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40 FT DGB PARACHUTE

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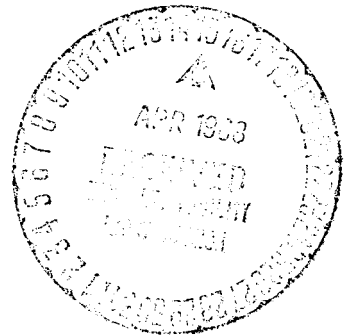
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ABSTRACT

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

<u>Symbol</u>	<u>Meaning</u>	<u>Units</u>
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
M_c	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
f	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

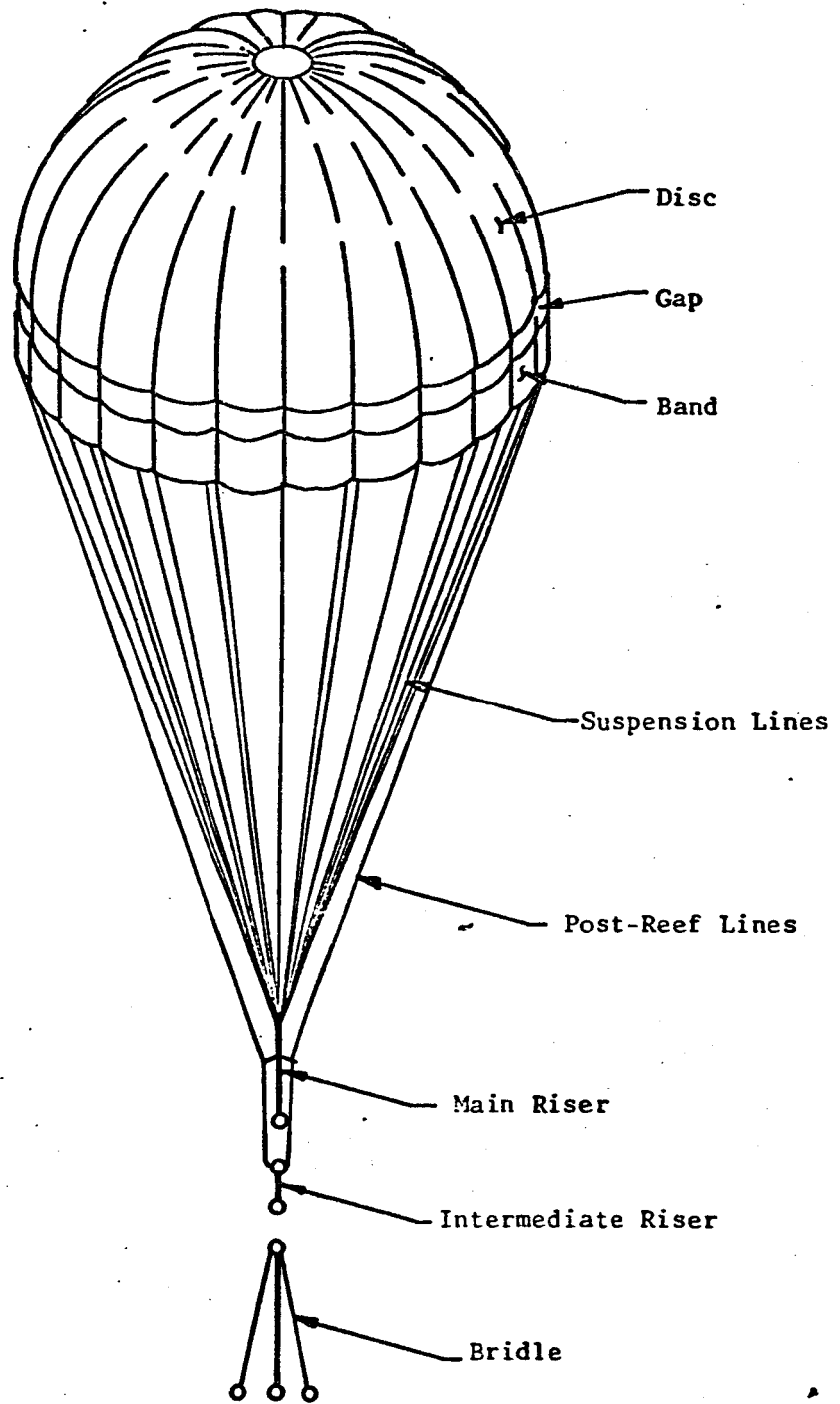


Figure I

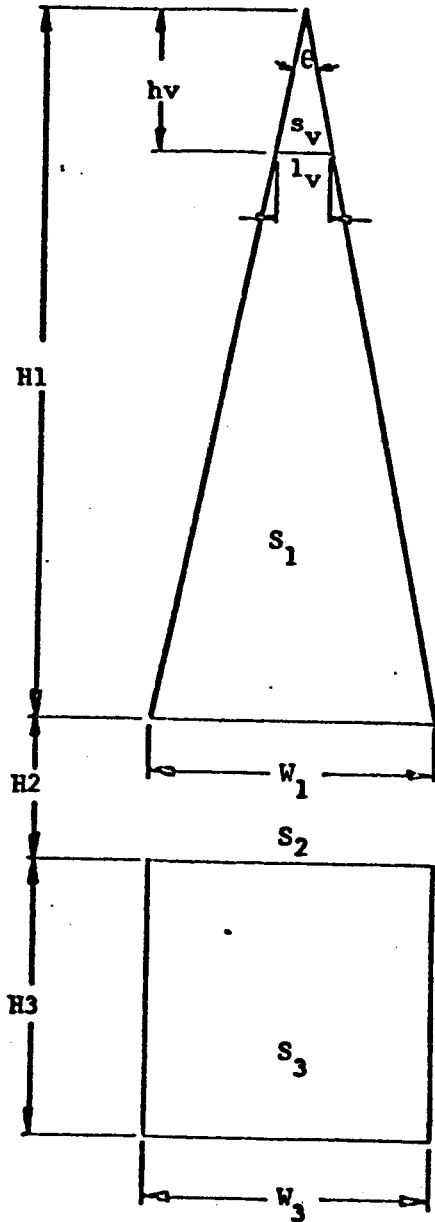
3.0 DESIGN DATA

(40 Ft D_o DGB)

Nominal Diameter (D _o)	40 ft
Geometric Porosity (λ_g)	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

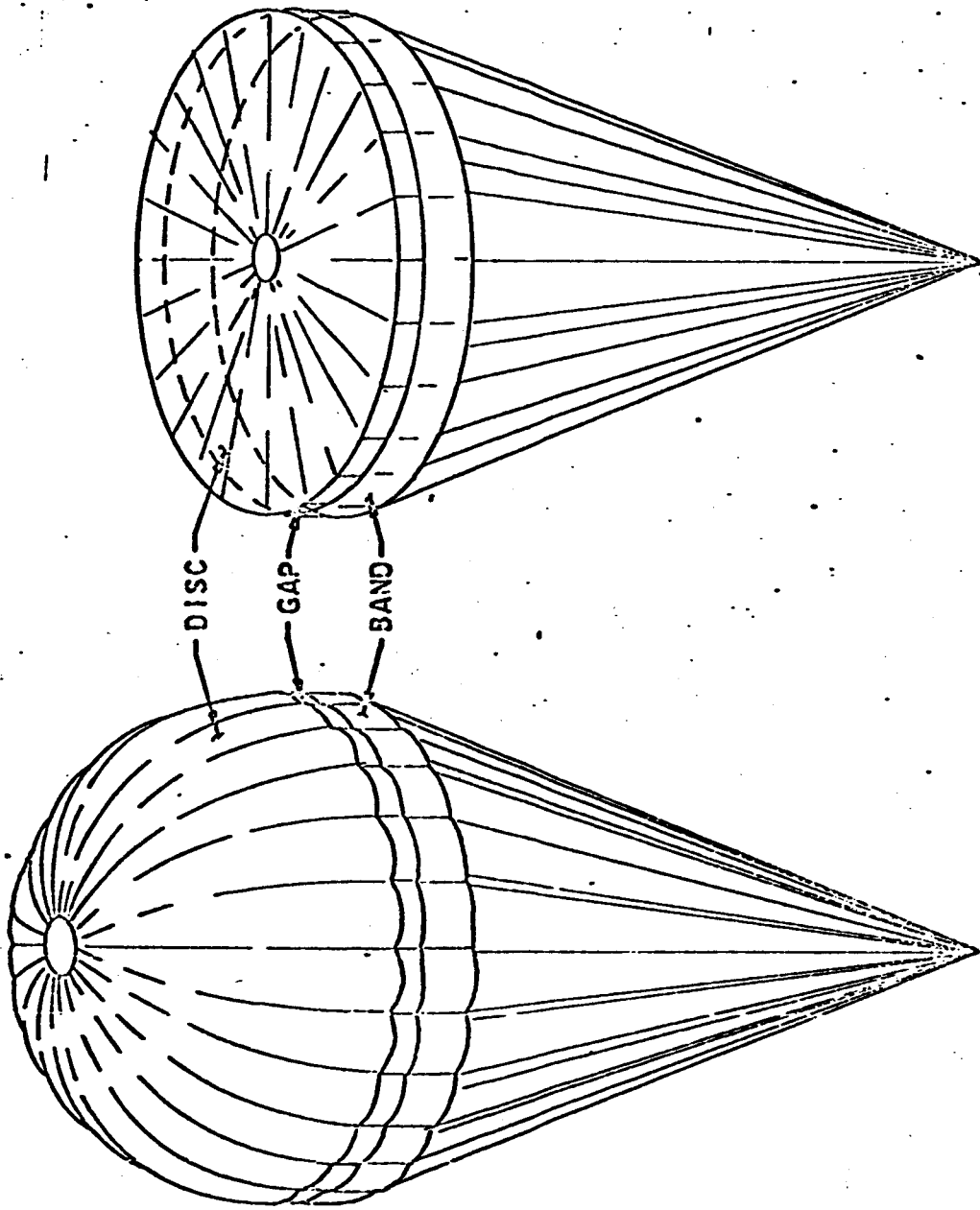
$$\tan \theta_{1/2} = \frac{34.352 - 3.71}{\frac{2}{174.53 - 16.95}} = .09735$$

