00	34.810	1.670	5.563										
	1.49	2250.0								186.4	33.00	34.810	1.670	5.563										
		1150.0								186.4	33.00	34.810	1.670	5.563										
		3250.0								186.4	33.00	34.810	1.670	5.563										
		2800.0								186.4	33.00	34.810	1.670	5.563										
		1690.0								186.4	33.00	34.810	1.670	5.563										
		4100.0								186.4	33.00	34.810	1.670	5.563										
		3700.0								186.4	33.00	34.810	1.670	5.563										
		2900.0								186.4	33.00	34.810	1.670	5.563										
		4150.0								186.4	33.00	34.810	1.670	5.563										
		4450.0								186.4	33.00	34.810	1.670	5.563										
		3275.0								186.4	33.00	34.810	1.670	5.563										
		2900.0								186.4	33.00	34.810	1.670	5.563										
	1.28	4200.0								186.4	33.00	34.810	1.670	5.563										
	1.12	1650.0								186.4	33.00	34.810	1.670	5.563										
	1.09	1375.0								186.4	33.00	34.810	1.670	5.563										
	1.11	1350.0								186.4	33.00	34.810	1.670	5.563										
		1875.0								186.4	33.00	34.810	1.670	5.563										
	.99	1625.0								186.4	33.00	34.810	1.670	5.563										
	1.02	1500.0								186.4	33.00	34.810	1.670	5.563										
		1400.0								186.4	33.00	34.810	1.670	5.563										
		915.0								186.4	33.00	34.810	1.670	5.563										
		1200.0								715.60	.750	.9276	.003	100.0			150.0	224.0	61.12	40.440	2.041	5.204	Free Fall	29
		1500.0										.9276	.003	100.0			150.0	24.40	280.000	1.140	4.870			
		1000.0										.9276	.004	100.0			150.0	24.40	280.000	1.140	4.870			
		1250.0										.9276	.003	100.0			150.0	24.40	280.000	1.140	4.870			
12.5% Extension																								
		4000.0	2605.00	.708	.9376	0	.004	104.5	.311	224.0	61.12	40.440	2.041	5.204	Free Fall	18								
		5100.0							.484	226.0	67.76	41.160	2.098	5.250										
		5650.0							.610	221.0	64.52	39.460	2.081	5.134										
		6600.0							.331	299.0	114.50	107.400	2.821	6.946										
		6400.0							.484	299.0	111.00	107.400	2.800	6.946										
		7200.0							.610	291.0	109.60	105.200	2.762	6.807										
		5400.0							.311	196.0	46.70	33.490	1.880	5.204										

Table 7. f
Summary of Data - Extended Skirt (12.5%) Parachute

C_D	t_f (sec)	P_0 (lba)	S_0 (ft ²)	l_a/D_0	H_R/D_0 (/ft)	l_r/D_0	S_v/S_0	λ at $\Delta P = 1/2 \rho V^2$ (ft ³ /ft ² min.)	W/S_0 (lbf)	V (ft/sec)	q (lbf)	$Ru \times 10^{-6}$	M	Pr	Type of Test	Ref.
	4700.0		2605.00	.708	.9376	0	.004	104.5	.331	236.0	112.50	105.000	.2814	6.876		16
	4250.0								.331	227.0	65.44	80.170	.2131	5.273		
	3350.0								.331	229.0	65.16	81.020	.2128	5.320		
	5900.0								.638	232.0	66.31	81.800	.2148	5.389		
	8000.0								.638	311.0	124.60	109.800	.2874	7.225		
6.8								0	.541	337.0	63.08	66.322	.2936	10.505	Free Fall	17
3.0	2250.0								.686	225.0	57.21	44.280	.1963	7.014		
3.3	2025.0								.561	224.0	57.52	44.138	.1965	6.983		
1.9	2100.0								.554	198.0	44.26	39.015	.1731	6.172		
3.5									.665	256.0	73.96	51.361	.2209	7.980		
2.7									.663	258.0	73.62	50.034	.2245	8.042		
3.6									.539	316.0	126.10	66.530	.2924	10.474		
6.4	2785.0								.686	259.0	71.84	51.034	.2235	8.073		
3.1									.540	224.0	56.15	44.356	.1953	6.982		
3.3	2260.0								.686	224.0	56.65	44.356	.1958	6.982		
1.3									.664	226.0	59.20	45.087	.1996	7.045		
1.2									.664	223.0	56.44	44.268	.1949	6.951		
1.2									.665	256.0	75.63	51.296	.2259	7.980		
1.5									.541	325.0	118.70	65.000	.2833	10.131		
1.5									.540	334.0	124.94	66.758	.2912	10.411		
1.1									.540	325.0	118.30	64.838	.2833	10.131		
1.8									.540	325.0	118.30	44.916	.2833	10.131		
2.2									.665	256.0	73.40	51.361	.2232	7.980		
2.9									.665	261.0	75.45	51.811	.2272	8.136		
0.7									.665	254.0	79.16	50.972	.2210	8.074		
1.1									.542	317.0	131.51	66.404	.2528	10.505		
2.2	4810.0								.686	224.0	57.55	44.138	.2000	6.983		
1.4	2475.0								.575	224.0	60.06	44.138	.2007	6.983		
	2825.0								.563	198.0	47.32	39.015	.1784	6.172		
1.5									.665	248.0	74.44	49.476	.2230	7.731		
1.6									.563	337.0	132.99	67.232	.2990	10.505		
	4050.0								.688	257.0	74.77	51.272	.2247	8.011		
	2980.0								.693	221.0	56.89	44.268	.1949	6.951		
	2800.0								.693	198.0	45.28	38.305	.1746	6.172		
1.3									.664	254.0	78.89	51.034	.2270	8.074		
4.5									.665	254.0	74.66	51.034	.2248	8.074		
4.1									.665	254.0	73.74	51.097	.2237	8.074		
8.2									.533	337.0	130.72	66.404	.3351	10.505		
1.2									.672	254.0	75.94	51.034	.2270	8.074		
3.8									.665	257.0	74.77	51.272	.2480	8.031		
2.9									.665	257.0	74.77	51.272	.2480	8.031		
2.0									.665	256.0	74.70	51.361	.2257	7.980		
1.5									.665	256.0	75.40	51.361	.2257	7.980		
6.9									.664	262.0	76.60	52.009	.2280	8.167		
4.7									.543	251.0	70.30	49.519	.2185	7.824		
2.7									.543	338.0	27.40	66.601	.2942	10.526		
1.6									.665	256.0	72.73	51.361	.2209	7.980		
4.1	1910.0								.674	226.0	56.97	44.532	.1950	7.045		
4.2									.665	258.0	79.41	51.216	.2310	8.041		
5.1									.665	258.0	79.41	51.216	.2310	8.041		
2.0									.665	258.0	74.95	51.216	.2293	8.041		
									.665	258.0	74.95	51.216	.2293	8.041		
3.7									.665	256.0	75.42	51.361	.2259	7.979		
2.1									.679	256.0	75.10	51.361	.2254	7.979		
1.8									.679	321.0	118.96	63.250	.2833	10.005		
3.1									.641	256.0	75.27		.2257	7.979		
1.8									.665	256.0	75.27		.2257			
1.9									.665	256.0	75.27		.2257			
1.9	2450.0								.665	256.0	72.94	51.370	.2201			
2.2	2550.0								.679	256.0	72.94		.2201	7.979		
1.9	2900.0								.679	256.0	72.94		.2201			
2.0	2200.0								.679	256.0	72.94		.2224			
1.25									.679	256.0	72.94		.2224			
1.4	2550.0								.679	256.0	72.94		.2224			
1.7									.641	317.0	221.63	66.404	.2967	10.503		
2.1									.665	257.0	73.97	51.272	.2241	8.011		
4.8									.677	255.0	74.86	51.034	.2254	8.074		
5.1									.677	255.0	74.86	51.034	.2254	8.074		
2.0									.665	255.0	72.14	51.034	.2254	8.074		
2.8									.641	317.0	221.63	66.404	.2967	10.500		

