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FINAL REPORT

40 FT DGB PARACHUTE

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ABSTRACT

The design presented describes a 40-foot nominal diameter Disk-Gap-Band parachute tested as a candidate in the Supersonic Planetary Entry Decelerator Program. This report includes design requirements, estimates of maximum expected loads on the parachute, parachute configuration, stress analysis, moment of inertia, and component structural test data.

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TABLE OF SYMBOLS

Symbol	Meaning	Units
V_o	Deployment Velocity	ft/sec
V_e	Ejection Velocity	ft/sec
V_{op}	Parachute Velocity at ejection	ft/sec
V_s	Parachute Velocity at snatch	ft/sec
M	Mach Number	
q	Dynamic Pressure	Psf
P	Snatch Force	lbs
Mc	Mass of Canopy	slugs
Z	No. of suspension lines	
P	Suspension line strength	lbs
L_s	Suspension line length	ft.
L_r	Riser length	ft.
ρ	Density	slugs/ft^3
ξ'	Break elongation	in/in
C_D	Drag Coefficient	
S_o	Nominal Canopy Area	ft^2
F_o	Opening shock load	lbs.
Pult	Ultimate strength	lbs.
Pall	Allowable load	lbs.
M.S.	Margin of safety	
fd	Design Factor	
P_{sl}	Suspension line load	lbs.

P_H	Horizontal suspension line load	lb
P_{vb}	Vent band load	lb
P_{sb}	Skirt Band Load	lb
r_b	Gore bulge radius	in
S_D	Nominal disc area	ft^2
R_p	Projected Radius	ft.
D_o	Nominal Diameter	ft.

1.0 INTRODUCTION

The design presented herein describes completely a 40-foot nominal diameter Disc-Gap-Band parachute to be tested as a candidate in the Planetary Entry Parachute Program. This report includes design requirements, estimates of maximum expected loads on the parachute, parachute configuration, stress analysis, moment of inertia, and component structural test data.

2.0 DESIGN SPECIFICATIONS

2.1 The parachute is a disc-gap-band type with a constructed geometric shape in accordance with the LRC drawing number LB-151822.
The nominal diameter of the parachute (D_o) is 40 ft.
The disc is a regular polygon with an even number of sides. There is a vent in the center of the disc and the area of the vent is equal to 0.5 per cent of S_o. The surface area of the disc, including the vent area, is 53.0 per cent of S_o.
The band is a right cylinder circumscribing the disc. The surface area of the band is 35 per cent of S_o.
The area of the gap is 12.0 per cent of S_o.
The number of suspension lines is equal to the number of sides on the disc. The length of each suspension line is 40 feet.

2.2 The parachute has a post-reef system in accordance with LRC drawing number LD-151817, capable of changing the terminal rate of descent to 40 ± 10 ft/sec at an altitude of 4,000 feet.

2.3 The weight of the canopy and suspension lines is not more than 35 pounds, including the weight of the deployment bag, but not including parachute riser system.

2.4 The parachute is designed to withstand the following deployment conditions without structural failure:

a) 205 pounds suspended on parachute

b) Mach number 1.6 at a dynamic pressure of 12 pounds/square ft

c) Mortar ejection velocity of 120 ft/sec.

2.5 All structural fabric material for the parachute system is dacron. All lines, tapes, webbing and threads are hi-tenacity type dacron material.

2.6 The complete parachute system is capable of withstanding 125°C for 120 hours while packed and is designed to be able to withstand deployment and opening loads without structural failure.

2.7 The canopy is white with a 6-inch wide blue stripe on the inside of the canopy from the vent to the bottom of the band and a 6-inch wide blue ring around the bottom of the skirt.

2.8 The parachute system (excluding deployment bag) is shown in Figure 1.

DGB Parachute System

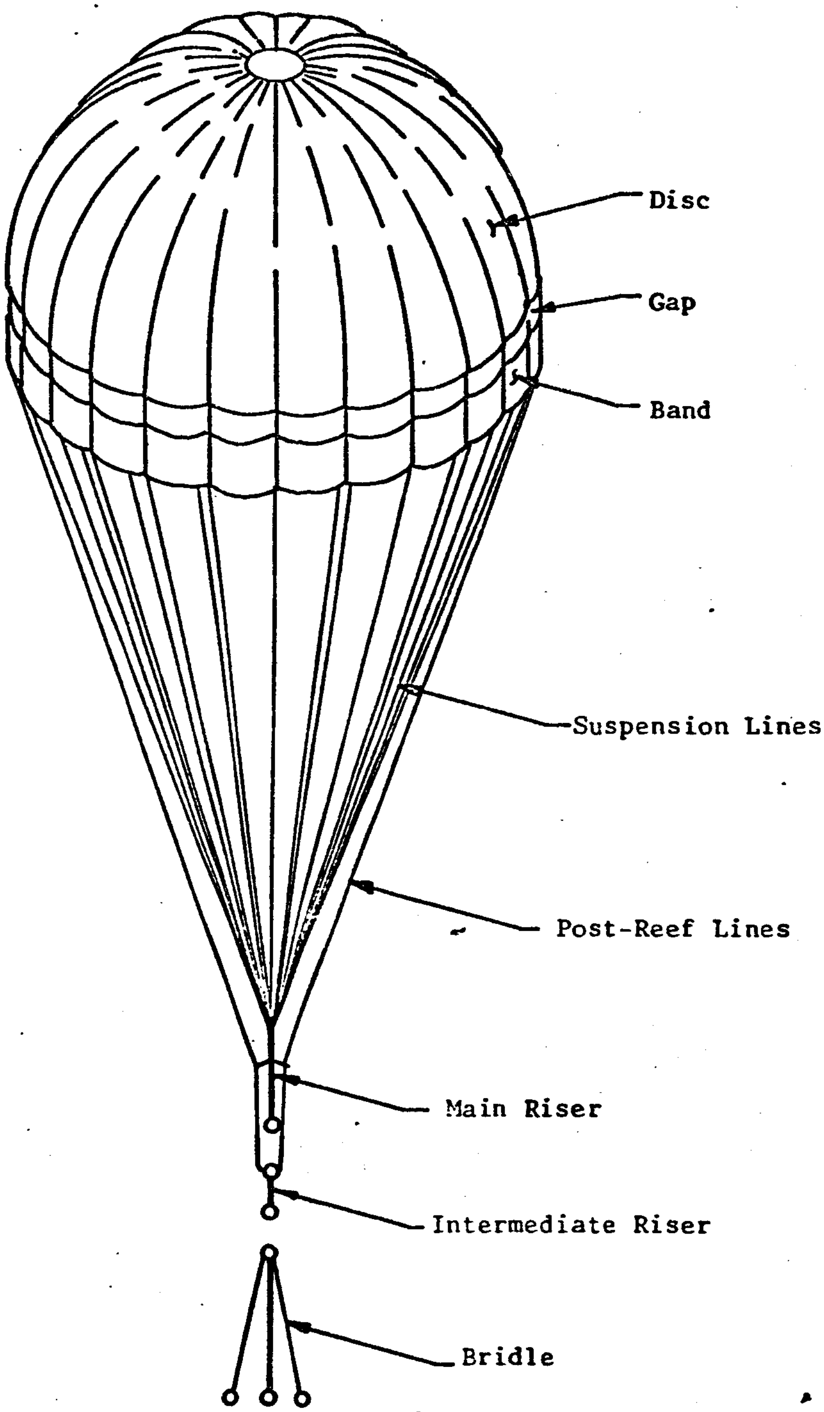


Figure I

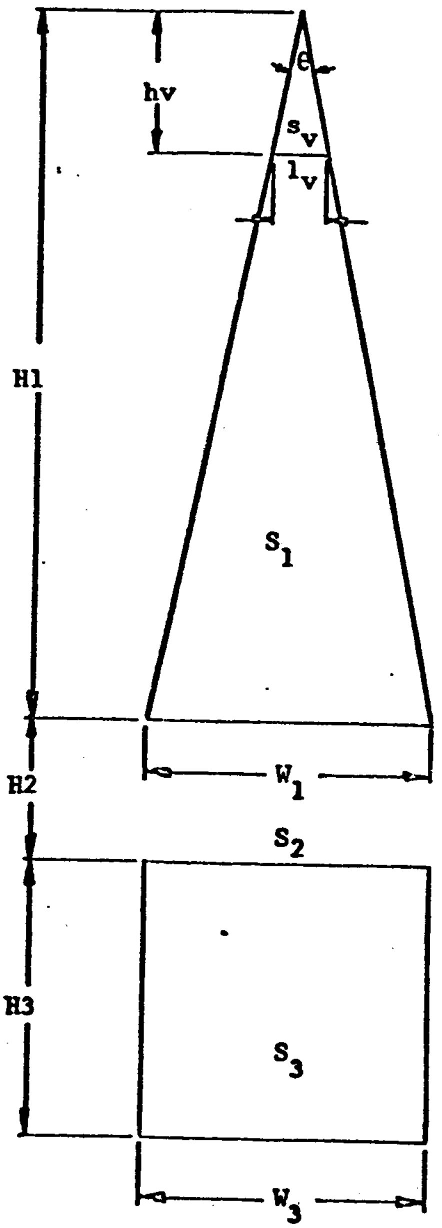
3.0 DESIGN DATA

(40 Ft D_o DGB)

Nominal Diameter (D_o)	40 ft
Geometric Porosity (λg)	12.5 per cent
Total Area (S_o)	1256.64 ft^2
Disc Area (.53 S_o)	666.02 ft^2
Disc Diameter	29.12 ft
Disc Circumference	91.48 ft
Gap Area (.12 S_o)	150.80 ft^2
Gap Width	1.648 ft
Band Area (.35 S_o)	439.82 ft^2
Band Width	4.808 ft
Vent Area (.005 S_o)	6.283 ft^2
Vent Diameter	2.829 ft
No. of suspension lines	32
Length of suspension lines	40 ft

4.0 GORE LAYOUT AND PARACHUTE CONFIGURATION

Based on a geometric porosity of 12.5 per cent, the gore layout is calculated as follows:



$$S_o = \frac{\pi}{4} D_o^2$$

$$Z = 32$$

$$\theta = \frac{360}{32} = 11^\circ\ 15'$$

$$S_o = \frac{1256.64}{32} \times 144 \text{ in}^2 = 5654.88 \text{ in}^2$$

$$S_1 = 0.53\ S_o = 2997.08 \text{ in}^2$$

$$S_2 = 0.12\ S_o = 678.58 \text{ in}^2$$

$$S_3 = 0.35\ S_o = 1979.21 \text{ in}^2$$

$$s_v = .005\ S_o = 28.27 \text{ in}^2$$

$$H_1 = \sqrt{\frac{2997.08}{.0984}} = 174.53 \text{ in}$$

$$W_1 = W_3 = \frac{2 \times 2997.08}{174.53} = 34.352 \text{ in}$$

$$H_2 = \frac{S_2}{W_1} = \frac{678.58}{34.352} = 19.754 \text{ in}$$

$$H_3 = \frac{S_3}{W_1} = \frac{1979.21}{34.352} = 57.62 \text{ in}$$

$$h_v = \sqrt{\frac{28.274}{.0984}} = 16.95 \text{ in}$$

$$l_v = \frac{2 \times s_v}{h_v} = 3.336 \text{ in}$$

To allow stress relief at vent, add 10 per cent fullness at vent

$$l_v' = \frac{l_v}{0.9} = 3.71 \text{ in}$$

New apex angle θ_1

$$\text{Tan } \theta_{1/2} = \frac{\frac{34.352-3.71}{2}}{174.53-16.95} = .09735$$

New construction height of disc

$$\text{Tan } \theta_{1/2} = \frac{\frac{34.352}{2}}{\text{height}}$$

$$\text{Height} = \frac{17.176}{\text{Tan } \theta_{1/2}} = \frac{17.176}{.09735} = 176.44 \text{ in}$$

With this gore layout, the constructed shape as well as the expected inflated shape is as shown in Figure 2.

