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DESIGN STRESS ANALYSIS AND PERFORMANCE  
CHARACTERISTICS FOR 140-FOOT DIAMETER  
RSR RIBCO (RAPID INFLATION BOWLINE CON-  
TROLLED OPENING) PARACHUTE SYSTEM

Joe A. Haden

Recovery Systems Research, Incorporated

Prepared for:

Air Force Cambridge Research Laboratories

30 July 1972

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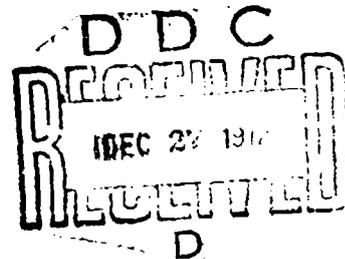
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P. O. Box 137  
Alamogordo, New Mexico 88310

Contract No. F19628-72-C-0131  
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2 December 1971  
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Contractor Monitor: James C. Payne  
Aerospace Instrumentation Laboratory

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AIR FORCE CAMBRIDGE RESEARCH LABORATORIES  
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| 14. Key Words<br>Multi Purpose<br>High Altitude<br>Rapid Inflation<br>Lightweight<br>Controlled Opening<br>Minimum Snatch Force<br>Minimum Opening Shock<br>No Ancillary Reefing<br>Heavy Payload<br>Fast Opening  |   |   |  |

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II

## ABSTRACT

This report presents the design, stress analysis and high altitude performance of the RSR RIBCO Parachute System. A 140-foot diameter parachute system was tested by Air Force Cambridge Research Laboratories. This system was released from a balloon at 100,000 feet altitude with a payload of 611 pounds.

Performance characteristics (opening time, opening shock, snatch force, rate of descent and total descent time) were very nearly as predicted. Test results indicate that the RIBCO System offers many advantages over conventional parachute systems.

III

## INTRODUCTION

Recovery Systems Research, Inc. has developed a parachute recovery system through a series of 40 test drops with parachutes ranging from 28-ft nominal diameter to 140-ft nominal diameter and recovered loads of 300 pounds to 5800 pounds. The purpose of this development effort was to produce a multi-purpose parachute system (utilizing one parachute) with optimum performance characteristics both at extremely high and low altitudes with heavy and light loads and without deployment aids such as time delay reefing and forced deployment mortars.

Testing has not been pursued to the extent that the RSR RIBCO (Rapid Inflation Bowline Controlled Opening) parachute system is operational for balloon payload recovery; however, it appears to be a substantial improvement over the presently used parachute systems.

The RIBCO parachute system design permits the use of one standard size parachute for recovery of minimum and maximum payloads since the unique rigging insures inflation at any velocity. This rigging also limits the opening dynamics to such an extent that very light canopy material can be used in construction thus permitting fabrication of larger parachutes with higher load carrying capability and eliminating the need for reefing to control parachute opening.

One high altitude balloon payload recovery test has been made by AFCRL utilizing the 140-ft RIBCO parachute system. The 611-pound payload for this test approached the minimum, 500 pounds, for which the parachute system was designed. Optimum performance is expected when the parachute system is utilized with maximum rated load of 8,000 pounds.

Reference AFCRL Preliminary Report on AFCRL Flight 72-26 Proceedings, Seventh AFCRL Scientific Balloon Symposium.

IV

DESIGN STRESS ANALYSIS AND PERFORMANCE  
CHARACTERISTICS FOR 140-FOOT DIAMETER RIBCO PARACHUTE

V

LIST OF MATERIALS

| <u>ITEM</u>        | <u>RATED TENSILE STRENGTH</u> |
|--------------------|-------------------------------|
| Fabric - 1.1 oz/yd | 40 lbf/in                     |
| Control Lines      | 6000 lbf                      |
| Suspension Lines   | 550 lbf                       |
| Apex Lines         | 750 lbf                       |
| Radial Tapes       | 250 lbf                       |
| Apex Loop Line     | 10,000 lbf                    |

### DESIGN DATA

| <u>Symbol</u> | <u>Meaning</u>                    | <u>Units</u>                                   |
|---------------|-----------------------------------|--|
| $D_o$         | Nominal Diameter                  | 140 ft   |
| $S_o$         | Total Area                        | 15,394 ft <sup>2</sup>                         |
| $S_f$         | Frontal Area                      | 10,776 ft <sup>2</sup>                         |
| $Z_s$         | Number of Suspension Lines        | 120  |
| $Z_c$         | Number of Control Lines (Bowline) | 12   |
| $R_p$         | Canopy Radius                     | 58.57 ft                                       |
| $\rho_{sl}$   | Sea Level Atmospheric Density     | $\frac{.002377 \text{ lb-sec}^2}{\text{ft}^4}$ |
| $P_{all}$     | Allowable Force                   | 1bf  |
| $P_{dev}$     | Developed Force                   | 1bf  |
| $F_{max}$     | Maximum Developed Force           | 1bf  |
| $F_d$         | $1/2 \times F_{max}$              | 1bf  |
| $V$           | Velocity                          | ft/sec   |
| $V_t$         | Terminal Velocity                 | ft/sec   |
| $C_{do}$      | Drag Coefficient                  | 1.05   |
| $W$           | Descent Weight                    | 1b   |
| M.S.          | Margin of Safety                  |  |

Design data in this report are based upon the results of several test programs. It has been established that, with a canopy loading of 0.53 lbf/ft<sup>2</sup>, the drag coefficient of 1.05 is experienced.