Table 7.g

Summary of Data - Extended Skirt (12.5%) Parachute

C_D	t_r (sec)	F_0 (lb)	S_0 (ft ²)	$1_s/b_0$	N_r/b_0 (/ft)	$1_r/b_0$	$U_{V/30}$	$at \Delta P = \lambda/2 \pi H_0$ (ft ^{1/2} /ft ^{1/2} min.)	W/S_0 (lb/ft ²)	V (ft/sec)	q (lb/ft ²)	$H_0 \times 10^3$	M	K_F	Pyro. of Skirt	Ref.
	1.20	1740.0	804.25		.7500				.607	229.0	56.17	94.130	1.171	6.791	17	
	1.00	2625.0							.609	229.0	56.17	94.130	1.171	6.791		
	1.40	3275.0							.609	229.0	56.17	94.130	1.171	6.791		
	1.50								.609	229.0	56.17	94.130	1.171	6.791		
	1.20								.607	229.0	56.17	94.130	1.171	6.791		
		4375.0							.607	229.0	56.17	94.130	1.171	6.791		
	1.60	3676.0							.607	229.0	56.17	94.130	1.171	6.791		
		2.60							.607	229.0	56.17	94.130	1.171	6.791		
	2.50	1775.0							.607	229.0	56.17	94.130	1.171	6.791		
	4.10								.607	229.0	56.17	94.130	1.171	6.791		
	3.20		800.00		.7520				.607	229.0	56.17	94.130	1.171	6.791	8	
	2.50								.607	229.0	56.17	94.130	1.171	6.791		
	5.50								.607	229.0	56.17	94.130	1.171	6.791		
		1100.0							.607	229.0	56.17	94.130	1.171	6.791		
	8.70								.607	229.0	56.17	94.130	1.171	6.791		
	2.80								.607	229.0	56.17	94.130	1.171	6.791		
	1.70								.607	229.0	56.17	94.130	1.171	6.791		
	1.20								.607	229.0	56.17	94.130	1.171	6.791		
	1.30								.607	229.0	56.17	94.130	1.171	6.791		
	2.50								.607	229.0	56.17	94.130	1.171	6.791		
	1.40		1.000		.7500			12.00	.607	229.0	56.17	94.130	1.171	6.791	17	
	1.20	2450.0							.607	229.0	56.17	94.130	1.171	6.791		
	1.20								.607	229.0	56.17	94.130	1.171	6.791		
	8.10								.607	229.0	56.17	94.130	1.171	6.791		
	1.10	2400.0							.607	229.0	56.17	94.130	1.171	6.791		
	2.10								.607	229.0	56.17	94.130	1.171	6.791		
	1.70	3100.0							.607	229.0	56.17	94.130	1.171	6.791		
	1.70								.607	229.0	56.17	94.130	1.171	6.791		
	1.30								.607	229.0	56.17	94.130	1.171	6.791		
	1.40								.607	229.0	56.17	94.130	1.171	6.791		
		3310.0	804.25		.7500			6	.607	229.0	56.17	94.130	1.171	6.791	17	
		4100.0							.607	229.0	56.17	94.130	1.171	6.791		
	1.90								.607	229.0	56.17	94.130	1.171	6.791		
	6.10	2290.0							.607	229.0	56.17	94.130	1.171	6.791		
	2.60								.607	229.0	56.17	94.130	1.171	6.791		
	2.70								.607	229.0	56.17	94.130	1.171	6.791		
		2050.0							.607	229.0	56.17	94.130	1.171	6.791		
	1.50								.607	229.0	56.17	94.130	1.171	6.791		
	5.90	2350.0							.607	229.0	56.17	94.130	1.171	6.791		
	3.60	1920.0							.607	229.0	56.17	94.130	1.171	6.791		
	3.70		111.11	1.000	1.000			1.000	.607	229.0	56.17	94.130	1.171	6.791	20	
	1.80	2100.0							.607	229.0	56.17	94.130	1.171	6.791		
	2.90	1700.0							.607	229.0	56.17	94.130	1.171	6.791		
	3.00								.607	229.0	56.17	94.130	1.171	6.791		
		2410.0							.607	229.0	56.17	94.130	1.171	6.791		
	1.50								.607	229.0	56.17	94.130	1.171	6.791		
	2.50								.607	229.0	56.17	94.130	1.171	6.791		
	5.50								.607	229.0	56.17	94.130	1.171	6.791		
		3100.0							.607	229.0	56.17	94.130	1.171	6.791		
	2.80								.607	229.0	56.17	94.130	1.171	6.791		
	1.70								.607	229.0	56.17	94.130	1.171	6.791		
	1.20								.607	229.0	56.17	94.130	1.171	6.791		
	1.30								.607	229.0	56.17	94.130	1.171	6.791		
	2.50								.607	229.0	56.17	94.130	1.171	6.791		
		2880.0	111.11	1.000	1.000			1.000	.607	229.0	56.17	94.130	1.171	6.791	20	
	.707								.607	229.0	56.17	94.130	1.171	6.791		
	.829								.607	229.0	56.17	94.130	1.171	6.791		
	.806								.607	229.0	56.17	94.130	1.171	6.791		
	.720								.607	229.0	56.17	94.130	1.171	6.791		
	.710								.607	229.0	56.17	94.130	1.171	6.791		
	.693								.607	229.0	56.17	94.130	1.171	6.791		
	.612								.607	229.0	56.17	94.130	1.171	6.791		
	.607								.607	229.0	56.17	94.130	1.171	6.791		
	.607								.607	229.0	56.17	94.130	1.171	6.791		
	.598								.607	229.0	56.17	94.130	1.171	6.791		
	.770		111.11	1.000	1.000			1.000	.607	229.0	56.17	94.130	1.171	6.791	20	
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		
	.760								.607	229.0	56.17	94.130	1.171	6.791		