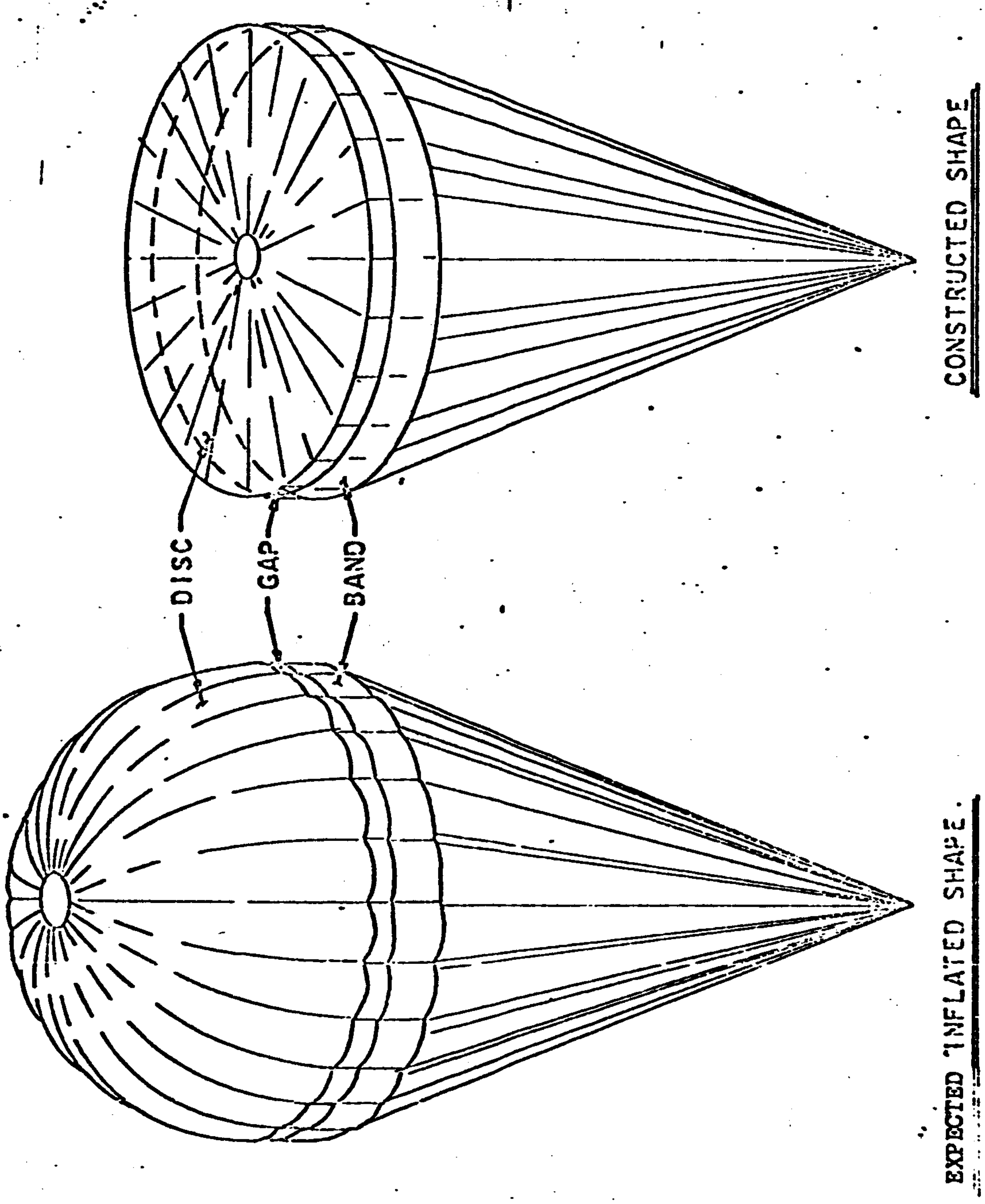


FIGURE 2

5.0 SNATCH FORCE CALCULATION

The parachute deployment bag is ejected rearward by means of a mortar and may, therefore, be treated in the classical manner as presented in reference 1.

Thus from equation 4-26

$$P = \sqrt{\frac{M_c (\Delta V)^2 \, ZP'}{L_s \, \xi'}}$$

where: $Z = 32$, $P' = 550$ lbs, $\xi' = 20\ \%$, $L_s = 40$ ft

and with the design conditions defined as

$M = 1.6$ @ $q = 12$ psf, $V_o = 1665$ fps

which for the worst case, can be assumed constant throughout the period of deployment.

Next, the velocity of the deployment bag mass may be determined by considering the following:

For a cylinder of l/d = 1.5 with blunt end forward, $C_D = 0.85$ (reference 2) and since the bag diameter = 1 ft., $C_D\,S = 0.67\ ft^2$.

Also, the time from mortar ejection to line stretch may be computed assuming a mortar ejection velocity, $V_e = 120$ fps and

$$t = \frac{L_s + L_R}{V_e} = 0.367 \text{ sec.}$$

hence, defining initial parachute velocity as

$$V_{op} = V_o - V_e \quad \underline{\text{or}} \quad V_{op} = 1545 \text{ fps}$$

Thus, velocity of the deployment bag system at line stretch is

$$V_s = \frac{V_{op}}{\rho/2 \, \frac{C_D S}{M_c} \, V_{op} t + 1} = 1542 \text{ fps}$$

and the velocity of the bag and canopy relative to the payload is

$$\Delta V = 1665 - 1542 = 123 \text{ fps}$$

and the snatch force is $P = 5593$ pounds

6.0 OPENING FORCE LOADS

The results of an earlier experiment with a 30-foot diameter DGB at essentially the same design conditions (q = 11.4 psf, M = 1.56) showed a maximum opening force of approximately 4000 pounds. Further, the opening process was of the so-called infinite mass type.

Calculating a "shock factor" for this case

$$X = \frac{F_o}{F_{s.s}} = \frac{4000}{4200} = 0.94$$

which is considerably below what would normally be expected for this type canopy. (Reference 1 and 3).

However, since the process is essentially infinite mass type, calculations using finite mass approaches yield extraneous results.

Using a shock factor of 0.94, the opening force is calculated as:

$$F_o = X \cdot C_D S_o \cdot q$$

$$F_o = 0.94 \times 0.52 \times 1256.64 \times 12$$

$$F_o = 7370 \text{ pounds}$$

7.0 WEIGHT ESTIMATE

The 30-ft D_o DGB, fabricated from 2.0 oz/yd² Dacron fabric, weighed less than 30 pounds. Therefore, it appeared feasible that the 40-ft D_o DGB could be fabricated from this same 2.0 oz/yd² Dacron fabric.

With the assumption, a weight estimate was made based on the weight of 2.0 oz/yd² fabric.

The number of suspension lines required, using the 550 pound tensile strength line as used on previous parachutes for the PEPP Program, was determined as follows:

For a positive margin of safety of 10 per cent, and using a design factor of 2.12,

$$P_{ult} = P_{dev} \times f_d \times M.S$$

$$P_{ult} = 7370 \times 2.12 \times 1.10$$

$$P_{ult} = 17{,}187 \text{ pounds}$$

Then $$Z = \frac{17{,}187}{550} = 31.25$$

We then designed for 32 lines to give a suspension line arrangement of four groups of eight lines.

The estimated component weight breakdown is tabulated below.

WEIGHT BREAKDOWN

Item		Qty	Units Wt.	Total (lbs)
1.	2.0 oz/yd² dacron	141 yd²	2.00 oz/yd²	17.60
2.	radial tape	230 yd	.2258 oz/yd	3.25
3.	suspension lines	435 yd	.60 yd/lb	7.25
4.	skirt reinforcement	31 yd	.2258 oz/yd	0.44
5.	gap reinforcement	62 yd	.2758 oz/yd	0.88
6.	vent reinforcement	7 yd	.2258 oz/yd	0.10
7.	radial gap reinforcement	27 yd	.2258 oz/yd	0.38
8.	reefing rings	30	0.125 oz	0.24
9.	reefing lines	65 yd	60 yd/lb	1.08
10.	main riser	6.7 yd	2.1 oz/yd	0.88
11.	deployment bag	-	-	1.00
12.	thread	-	-	1.00
13.	striping ink	-	-	0.38
14.	cotton webbing	3.53 yd	.33 oz/yd	0.07
		Total Estimated Weight	=	34.55

8.0 STRESS ANALYSIS

8.1 Suspension lines (610 lb min. strength)

$$\frac{F_o}{z} = \frac{7370}{32} = 230.3 \text{ lbs}$$

Using a design factor of 2.04 for suspension lines (see table I)

$$P_{all} = \frac{610}{2.04} = 297 \text{ lbs.}$$

$$M.S. = \frac{P_{all}}{P_{dev}} - 1.0$$

$$M.S. = \frac{297}{230.3} - 1.0 = 0.290$$

$$M.S. = +29\%$$

8.2 Radial Tapes (575 lb rated strength)

$$P_{dev} = \frac{F_o}{z} = 230.3 \text{ lbs.}$$

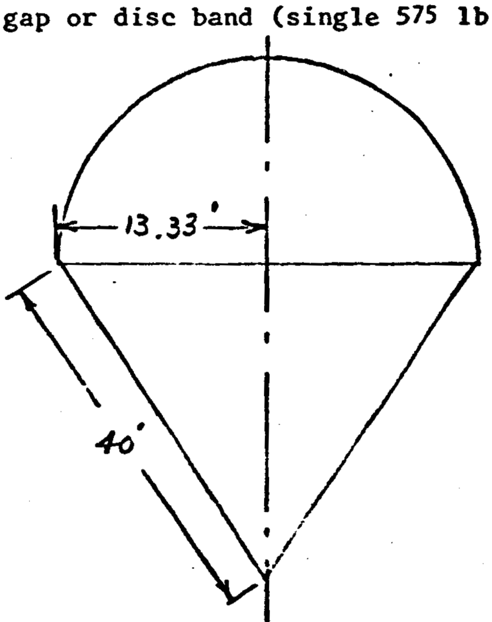
Design Factor = 1.86

$$P_{all} = \frac{575}{1.86} = 309 \text{ lbs}$$

$$M.S. = \frac{309}{230.3} - 1.0 = .34$$

$$M.S. = +34\%$$

8.3 Skirt, gap or disc band (single 575 lb tape)

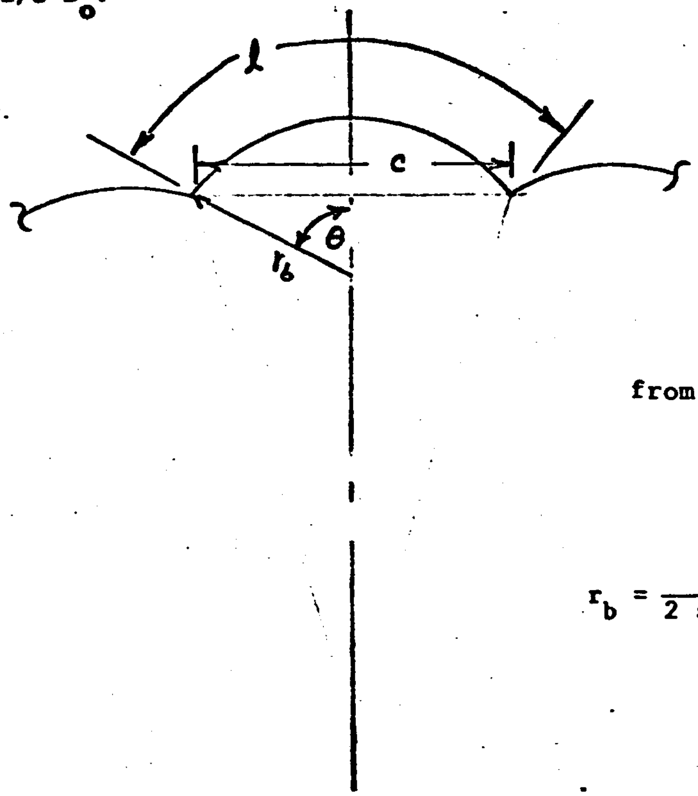


$$P_H = P_{S.L} \times \frac{13.33}{40.0}$$

$$P_{S.L} = 230.3 \text{ lbs}$$

$$\underline{P_H = 76.86 \text{ lbs}}$$

Looking at the cross-section at the skirt, assuming the inflated diameter is 2/3 D_o.



$$l = 34.35"$$

$$c = 31.40"$$

from ratio of $l/c = 1.095$

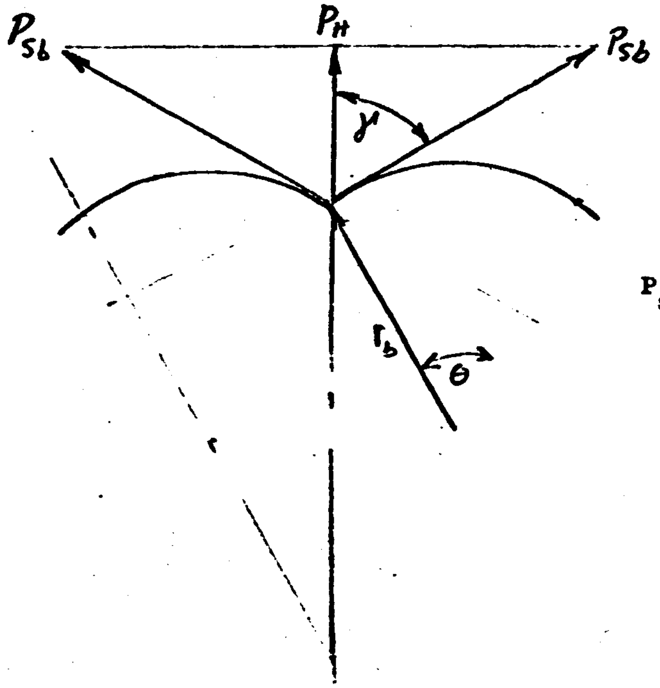
$$2\theta = 84^\circ$$

$$\theta = 42^\circ$$

$$r_b = \frac{C}{2 \sin \theta} = \frac{31.40}{2 \times 0.67}$$

$$r_b = 23.50 \text{ inch}$$

by Geometry:



$$\theta = 42^\circ$$

$$\gamma = 53.625^\circ$$

then:

$$P_{sb} = \frac{P_H}{2} \times \frac{1}{\cos \gamma} = \frac{76.86}{2} \times \frac{1}{0.59} = 65.14 \text{ lbs}$$

$$P_{all} = \frac{575}{1.97} = 292 \text{ lbs}$$

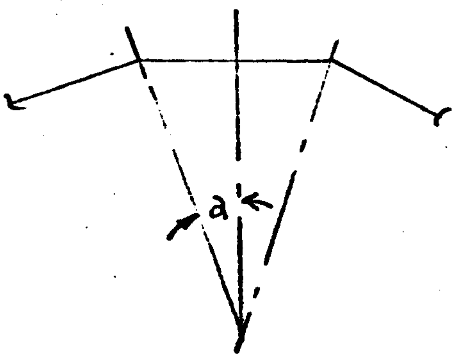
$$P_{dev} = P_{sb} = 65.14 \text{ lbs}$$

$$M.S. = \frac{292}{65.14} - 1.0 = 3.48$$

$$M.S. = + 348\%$$

8.4 Vent Band

From the geometry of the vent, the tension in the vent tape can be determined:



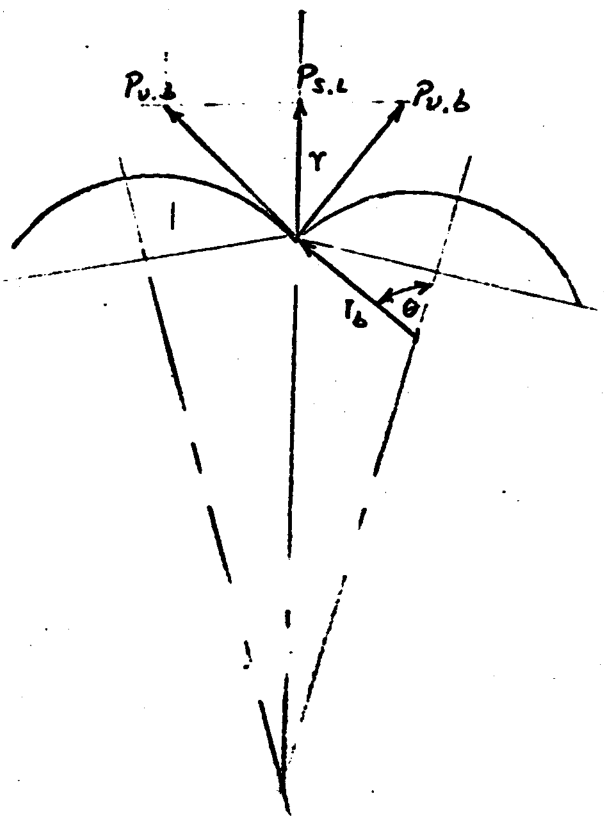
$$\alpha = \frac{360}{2z} = 5.625^{\circ}$$

Taking into consideration the fact that the constructed length of the vent band is longer than the circumference of the vent band based on the diameter of the vent, the vent band loading will be determined.

The vent band length between radial tapes is 3.71 inches while the cord length based on the vent diameter is 3.34 inches.

From the ratio $\frac{3.71}{3.34} = 1.1107$, the included angle between radial tapes and the bulge radius is found to be 90 degrees.

by geometry:



$$\gamma = 50.625^\circ$$

$$P_{v.b} = \frac{P_{s.1}}{2} \times \frac{1}{\cos\gamma}$$

$$P_{v.b} = \frac{230.3}{2} \times \frac{1}{0.635}$$

$$P_{v.b} = 181.3$$

The vent band consists of two 575 lb tapes, using a design factor of 1.97:

$$P_{all} = \frac{1150}{1.97} = 584 \text{ lbs}$$

$$P_{dev} = 181.3 \text{ lbs}$$

$$M.S. = \frac{584}{181.3} - 1.0 = 2.22 \text{ lbs}$$

$$M.S. = +222\ \%$$

8.5 Main Seams

a. Disc

The worst case is when F_o is absorbed by the disc area of the canopy.

Then the disc load $= \frac{7370}{S_D} \times R_{P_{disc}}$

assuming a thin shell with no bulge

$$\Delta P_{disc} = \frac{7370}{S_D} = \frac{7370\ lb}{666\ ft^2} \times \frac{1\ ft^2}{144\ in^2} = 0.768\ lbs/in^2$$

$$\text{Cloth stress} = \Delta P \times R_p = .768 \frac{lb}{in^2} \times 160\ in$$

$$\text{Cloth stress} = 12.29\ lb/in.$$

Using a design factor of 1.75 (i.e., joint efficiency of 100%) and the minimum strip tensile strength of the canopy cloth = 60 lbs.

$$P_{all} = \frac{60}{1.75} = 34\ lb/in$$

$$P_{dev} = 12.29\ lb/in$$

$$M.S. = \frac{34}{12.29} - 1.0 = 1.77$$

$$M.S. = +177\%\ \text{(ignoring gore bulge)}$$

b. <u>Band</u>

The most severe case on the band is if the total force F_o is absorbed by the total canopy uniformly. Then

$$P_{dev} = \frac{7370\ lb}{S_o(in^2)} \times 160\ in = \frac{7370 \times 160}{180{,}000} = 6.55\ lb/in$$

$$P_{all} = 34\ lb/in$$

$$M.S. = \frac{34}{6.55} - 1.0 = 4.19$$

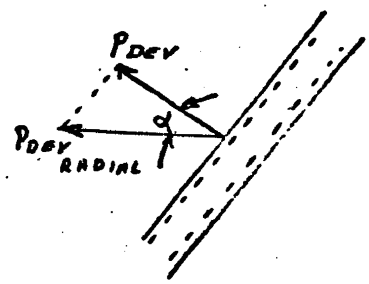
$$M.S. = +\ 419\%$$

8.6 Cross Seams

a. Disc

Using same assumptions as for main seam analysis, except seam efficiency = 100%.

$$P_{all} = \frac{60\text{-lb/in}}{1.74} = 34 \text{ lb/in}$$



$$P_{dev} = P_{dev\ radially} \times \sin \alpha$$

$$P_{dev} = 12.29 \times 0.707 = 8.7 \text{ lb/in}$$

$$\text{M.S.} = \frac{34}{8.7} - 1.0 = 2.91$$

M.S. = 291%

b. Band

$$P_{all} = 34 \text{ lb/in}$$

$$P_{dev} = 6.55 \times 0.707 = 4.63 \text{ lb/in}$$

$$\text{M.S.} = \frac{34}{4.63} - 1.0 = 6.34$$

M.S. = 634%.

8.7 Canopy Cloth

The worst case is assumed when F_o is absorbed by the disc area.

$$\Delta P_{dev} = \frac{F_o}{S_d} = \frac{7370 \text{ lb}}{666 \text{ ft}^2} = 11.13 \text{ lb/ft}^2 = 0.768 \text{ lb/in}^2$$

assuming the inflated disc diameter is equal to the inflated skirt diameter and is equal to 2/3 D_o,

Cloth tension = 0.768 lbs/in² × 160 in = 12.29 lb/in = P_{dev}

using a design factor of 1.75 (no joints, therefore joint efficiency = 100%)

$$P_{all} = \frac{60}{1.75} = 34.2 \text{ lb/in}$$

$$P_{dev} = 12.29 \text{ lb/in}$$

$$M.S. = \frac{34.2}{12.29} - 1.0 = 1.77$$

M.S. = +177 % neglecting gore bulge

8.8 <u>Vent Radial Tapes</u>

Assume vent radials carry 100% of the load at instant of opening.

$$P_{dev} = \frac{7370}{32} = 230.3 \text{ pounds}$$

$$P_{ult} = 575 \text{ lbs}$$

$P_{all} = \frac{575}{2.0} = 288$ pound where $F_d = 2.0$ is used as a flutter factor.

$$M.S. = \frac{288}{230.3} - 1.0 = .25$$

M.S. = +25%

8.9 Main Riser to Load Cell Junction

The main riser consists of 4 layers of dacron web, MIL-W-25361 Type II, rated tensile strength of 6000 lbs. (Actual is greater than 6000 lb).

$$P_{ult} = 4 \times 6000 = 24,000 \text{ lbs}$$

using a design factor of 2.0

$$P_{all} = \frac{24,000}{2.0} = 12,000 \text{ lbs}$$

$$P_{dev} = 7370 \text{ lbs}$$

$$M.S. = \frac{12,000}{7370} - 1.0 = 0.63$$

M.S. = + 63%.

8.10 Riser to Suspension Line Junction

There are 8-575 lb suspension lines attached to each web of the main riser.

The load carried by each web/suspension line combination, assuming equal load distribution is fo/4.

$$P_{dev} = F_o = \frac{7370}{4} = 1842.50 \text{ lbs.}$$

The ultimate strength of the 8 suspension lines is:

$$P_{ult} = 8 \times 575 = 4600 \text{ lbs}$$

Using a design factor of 2.00 for main riser seam,

$$P_{all} = \frac{4600}{2.0} = 2300 \text{ lbs.}$$

$$M.S. = \frac{2300}{1842.5} - 1.0 = 0.25$$

$$M.S. = + 25\%$$

8.11 Lower Riser Bridle

Lower bridle consists of 3 webs of 10,000 lbs nylon, MIL-W-4088 type XIX. (10,000 lb rated - actual is greater).

$$P_{ult} = 30,000 \text{ lbs.}$$

$$F_d = 1.96 \text{ (no heat loss factor)}$$

$$P_{all} = \frac{30,000}{1.96} = 15,306 \text{ lbs.}$$

$$P_{dev} = 7370 \text{ lbs.}$$

$$M.S. = \frac{15,306}{7370} - 1.0 = 1.07$$

$M.S. = + 107\%$ assuming load is equally distributed between the 3 legs of the bridle

8.11a Based on the results of one tensile test on an actual constructed bridle assembly, the actual joint efficiency was found to be 80%. Using a joint efficiency of 80% gives a design factor of 2.26.

Then:

$P_{dev} = 7370$

$P_{all} = \frac{30,000}{2.26} = 13,274$ lbs

$M.S. = \frac{13274}{7370} - 1.0 = 0.80$

M.S. = + 80%

8.12 Intermediate Riser

Riser consists of 4 layers of 10,000 lbs nylon web (rated).

$P_{ult} = 40,000$ lbs.

$f_d = 1.56$ (no heat loss, line convergence, or asymmetric loading)

$P_{all} = \frac{40,000}{1.56} = 25,641$

$P_{dev} = 7370$

$M.S. = \frac{25,641}{7370} - 1.0 = 2.48$

M.S. = + 248%.

Table I

STRENGTH - LOSS AND SAFETY FACTORS

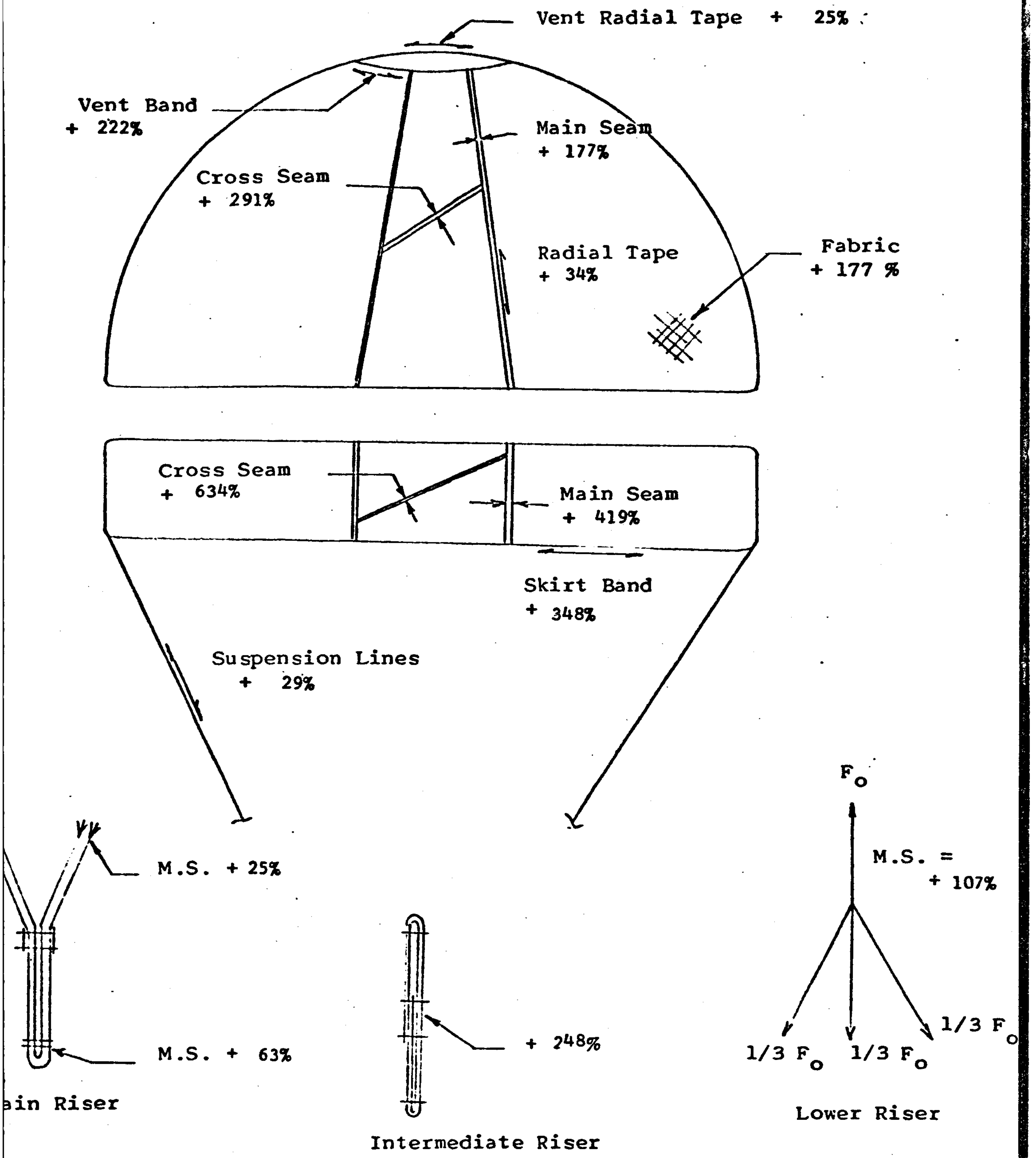
(a) Strength-loss factors

Symbol	Function	Canopy Cloth	Skirt & Vent Tapes	Radials	Lines	Risers: Main	Risers: Inter-mediate	Risers: Lower	Seams: Main	Seams: Cross
b	joint efficiency	1.00	0.89	0.98	0.94	1.00	1.00	0.92	1.00	1.00
n	heat-loss factors	0.90	0.90	0.90	0.90	0.90	1.00	1.00	0.90	0.90
l	abrasion	1.00	1.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96