New construction height of disc

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

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

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



CONSTRUCTED SHAPE

EXPECTED INFLATED SHAPE

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

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

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

and with the design conditions defined as

$$M = 1.6 @ \quad q = 12 \text{ psf}, \quad V_o = 1665 \text{ fps}$$

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., $C_D S = 0.67 \text{ ft}^2$.

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

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

hence, defining initial parachute velocity as

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

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:

$$F_o = X \cdot C_{D_o} \cdot S \cdot q$$

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

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

7.0 WEIGHT ESTIMATES

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,

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

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

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

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

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

<u>Item</u>	<u>Qty</u>	<u>Units Wt.</u>	<u>Total (lbs)</u>
1. 2.0 oz/yd ² dacron	141 yd ²	2.00 oz/yd ²	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
			<hr/>
	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)

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

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

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

$$\text{M.S.} = + 29\%$$

8.2 Radial Tapes (575 lb rated strength)

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

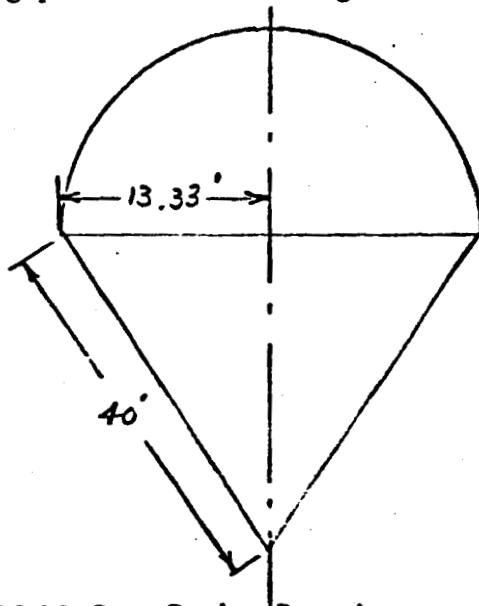
$$\text{Design Factor} = 1.86$$

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

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

$$\text{M.S.} = + 34\%$$

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

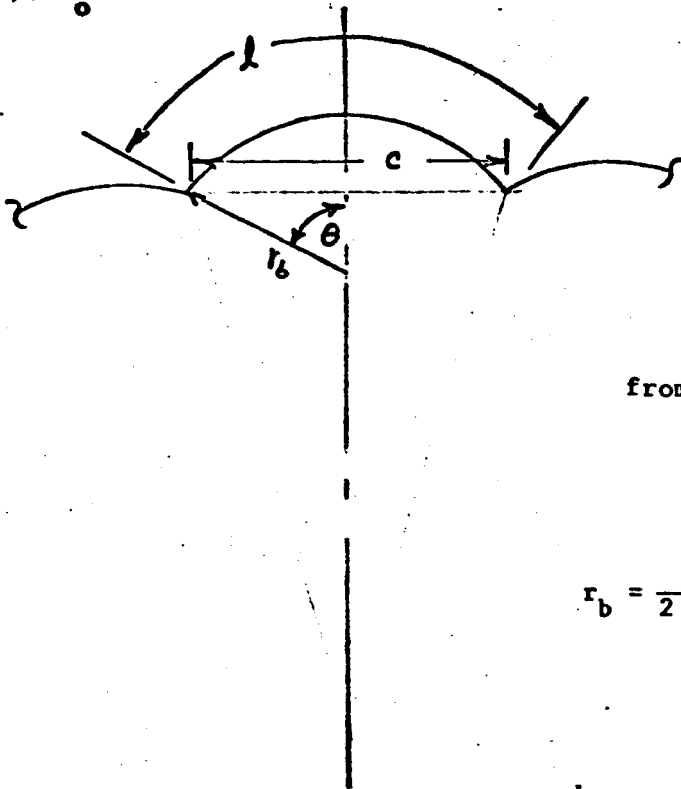


$$P_H = P_{S.L} \times \frac{13.33}{40.0}$$

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

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

Looking at the cross-section at the skirt, assuming the inflated diameter is $\frac{2}{3} D_o$.