Table 7. h

Summary of Data - Extended Skirt (12.5%) Parachute

C_D	t_r (sec)	F_0 (lbs)	S_0 (ft ²)	l_b/D_0	M/D_0 (/ft)	l_r/D_0	S_v/S_0	λ at $\Delta P = 1/2 \rho V^2$ (ft ³ /ft ² min.)	u/S_0 (ft/sec)	V (ft/sec)	q (lb/ft ²)	$l_b \times 10^{-6}$	M	Pr	Type of Test	Ref.
.010			111.1	1,009	1,345	0	.004	108.0	.229	16.0	.280	1,207	.0140	.015	Free Fall	28
.708									.229	17.2	.324	1,290	.0151	.076		
.677									.229	17.6	.339	1,328	.0154	.096		
.587									.589	24.6	1.012	2,234	.0269	1.508		
.655									.589	27.9	.899	2,105	.0253	1.421		
.673									.635	30.5	1.112	2,101	.0268	1.554		
.588									1.028	51.9	1.111	3,916	.0460	2.644		
.011									.331	18.0	.400	6,464	.0168	.410		
.548			2605.0	.708	.4476	0	.004	104.5	.484	26.2	.004	9,400	.0243	.608		
.662									.618	27.0	.963	9,696	.0254	.627		
.473									1.310	23.4	.702	8,403	.0221	.544		
.632									.484	24.6	.765	8,844	.0230	.572		
.585									.311	21.1	.565	7,446	.0190	.490		
.665									.111	20.0	.497	8,841	.0186	.465		
.445									.638	32.3	1.248	11,400	.0299	.730		
.597									.640	28.8	1.060	10,160	.0266	.669		
.313									.689	44.2	2.200	8,180	.0306	1.375		
.368									.690	39.7	1.875	7,490	.0354	1.235		

14.3% Extension

.112			111.1	1,009	.844	.01	105.0	.143	10.7	.124	.007	.0094	.547	Free Fall	28
.103								.143	10.8	.127	.015	.0094	.552		
.1161								.143	10.4	.119	.785	.0092	.532		
.874								.274	17.0	.114	1,283	.0149	.869		
.874								.274	17.0	.114	1,283	.0149	.869		
.927								.274	16.5	.295	1,245	.0144	.844		
.827								.724	28.4	.875	2,343	.0248	1.452		
.783								.724	29.2	.925	2,203	.0255	1.493		
.757								.724	29.6	.955	2,234	.0259	1.513		
.905								1.018	41.1	2.010	3,101	.0374	2.101		
.950								1.018	40.1	1.913	3,076	.0365	2.050		
.913								1.018	40.9	1.991	3,086	.0372	2.091		
1.041								.143	11.0	.143	.810	.0097	.562		
1.061								.143	10.7	.131	.023	.0096	.557		
1.287								.143	9.9	.108	.747	.0087	.506		
.849								.274	17.2	.123	1,278	.0150	.879		
1.007								.274	15.7	.269	1,185	.0139	.803		
.912								.274	16.6	.100	1,253	.0146	.849		
.738								.724	30.0	.980	2,264	.0263	1.534		
.690								.724	31.0	1.047	2,139	.0272	1.585		
.822								.724	28.4	.742	2,143	.0249	1.452		
.781								1.027	45.0	2.119	3,196	.0406	2.301		
.720			2605.0	1,200	.844	.003	175.2	.588	26.1	.775	10,750	.0237	.566	Free Fall	5
1.020								1.752	22.0	.543	8,993	.0190	.473		
1.320								1.752	22.2	.413	7,848	.0173	.413		
.990								1.752	22.3	.550	9,115	.0201	.480		
.990								1.752	22.5	.568	9,197	.0203	.484		
.990								1.752	22.8	.581	9,320	.0205	.490		
.800								1.752	24.9	.675	10,100	.0224	.536		
.879								1.752	23.8	.635	9,728	.0214	.512		
.830								1.752	24.4	.667	9,974	.0220	.525		
.690								1.752	26.7	.799	10,910	.0243	.574		
.970								1.752	22.6	.573	9,240	.0204	.486		
.790								1.752	25.2	.712	10,100	.0227	.542		
.970								1.752	23.0	.591	9,401	.0207	.495		
.910								1.752	21.1	.509	8,707	.0192	.458		
1.110								1.752	23.3	.609	9,524	.0219	.501		
.890								1.752	21.1	.499	8,675	.0190	.454		
.636			1,000	.70	.04	.04	115.0	.587	21.6	.624	9,647	.0213	.508	Free Fall	35
.827								28.6	.924	11,790	.0250	.615			
.870								25.5	.710	10,200	.0219	.548			
.551								24.7	.675	9,993	.0213	.531			
.733								30.7	1.062	12,610	.0267	.660			
.603								27.3	.801	10,790	.0213	.587			
.782								27.6	.974	12,030	.0256	.637			
.855								26.2	.751	10,540	.0225	.563			
.816								21.2	.686	9,937	.0201	.479			
.846								24.7	.720	10,510	.0220	.531			
.727								24.1	.655	9,917	.0210	.518			

Table 7.i
Summary of Data - Extended Skirt (14.3%) Parachute

C_D	t_r (sec)	t_D (hr)	S_0 (ft ²)	L_3/D_0	H_1/D_0 (/ft)	L_r/D_0	S_v/S_0	λ $\pi L \Delta P^* / 2 \pi H_0$ (ft ^{1/2} /ft ² min.)	W/P_0 (lbf)	V (ft/sec)	q (lbf)	10×10^{-6}	M	Fr	Type of Test	Ref.
.706									.507	27.0	.032	11.200	.0217	.581		
.832									.501	29.6	.710	10.960	.0210	.529		
.763									.500	26.5	.779	10.210	.0208	.520		
.808									.510	25.3	.711	10.330	.0222	.599		
1.090									.500	22.0	.540	8.971	.0190	.573		
.682									.507	22.7	.861	11.320	.0291	.586		
.685									.507	21.7	.857	11.300	.0290	.585		
.679			3540.00	1.000	.8341	.04	.003	115.0	.507	21.3	.865	11.500	.0290	.587		35
.754									.507	25.7	.778	10.410	.0228	.553		
.756									.507	25.2	.777	10.450	.0228	.597		
.925									.500	22.9	.630	9.766	.0206	.592		
.975									.500	21.0	.605	9.529	.0202	.595		
.756									.530	26.9	.780	10.890	.0229	.559		
.987									.500	22.8	.598	9.540	.0200	.590		
.758			5319.73	.972	.7776				.575	25.5	.759	12.765	.0226	.596		
.969			5319.73	.972	.7776				.571	22.5	.591	11.264	.0199	.597		
.855			5319.73	.972	.7776				.575	23.5	.672	12.350	.0212	.597		
.911									.282	17.5	.352	7.164	.0154	.376		
.911									.282	17.9	.365	6.872	.0157	.379		
.846									.546	25.2	.753	10.316	.0226	.592		
.774			4157.00	.920	.7697	0	0	100.0	.596	27.8	.906	11.211	.0297	.598		
.653									.815	35.3	1.513	14.451	.0319	.759		25
.661									.835	39.9	1.994	14.124	.0317	.750		
.544									1.027	42.9	2.231	17.561	.0325	.922		
.530									1.027	44.1	2.277	18.053	.0331	.948		
	9180.0			.990					.353	32.7	116.1	157.900	.280	6.436		
	9750.0			.990					.365	36.5	149.0	181.100	.3160	7.198		
	9600.0								.480	278.7	86.8	148.900	.2419	5.473		
	9540.0		5230.00	.990	.7843				.480	324.3	116.6	159.600	.2804	6.369		
	14,350								.480	404.0	183.5	201.000	.3514	7.934		
	17,300								.480	446.6	225.8	221.400	.3896	8.771		