Accordingly for a payload weight of 8000 lbs. and a parachute weight of 183 lbs., sea level terminal velocity will be:

$$V_t^2 = \frac{2W}{\rho C_{do} S_o}$$

$$W = 8000 + 183 = 8183 \text{ lbs}$$

$$V_t = \sqrt{\frac{2(8183) \times 10^4}{23.77(1.05) 15,394}} = \sqrt{425.95}$$

$$V_t = 20.64 \text{ ft/sec at sea level}$$

Due to the zero velocity drop condition an opening shock factor of 1.5 is assumed.

$$F_{\max} = 1.5 \times 8000 = 12,000 \text{ lbf}$$

For a payload of 611 pounds sea level terminal velocity will be:

$$V_t = \sqrt{\frac{2 \times (611 + 183)}{.002377 \times 1.0 \times 15,394}} = \sqrt{\frac{1588}{36.59}} = \sqrt{43.4}$$

$$V_t = 6.6 \text{ ft/sec}$$

And at 5000 ft MSL terminal velocity will be:

$$V_t = \sqrt{\frac{1588}{2.10 \times 15,394}} = \sqrt{\frac{1588}{32.33}} = \sqrt{49.1}$$

$$V_t = 7.0 \text{ ft/sec}$$

The maximum force developed is assumed to be transmitted equally between the vent and skirt due to the geometrical relationship existing during the period of highest loading.

$$F_d = \frac{F_{\max}}{2} = \frac{12,000}{2} = 6000 \text{ lbf}$$

SUSPENSION LINES (550 lbf Rated Strength)

$$P_{\text{dev}} = \frac{F_d}{Z_s} = \frac{6000}{120} = 50.0 \text{ lbf}$$

Using a design factor of 4.07 (see Table I)

$$P_{\text{all}} = \frac{550}{4.07} = 135 \text{ lbf}$$

$$\text{M.S.} = \frac{135}{50.0} - 1.00 = 2.70 - 1.00 = 1.70$$

$$\text{M.S.} = +170\%$$

LOWER CONTROL LINES (6000 lbf Rated Strength)

$$P_{\text{dev}} = \frac{F_{\max}}{Z_c} = \frac{12000}{12} = 1000 \text{ lbf}$$

$$\text{Design Factor} = 2.72$$

$$P_{\text{all}} = \frac{6000}{2.72} = 2206 \text{ lbf}$$

$$\text{M.S.} = \frac{2206}{1000} - 1.00 = 2.21 - 1.00 = 1.21$$

$$\text{M.S.} = +121\%$$

UPPER CONTROL LINES (6000 lbf Rated Strength)

$$P_{dev} = \frac{F_d}{Z_c} = \frac{6000}{12} = 500 \text{ lbs}$$

$$\text{Design Factor} = 3.00$$

$$P_{all} = \frac{6000}{3.00} = 2000 \text{ lbf}$$

$$\text{M.S.} = \frac{2000}{500} - 1.00 = 4.00 - 1.00 = 300$$

$$\text{M.S.} = +300\%$$

CONTROL LINE TO SUSPENSION LINE JUNCTION

There are ten 550 lbf test suspension lines connected to each of 12 control line junctions. The load carried by each junction, assuming symmetrical load distribution, is:

$$P_{dev} = \frac{F_d}{Z_c} = \frac{6000}{12} = 500 \text{ lbf}$$

The ultimate strength of the junction is 6000 lbf. Using the highest applicable design factor (4.07):

$$P_{all} = \frac{6000}{4.07} = 1474 \text{ lbf}$$

$$\text{M.S.} = \frac{1474}{500} - 1.00 = 2.95 - 1.00 = 1.95$$

$$\text{M.S.} = +195\%$$

APEX RADIAL LINES (750 lbf Rated Strength)

Assume vent radials carry 50% of the load at the instant of opening. Sixty (60) radial lines are used.

$$P_{dev} = \frac{6000}{60} = 100 \text{ lbf}$$

Design factor = 3.70

$$P_{all} = \frac{750}{3.70} = 203 \text{ lbf}$$

$$M.S. = \frac{203}{100} - 1.00 = 2.03 - 1.00 = 1.03$$

$$M.S. = +103\%$$

RADIAL TAPES (250 lbf Rated Strength)