$$l = 34.35''$$

$$c = 31.40''$$

from ratio of $l/c = 1.095$

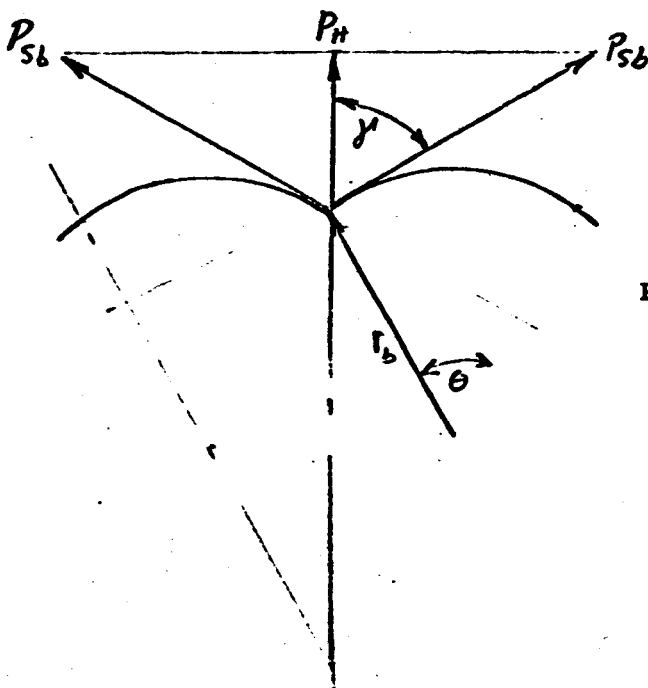
$$2\theta = 84^\circ$$

$$\theta = 42^\circ$$

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

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

by Geometry:



$$\theta = 42^\circ$$

$$\gamma = 53.625^\circ$$

then:

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

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

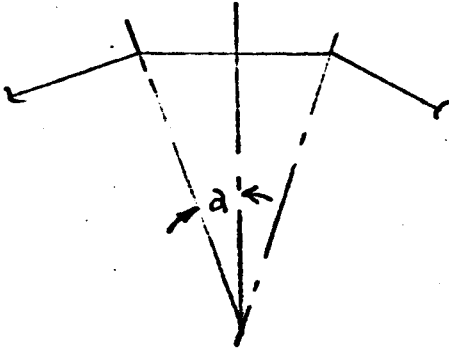
$$P_{dev} = P_{sb} = 65.14 \text{ lbs}$$

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

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

8.4 Vent Band

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



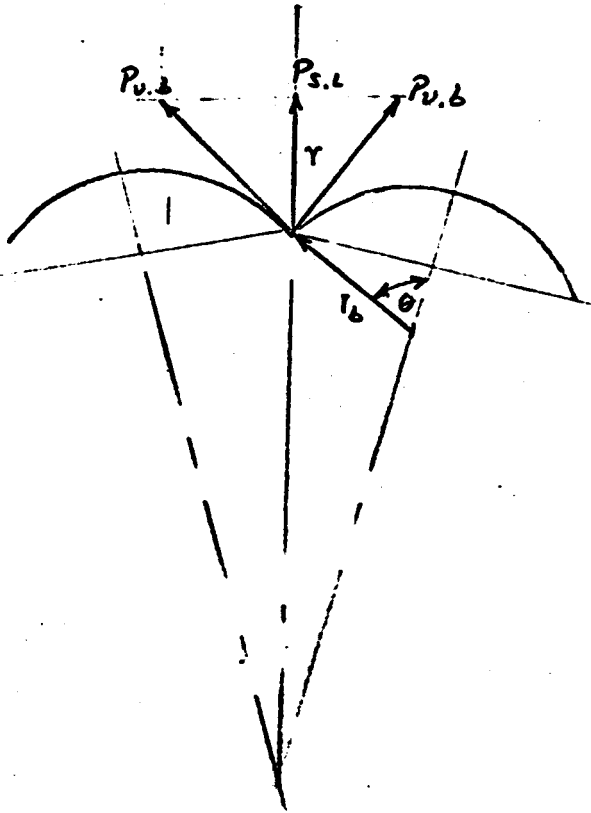
$$\alpha = \frac{360}{2z} = 5.625^\circ$$

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:



$$\gamma = 50.625^\circ$$

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

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

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

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.