(b) Safety Factors

Symbol	Function	Canopy Cloth	Skirt & Vent Tapes	Radials	Lines	Risers: Main	Risers: Inter-mediate	Risers: Lower	Seams: Main	Seams: Cross
j	safety factors	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
h	line convergence	NA	NA	NA	1.05	1.05	1.00	1.05	NA	NA
f	asymmetrical loading	1.05	1.05	1.05	1.05	1.10	1.00	1.10	NA	NA
Design Factor Jhf/bnl		1.75	1.97	1.86	2.05	2.00	1.56	1.96	1.74	1.74

From Ref. 1



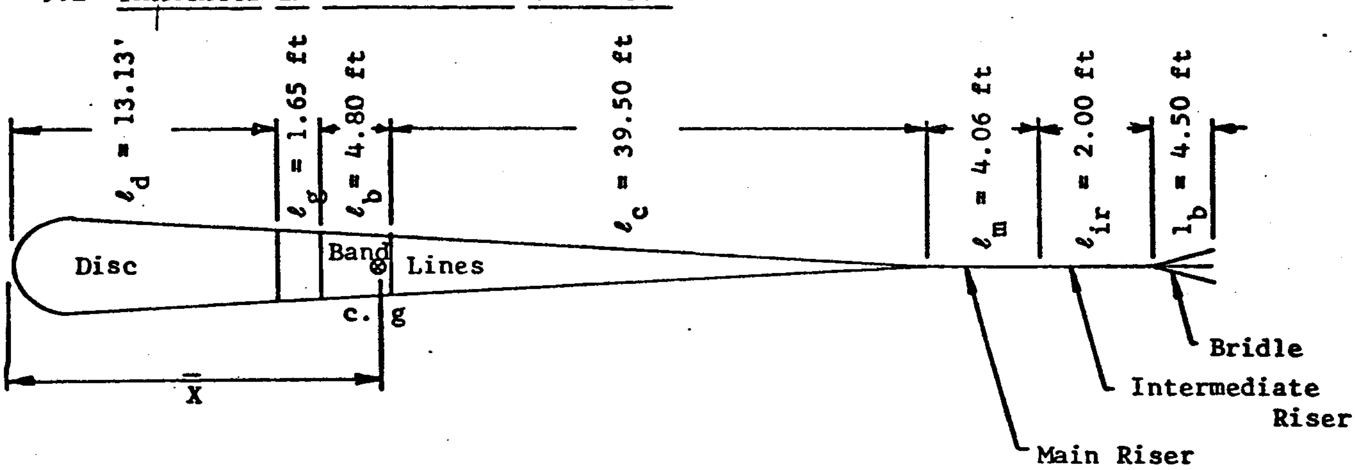
MARGIN OF SAFETY AT CRITICAL POINTS ON PARACHUTE

9.0 CENTER OF GRAVITY

9.1 PACKED PARACHUTE

The center of gravity of the packed parachute is assumed to be at the center of the deployment bag.

9.2 PARACHUTE IN "STRING-OUT" CONDITION



Because the parachute materials are homogenous, the c.g. of each component is assumed to be at its center.

$$\sum M_{c.g} = 0 = \bar{X}\,W_T - \frac{\ell d}{2} W_d - \left(\ell_d + \ell_g + \frac{\ell b}{2}\right) W_b$$

$$- \left(\ell_d + \ell_g + \ell_b + \frac{\ell e}{2}\right) W_\ell - \left(\ell_d + \ell_g + \ell_b + \ell_e + \frac{\ell_{mr}}{2}\right) W_{mr}$$

$$- \left(\ell_d + \ell_g + \ell_b + \ell_e + \frac{\ell_{ir}}{2} + \ell_{mr}\right) W_{ir}$$

$$- \left(\ell_d + \ell_g + \ell_b + \ell_e + \ell_{mr} + \ell_{ir} + \frac{\ell_b}{2}\right) W_b$$

$$- \left(\ell_d + \ell_g + \ell_b\right) (W_{rad})/2$$

With the measured weights from Table II, the center of gravity is calculated as:

$$(575.9)\ \bar{X} = \frac{13.13}{2}\ (187.7) + 17.18\ (141.0)$$

$$+ 39.33\ (122.0) + 61.11\ (26.0)$$

$$+ 64.14\ (24.0) + 67.39\ (23.8)$$

$$+ \frac{19.58}{2}\ (51.4)$$

$$\bar{X} = \frac{13688.19}{575.90} = 23.77 \text{ ft}$$

TABLE II

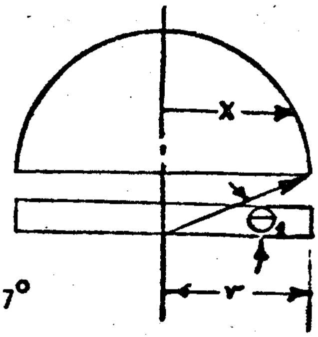
MEASURED WEIGHT BREAKDOWN

Item	Wt. (ounces)
Disc	187.7
Band (including reefing rings & post reef lines)	141.00
Radial Tapes	51.40
Suspension Lines & Post Reef Lines	122.00
Main Riser	26.00
Intermediate Riser (including secondary riser)	24.00
Bridle	23.80
Total Weight	575.9

10.0 MOMENTS OF INERTIA

10.1 ROLL MOMENTS OF INERTIA

10.1.1 Disc



$$Ig = \int x^2 \, dA \Delta W_d$$

$$dA = 2\pi x dy$$

$$\Delta W_d = \text{unit wt.} - .0175 \text{ lb/ft}^2$$

$$x = \sqrt{r^2 - y^2}, \quad r = 13.33 \text{ ft} \quad , \theta_1 = 27.7^\circ$$

$$Ig = 2\pi \Delta W_d \int (r^2 - y^2)\sqrt{r^2 - y^2} \, dy$$

Substituting; $y = 4 \sin \theta$

$$Ig = 2\pi r^4 \Delta W_d \int_{\theta_1}^{\pi/2} \cos^3\theta \, d\theta$$

$$Ig = 2\pi r^4 \Delta W_d \frac{1}{3} \text{ Sin } \theta (\cos \theta + 2) \Big|_{\theta_1}^{\pi/2}$$

$$Ig = 817 \text{ lb-ft}^2$$

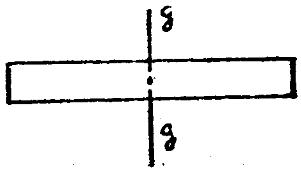
10.1.2 Band

$$Ig = MR^2$$

$m = 8.81$ lb

$r = 13.33$ ft

$$Ig = 1565 \text{ lb-ft}^2$$



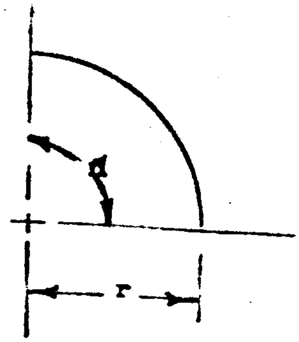
10.1.3 Radial Tapes

For thin rod bent into a circular arc

$$I_g = \frac{mr}{2}\left(1 + \frac{\sin\alpha \cos\alpha}{\alpha}\right)$$

$$C = 90^\circ$$

$$I_g = \frac{mr}{2}$$



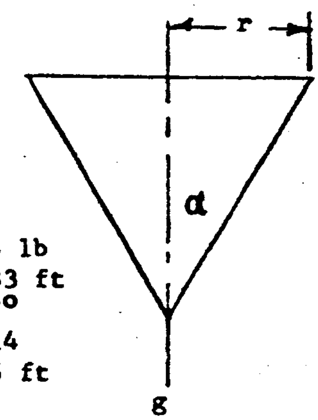
m = 3.21 lb
r = 13.33 ft

$$I_g = 3.21 \times (13.33)^2/2$$

$$I_g = 284 \text{ lb-ft}^2$$

10.1.4 Suspension Lines

$$I_g - m\ell^2 \sin^2\alpha \;/3$$



m = 7.63 lb
r = 13.33 ft
α = 19.7°
$\sin^2\alpha$ = 0.114
ℓ = 39.5 ft

$$I_g - 7.63 \times (39.5)^2 \times 0.114/3$$

$$I_g - 454 \text{ lb-ft}^2$$

10.1.5 Included Air Mass

Assuming a hemispherical canopy, the moment of inertia of the included air mass is:

$$Ig = \frac{2}{5} mr^2$$

Since the weight of the included air mass is a function of altitude, the moment of inertia of the included air mass will vary with altitude.

$$M_a = V\rho_o\sigma$$

Where V = Canopy volume = $2/3\ \pi r^3$

ρ_o = Sea level density

σ = density ratio = ρ/ρ_o

$$M_a = 372\ \sigma \text{ lb}$$

$$Ig = 26{,}442\ \sigma \text{ lb-ft}^2$$

At 130,000 ft altitude $Ig = 91.22$ lb-ft^2

At sea level $Ig = 26{,}442$ lb-ft^2

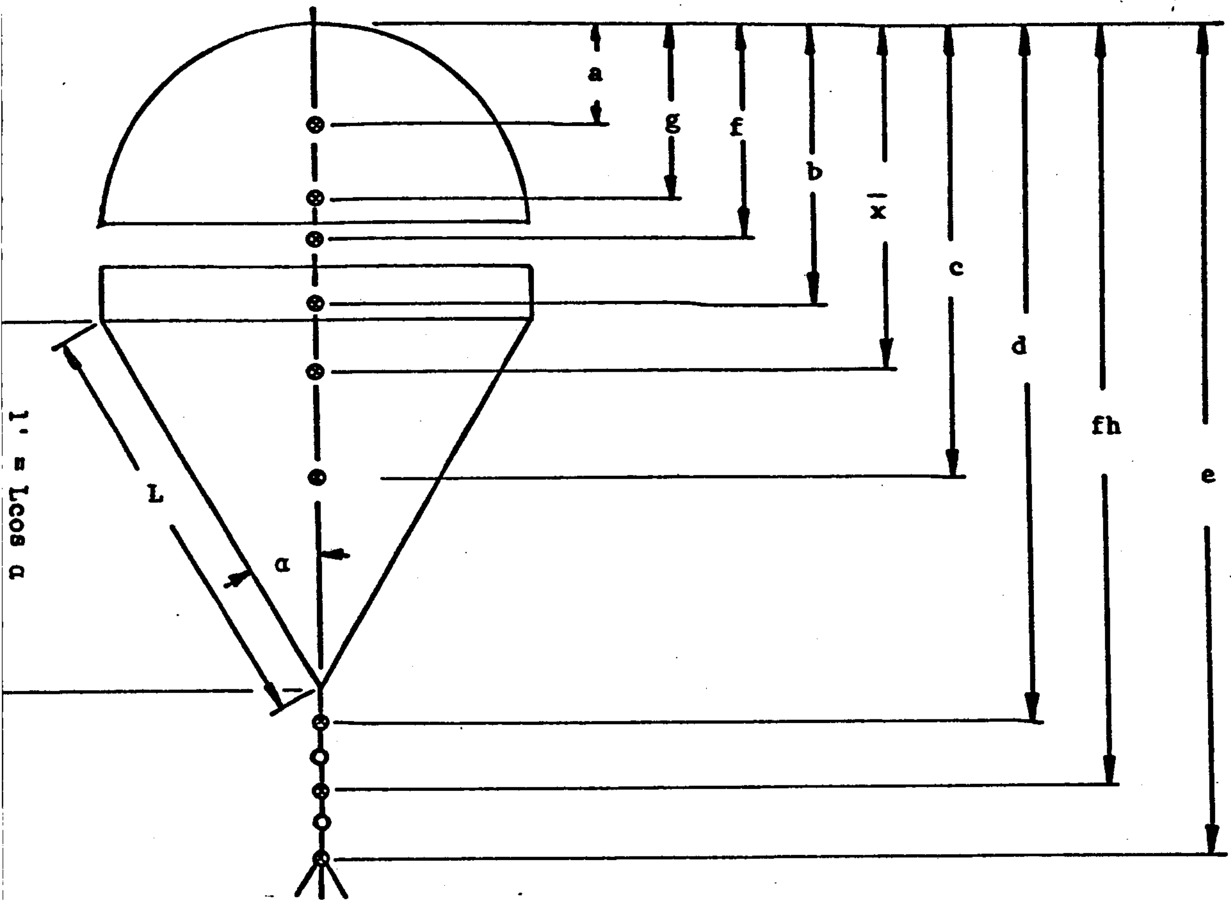
10.1.6 Total Roll Moment of Inertia

The roll moment of inertia of the riser and bridle are considered negligible and have not been included in the total roll moment.