Table 8. a
Summary of Data - Ringslot Parachute

C_D	t_r (sec)	F_0 (lbs)	S_0 (ft ²)	$1/a/D_0$	N_r/D_0 (/ft)	$1/r/D_0$	S_v/S_0	λ Geometric (%)	W/S_0 (psf)	V (ft/sec)	q (psf)	$R_0 \times 10^{-6}$	M	Pr	Type of Test	Ref.
.670										465.0	234.00	20.720	.413	29.250		
	.60	8,247								529.0	402.00	22.600	.471	33.200		
.660										450.0	219.00	20.000	.400	28.400		
.570										407.0	176.00	17.850	.358	25.420		
.660										428.0	238.00	15.750	.318	22.580		
.650										428.0	116.00	14.620	.292	20.700		
.680										278.0	86.00	11.280	.265	18.780		
.710										269.0	78.00	11.960	.239	16.950		
.780										240.0	61.00	10.680	.213	15.120		
	.50	10,166								584.0	459.00	25.550	.518	36.830		
.660										500.0	267.00	21.850	.443	31.550		
.630										481.0	243.00	21.150	.427	30.500		
.640										465.0	211.00	20.350	.411	29.330		
.710										415.0	184.00	18.180	.367	26.150		
.730										402.0	140.00	15.850	.320	22.850		
.710										440.0	110.00	14.450	.292	20.800		
.770										287.0	88.00	12.560	.254	18.100		
.700										267.0	66.00	11.670	.230	17.850		
.770										271.0	67.00	10.000	.222	15.840		
.530										514.0	286.00	23.270	.457	32.350		
.570										480.0	249.00	21.430	.427	30.220		
.640										478.0	247.00	21.430	.425	30.150		
.750										385.0	160.00	17.250	.342	24.270		
.790										341.0	126.00	15.270	.303	21.500		
.810										311.0	105.00	11.790	.276	19.600		
.890										271.0	81.00	12.240	.243	17.200		
.880										250.0	71.00	11.480	.228	16.140		
.610										508.0	280.00	22.080	.454	32.100		
.600										476.0	249.00	20.650	.425	30.000		
.600										421.0	192.00	18.270	.376	26.600		
.620										408.0	161.00	16.850	.346	24.440		
.610										352.0	146.00	15.200	.314	22.180		
.600										327.0	111.00	13.830	.286	20.180		
.6400			48.00	1.535	1.535			14.50	48.20	400.0	503.00	13.020	.268	18.910	Sled Test	
.690										507.0	321.00	24.050	.485	34.910		
.700										518.0	308.00	21.850	.454	32.600		
.710										460.0	271.00	19.850	.429	28.130		
.750										385.0	160.00	17.450	.353	24.900		
.720										377.0	137.00	15.750	.316	22.480		
.720										351.0	110.00	14.360	.285	20.220		
.740										341.0	97.00	11.280	.262	18.750		
.710										277.0	82.00	12.210	.246	17.950		
.590										534.0	307.00	23.380	.472	33.880		
.610										521.0	281.00	22.800	.465	32.860		
.610										500.0	266.00	22.210	.450	32.100		
.650										480.0	214.00	19.550	.437	28.250		
.680										460.0	171.00	17.450	.424	25.250		
.680										400.0	140.00	15.700	.373	22.700		
.710										358.0	115.00	14.110	.320	20.650		
.680										300.0	87.00	13.090	.265	18.020		
.690										280.0	86.00	12.220	.247	17.650		
.670										407.0	265.00	21.350	.441	31.100		
.670										478.0	208.00	21.200	.440	31.250		
.660										484.0	201.00	21.050	.440	31.100		
.670										480.0	202.00	21.350	.441	30.950		
.650										474.0	208.00	21.250	.440	30.150		
.620										462.0	209.00	20.720	.437	29.500		
.690										420.0	206.00	20.270	.430	28.850		
.660										408.0	217.00	19.810	.428	28.250		
.670										434.0	207.00	19.180	.435	27.100		
.650										400.0	172.00	17.070	.422	25.260		
.680										362.0	150.00	16.000	.381	22.800		
.680										340.0	117.00	14.200	.343	20.770		
.660										312.0	104.00	13.790	.317	19.650		
.660										270.0	90.00	12.810	.275	18.260		
.660										270.0	78.00	11.920	.240	17.000		
.584										270.0	13.3	1.110	.010	1.007		
.710										270.0	272.1	4.110	.026	.000	Free Fall	
.584										270.0	13.3	1.110	.010	1.007		
.529										270.0	89.3	1.914	.011	1.037		