120 Radial tapes are used

$$P_{dev} = \frac{6000}{120} = 50.0$$

Design factor = 3.00

$$P_{all} = \frac{250}{3.00} = 83.3 \text{ lbf}$$

$$M.S. = \frac{83.3}{50.0} - 1.00 = 1.66 - 1.00 = 0.66$$

$$M.S. = +66\%$$

### REEFED CONDITION - LIFTING

This condition exists prior to drop of the payload/canopy system. An apex loop load line, consisting of four thicknesses of 10 lbf rated strength webbing, support the system weight.

$$P_{dev} = 8183 \text{ lbf}$$

$$\text{Design Factor} = 2.24$$

$$P_{all} = \frac{4(10,000)}{2.24} = 17,857 \text{ lbf}$$

$$\text{M.S.} = \frac{17,857}{8183} - 1.00 = 2.18 - 1.00 = 1.18$$

$$\text{M.S.} = +118\%$$

### CANOPY MAIN SEAMS

Assuming that 100% of the total maximum force is absorbed by the canopy fabric,

$$\Delta P = \frac{F_{max}}{SF} = \frac{12,000}{10,776} = 1.11 \frac{\text{lbf}}{\text{ft}^2} = 0.0077 \frac{\text{lbf}}{\text{in}^2}$$

$$\text{Cloth Stress} = \Delta P \times \frac{R_p}{2} = 0.0077 \times \frac{58.57 \times 12}{2}$$

$$\text{Cloth Stress} = 2.71 \frac{\text{lb}}{\text{in}}$$

Using a design factor of 2.60 and the minimum tensile strength for 1.1 oz/yd material (40 lbf/in):

$$P_{all} = \frac{40}{2.60} = 15.4 \text{ lbf/in}$$

$$P_{dev} = 2.71 \text{ lbf/in}$$

$$\text{M.S.} = \frac{15.4}{2.71} - 1.00 = 5.68 - 1.00 = 4.68$$

$$\text{M.S.} = +468\%$$

### CROSS SEAMS

Using a design factor of 2.92 and worst case loading:

$$P_{\text{all}} = \frac{40}{2.92} = 13.7 \frac{\text{lb}}{\text{in}}$$

$$P_{\text{dev}} = 1.90 \times \cos A$$

$$P_{\text{dev}} = 1.90 \times 0.707 = 1.34 \text{ lb/in}$$

$$\text{M.S.} = \frac{13.7}{1.34} - 1.00 = 10.22 - 1.00 = 9.22$$

$$\text{M.S.} = +922\%$$

### CANOPY CLOTH

Using a design factor of 3.33

$$P_{\text{all}} = \frac{40}{3.33} = 12.00 \text{ lb/in}$$

$$P_{\text{dev}} = 1.90 \text{ lb/in}$$

$$\text{M.S.} = \frac{12.00}{1.90} - 1.00 = 6.32 - 1.00 = 5.32$$

$$\text{M.S.} = +532\%$$

## HIGH ALTITUDE OPENING FORCES

Tests made at El Centro, California in 1967, demonstrated that the opening time of a 100-ft diameter RIBCO canopy is four (4) seconds when dropped from an aircraft. Assuming similar characteristics for the 140-ft diameter RIBCO/High Altitude Balloon drop, maximum opening force as a function of drop altitude can be estimated. For a 5000-lb payload with 183 lb of parachute, predicted values for maximum drag force are:

72,500 ft release:  $F_{\max} = 6824$  lbf

100,000 ft release:  $F_{\max} = 5268$  lbf

120,000 ft release:  $F_{\max} = 5426$  lbf

It should be noted that the stress analysis assumed  $F_{\max} = 12,000$  lbf with a payload of 8000 lbs.

Appendix I includes equations and computations used in arriving at the above characteristics.

STRENGTH LOSS AND SAFETY FACTORS

| Symbol                            | Function             | STRENGTH LOSS FACTORS |              |                  |               |       |       |       |            |            |  |
|-----------------------------------|----------------------|-----------------------|--------------|------------------|---------------|-------|-------|-------|------------|------------|--|
|                                   |                      | Canopy Cloth          | Radial Lines | Suspension Lines | Control Lines |       | Seams |       | Vent Tapes | Apex Lines |  |
|                                   |                      |                       |              |                  | Upper         | Lower | Main  | Cross |            |            |  |
| B                                 | Joint Efficiency     | 1.00                  | 0.90         | 0.90             | 0.90          | 0.90  | 0.90  | 0.80  | 0.90       | 0.90       |  |
| N                                 | Heat-Loss Factors    | 0.90                  | 0.90         | 0.90             | 0.90          | 0.95  | 0.90  | 0.90  | 0.90       | 0.90       |  |
| L                                 | Abrasion             | 1.00                  | 1.00         | 0.95             | 0.95          | 0.95  | 0.95  | 0.95  | 0.95       | 0.95       |  |
| SAFETY FACTORS                    |                      |                       |              |                  |               |       |       |       |            |            |  |
| J                                 | Safety Factors       | 2.00                  | 2.00         | 2.00             | 2.00          | 2.00  | 2.00  | 2.00  | 2.00       | 2.00       |  |
| H                                 | Line Convergence     | NA                    | NA           | 1.25             | 1.05          | 1.05  | NA    | NA    | 1.05       | 1.05       |  |
| F                                 | Asymmetrical Loading | 1.50                  | 1.50         | 1.25             | 1.10          | 1.05  | NA    | NA    | 1.10       | 1.10       |  |
| DESIGN FACTORS                    |                      |                       |              |                  |               |       |       |       |            |            |  |
| Design Factor = $\frac{JHF}{BNL}$ |                      | 3.33                  | 3.70         | 4.07             | 3.00          | 2.72  | 2.60  | 2.92  | 3.00       | 2.24       |  |