$$Ig_{total} = 3376 + 26{,}442\ \sigma \text{ lb-ft}^2$$

10.2 PITCH AND YAW MOMENTS OF INERTIA-INFLATED CANOPY

10.2.1 Center of gravity-inflated canopy



a = c.g of disc

b = c.g. of band

c = c.g. of lines

d = c.g. of main riser

e = c.g. of bridle

f = c.g. of air mass

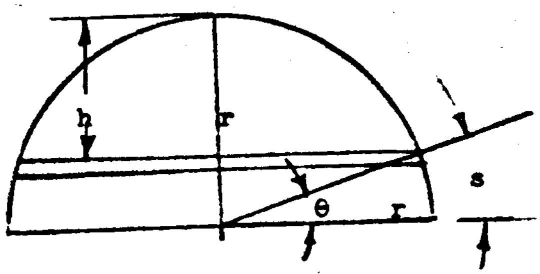
$\bar{x}$ = c.g. of system

g = c.g. of radial tapes

h = c.g. of intermediate riser

From flight photos, the inflated diameter is approximately $\frac{2}{3}$ D_o

$$r = \frac{2}{3}\frac{D_o}{2} = D_o/3$$



$r = 13.33'$

$h = r(1 - \sin\theta)$

$\theta = \frac{s}{r} = \frac{6.45}{13.33} \times 57.3 = 27.7$ degrees

$\sin\theta = .465$

$h = 13.33\ (1 - 0.465)$

$h = 7.15$ ft

Then; c.g. of disc, $a = \frac{h}{2} = 3.575$ ft

c.g of band, $b = r\ (1 - \sin \frac{2.4}{13.33} \times 57.3)$

$b = 10.90$ ft

c.g of lines, $c = r + \frac{1'}{2}$

$c = 13.33 + 18.59$

$c = 31.92$ ft

c.g. of main riser, $d = r + 1' + \frac{4.06}{2}$

$d = 52.53$ ft

c.g. of intermediate riser $h = 54.56 + 1.0$

$h = 55.56$

c.g. of bridle, $e = 55.56 + \frac{4.50}{2}$

$e = 57.81$ ft

c.g. of included air mass, $f = r - \frac{3}{8}r$

$f = \frac{5}{8}r$

$f = 8.35$ ft

c.g. of radial tapes, $g = \frac{2r}{\pi} \left(\frac{\pi}{2} - 1\right) = .363r$

$$g = 4.835 \text{ ft}$$

c.g. of system, $\overline{X}$, $= \sum M_i X_i / \sum M_i$

Where Mi = Weight of i th component

Xi = c.g of i th component

Since the mass of the included air is a function of altitude, the c.g. of the system will change with altitude.

$$(575.9 + Ma)\,\overline{X} = (3.575)(187.7) + (141)(10.9) + (122)(31.92) + (26)(52.53)$$
$$+ (24)(55.56) + (23.8)(57.81) + (51.4)(4.835) + (8.35)(Ma)$$

Where Mi is given in ounces

Xi is given in feet

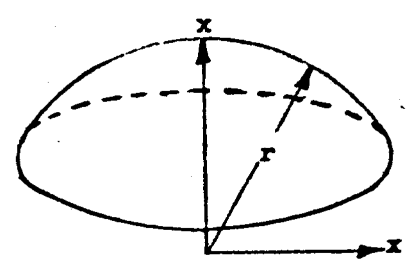
Ma = mass of included air

$$X = \frac{10{,}424.4 + 8.35\ Ma}{575.9 + Ma}$$

Evaluated at 130,000 ft altitude, $M_a = 20.5$ oz

$$X = \frac{10{,}595.6}{596.4} = 17.77 \text{ ft}$$

10.2.2 Moment of inertia-disc



$$x^2 + y^2 = r^2$$

$$dm = 2\pi x\, dy$$

$$I_x = \int y^2 dm = \int 2\pi\, x\, y^2 dy \cdot \Delta W_d$$

$$\Delta W_d = .0175 \text{ lb/ft}^2$$

$$I_x = 2\pi \left[\frac{r^4}{8} \arcsin \frac{y}{r} - \frac{y}{8} (r^2 - 2y^2) \sqrt{r^2 - y^2} \right]_{.465r}^{r} \cdot \Delta W_d$$

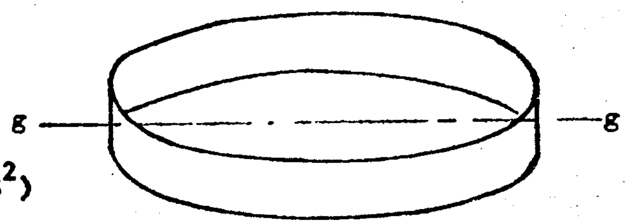
$I_x = 573 \text{ lb-ft}^2$

$$I_{c.g_{system}} = I_x + m\left[(\bar{x} - a)^2 - (r - a)^2\right]$$

$$I_{c.g_{system}} = 573 + 11.7\left[(14.195)^2 - (9.755)^2\right]$$

$$I_{c.g_{system}} = 1816 \text{ lb-ft}^2$$

10.2.3 <u>Moment of Inertia-Band</u>



$$Ig = \frac{m}{12}(6r^2 + h^2)$$

$$Ig = \frac{8.8}{12}(6 \times 13.33^2 + 4.8^2)$$

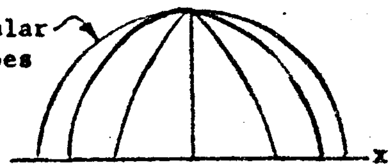
$$Ig = 800 \text{ lb-ft}^2$$

$$I_{c.g_{system}} = 800 + 8.8(\bar{x} - b)^2$$

$$I_{c.g_{system}} = 800 + 8.8(17.77 - 10.90)^2$$

$$I_{c.g_{system}} = 1216 \text{ lb-ft}^2$$

10.2.4 <u>Moment of Inertia</u> - <u>Radial Tapes</u>



$$I_x = 16\ (mr^2/2)$$

$$I_x = 4563 \text{ lb-ft}^2$$

$$I_{c.g_{system}} = I_x + m\left[(\bar{x} - g)^2 - (r - g)^2\right]$$

$$I_{c.g_{system}} = 4563 + 3.21\left[(12.935)^2 - (8.495)^2\right]$$

$$I_{c.g_{system}} = 4868.4 \text{ lb-ft}^2$$

10.2.5 Moment of Inertia-Suspension Lines

$$I_g = \frac{mL^2 \sin^2 \alpha}{12}$$

$$\alpha = 70.4^\circ$$

$$\sin\alpha = .942$$

$$I_g = 880 \text{ lb-ft}^2$$

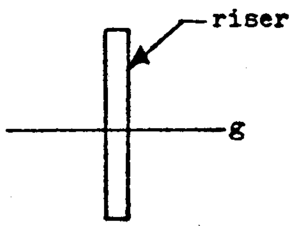
$$I_{c.g\ \text{system}} = 880 + m(c-\overline{x}^2)$$

$$I_{c.g\ \text{system}} = 880 + 7.63\ (31.92 - 17.77)^2$$

$$I_{c.g\ \text{system}} = 2408 \text{ lb-ft}^2$$

10.2.6 Moment of Inertia-Main Riser

$$I_g = \frac{mL^2}{2}$$



$$I_g = \frac{1.63}{12}(4.06)^2$$

$$I_g = 2.23 \text{ lb-ft}^2$$

$$I_{c.g\ \text{system}} = 2.23 + 1.63\ (d - \overline{x})^2$$

$$= 2.23 + 1.63\ (52.53 - 17.77)^2$$

$$= 1972.23 \text{ lb-ft}^2$$

10.2.7 Moment of Inertia - Intermediate Riser

$$I_g = \frac{mL^2}{12}$$

$$I_g = \frac{1.5}{12} \times (2.0)^2$$

$$I_g = 0.50 \text{ lb-ft}^2$$

$$I_{c.g} = 0.50 + 1.5\ (n-\overline{x})^2$$

$$I_{c.g} = 0.50 + 1.5\ (55.56 - 17.77)^2$$

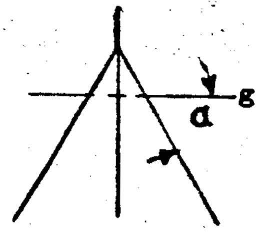
$$I_{c.g} = 2146.5 \text{ lb-ft}^2$$

10.2.8 Moment of Inertia - Bridle

$Ig = \frac{1}{12} mL^2 \sin^2$

$= 82^o$

$\sin = .990$



$Ig = 1.50/12\ (4.50)^2\ (0.990)^2$

$Ig = 2.48$ lb-ft^2

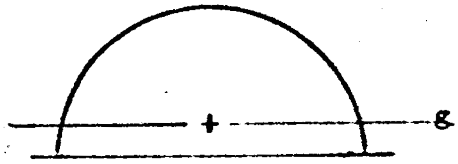
$I_{c.g_{system}} = 2.48 + 1.5\ (57.81 - 17.77)^2$

$I_{c.g_{system}} = 2404.48$ lb-ft^2

10.2.9 Moment of Inertia - Included Air Mass

$Ig = \frac{2}{5} mr^2 - m(\frac{3}{8}r)^2$

$Ig = .26\ mr^2$



$Ig = .26 \times 1.3 \times 177.69$

$Ig = 60$ lb-ft^2

$I_{c.g_{system}} = 60 + 1.3\ (\bar{x} - f)^2$

$= 60 + 1.3\ (17.77 - 8.35)^2$

$I_{c.g_{system}} = 173.6$ lb-ft^2

10.2.10 Total Pitch and Yaw Moment of Inertia

The total pitch and yaw moment of inertia at 130,000 ft altitude:

$I_{c.g_{Total}} = 17{,}005.21$ lb-ft^2

LIST OF REFERENCES

1. "Performance and Design Criteria for Deployable Aerodynamic Decelerators", American Power Jet Company, Ridge Field, New Jersey, ASD-TR-61-579, December 1965.

2. "Fluid Dynamic Drag", Dr. S. F. Hoener, Midland Park, New Jersey.

3. Design, Stress Analysis and Drawings for 30' Diameter Disc Gap Band Parachutes - Planetary Entry Parachute Program, C. V. Eckstrom, G. T. Schjeldahl Co., Sept. 1966.

11.0 POST REEFING SYSTEM

To obtain an equilibrium descent velocity of 40 ft/sec at 4000 ft altitude, the parachute must be reefed to provide a smaller drag area (C_D S).

$$(C_D S)_{Reefed} = \frac{W}{\rho/_2 V^2}$$ where: V = 40 ft/sec

ρ = density at 4000 ft

$$(C_D S)_{Reefed} = 142.07 \text{ ft}^2$$

$$(C_D S)_o = 628.32 \text{ ft}^2$$ where: $(C_D S)_o$ = unreefed drag area

then:

$$\frac{(C_D S)_{Reefed}}{(C_D S)_o} = .2261 = 22.61\%$$

Therefore, the drag area reduction required = 77.39%.

The reefing line diameter required to obtain a reefed drag area of 142.07 ft² is found by the methods presented in reference 1, based on a flat circular canopy.

$$C = \frac{\text{Reefing line diameter}(D_{RO})}{\text{Flat Diameter}}$$

$$\delta = \frac{\text{Diameter of Reefing line of Reefed Parachute}}{\text{Diameter of Reefing line of Fully Inflated Parachute}}$$

The diameter of the reefing line circle is then given as

$$D_{Ri} = D_o \times C \times \delta$$

From the curves presented in reference 1:

$C = 0.65$

$\delta = 0.31$

then:

$$D_{Ri} = 40 \times 0.65 \times 0.31 = 8.1 \text{ ft}$$

then the reefing line circumference is 25.5 feet.

In order for the reefing line to operate on a non-interference basis, it should be equal in length to the circumference of the Band.

Band Circumference = 91.5 feet

Reefing loop circumference = 91.5 feet

Reefing line take-up = 91.5 - 25.5 = 66.0 feet

The reefing method used gives four feet of take-up for each one foot of secondary riser extension.