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

assuming a thin shell with no bulge

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

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

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

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.

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

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

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

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

b. Band

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

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

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

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

$$\text{M.S.} = +419\%$$

8.6 Cross Seams

a. Disc

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

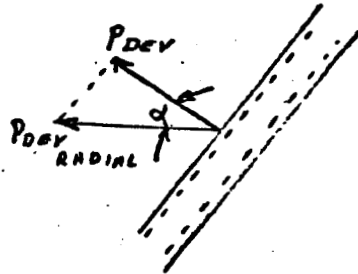
$$P_{\text{all}} = \frac{60\text{-lb/in}}{1.74} = 34 \text{ lb/in}$$

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

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

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

$$\text{M.S.} = 291\%$$



b. Band

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

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

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

$$\text{M.S.} = 634\%$$

8.7 Canopy Cloth

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

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

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

$$\text{Cloth tension} = 0.768 \text{ lbs/in}^2 \times 160 \text{ in} = 12.29 \text{ lb/in} = P_{\text{dev}}$$

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

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

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

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

$$\text{M.S.} = +177 \% \text{ neglecting gore bulge}$$

8.8 Vent Radial Tapes

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

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

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

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

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

$$\text{M.S.} = +25\%$$

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).

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

using a design factor of 2.0

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

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

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

$$\text{M.S.} = +63\%$$

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 $f_o/4$.

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

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,

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

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

$$\text{M.S.} = + 25\%$$

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).

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

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

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

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

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

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

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:

$$P_{dev} = 7370$$

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

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

$$M.S. = + 80\%$$

8.12 Intermediate Riser

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

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

$$f_d = 1.56 \text{ (no heat loss, line convergence, or asymmetric loading)}$$

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

$$P_{dev} = 7370$$

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

$$M.S. = + 248\%.$$

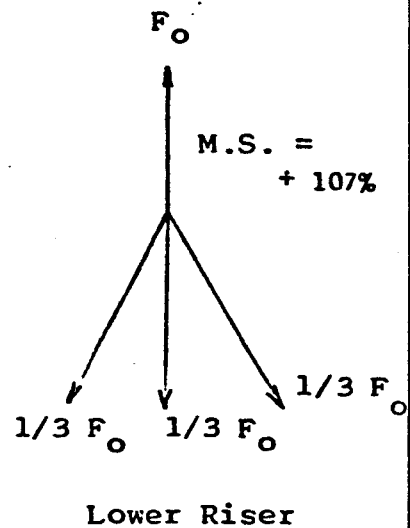
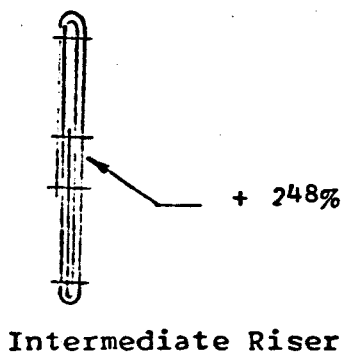
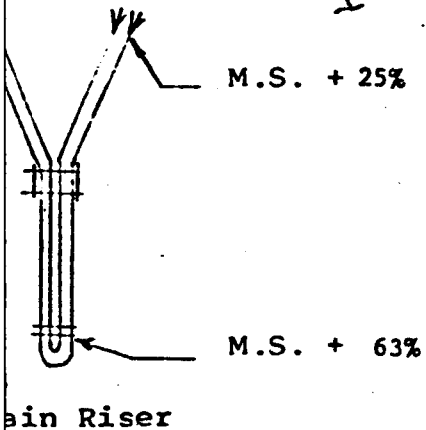
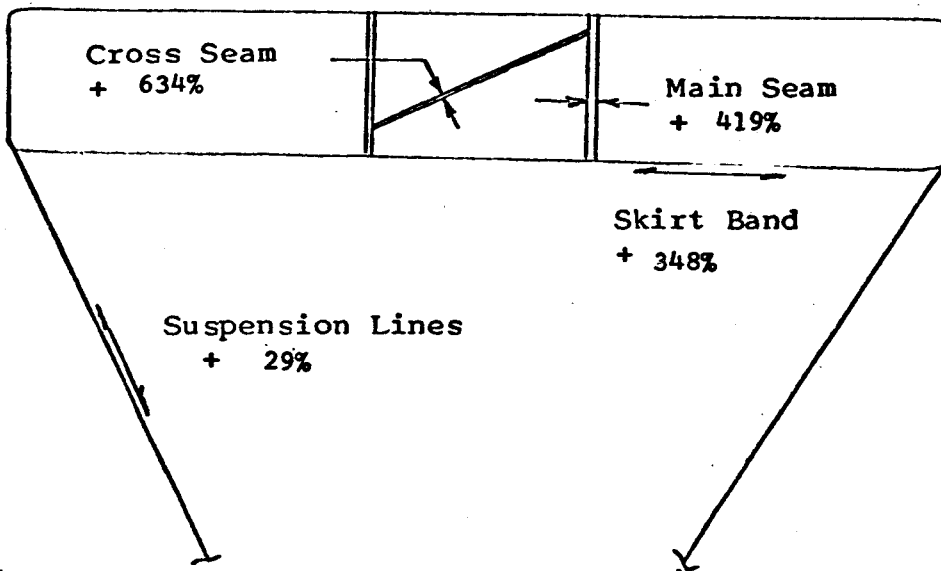
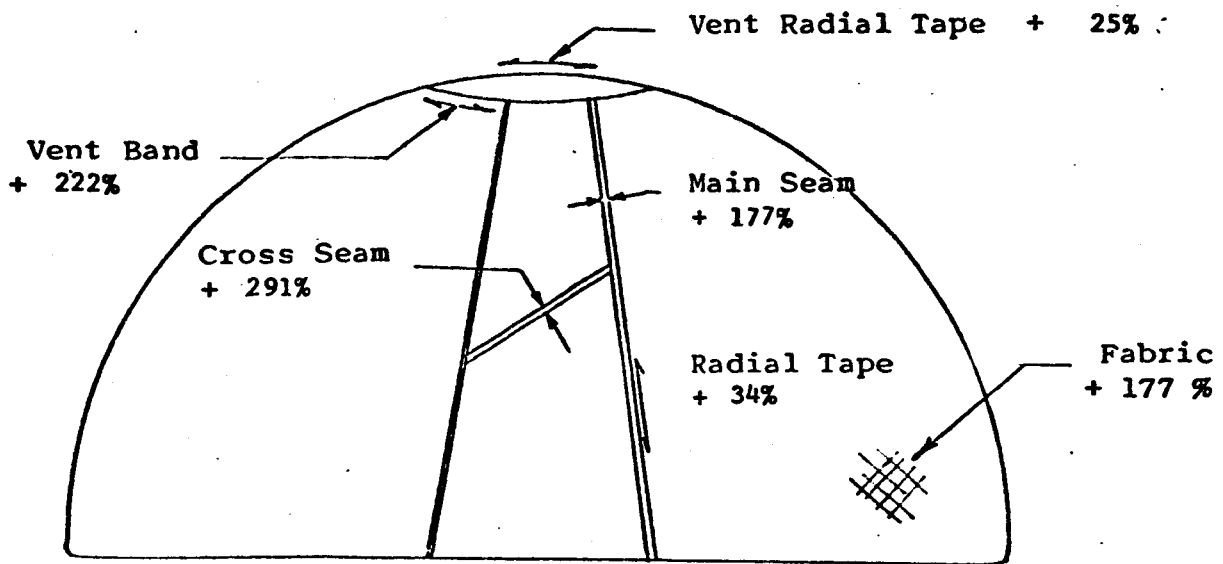
Table I
STRENGTH - LOSS AND SAFETY FACTORS

(a) Strength-loss factors

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

(b) Safety Factors

j	safety factors	1.50	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	NA
f	asymmetrical loading	1.05	1.05	1.05	1.05	1.10	1.00	1.10	NA	NA	NA
Design Factor J _{hf} /bn _l		1.75	1.97	1.86	2.05	2.00	1.56	1.96	1.74	1.74	1.74