Table I

## APPENDIX I

### OPENING FOR CHARACTERISTICS

For an object falling vertically through the atmosphere,

$$\Delta V = (G - \frac{D}{M}) \Delta T, \text{ where:}$$

- $\Delta V$  = The change in vertical velocity during time  $t$
- $G$  = The acceleration due to gravity
- $D$  = Aerodynamic Drag ( $1/2 \rho v^2 C_d S$ )
- $M$  =  $W/G$

If the canopy is assumed to inflate linearly from a frontal diameter of 3.0 ft to that of 117.1 ft over a period of four seconds, commencing at the time of release\* then the drag forces can be computed and values of vertical velocity,  $V = V_0 + V$ , can be determined using the progressive calculation method with small time increments by varying atmospheric density with changes in altitude. Altitude is computed by:  $H = (H_0 - V \Delta T)$  for each increment. Aerodynamic drag of the payload has been neglected, and gravitational acceleration has been assumed constant as has the drag coefficient.

\*It is further assumed that the systems initial velocity relative to the surrounding atmosphere will be zero.

The time of maximum drag force occurs at 4.0 seconds for the 72,500 ft. drop, 10.4 seconds for the 100,000 ft. drop, and 18 seconds for the 120,000 ft. drop. This is due to the low atmospheric densities at the higher altitudes, which allow the payload/canopy system to accelerate even after full opening, until the parachute drag increases to a force equal to the system's weight, after which the terminal (equilibrium) descent phase begins.

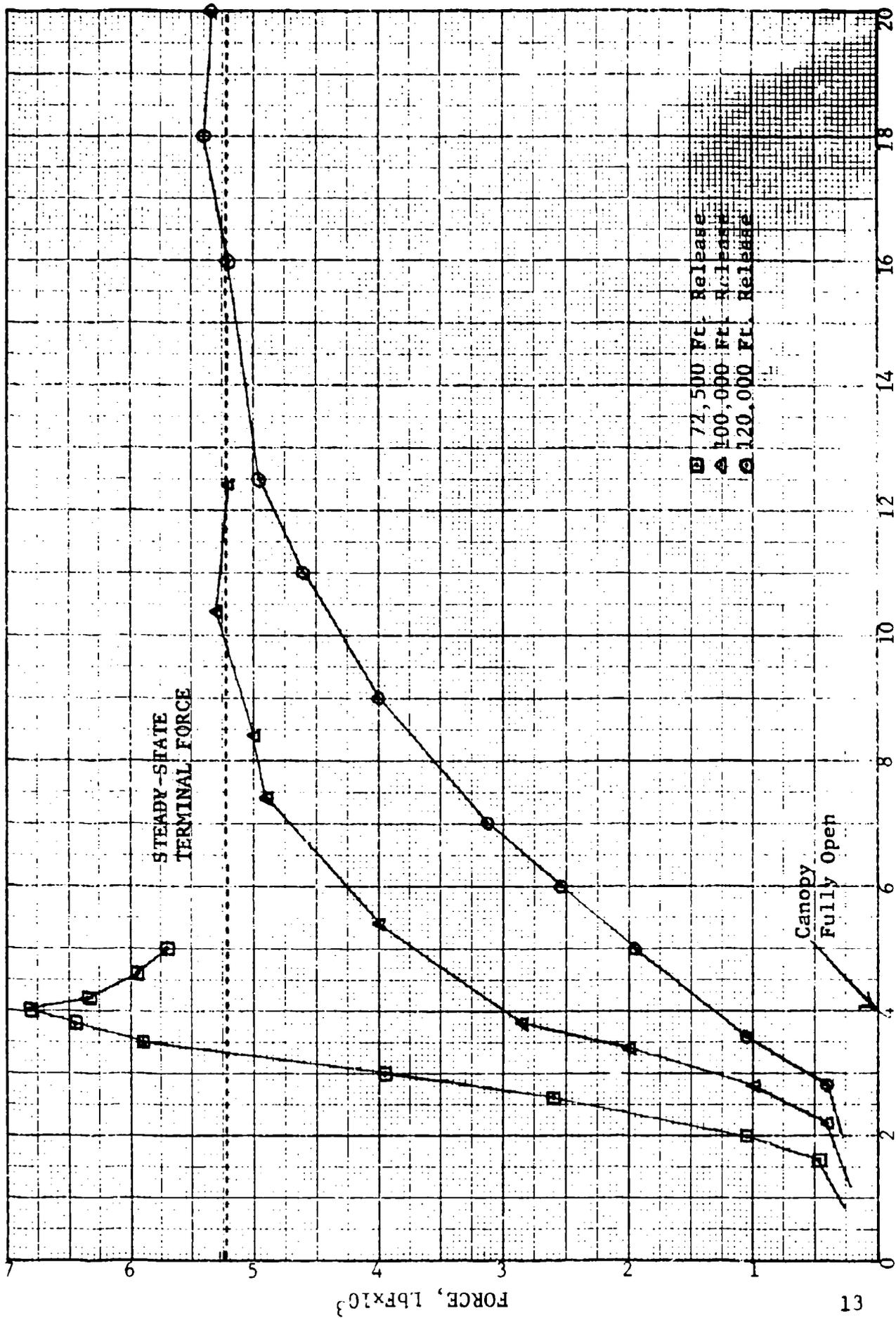
Sea level terminal velocity for the 5000-lb payload should be:

$$V_t = \sqrt{\frac{2(5183) \times 10^4}{23.77(.95)15,394}} = \sqrt{298.19}$$

$$V_t = 17.27 \text{ ft/sec}$$

The drag coefficient used in computing terminal velocity for the 5000-lb payload is approximately 10% lower than that used for the 8000-lb payload, due to lower canopy loading.

DECELERATION FORCE VS. TIME



TIME, SECONDS

□ 72,500 Ft. Release  
 ▲ 100,000 Ft. Release  
 ● 120,000 Ft. Release

STEADY-STATE  
 TERMINAL FORCE

Canopy  
 Fully Open

FORCE,  $10^3$  LB

| T    | CDS     | V     | V <sup>2</sup> x 10 <sup>-4</sup> | $\frac{Q}{Z} \times 10^{-4}$ | Q PSF  | D Lbf | $\frac{W-D}{M}$ | $\frac{W-D}{M} \Delta T$ | $\Delta T$ | $\Sigma \Delta H$ |
|------|---------|-------|-----------------------------------|------------------------------|--------|-------|-----------------|--------------------------|------------|-------------------|
| 0.0  | 10.6    | 0     | 0                                 | .1659                        | 0      | 0     | 32.19           | 6.44                     | 0.2        | 0                 |
| 0.2  | 89.4    | 6.44  | .00415                            | .1559                        | .00688 | .062  | 32.19           | 6.44                     | 0.2        | 1.29              |
| 0.4  | 244.5   | 12.88 | .0166                             | .1659                        | .00275 | .67   | 32.18           | 6.44                     | 0.2        | 3.87              |
| 0.6  | 492.0   | 19.32 | .0373                             | .1659                        | .00619 | 3.04  | 32.17           | 6.43                     | 0.2        | 7.73              |
| 0.8  | 785.0   | 25.75 | .0663                             | .1659                        | .0110  | 8.64  | 32.14           | 6.43                     | 0.2        | 12.88             |
| 1.0  | 1098.0  | 32.18 | .1036                             | .1659                        | .0172  | 18.9  | 32.07           | 6.41                     | 0.2        | 19.32             |
| 1.2  | 1636.0  | 38.59 | .1489                             | .1659                        | .0147  | 40.4  | 31.94           | 6.39                     | 0.2        | 27.04             |
| 1.4  | 2168.0  | 44.98 | .2023                             | .1659                        | .0336  | 72.8  | 31.74           | 6.35                     | 0.2        | 36.04             |
| 1.6  | 2793.0  | 51.33 | .2635                             | .1659                        | .0437  | 122   | 31.43           | 6.29                     | 0.2        | 46.3              |
| 1.8  | 3495.0  | 57.62 | .3320                             | .1659                        | .0551  | 193   | 30.99           | 6.20                     | 0.2        | 57.8              |
| 2.0  | 4245.0  | 63.82 | .4073                             | .1659                        | .0676  | 287   | 30.41           | 6.08                     | 0.2        | 70.6              |
| 2.2  | 5093.0  | 69.90 | .4886                             | .1659                        | .0811  | 413   | 29.63           | 5.93                     | 0.2        | 84.6              |
| 2.4  | 6083.0  | 75.83 | .5750                             | .1659                        | .0954  | 580   | 28.59           | 5.72                     | 0.2        | 100.0             |
| 2.6  | 7035.0  | 81.55 | .6650                             | .1659                        | .1103  | 776   | 27.37           | 5.47                     | 0.2        | 116.3             |
| 2.8  | 8100.0  | 87.02 | .7572                             | .1659                        | .1256  | 1017  | 25.88           | 5.18                     | 0.2        | 133.7             |
| 3.0  | 9255.0  | 92.20 | .8501                             | .1659                        | .1410  | 1305  | 24.09           | 4.82                     | 0.2        | 152.1             |
| 3.2  | 10500.0 | 97.02 | .9413                             | .1659                        | .1562  | 1640  | 22.01           | 4.40                     | 0.2        | 171.5             |
| 3.4  | 11783.0 | 101.4 | 1.028                             | .1659                        | .1705  | 2007  | 19.72           | 3.94                     | 0.2        | 191.8             |
| 3.6  | 13170.0 | 105.3 | 1.109                             | .1659                        | .1840  | 2423  | 17.14           | 3.43                     | 0.2        | 212.9             |
| 3.8  | 14683.0 | 108.7 | 1.182                             | .1659                        | .1961  | 2880  | 14.30           | 2.86                     | 0.2        | 234.6             |
| 4.0  | 16164.0 | 111.6 | 1.245                             | .1659                        | .2065  | 3338  | 11.46           | 2.29                     | 0.2        | 256.9             |
| 4.2  | 16164.0 | 113.9 | 1.297                             | .1659                        | .2152  | 3478  | 10.59           | 2.12                     | 0.2        | 297.7             |
| 4.4  | 16164.0 | 116.0 | 1.346                             | .1659                        | .2233  | 3609  | 9.78            | 1.96                     | 0.2        | 302.9             |
| 4.9  | 16164.0 | 118.0 | 1.392                             | .1659                        | .2309  | 3732  | 9.01            | 4.51                     | 0.5        | 361.9             |
| 5.4  | 16164.0 | 122.5 | 1.501                             | .1659                        | .2497  | 4036  | 7.12            | 3.56                     | 0.5        | 423.2             |
| 6.4  | 16164.0 | 126.1 | 1.590                             | .1659                        | .2638  | 4264  | 5.70            | 5.70                     | 1.0        | 549.3             |
| 7.4  | 16164.0 | 133.8 | 1.790                             | .1698                        | .3039  | 4912  | 1.68            | 1.68                     | 1.0        | 683.1             |
| 8.4  | 16164.0 | 135.5 | 1.836                             | .1698                        | .3118  | 5040  | .89             | .89                      | 1.0        | 818.6             |
| 9.4  | 16164.0 | 136.4 | 1.860                             | .1698                        | .3158  | 5168  | .48             | .48                      | 1.0        | 955.0             |
| 10.4 | 16164.0 | 136.9 | 1.874                             | .1739                        | .3259  | 5268  | -.53            | -.53                     | 1.0        | 1091.0            |