Therefore, the length of secondary riser must be 66/4 = 16.5 feet.

APPENDIX A

DETAILED WEIGHT BREAKDOWN

OF 40 FT DGB'S

S/N 671, AND S/N 672

RECOVERY SYSTEMS RESEARCH, INC.
P. O. BOX 137
ALAMOGORDO, NEW MEXICO
PHONE (505) 437-6182
Specialists in Mid-Air Recovery Systems

15 September 1967

WEIGHTS ON 40' D_o DGB PARACHUTE SYSTEMS

	S/N 671 lb	S/N 671 oz	S/N 672 lb	S/N 672 oz
Deployment Bag		13		13
Bridle	1	7.8	1	7.8
Upper Riser	1	10	1	10
Intermediate Riser	1	8	1	8
Reefing Rings - 30 each		2.75		2.75
Upper Lateral Tapes W/Splices		1.2		1.2
Lower Tape of Disc "A"		6.7		6.7
Top Tape of Band "B"		6.7		6.7
Bottom Tape of Band "C"		6.7		6.7
Gap Reinforcing Tapes - 32 each		5.4		5.4
Radial Tapes - 32 each	3	3.4	3	3.4
Band Less "B" & "C" Tapes	7	3	7	3
Band W/"B" & "C" Tapes	8	2.3	8	3.1
Disc Less Top & Bottom Tape	11	2.4	11	2.9
Disc W/Top & Bottom Tape	11	11.75	11	12.5
Canopy Disc & Band W/Radial Tapes (Less Reefing Rings, Post Reefing Loop, Post Reefing Lines and Suspension Lines)	23	14	23	15
Suspension Lines - 32 each	7	2	7	1
Canopy W/Suspension Lines & Reefing Rings	30	12.8	31	2
Canopy W/Suspension Lines, Reefing Rings, Post Reefing Loop, and Post Reefing Lines	32	3.4	32	5.3
Total Canopy	34	.4	34	.9

APPENDIX B

SECONDARY RISER LOADING

The load developed in the secondary riser during post reefing of the parachute is analyzed as a function of the relative velocity between the parachute and payload after the intermediate riser is disconnected from the main riser.

The relative velocity between payload and parachute is a function of the tension in the post reefing lines and the payload weight.

Assuming a linear stress-strain relation for the secondary riser, the snatch force in the secondary riser is given as:

$$F_s = \Delta V \sqrt{\frac{P_{max}}{e_{max}} \frac{W}{g}}$$

where ΔV = relative velocity

P_{max} = ult strength = 2000 lb

e_{max} = break elongation = 20%

The relative velocity between parachute and payload after disconnect is determined as a function of tension in the post reef lines at 75,000 ft altitude.

VELOCITY OF PARACHUTE

Assume an average drag area of $0.62(C_DS)_o$ during the reefing process.

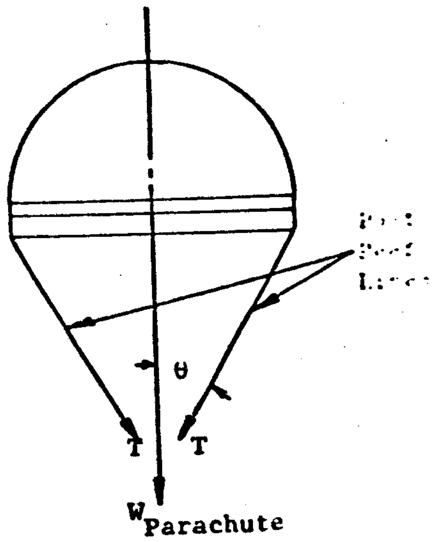
Then: $$V^2 = \frac{2W}{\rho C_D S}$$

where $W = W_{parachute} + 2T \cos\theta$

$C_DS = 0.62 \times 0.52 \times 1256.64$

$C_DS = 413\ ft^2$

$\theta = 19.5^o$, $\cos\theta = 0.941$



Tension values are then arbitrarily selected, and the corresponding parachute velocity is calculated (see Table I below).

TABLE I

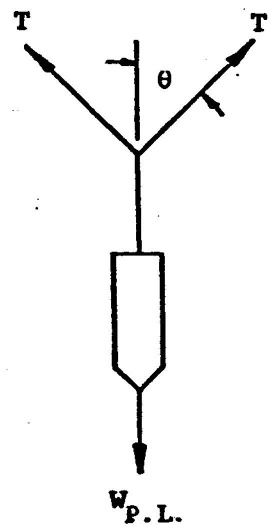
T (lb)	2T cos θ	W (lb)	V_{par} (ft/sec)
0	0	35	39.4
20	37.6	72.6	58.5
40	75.2	110.2	73
60	113	148	85
80	150	185	96
100	188	223	111
120	226	261	114

VELOCITY OF PAYLOAD (Neglecting Drag)

$$M \frac{dv}{dt} = W_{P.L.} - 2T \cos \theta$$

$$M \frac{dv}{dt} \cdot \frac{dt}{dx} \cdot v = W_{P.L.} - 2T \cos \theta$$

$$\frac{V^2}{2} = \left(\frac{W_{P.L.} - 2T \cos \theta}{M}\right) \ell_s + \frac{V_o^2}{2}$$



where l_s = length of secondrary riser = 16.5 ft

V_o = payload velocity at time of disconnect

V_o = 81 ft/sec, V_o^2 = 656

TABLE II

Payload Velocity vs T

(1) T (lb)	(2) $W_{P.L.} - 2T \cos \theta$	(3) $2\left(\frac{WP-2T\cos\theta}{M}\right)\ell s$	(4) $(3) + V_o^2$	(5) $\sqrt{4} = V_{p.l.}$
0	243	$.107 \times 10^4$	$.763 \times 10^4$	87.6
20	205.4	$.090 \times 10^4$	$.746 \times 10^4$	86.2
40	167.8	$.073 \times 10^4$	$.729 \times 10^4$	85.0
60	130	$.057 \times 10^4$	$.713 \times 10^4$	83.2
80	93	$.041 \times 10^4$	$.697 \times 10^4$	82.4
100	55	$.024 \times 10^4$	$.680 \times 10^4$	81.5
120	17	$.0075 \times 10^4$	$.663 \times 10^4$	80.6

RELATIVE VELOCITY (ΔV)

TABLE III

T	$V_{P.L.}$	$V_{Parachute}$	ΔV	$P = \Delta V\sqrt{\frac{P_{max}}{e_{max}}\frac{W}{g}}$
0	87.6	39.4	48.2	3420
20	86.2	58.5	27.7	1970
40	85.0	73.0	12.0	850
60	83.2	85.0	-	-
80	82.4	96.0	-	-
100	81.5	111.0	-	-
120	80.6	114.0	-	-

As shown by Table III, with a tension of 60 lbs in the post reef lines, there would be no relative velocity between parachute and payload. Any tension less than 60 lbs will allow the payload and parachute to separate.

With zero tension in the post reef lines, the secondary riser loading exceeds the ultimate strength of the secondary riser.

No known analytical method for determining the tension in the post reef lines has been founa. This analysis was made primarily to determine the effect on the secondary riser if the post reefing lines failed during disconnect.

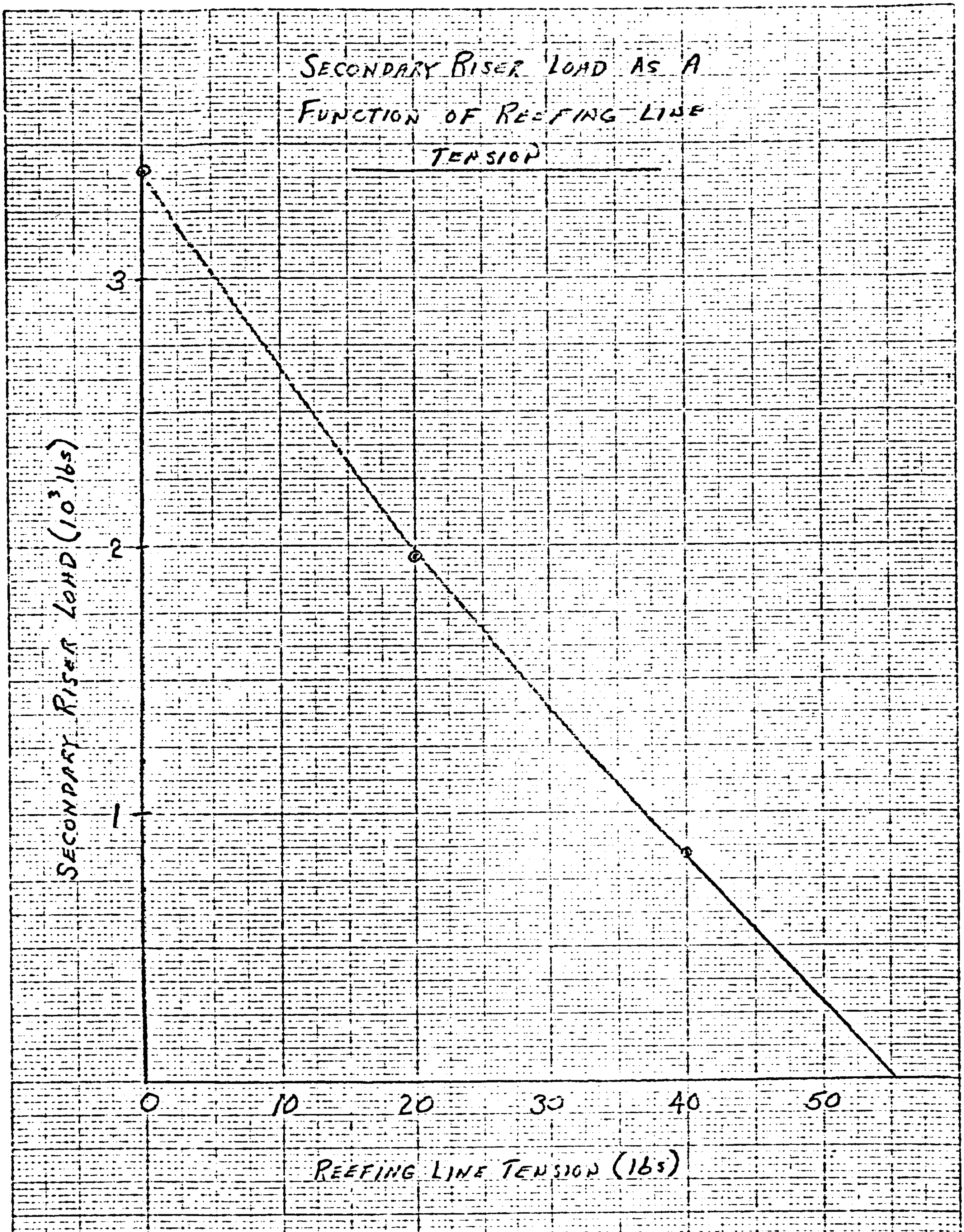

SECONDARY RISER LOAD AS A
FUNCTION OF REEFING LINE
TENSION
SECONDARY RISER LOAD (10³ lbs)
3
2
1
0
10
20
30
40
50
REEFING LINE TENSION (lbs)

FIGURE 1.0

APPENDIX C

COMPONENT STRUCTURAL TEST REPORTS

TEST REPORT

TEST ITEM

MAIN RISER WEB JOINT

PROJECT

15092

PURPOSE

X ULTIMATE STRENGTH

X POINT OF FAILURE

X EFFICIENCY

OTHER

TEST METHOD

INSTRON TENSILE TESTER, 5 in/min JAW SEPARATION RATE,
18 INCH JAW SPEED

REQUESTED BY	DATE	APPROVED BY
R. LEMKE	6-14-67	R. LEMKE

TABLE

SAMPLE	TENSILE STRENGTH (lbs)
1	7000
2	7050
3	7200
AVG.	7083

COMMENTS

ALL SAMPLES FAILED IN WEB STITCHING. RATED STRENGTH OF MIL-W-25361, TYPE III DACRON WEBBING IS 7000 lb.

RESULTS

MINIMUM JOINT STRENGTH/RATED WEB STRENGTH x 100 =
JOINT EFFICIENCY = 7000/7000 x 100 = 100%

CONCLUSIONS

JOINT ACCEPTABLE FOR USE, AND MEETS DESIGN REQUIREMENTS

TESTED BY: [signature]

DATE TESTED: 6-14-67

TEST REPORT

TEST ITEM	PROJECT
INTERMEDIATE RISER	15092

PURPOSE

- X ULTIMATE STRENGTH
- X POINT OF FAILURE
- X EFFICIENCY
- OTHER

TEST METHOD

TINIUS OLSON TENSILE TESTER, 14 INCH JAW SPREAD
4½ in/min JAW SPEED

REQUESTED BY	DATE	APPROVED BY
R. LEMKE	7-12-67	R. LEMKE

TABLE

SAMPLE	TENSILE STRENGTH (lbs)
1	26,250
2	25,650
AVG.	25,950

COMMENTS

SAMPLES FAILED AT LOOP END OF RISER, JOINTS SHOWED NO SIGN OF DAMAGE.