Table 8.b
Summary of Data - Ringslot Parachute

C_D	t_T (sec)	F_0 (lb)	β_0 (ft ²)	$1_s/D_0$	N_s/D_0 (/ft)	$1_T/D_0$	β_T/β_0	λ (geometric) (L)	W/β_0 (lb/ft)	V (ft/sec)	q (psf)	$Re \times 10^{-4}$	B	Pr	Type of Test	Ref.
.502			920.80	1.000	.0006		.00050	1.02	.700	37.8	1.220	7.121	.0415	.292		1
.502									.700	37.8	1.220	7.121	.0415	.292		
.502									.700	37.8	1.220	7.121	.0415	.292		
.640									.700	37.8	1.220	7.121	.0415	.292		
.672									.700	37.8	1.220	7.121	.0415	.292		
.522									.700	37.8	1.220	7.121	.0415	.292		
.602									.700	37.8	1.220	7.121	.0415	.292		
.657									.700	37.8	1.220	7.121	.0415	.292		
.645									.700	37.8	1.220	7.121	.0415	.292		
.588									.700	37.8	1.220	7.121	.0415	.292		
.626			101.46		1.155		.00010	17.00	.700	37.8	1.220	7.121	.0415	.292		
.639									.700	37.8	1.220	7.121	.0415	.292		
.676									.700	37.8	1.220	7.121	.0415	.292		
.606									.700	37.8	1.220	7.121	.0415	.292		
.669									.700	37.8	1.220	7.121	.0415	.292		
.676									.700	37.8	1.220	7.121	.0415	.292		
.654									.700	37.8	1.220	7.121	.0415	.292		
.542									.700	37.8	1.220	7.121	.0415	.292		
.902									.700	37.8	1.220	7.121	.0415	.292		
.822									.700	37.8	1.220	7.121	.0415	.292		
.809			100.00		1.164		.00070	10.00	.700	37.8	1.220	7.121	.0415	.292		
.812									.700	37.8	1.220	7.121	.0415	.292		
.789									.700	37.8	1.220	7.121	.0415	.292		
.780									.700	37.8	1.220	7.121	.0415	.292		
.676									.700	37.8	1.220	7.121	.0415	.292		
.724									.700	37.8	1.220	7.121	.0415	.292		
.705									.700	37.8	1.220	7.121	.0415	.292		
.676									.700	37.8	1.220	7.121	.0415	.292		
.505									.700	37.8	1.220	7.121	.0415	.292		
.678									.700	37.8	1.220	7.121	.0415	.292		
.792			101.46	1.020			.00010	11.5	.700	37.8	1.220	7.121	.0415	.292		28
.846									.700	37.8	1.220	7.121	.0415	.292		
.846									.700	37.8	1.220	7.121	.0415	.292		
.846									.700	37.8	1.220	7.121	.0415	.292		
.719									.700	37.8	1.220	7.121	.0415	.292		
.797									.700	37.8	1.220	7.121	.0415	.292		
.787									.700	37.8	1.220	7.121	.0415	.292		
.665									.700	37.8	1.220	7.121	.0415	.292		
.781									.700	37.8	1.220	7.121	.0415	.292		
.671									.700	37.8	1.220	7.121	.0415	.292		
.621			101.46	1.155			.00010	17.00	.700	37.8	1.220	7.121	.0415	.292		
.769									.700	37.8	1.220	7.121	.0415	.292		
.810									.700	37.8	1.220	7.121	.0415	.292		
.814									.700	37.8	1.220	7.121	.0415	.292		
.688									.700	37.8	1.220	7.121	.0415	.292		
.766									.700	37.8	1.220	7.121	.0415	.292		
.679									.700	37.8	1.220	7.121	.0415	.292		
.641									.700	37.8	1.220	7.121	.0415	.292		
.662									.700	37.8	1.220	7.121	.0415	.292		
.758									.700	37.8	1.220	7.121	.0415	.292		
.645			101.46	1.020			.00010	11.5	.700	37.8	1.220	7.121	.0415	.292		
.587									.700	37.8	1.220	7.121	.0415	.292		
.707									.700	37.8	1.220	7.121	.0415	.292		
.803									.700	37.8	1.220	7.121	.0415	.292		
.818									.700	37.8	1.220	7.121	.0415	.292		
.844									.700	37.8	1.220	7.121	.0415	.292		
.810									.700	37.8	1.220	7.121	.0415	.292		
.799									.700	37.8	1.220	7.121	.0415	.292		
.745									.700	37.8	1.220	7.121	.0415	.292		
.684									.700	37.8	1.220	7.121	.0415	.292		
.667			101.46	1.020			.00010	11.5	.700	37.8	1.220	7.121	.0415	.292		
.746									.700	37.8	1.220	7.121	.0415	.292		
.467									.700	37.8	1.220	7.121	.0415	.292		
.692									.700	37.8	1.220	7.121	.0415	.292		
.758									.700	37.8	1.220	7.121	.0415	.292		
.772									.700	37.8	1.220	7.121	.0415	.292		
.707									.700	37.8	1.220	7.121	.0415	.292		
.678									.700	37.8	1.220	7.121	.0415	.292		
.678									.700	37.8	1.220	7.121	.0415	.292		
.648									.700	37.8	1.220	7.121	.0415	.292		

Table 8. c
Summary of Data - Ringslot Parachute

C_D	U_F (m/sec)	F_0 (lb.)	S_U (ft ²)	L_U/D_U	M_F/D_U (ft/lb)	L_F/D_U	S_F/S_U	λ (Aerodynamic) (%)	M/D_U (ft/lb)	V (ft/sec)	q (ft ²)	$Re \times 10^{-6}$	N	FF	Type of Test	Ref.
.007			109.44	1.020	1.355		.008	17.80	.004	24.0	.118	1.055	.0221	1.200	Free Fall	28
.017									.012	49.5	.230	3.200	.0408	2.405		
.030									.020	92.2	.415	5.700	.0880	2.405		
.041									.0212	92.4	.415	5.700	.0880	2.405		
.051									.0212	92.4	.415	5.700	.0880	2.405		
.072									.031	102.7	.618	6.600	.0017	.547		
.100									.0400	102.6	.812	.798	.0080	.542		
.111									.0400	102.6	.812	.798	.0080	.542		
.130									.041	102.6	.812	.798	.0080	.542		
.141									.041	102.6	.812	.798	.0080	.542		
.171			107.92	1.024				10.00	.041	102.6	.812	.798	.0080	.542	Free Fall	27
.185									.041	102.6	.812	.798	.0080	.542		
.211									.041	102.6	.812	.798	.0080	.542		
.227									.041	102.6	.812	.798	.0080	.542		
.241									.041	102.6	.812	.798	.0080	.542		
.260									.041	102.6	.812	.798	.0080	.542		
.277									.041	102.6	.812	.798	.0080	.542		
.290									.041	102.6	.812	.798	.0080	.542		
.300									.041	102.6	.812	.798	.0080	.542		
.311									.041	102.6	.812	.798	.0080	.542		
.327			109.38	1.017				11.5	.041	102.6	.812	.798	.0080	.542	Free Fall	27
.341									.041	102.6	.812	.798	.0080	.542		
.360									.041	102.6	.812	.798	.0080	.542		
.377									.041	102.6	.812	.798	.0080	.542		
.390									.041	102.6	.812	.798	.0080	.542		
.400									.041	102.6	.812	.798	.0080	.542		
.411									.041	102.6	.812	.798	.0080	.542		
.427									.041	102.6	.812	.798	.0080	.542		
.441									.041	102.6	.812	.798	.0080	.542		
.460									.041	102.6	.812	.798	.0080	.542		
.477								17.0	.041	102.6	.812	.798	.0080	.542		
.490									.041	102.6	.812	.798	.0080	.542		
.500									.041	102.6	.812	.798	.0080	.542		