W<sub>P</sub> = 5000 Lb      H<sub>0</sub> = 100,000 ft MSL

W<sub>Tot</sub> = 5183 Lb      V<sub>0</sub> = 0

M =  $\frac{5183}{32.2} \approx 161$        $\rho_0 = 0.3318 \times 10^4$

Max G =  $\frac{5268}{5183} \approx 1.02G$

Sample calculations for descents from 100,000 ft.

## TEST DESCRIPTION AND RESULTS

A 140-foot nominal diameter RSR RIBCO parachute system was tested by Air Force Cambridge Research Laboratories at the Holloman Air Force Base, New Mexico Balloon Flight Facility\*. This was a full scale, high altitude test with a 611-pound suspended load. The parachute was rigged according to standard balloon practice with the payload consisting of several instrument packages fastened to a horizontal bar.

To contain the large area of material during balloon launch, in addition to the command-controlled reefing line near the skirt, loops of 25-1b test, 3-cord cotton were tied at 10-ft intervals along the canopy. All of these cotton ties failed during balloon inflation on the runway, and the parachute acted like a spinnaker sail during the launch run.

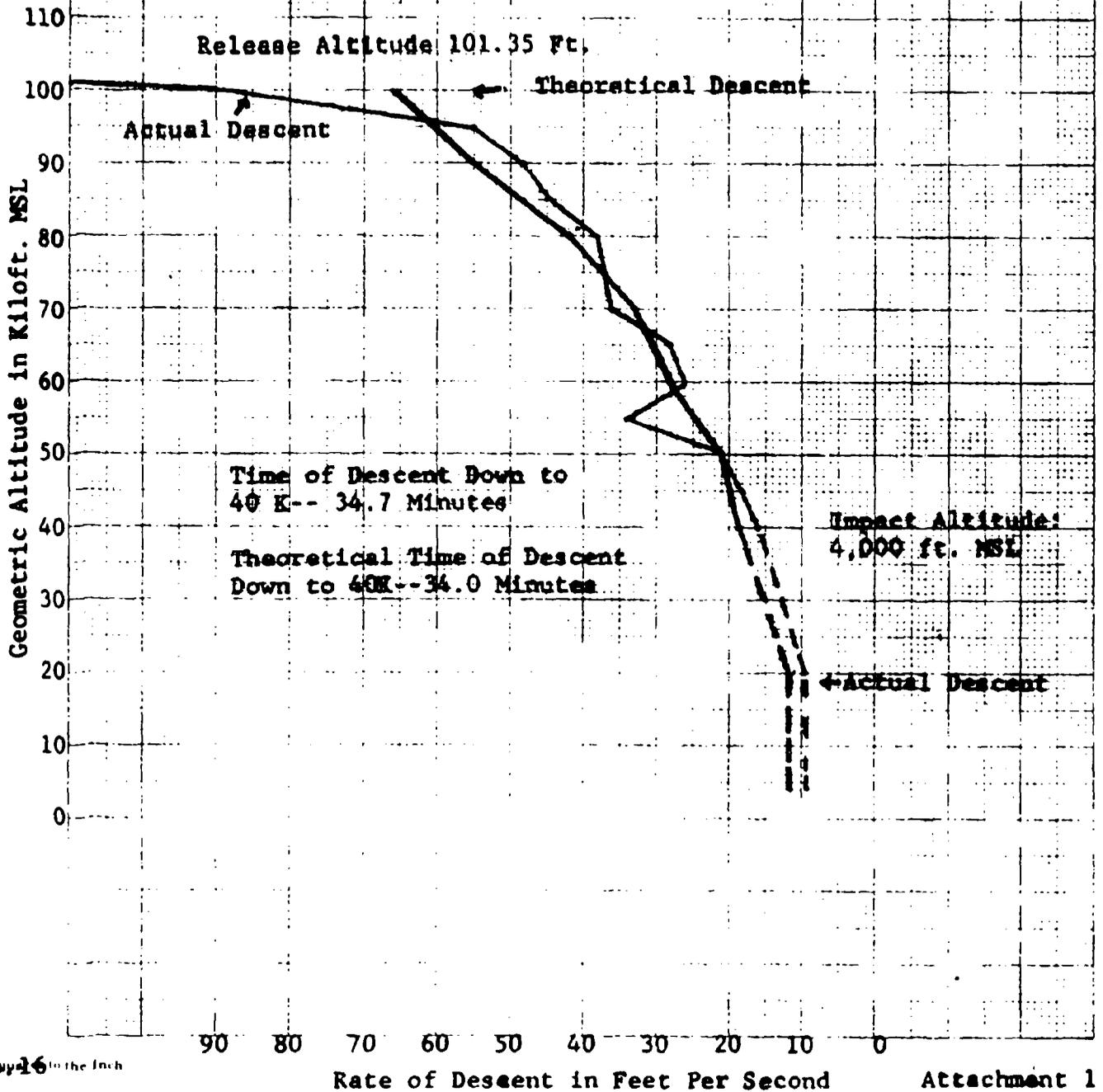