RESULTS

JOINT EFFICIENCY IS 100% SINCE NO FAILURES OCCURRED IN JOINT

CONCLUSIONS

RISER CONSTRUCTION ACCEPTABLE FOR INTENDED USE, AND MEETS DESIGN REQUIREMENTS.

TESTED BY: [signature]	DATE TESTED: 7-12-67

TEST REPORT

TEST ITEM

BRIDLE LEG

PROJECT

15092

PURPOSE X ULTIMATE STRENGTH X POINT OF FAILURE
X EFFICIENCY OTHER

TEST METHOD

TINIUS OLSON TENSILE TESTER, JAW SEPARATION 18 INCHES,
JAW SPEED 4½ in/min.

REQUESTED BY	DATE	APPROVED BY
R. LEMKE	7-12-67	R. LEMKE

TABLE

SAMPLE	TENSILE STRENGTH (lbs)
1	9150
2	9750
3	9550
AVG.	9483

COMMENTS

ALL SAMPLES FAILED AT END OF JOINT STITCHING

RESULTS

$$\text{JOINT EFFICIENCY} = \frac{9150}{10000} \times 100 = 91.5\%$$

CONCLUSIONS

JOINT EFFICIENCY ACCEPTABLE AND MEETS DESIGN REQUIREMENT.

TESTED BY: [signature]

DATE TESTED: 7/12/67

TEST REPORT

TEST ITEM

SUSPENSION LINE TO RADIAL TAPE

PROJECT

15092

PURPOSE

X ULTIMATE STRENGTH
X EFFICIENCY
X POINT OF FAILURE
OTHER

TEST METHOD

INSTRON TENSILE TESTER, 12 INCH JAW SPREAD, 12 in/min JAW SEPARATION

REQUESTED BY R. LEMKE

DATE 6-5-67

APPROVED BY R. LEMKE

TABLE

SAMPLE	TENSILE STRENGTH (lbs)
1	475
2	550
3	585
AVG.	536

COMMENTS

SAMPLES FAILED IN RADIAL TAPE LOOP

RESULTS

JOINT EFFICIENCY = MINIMUM JOINT STRENGTH/MINIMUM TAPE STRENGTH = 475/510 x 100 = 93.5%

CONCLUSIONS

JOINT STRENGTH IS ACCEPTABLE FOR INTENDED APPLICATION AND MEETS DESIGN REQUIREMENTS.

TESTED BY: [signature]

DATE TESTED: 6-5-67

TEST REPORT

TEST ITEM	PROJECT
SUSPENSION LINE TO MAIN RISER	15092

PURPOSE X ULTIMATE STRENGTH   X POINT OF FAILURE   X EFFICIENCY   OTHER

TEST METHOD

INSTON TENSILE TESTER, 12 INCH JAW SPREAD, 12 in/min SEPARATION RATE

REQUESTED BY	DATE	APPROVED BY
R. LEMKE	6-6-67	R. LEMKE

TABLE

SAMPLE	TENSILE STRENGTH (lbs)
1	4400
2	4290
3	4200
AVG.	4296

COMMENTS

SAMPLES NO. 1 AND 3 WERE TESTED AS A GROUP OF EIGHT LINES, AND ON SAMPLE NO. 2, LINES WERE TESTED INDIVIDUALLY AND STRENGTHS ADDED. IN ALL SAMPLES, FAILURE WAS IN LINE, NOT JOINT.

RESULTS

JOINT IS 100% EFFICIENT SINCE NO JOINT FAILURES OCCURRED.

CONCLUSIONS

JOINT ACCEPTABLE FOR INTENDED PURPOSE, AND MEETS DESIGN REQUIREMENT

TESTED BY: [signature]	DATE TESTED: 7/11/67

TEST REPORT

TEST ITEM	PROJECT
Radial Tape To Vent Reinforcement Tape - Load Applied To Radial Tape	15092

PURPOSE

X ULTIMATE STRENGTH X POINT OF FAILURE

X EFFICIENCY OTHER

TEST METHOD

Instron Tensile Tester, Jaw Spread, 5 inches, Jaw Speed 6 in/min.

REQUESTED BY	DATE	APPROVED BY
R. Lemke	6-5-67	R. Lemke

TABLE

Sample	Tensile
1	570
2	620
3	630
4	660
Avg	620 lb.

COMMENTS

Avg Ultimate Strength of Dacron Tape is 611.6 based on control sample tests.

RESULTS

Min. joint strength/ min. tape strength $\times 100 = \frac{570}{575} \times 100 = 99\%$.

CONCLUSIONS

Joint Strength Is Acceptable For Intended Application and Meets Requirements.

TESTED BY: [signature] DATE TESTED: 6-5-67

TEST REPORT

TEST ITEM	PROJECT
1500 lb. Dacron Line	15092

PURPOSE X ULTIMATE STRENGTH | POINT OF FAILURE | EFFICIENCY | OTHER

TEST METHOD

Instron Tensile Tests, 4" Jaw Spread, 12 inch/min. Crosshead Speed

REQUESTED BY	DATE	APPROVED BY
R. Lemke	6-5-67	R. Lemke

TABLE

Sample Number	Tensile Strength
1	2500
2	2700
Avg	2600 lbs.

COMMENTS

One end of sample contained a loop through which a 1/2" dia. pin was inserted for test. Other end was clamped in smooth jaw.

RESULTS

Line Broke Remote From Loop or Clamp.

CONCLUSIONS

Line Acceptable For Application Intended.

TESTED BY: [signature]	DATE TESTED: 6-5-67

TEST REPORT

TEST ITEM	PROJECT
550 lb. Dacron Line — Pioneer Parachute Co. Specification E-0067-2	15092

PURPOSE X ULTIMATE STRENGTH / EFFICIENCY / POINT OF FAILURE / OTHER

TEST METHOD

Instron Tensile Tester, 10" Jaw Spread, 12-inch/min. Jaw Speed

REQUESTED BY	DATE	APPROVED BY
R. Lemke	6-6-67	R. Lemke

TABLE

Sample No.	Tensile (lb.)	Elong %
1	650	44
2	650	44
3	660	44
4	610	49
5	630	60
Avg.	640 lb	48 %

COMMENTS

Samples Broke at Jaw

RESULTS

Average Strength Well Over Rated Strength of 550 #

CONCLUSIONS

Line Acceptable For Intended Use. Exceeds Design Requirements.

TESTED BY: [signature] | DATE TESTED: 6-6-67

TEST REPORT

TEST ITEM	PROJECT
Tape Splice - 550 lbs. Dacron Tape	15092

PURPOSE

X ULTIMATE STRENGTH | X POINT OF FAILURE

X EFFICIENCY | OTHER

TEST METHOD

Instron Tensile Tester, Jaw Spread 5 inches, Jaw Speed 6 in./min.

REQUESTED BY	DATE	APPROVED BY
R. Lemke	6-5-67	R. Lemke

TABLE

Sample	Tensile Strength
1	510
2	560
3	510
4	560
Avg	535

COMMENTS

Avg tensile Strength of Dacron tape, lot no. 2344 was 611.6 lb. joints failed at end of stitching.

RESULTS

Joint Efficiency = Min.Joint Strength/Min . Tensile Strength of Tape X 100 =

$\frac{510}{610}$ X 100 = 84%

CONCLUSIONS

TESTED BY: R. J. Lemke

DATE TESTED: 6-5-67

TEST REPORT

TEST ITEM	PROJECT
Dacron Tape, 3/4 Wide, Balley Ribbon Lot No. 2344.	15092

PURPOSE X ULTIMATE STRENGTH X POINT OF FAILURE
EFFICIENCY OTHER

TEST METHOD
Instron Tensile Tests, 4" Jaw Spread, 12 inch/min. Crosshead Speed

REQUESTED BY	DATE	APPROVED BY
R. Lemke	5-16-67	R. Lemke

TABLE

Sample Number	Tensile (lb)	Elong %
1.	670	33
2.	590	31
3.	575	31
Avg.	611.6	31.6%

COMMENTS

RESULTS

All Samples Failed At Edge of Jaws

CONCLUSIONS
Material Suitable For Use In Fabrication Of 40-foot D.G.B.'s

TESTED BY: [signature] DATE TESTED: 5-16-67

TEST REPORT

TEST ITEM
2.0 oz/yd^2 Dacron fabric, 15586, lot no. 2344

PROJECT
15092

PURPOSE
X ULTIMATE STRENGTH
EFFICIENCY
X POINT OF FAILURE
OTHER

TEST METHOD
Instron Tensile Tester, CCC-T-191b method 5100.

REQUESTED BY R. Lemke
DATE 5-16-1967
APPROVED BY R. Lemke

TABLE

	Warp		Fill	
	Tensile	Elong%	Tensile	Elong%
1.	110	36	105	42
2.	105	38	110	39
3.	110	42	110	42
Avg.	108	38+%	108	41%

COMMENTS

RESULTS

All Samples Failed at Edge of Jaws.

CONCLUSIONS
Material Suitable for Use in Fabrication of 40-foot D. G. B. Parachutes.

TESTED BY: [signature]
DATE TESTED: 5-16-67

TEST REPORT

TEST ITEM	PROJECT
2.0 oz/yd2 Dacron Fabric, 15586, lot no. 2097	15092

PURPOSE X ULTIMATE STRENGTH X POINT OF FAILURE

EFFICIENCY OTHER

TEST METHOD

Instron Tensile Tester, CC-T-191b method 5100

REQUESTED BY	DATE	APPROVED BY
R. Lemke	5-16-67	R. Lemke

TABLE

	Warp		Fill	
	Tensile	Elong%	Tensile	Elong%
	104	41	113	47
	84	43	104	35
	107	45	110	38
Avg.	98	43%	109	40%

COMMENTS

RESULTS

All Samples Failed at Edge of Jaws

CONCLUSIONS

Material Acceptable for Use in Fabrication of 40 foot D. G. B.

TESTED BY: [signature] DATE TESTED: 5-16-67

TEST REPORT

TEST ITEM	PROJECT
Main Seam	15092

PURPOSE

- X ULTIMATE STRENGTH
- X EFFICIENCY
- POINT OF FAILURE
- OTHER

TEST METHOD

Instron Tensile Tester, CCC-T-191b, method 5100

REQUESTED BY	DATE	APPROVED BY
R. Lemke	5-15-67	R. Lemke

TABLE

Sample No.	Tensile Strength (lbs/in.)
1	104
2	84
3	115
4	90
Avg	98.25

COMMENTS

Avg. material strength is 109 lb/in.

RESULTS

Min. seam strength/minimum material strength X 100 =

84 / 84 X 100 = 100 % joint efficiency

If thread strength had been taken into account in the min. material strength, the joint efficiency would be slightly less than 100%.

CONCLUSIONS

Joint acceptable for application intended and meets design requirements.

TESTED BY:	DATE TESTED:
[signature]	5-16-67

TEST REPORT

TEST ITEM	PROJECT
Cross Seam	15092

PURPOSE X ULTIMATE STRENGTH X POINT OF FAILURE
X EFFICIENCY OTHER

TEST METHOD

Instron Tensile Tester, CC-T-191b, method 5100

REQUESTED BY	DATE	APPROVED BY
R. Lemke	5-16-67	R. Lemke

TABLE

Sample Number	Tensile No. (lb/in)
1	89
2	92
3	88
4	84
Avg	88.25

COMMENTS

Avg. tensile strength of fabric in fill direction, lot no. 2097 is 109 lbs/in.

RESULTS

Min seam strength/min Mat'l strength X 100 = 100 % = seam efficiency.

If the thread strength had been taken into account in min. material strength, joint efficiency would be slightly less than 100%.

CONCLUSIONS

Seam Strength is Acceptable for Application Intended and Meets Design Requirements.

TESTED BY: [signature] DATE TESTED: 5-16-67

APPENDIX D

PARACHUTE PACKING PROCEDURE

Schjeldahl Company

G.T. SCHJELDAHL COMPANY • NORTHFIELD, MINNESOTA 55057

SPECIFICATION

CLASSIFICATION

PACKING PROCEDURE 40' Do DGB

Page 1 of 4

Specification NO. P-450

Date Issued 5-22-67

Revision A

Prepared By: [signature]

Approved By: [signature]

Approved By: [signature]

Released By: [signature]

REV.	ECO	CHANGED
A	8930	8-11-67 Revised & Retyped pages 3.4

1. Lay the parachute on the packing table in the stretched out condition. Check the parachute to assure that the disc has not inverted through one of the gap openings.

2. Attach a tie cord from the parachute vent lines to the packing table. Working from the riser end, put the parachute under moderate tension (about 20#) and secure the riser to the packing table.

3. Check all suspension lines to assure that they are not knotted, twisted, or tangled.

4. Place all canopy material on one side of suspension lines. Then change to opposite side, one gore at a time in such a way that the material is laid neat and flat.

5. After each gore has been inspected and laid out, the gores are to be divided so that gores 1 to 16 are on one side, and gores 17-32 are on the other side.

6. Inspect each gore tape to assure that all are laid with the same side up, and that no twists are inserted in the tapes in the band and gap areas.

7. Because of the bulkiness of the canopy in the vent area the gore edges at the vent cannot be folded the same as the main part of the gore. At the vent, every other gore is folded in on both sides of the stack, as illustrated in Figure 1.