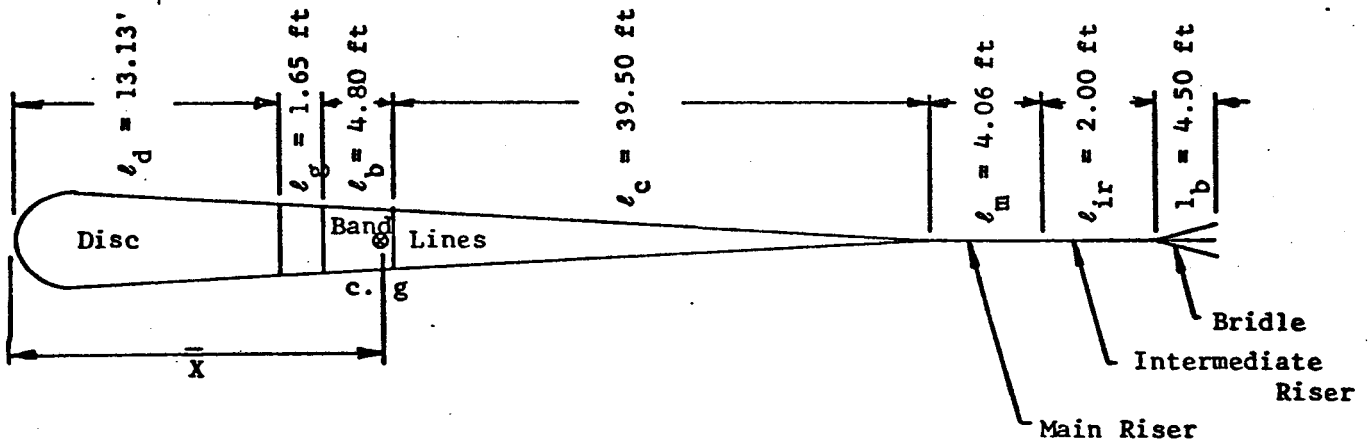


9.0 CENTER OF GRAVITY

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.

$$\begin{aligned}
 \sum M_{c.g.} = 0 = & \bar{x} W_T - \frac{l_d}{2} W_d - (l_d + l_g + \frac{l_b}{2}) W_b \\
 & - (l_d + l_g + l_b + \frac{l_e}{2}) W_l - (l_d + l_g + l_b + l_e + \frac{l_{mr}}{2}) W_{mr} \\
 & - (l_d + l_g + l_b + l_e + \frac{l_{ir}}{2} + l_{mr}) W_{ir} \\
 & - (l_d + l_g + l_b + l_e + l_{mr} + l_{ir} + \frac{l_b}{2}) W_b \\
 & - (l_d + l_g + l_b) (W_{rad})/2
 \end{aligned}$$

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

$$\begin{aligned}(575.9) \bar{X} &= \frac{13.13}{2} (187.7) + 17.18 (141.0) \\ &+ 39.33 (122.0) + 61.11 (26.0) \\ &+ 64.14 (24.0) + 67.39 (23.8) \\ &+ \frac{19.58}{2} (51.4)\end{aligned}$$

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

TABLE II
MEASURED WEIGHT BREAKDOWN

<u>Item</u>	<u>Wt. (ounces)</u>
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	<u>23.80</u>
Total Weight	575.9

10.0 MOMENTS OF INERTIA

10.1 ROLL MOMENTS OF INERTIA

10.1.1 Disc

$$I_g = \int x^2 dA \Delta W_d$$

$$dA = 2\pi x dy$$

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

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

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

Substituting; $y = 4 \sin \theta$

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

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

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

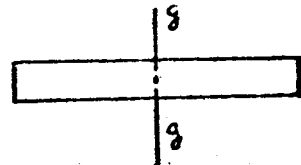
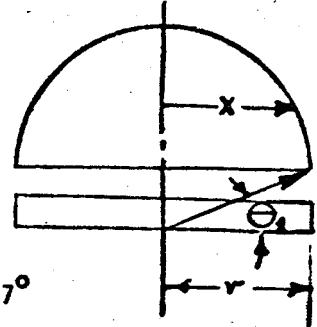
10.1.2 Band

$$I_g = MR^2$$

$$m = 8.81 \text{ lb}$$

$$r = 13.33 \text{ ft}$$

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



10.1.3 Radial Tapes

For thin rod bent into a circular arc

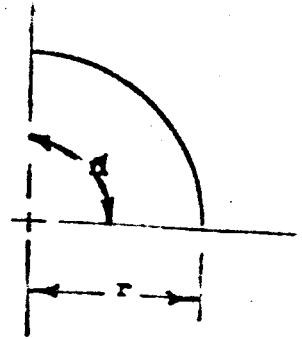
$$I_g = \frac{mr}{2} \left(1 + \frac{\sin \alpha \cos \alpha}{\alpha} \right)$$

$$C = 90^\circ$$

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

$$m = 3.21 \text{ lb}$$

$$r = 13.33 \text{ ft}$$



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

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

10.1.4 Suspension Lines

$$I_g = ml^2 \sin^2 \alpha / 3$$

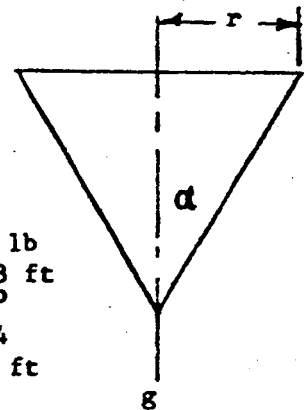
$$m = 7.63 \text{ lb}$$

$$r = 13.33 \text{ ft}$$

$$\alpha = 19.7^\circ$$

$$\sin^2 \alpha = 0.114$$

$$l = 39.5 \text{ ft}$$



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

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

10.1.5 Included Air Mass

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

$$I_g = \frac{2}{5} m r^2$$

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.

$$M_a = V \rho_o \sigma$$

$$\text{Where } V = \text{Canopy volume} = \frac{2}{3} \pi r^3$$

$$\rho_o = \text{Sea level density}$$

$$\sigma = \text{density ratio} = \rho/\rho_o$$

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

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

$$\text{At 130,000 ft altitude } I_g = 91.22 \text{ lb-ft}^2$$

$$\text{At sea level } I_g = 26,442 \text{ lb-ft}^2$$

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.