The parachute system performance very nearly approached that desired as optimum for very light loads: Initial snatch force of 2.1 g's at 3.05 seconds after cutdown, an opening shock force of 4.5 g's at 6 seconds after cutdown and a steady state deceleration of approximately 1 g at 10.6 seconds after cutdown. The actual descent time from 100,000 feet to 4,000 feet was 92.3 minutes with theoretical descent time being 90 minutes.

\*For complete test description and results see AFCRL Preliminary Report on AFCRL Flight 72-26 Proceedings, Seventh AFCRL Scientific Balloon Symposium.

~~Parachute Descent Data~~

Test Flight #72-26  
19 April 1972

Parachute Tested: SSR 140 Ft. RIBCH  
Recovered Weight: 600 lbs.



## CONCLUSION

Based upon the single flight test with the minimum-load requirement, the parachute has substantial improvements over present parachute systems in substantially reduced weight and stability at lower altitudes (20,000 feet to impact). Successful flights with 5000 and 8000 pound payloads can be predicted with confidence in meeting the upper limits of design.

The success of this parachute design provides the user with a single lightweight parachute for use in the wide range of payload weights of 500 lbs to 8000 lbs. It eliminates the need for parachute clustering when recovering payloads in excess of 3000 pounds thereby eliminating problems encountered when using a cluster of parachutes.