Summary of Data - Ribbon Parachute

U_D	L_T (mic)	T (sec)	U_D (ft ²)	L_D/U_D	H_D/U_D (ft)	L_T/U_D	T/U_D	λ Geometric (ft)	λ^2 (ft ²)	λ^3 (ft ³)	λ^4 (ft ⁴)	λ^5 (ft ⁵)	λ^6 (ft ⁶)	λ^7 (ft ⁷)	λ^8 (ft ⁸)	λ^9 (ft ⁹)	λ^{10} (ft ¹⁰)	λ^{11} (ft ¹¹)	λ^{12} (ft ¹²)	λ^{13} (ft ¹³)	λ^{14} (ft ¹⁴)	λ^{15} (ft ¹⁵)	λ^{16} (ft ¹⁶)	λ^{17} (ft ¹⁷)	λ^{18} (ft ¹⁸)	λ^{19} (ft ¹⁹)	λ^{20} (ft ²⁰)	λ^{21} (ft ²¹)	λ^{22} (ft ²²)	λ^{23} (ft ²³)	λ^{24} (ft ²⁴)	λ^{25} (ft ²⁵)	λ^{26} (ft ²⁶)	λ^{27} (ft ²⁷)	λ^{28} (ft ²⁸)	λ^{29} (ft ²⁹)	λ^{30} (ft ³⁰)	λ^{31} (ft ³¹)	λ^{32} (ft ³²)	λ^{33} (ft ³³)	λ^{34} (ft ³⁴)	λ^{35} (ft ³⁵)	λ^{36} (ft ³⁶)	λ^{37} (ft ³⁷)	λ^{38} (ft ³⁸)	λ^{39} (ft ³⁹)	λ^{40} (ft ⁴⁰)	λ^{41} (ft ⁴¹)	λ^{42} (ft ⁴²)	λ^{43} (ft ⁴³)	λ^{44} (ft ⁴⁴)	λ^{45} (ft ⁴⁵)	λ^{46} (ft ⁴⁶)	λ^{47} (ft ⁴⁷)	λ^{48} (ft ⁴⁸)	λ^{49} (ft ⁴⁹)	λ^{50} (ft ⁵⁰)	λ^{51} (ft ⁵¹)	λ^{52} (ft ⁵²)	λ^{53} (ft ⁵³)	λ^{54} (ft ⁵⁴)	λ^{55} (ft ⁵⁵)	λ^{56} (ft ⁵⁶)	λ^{57} (ft ⁵⁷)	λ^{58} (ft ⁵⁸)	λ^{59} (ft ⁵⁹)	λ^{60} (ft ⁶⁰)	λ^{61} (ft ⁶¹)	λ^{62} (ft ⁶²)	λ^{63} (ft ⁶³)	λ^{64} (ft ⁶⁴)	λ^{65} (ft ⁶⁵)	λ^{66} (ft ⁶⁶)	λ^{67} (ft ⁶⁷)	λ^{68} (ft ⁶⁸)	λ^{69} (ft ⁶⁹)	λ^{70} (ft ⁷⁰)	λ^{71} (ft ⁷¹)	λ^{72} (ft ⁷²)	λ^{73} (ft ⁷³)	λ^{74} (ft ⁷⁴)	λ^{75} (ft ⁷⁵)	λ^{76} (ft ⁷⁶)	λ^{77} (ft ⁷⁷)	λ^{78} (ft ⁷⁸)	λ^{79} (ft ⁷⁹)	λ^{80} (ft ⁸⁰)	λ^{81} (ft ⁸¹)	λ^{82} (ft ⁸²)	λ^{83} (ft ⁸³)	λ^{84} (ft ⁸⁴)	λ^{85} (ft ⁸⁵)	λ^{86} (ft ⁸⁶)	λ^{87} (ft ⁸⁷)	λ^{88} (ft ⁸⁸)	λ^{89} (ft ⁸⁹)	λ^{90} (ft ⁹⁰)	λ^{91} (ft ⁹¹)	λ^{92} (ft ⁹²)	λ^{93} (ft ⁹³)	λ^{94} (ft ⁹⁴)	λ^{95} (ft ⁹⁵)	λ^{96} (ft ⁹⁶)	λ^{97} (ft ⁹⁷)	λ^{98} (ft ⁹⁸)	λ^{99} (ft ⁹⁹)	λ^{100} (ft ¹⁰⁰)	λ^{101} (ft ¹⁰¹)	λ^{102} (ft ¹⁰²)	λ^{103} (ft ¹⁰³)	λ^{104} (ft ¹⁰⁴)	λ^{105} (ft ¹⁰⁵)	λ^{106} (ft ¹⁰⁶)	λ^{107} (ft ¹⁰⁷)	λ^{108} (ft ¹⁰⁸)	λ^{109} (ft ¹⁰⁹)	λ^{110} (ft ¹¹⁰)	λ^{111} (ft ¹¹¹)	λ^{112} (ft ¹¹²)	λ^{113} (ft ¹¹³)	λ^{114} (ft ¹¹⁴)	λ^{115} (ft ¹¹⁵)	λ^{116} (ft ¹¹⁶)	λ^{117} (ft ¹¹⁷)	λ^{118} (ft ¹¹⁸)	λ^{119} (ft ¹¹⁹)	λ^{120} (ft ¹²⁰)	λ^{121} (ft ¹²¹)	λ^{122} (ft ¹²²)	λ^{123} (ft ¹²³)	λ^{124} (ft ¹²⁴)	λ^{125} (ft ¹²⁵)	λ^{126} (ft ¹²⁶)	λ^{127} (ft ¹²⁷)	λ^{128} (ft ¹²⁸)	λ^{129} (ft ¹²⁹)	λ^{130} (ft ¹³⁰)	λ^{131} (ft ¹³¹)	λ^{132} (ft ¹³²)	λ^{133} (ft ¹³³)	λ^{134} (ft ¹³⁴)	λ^{135} (ft ¹³⁵)	λ^{136} (ft ¹³⁶)	λ^{137} (ft ¹³⁷)	λ^{138} (ft ¹³⁸)	λ^{139} (ft ¹³⁹)	λ^{140} (ft ¹⁴⁰)	λ^{141} (ft ¹⁴¹)	λ^{142} (ft ¹⁴²)	λ^{143} (ft ¹⁴³)	λ^{144} (ft ¹⁴⁴)	λ^{145} (ft ¹⁴⁵)	λ^{146} (ft ¹⁴⁶)	λ^{147} (ft ¹⁴⁷)	λ^{148} (ft ¹⁴⁸)	λ^{149} (ft ¹⁴⁹)	λ^{150} (ft
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Table 9. b
Summary of Data - Ribbon Parachute