8. The post reefing lines should now be straightened and placed in the lower edge of the canopy gore fold.

Schjeldahl Company

G.T. SCHJELDAHL COMPANY • NORTHFIELD, MINNESOTA 55057

SPECIFICATION

CLASSIFICATION

Specification NO. P-450

Date Issued 5-22-67

Revision A

REV.	ECO	CHANGED

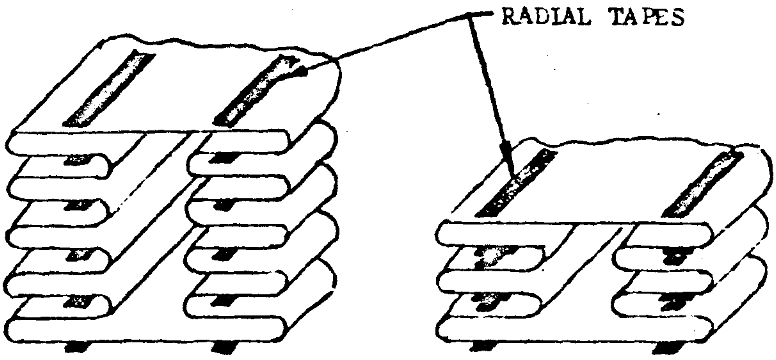


FIGURE 1

9. After the folding of the gore material is complete, place weights on the canopy to maintain the folds, and weight the upper riser to maintain tension in the suspension lines when the table tie cords are removed from the vent lines and riser.

10. Remove weights from the riser and fold the suspension lines (as a single unit) into ten-inch accordian fold loops, holding the ends of the loops in place with rubber bands. These rubber bands are to be removed when the parachute is placed in the deployment bag.

11. Two long strips of 10 mil Mylar are to be used as a folding jig to make the lengthwise canopy folds. Only two folds are made lengthwise and these are one each five-inches out from the center-line of the canopy. One edge of the gore stack is folded up and laid over the top of the original stack. The other edge is folded down and under the original stack. As a result, the suspension lines go to the center of the folded parachute (See Figure 2)

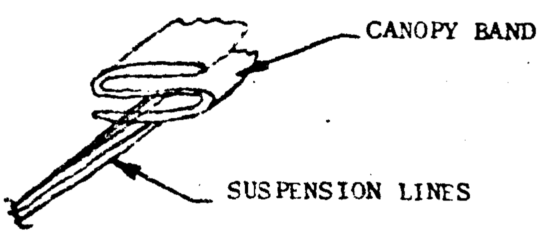


FIGURE 2

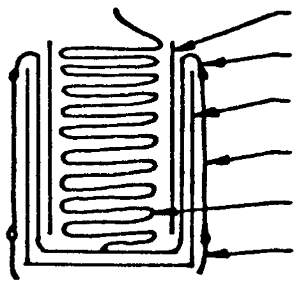
REV.	ECO	CHANGED

12. Place a 1-3/4 wide by 1/4 thick cloth webbing inside the riser protector flops to simulate the stowed riser and tack in place with several loops of thread.

13. Insert the deployment bag in the shipping container. GTS P/N 1004797.

14. Fold the bag flaps over the top rim of the can and tie them to the bottom using a web strap as a bottom tie (See Figure 3)

FIGURE 3



15. Fasten a 6 foot long break cord of 300 lb. tensile dacron from the inside base of the bag to the canopy vent lines.

16. The canopy is now ready for insertion into the deployment bag. The loosely folded canopy will extend beyond the length of the deployment bag. Therefore a 10 mil Mylar liner is to be inserted in the deployment bag which is approximately 4 inches longer than the bag.

17. The canopy vent is placed in the bag first. The canopy is then accordian folded into the bag in such a way that the bag is completely filled. Care must be taken to assure that folds are neat and long enough to fill all available spaces (See Figure 3).

18. Continue packing the parachute into the deployment bag until the bag is completely filled. This should encompass all of disc portion of the canopy.

19. Place shipping container with deployment bag inside under the press and slowly press parachute into the bag. When more space is obtained by this method continue packing remainder of parachute. Press as far into bag as possible and let stand 20 minutes under pressure.

SPECIFICATION

CLASSIFICATION

REV.	ECO	CHANGED

20. Fold the suspension lines into the bag in accordian fashion. Several layers of line will be required, and each layer shall be folded perpendicular to the preceding layer to prevent the possibility of line entanglement.

21. The entire upper riser is then folded into the deployment bag. After pressure packing, a portion of this riser will be outside the bag when it is finally tied off.

22. Using the packing press, slowly press parachute into the bag until it is below the bag mouth. Remove Mylar liner at this time.

23. The final pressing of the parachute into the bag shall be gradual to allow settling and escape of entrapped air. After the parachute is pressed completely into the bag, the system shall be allowed to set for about 1/2 hour.

24. Before the final bag closure is performed, tack the post reefing lines to the main riser with 2 loops of dacron thread making sure the two post reefing lines are on the correct side of the main riser. "F"

25. Bag Closure-String a 1000 pound line through the bag tie loops. Pull the upper riser out of the deployment bag until the knife is aligned with the bag loops. The bag mouth is then pulled closed using the 1000 pound line. (The packing press may be required to assist in the closing operation). When the bag mouth is pulled closed, tie off the 1000 pound line. Now string a 300 pound dacron line through the bag tie loops and through the knife on the upper riser. Pull tight and tie off. CAUTION: REMOVE THE SAFETY LINE BEFORE FLIGHT.

26. Place cover on shipping container and bolt it in place.

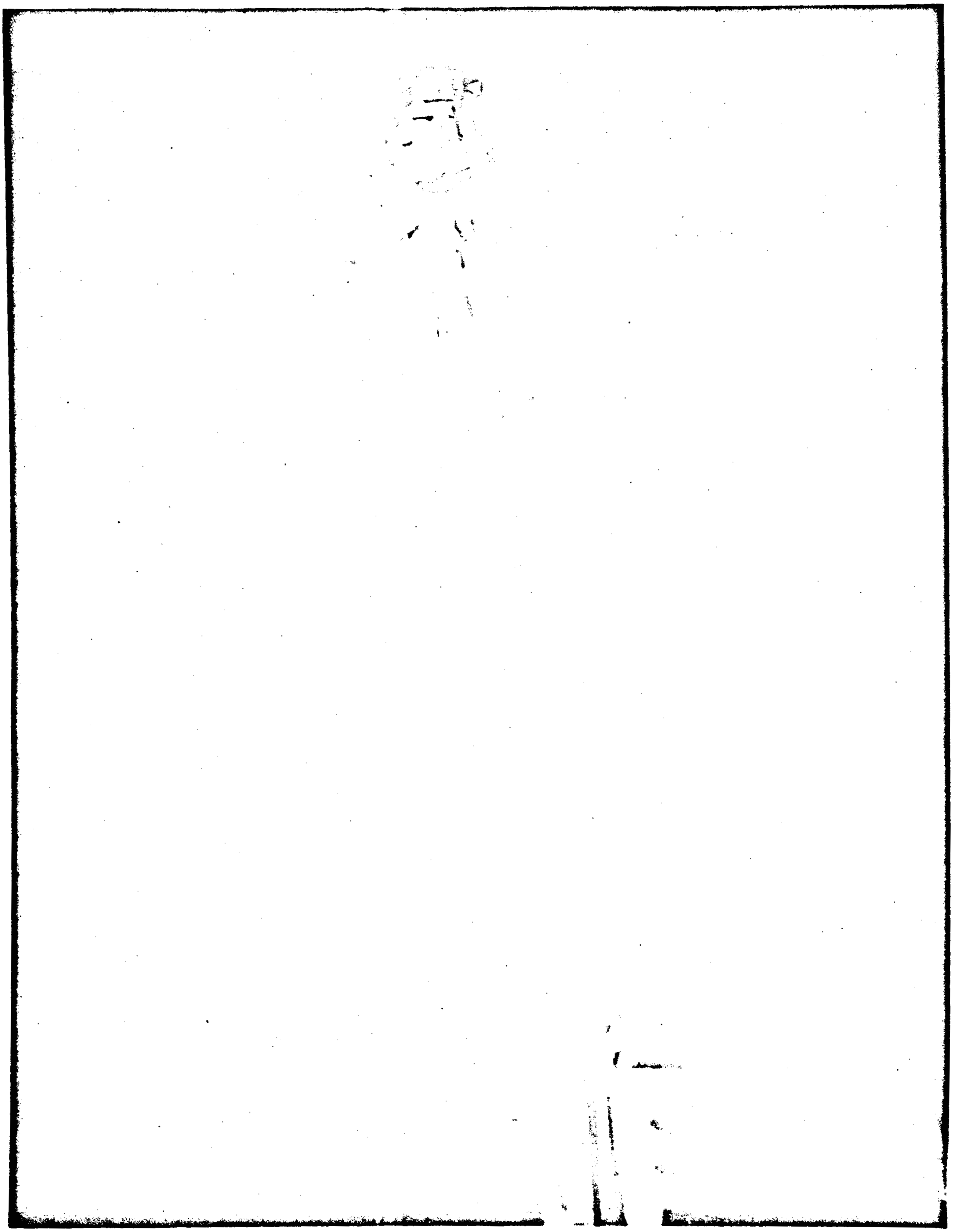


Figure 3 Parachute Folded Lon_itudinally

Figure 4 Folded Suspension Lines

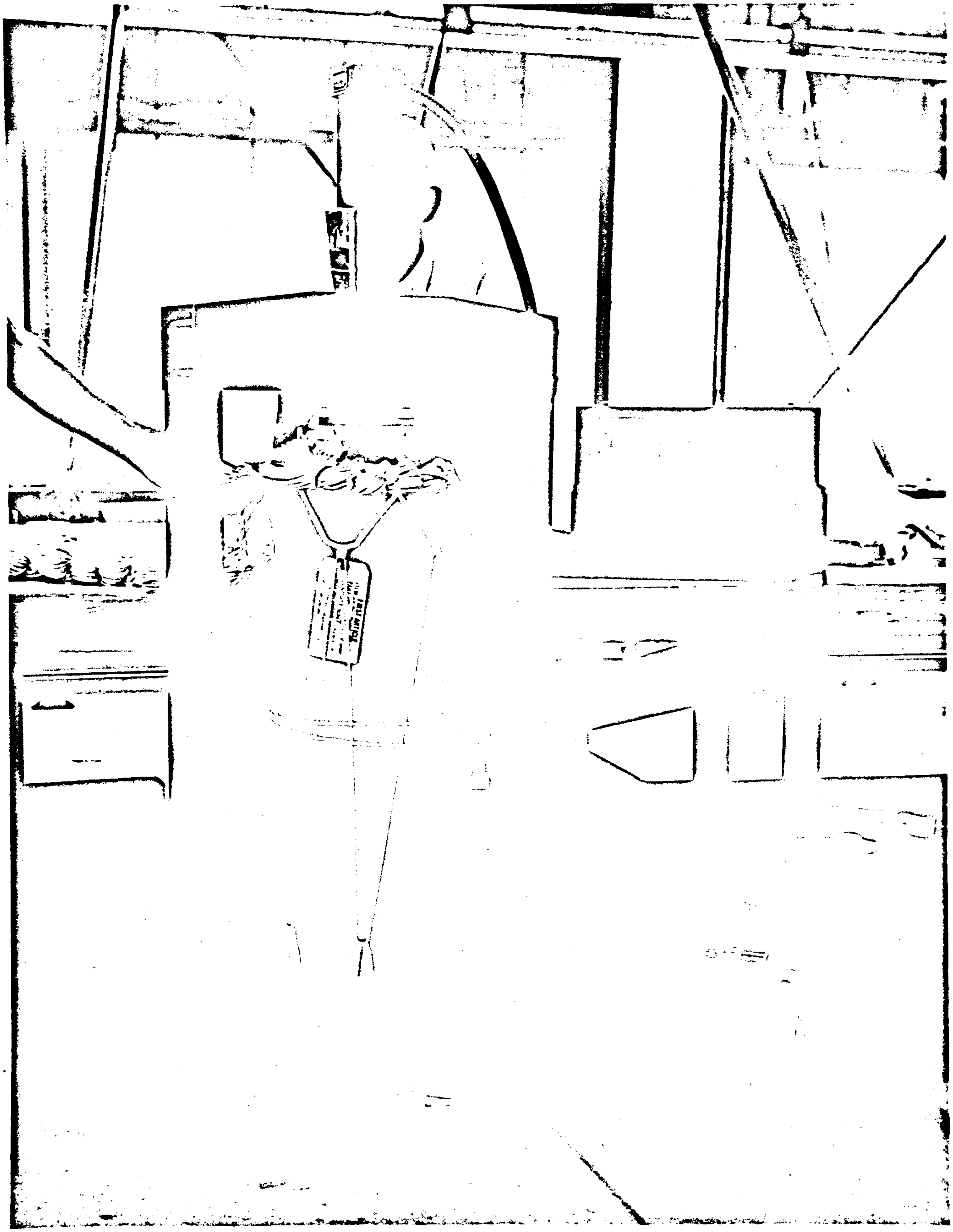


Figure 5 Typical Pressure Packing