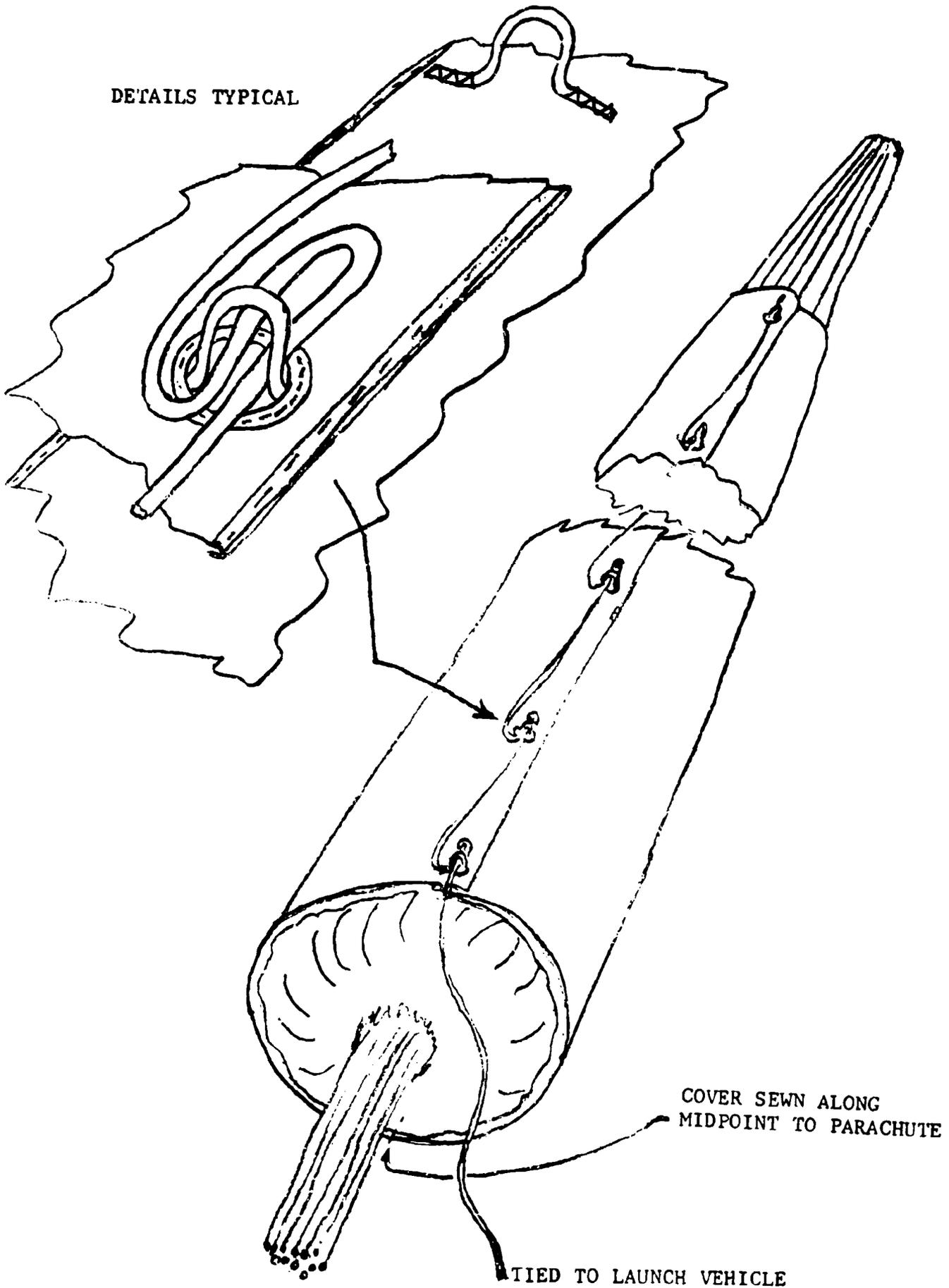
Serious consideration should be given to the continued use and development of the RSR RIBCO parachute for balloon recovery. It is the most advanced parachute system design available for recovering sensitive payloads which are not designed to sustain heavy g-load normally experienced during opening shock or ground impact.

It is further concluded, as reported by AFCRL, that during the preparation for and during balloon launch, the parachute did become difficult to handle in surface winds. Although this was the only problem encountered in using the RIBCO, the canopy can be controlled on the ground by the use of a sleeve arrangement which can be opened by a lanyard when the balloon and payload reach the vertical position at launch. This will also eliminate the need for a skirt retention line and electrically initiated cutters for skirt release.

## RECOMMENDATIONS

1. Testing of the RSR RIBCO parachute system be continued through its maximum design payload weight of 8000 pounds to verify design parameters.
2. Recommend that a sleeve arrangement be used to retain and control the parachute canopy during ground operation and launch. Because of design, the canopy cloth has no tension on it during string-out in its prelaunch and flight position. The sleeve method will maintain complete control of the canopy material until released at launch (see Attachment No. 2).
3. Recommend that the riser between the payload and parachute be removed and let the payload be connected directly to the parachute at the lower confluence of the bowline.

DETAILS TYPICAL



## REFERENCES

1. "The Opening Performance of 100-foot and 140-foot Diameter RSR Parachutes Near 100,000 ft. Altitude With Balloon-Borne Payloads". F. Corbalis, AFCRL.
2. "Performance and Design Criteria for Deployable Aerodynamic Decelerators". Air Force Systems Command, Wright Patterson AFB, ASD-TR-61-579, 1963.
3. "Design Stress Analysis for 100-Foot Diameter Re-Reef Parachute". Recovery Systems Research, Inc., Alamogordo, New Mexico, 1967.
4. "Design Stress Analysis for 200-Foot Diameter Re-Reef Parachute". Recovery Systems Research, Inc., Alamogordo, New Mexico, 1968.
5. "Design Stress Analysis for 40-Foot Diameter Disc-Gap-Band Parachute". G. T. Schjeldahl Company, Northfield, Minnesota.