C_D	t_r (sec)	F_o (lbs)	S_o (ft ²)	l_B/D_o	N_B/D_o (/ft)	l_P/D_o	S_v/S_o	λ Geometric (%)	W/S_o (lbf)	V (ft/sec)	q (lbf)	$H_o \times 10^{-6}$	M	Pr	Type of Test	Ref.
.469			109.29	1.018	1.356		.008	20.0	1.168	46.3	2.487	3.464	.0416	2.377	Free Fall	20
.555									.080	11.2	.144	.874	.0100	.577		
.609									.080	10.7	.132	.797	.0096	.551		
.581									.156	15.3	.269	1.139	.0137	.788		
.574									.156	15.4	.273	1.146	.0138	.793		
.574									.156	15.4	.273	1.146	.0138	.793		
.531									.387	25.2	.730	1.876	.0226	1.237		
.506									.387	25.8	.765	1.920	.0231	1.328		
.487									.387	26.3	.745	1.958	.0236	1.354		
.498									.850	38.5	1.705	2.866	.0345	1.982		
.478									.850	39.3	1.776	2.926	.0352	2.023		
.506									.850	38.2	1.678	2.844	.0343	1.966		
.595			108.12	1.023	1.364		.010	25.0	.080	10.8	.114	.804	.0097	.556		
.595									.080	10.8	.114	.804	.0097	.556		
.628									.080	10.5	.127	.782	.0094	.541		
.586									.156	15.2	.266	1.132	.0136	.783		
.564									.156	15.5	.276	1.154	.0139	.798		
.564									.156	15.5	.276	1.154	.0139	.798		
.492									.387	26.1	.783	1.943	.0234	1.344		
.500									.387	25.9	.771	1.928	.0232	1.333		
.463									.387	26.9	.832	2.003	.0241	1.385		
.437									.850	41.1	1.943	3.060	.0369	2.116		
.473									.850	39.5	1.794	2.941	.0354	2.033		
.441									.850	40.9	1.924	3.045	.0367	2.105		
.565									.080	11.1	.142	.826	.0100	.571		
.520			3.84	1.020	7.236			20.0	11.200	233.8	60.000	2.774	.2040	27.710	Infinite Mass	21
.480				1.030				10.0	2.400	67.5	5.000	.800	.0580	8.040		
.460				1.030				30.0	11.500	151.0	25.000	1.790	.1320	17.980		
.490			3.77	1.030	7.296			30.0	29.400	233.8	60.000	2.771	.2040	27.830		
.490				1.030				30.0	29.400	233.8	60.000	2.771	.2040	27.830		
.490				1.030				10.0	29.400	233.8	60.000	2.771	.2040	27.830		
.450				1.030				10.0	27.000	233.8	60.000	2.771	.2040	27.830		
.600				1.020					3.000	67.5	5.000	.789	.0580	8.090		
.570				1.020					14.250	151.0	25.000	1.765	.1320	18.090		
.600				1.020					36.000	233.8	60.000	2.732	.2040	28.000		
.680			3.66	1.020	7.413			10.0	40.000	233.8	60.000	2.732	.2040	28.000		
.440				1.000					2.200	67.5	5.000	.789	.0580	8.090		
.640				1.000					3.200	67.5	5.000	.789	.0580	8.090		
.560				1.000					14.000	151.0	25.000	1.765	.1320	18.090		
.600				1.000					36.000	233.8	60.000	2.732	.2040	28.000		
.470									2.250	67.5	5.000	.807	.0580	8.000		
.510									12.750	151.0	25.000	1.805	.1320	17.900		
.460			3.84	1.020	7.236			20.0	11.500	151.0	25.000	1.805	.1320	17.900		
.520									31.200	233.8	60.000	2.794	.2040	27.710		
.530									31.800	233.8	60.000	2.794	.2040	27.710		
.600									.070	10.6	.136	.799	.0097	.542	Free Fall	28
.636			111.10	1.009	1.345			26.0	.070	10.1	.146	.777	.0094	.527		
.622									.142	14.2	.229	1.072	.0127	.726		
.639									.142	14.0	.222	1.056	.0125	.716		
.630			3.66	1.000	7.412			10.0	147.200	233.8	60.000	2.732	.2040	28.000	Infinite Mass	29
.409									.265	23.6	.406	1.781	.0214	1.207		
.413									.265	23.4	.402	1.766	.0212	1.196	Free Fall	28
.502									.277	20.3	.468	1.532	.0181	1.038		
.494									.617	11.7	1.283	2.543	.0301	1.723		
.432									.637	16.5	1.721	2.754	.0322	1.866		
.451									.637	15.7	1.608	2.634	.0315	1.825		
.604									.078	10.2	.118	.770	.0091	.521		
.722									.078	9.9	.108	.747	.0087	.506		
.700			111.10	1.009	1.345			26.0	.078	10.0	.110	.755	.0088	.511		
.607									.142	14.1	.220	1.064	.0125	.721		
.626									.142	14.3	.227	1.079	.0127	.731		
.672									.142	14.0	.211	1.041	.0122	.706		
.464									.277	23.2	.458	1.551	.0205	1.188		
.489									.277	22.6	.447	1.505	.0200	1.155		
.510									.277	21.9	.437	1.453	.0192	1.120		
.366									.637	19.6	1.741	2.888	.0350	2.024		
.454									.637	18.9	1.695	2.809	.0345	1.935		
.607			101.29	1.018	1.344		.008	20.0	.092	11.0	.145	.823	.0100	.565		
.604			101.29	1.018	1.344		.008	20.0	.099	11.2	.151	.838	.0102	.575		
.603			101.29	1.018	1.344		.008	20.0	.099	11.2	.151	.838	.0102	.575		

Table 9. c

Summary of Data - Ribbon Parachute

C_D	t_T (sec)	F_0 (lbs)	S_0 (ft ²)	$1_s/D_0$	N_{P/D_0} (/ft)	$1_r/D_0$	S_v/D_0	λ Geometric (%)	W/S_0 (lb/ft ²)	V (ft/sec)	q (lb/ft ²)	$Re \times 10^{-6}$	M	Pr	Type or Test	Ref.
.592																
.585																
.607																
.532																
.514																
.517																
.499																
.497																
.527																
.652																
.520																
.631																
.610																
.517																
.625																
.522																
.530																
.471																
.422																
.461																
.500																
.460																
.470																
.470																
.460																
.480																
.470																
.440																
.590																
.590																
.540																
.580																
.530																
.600																
.550																
.520																
.500																
.510																
.570																
.550																
.600																
.136	12.805	54.00			1.930	1.41			2.7	42.600	488.0	270.0	25.000	4.440	21.700	
.122	11.158	54.00			1.930	1.41			2.7	42.600	488.0	270.0	25.000	4.440	21.700	
.185	4.751	56.60			1.885	1.41			2.7	42.600	488.0	270.0	25.000	4.440	21.700	
.610		1.67	1.000		7.402		.001		10.0	1.050	67.5	5.0	2.00	0.00	8.100	
.500		1.82	1.350		7.255		.001		20.0	2.500	67.5	5.0	8.01	0.00	8.100	
.500		1.78	1.400		7.293		.001		30.0	2.500	67.5	5.0	8.01	0.00	8.100	
.570		3.67	1.060		7.402		.001		10.0	14.240	151.0	25.0	1.894	1.150	18.000	
.520		1.82	1.350		7.255		.001		20.0	14.000	151.0	25.0	1.890	1.150	17.000	
.470		1.78	1.400		7.293		.001		30.0	11.230	151.0	25.0	1.878	1.150	18.000	
.610		1.67	1.060		7.402		.001		10.0	30.300	233.8	60.0	2.000	2.040	28.000	
.520		3.82	1.350		7.255		.001		20.0	11.200	233.8	60.0	2.110	2.040	27.000	
.490		3.78	1.400		7.293		.001		30.0	29.000	233.8	60.0	2.310	2.040	27.000	
.650		23.30			2.203				18.6	6.500	101.0	10.0	1.230	0.00	6.000	
.630		22.80			2.227				18.6	6.500	101.0	10.0	1.230	0.00	6.000	
.440		16.10		1.010			1.12		29.4	5.500	118.0	11.4	4.350	1.000	8.000	
.460		20.10			2.360				29.4	4.700	101.0	10.2	3.770	0.00	6.000	
.490		21.30			2.304				29.4	4.700	100.0	9.6	3.660	0.00	6.000	
.680										42.600	422.0	201.0	21.000	3.000	27.000	
.570										42.600	418.0	197.0	21.000	3.000	27.000	
.520										42.600	381.0	179.0	20.000	3.000	24.000	
.540										42.600	378.0	181.0	19.000	3.000	23.000	
.710										42.600	355.0	142.0	18.000	3.000	21.000	
.820										42.600	341.0	116.0	16.700	2.900	19.000	
.770										42.600	294.0	98.0	16.000	2.670	17.000	
.470										42.600	267.0	80.0	14.900	2.040	16.000	
.470										42.600	248.0	63.0	14.000	2.000	15.000	
.410										42.600	236.0	61.0	14.170	2.000	14.000	
.710										42.600	236.0	57.0	14.200	2.000	14.000	
.710										42.600	236.0	57.0	14.200	2.000	14.000	

Summary of Data - Ribbon Parachute

C _D	t _r (sec)	F ₀ (lbs)	S ₀ (ft ²)	I _s /D ₀	M _R /D ₀ (/ft)	I _r /U ₀	S _v /S ₀	λ Geometric (%)	U/S ₀ (in)	V (ft/sec)	q (in)	Re x 10 ⁻⁶	M	Pr	Type of Test	Ref.																													
.530			58.00	1.862	1.379			24.0	42.70	473.0	242.0	23.58	.421	28.27																															
.540										459.0	228.0	22.68	.409	27.43																															
.540										443.0	212.0	22.08	.394	26.48																															
.540										425.0	195.0	21.18	.378	25.40																															
.540										414.0	168.0	19.64	.351	23.55																															
.540										374.0	151.0	16.64	.333	22.36																															
.540										338.0	124.0	15.00	.301	20.20																															
.530										317.0	108.0	15.80	.282	18.95																															
.560										295.0	94.0	14.71	.263	17.63																															
.540										279.0	84.0	13.91	.248	16.68																															
.540			263.0	75.0	13.11	.234	15.72																																						
.620			455.0	225.0	22.79	.406	27.33																																						
.590			451.0	221.0	22.59	.402	27.09																																						
.600			440.0	210.0	22.04	.392	26.43																																						
.570			436.0	206.0	21.84	.389	26.19																																						
.550			434.0	205.0	21.74	.387	26.07																																						
.560			420.0	192.0	21.03	.375	25.23																																						
.560			383.0	159.0	19.18	.342	23.00																																						
.550			348.0	132.0	17.43	.310	20.90																																						
.550			334.0	107.0	15.73	.280	18.86																																						
.540			291.0	92.0	14.58	.260	17.48																																						
.520			282.0	86.0	14.12	.252	16.94																																						
	.28	7938.0		1.885		0								19.50	42.80	466.0	236.0	23.24	.416	27.99																									
	.22	8316.0														455.0	272.0	25.38	.445	29.73																									
.560																486.0	262.0	24.92	.437	29.19																									
.550																486.0	262.0	24.92	.437	29.19																									
.550																486.0	262.0	24.92	.437	29.19																									
.540																470.0	245.0	24.10	.423	28.23																									
.530																460.0	235.0	23.59	.414	27.63																									
.540																446.0	221.0	22.87	.401	26.79																									
.540								437.0	212.0	22.43	.393	26.27																																	
.550								425.0	200.0	21.79	.382	25.53																																	
.560			380.0	160.0	19.44	.342	22.82																																						
			342.0	130.0	17.54	.308	20.54																																						
	122.00	7.84	1.020	7.246		0								20.0	233.8	60.0	2.794	.2040	27.71																										
	12.00		1.010														10.0		67.5	5.0	.789	.0580	8.09																						
	50.00		1.010																		10.0		151.0	25.0	1.790	.1320	17.90																		
	119.00	3.77	1.010																						10.0		233.8	60.0	2.771	.2040	27.83														
	119.00		1.010																										10.0		233.8	60.0	2.771	.2040	27.83										
	119.00		1.010																														10.0		233.8	60.0	2.771	.2040	27.83						
	109.00		1.010																																		10.0		233.8	60.0	2.771	.2040	27.83		
	400	17.00	1.020																																						10.0		67.5	5.0	.789
	130	75.00	1.020						10.0		151.0	25.0	1.765																															.1320	18.09
	173.00	3.06	1.020										10.0																																233.8
	1080	195.00	1.020			10.0								233.8	60.0																														
	17.00		1.000													10.0		67.5	5.0																										
	18.00		1.000																	10.0		67.5	5.0																						
	71.00		1.000																					10.0		151.0	25.0																		
	168.00		1.000																									10.0		233.8	60.0														
	12.00																															10.0		67.5	5.0										
	270	55.00																																		10.0		151.0	25.0						
	47.00	3.84																																						10.0		151.0	25.0		
	180	120.00							10.0		233.8																																60.0		
	190	125.00											10.0																															233.8	60.0
	186.00	1.60	1.000	7.412		10.0								233.8																															60.0

Table 10

Summary of Data - Ribless Guide Surface Parachute

[illegible]

Aeronautical Systems Division, Dir./Aero-Mechanics, Flight Accessories Lab, Wright-Patterson AFB, Ohio.
Rpt No. ASD-TDR-62-1023. STUDY OF PARACHUTE SCALE EFFECTS. Final report, Dec 62, 92p.. incl illus., tables, 158 refs.

A study was conducted to determine the effects of changing scale upon drag coefficient, filling time, peak opening force, and stability for single, unreefed textile parachute canopies. The investigation was confined to Flat Circular, Extended Skirt, Ringslot, Ribless Guide Surface, Circular Flat Ribbon, and Conical Ribbon parachutes operating in the subsonic flow regime at altitudes below 20,000

feet. As an integral part of the study, a survey of the existing literature and test data, compilation of all pertinent data, and recommendations for future experimental investigations were made. Scaling equations with associated 95-percent confidence intervals were developed for the drag coefficient of the Flat Circular and Extended Skirt parachutes through the use of a multiple regression analysis which indicates the significant variables and their functional forms. Because the available data was poorly distributed, the equations will have to be used circumspectly to avoid misleading conclusions.

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- I. AFSC Proj 6065, Task 606502
 - II. Contract No. AF 33(657)-8073
 - III. Technology Inc., Dayton, Ohio
 - IV. Walcott, William B.
 - V. Aval fr OTS
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