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

January 16, 1968

From flight photos, the inflated diameter is approximately $\frac{2}{3} D_0$

$$r = \frac{2}{3} D = \frac{D}{1.5}$$

$$r = 13.33'$$

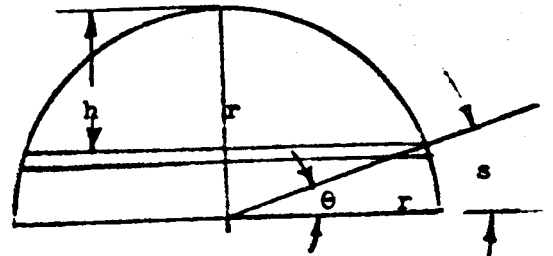
$$h = r(1 - \sin \theta)$$

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

$$\sin \theta = .465$$

$$h = 13.33 (1 - 0.465)$$

$$h = 7.15 \text{ ft}$$



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

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

$$b = 10.90 \text{ ft}$$

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

$$c = 13.33 + 18.59$$

$$c = 31.92 \text{ ft}$$

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

$$d = 52.53 \text{ ft}$$

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

$$h = 55.56$$

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

$$e = 57.81 \text{ ft}$$

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

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

$$f = 8.35 \text{ ft}$$

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, \bar{X} , $= \frac{\sum M_i X_i}{\sum M_i}$

Where M_i = Weight of i th component

X_i = 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.

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

Where M_i is given in ounces

X_i is given in feet

M_a = mass of included air

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

Evaluated at 130,000 ft altitude, $M_a = 20.5 \text{ oz}$

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

10.2.2 Moment of inertia-disc

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

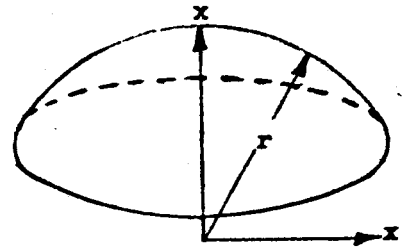
$$dm = 2\pi x dy$$

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

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

$$I_x = 2\pi \left[\frac{r^4}{8} \arcsin \frac{y}{r} - \frac{y}{8} (r^2 - 2y^2) \sqrt{r^2 - y^2} \right]_0^r \cdot \Delta W_d$$

$.465r$



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

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

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

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

10.2.3 Moment of Inertia-Band

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

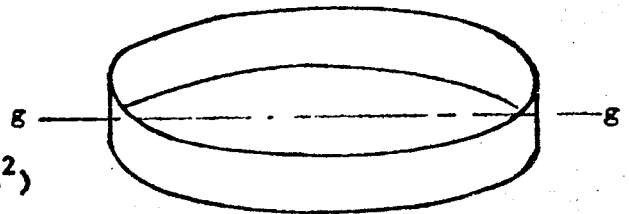
$$I_g = \frac{8.8}{12} (6 \times 13.33^2 + 4.8^2)$$

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

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

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

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



10.2.4 Moment of Inertia - Radial Tapes

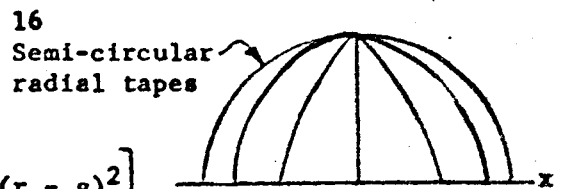
$$I_x = 16 (mr^2/2)$$

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

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

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

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



10.2.5 Moment of Inertia-Suspension Lines

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

$$\alpha = 70.4^\circ$$

$$\sin \alpha = .942$$

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

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

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

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

10.2.6 Moment of Inertia-Main Riser

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

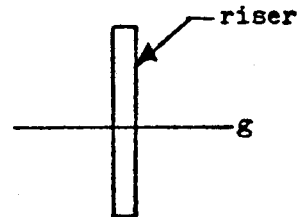
$$I_g = \frac{1.63}{12} (4.06)^2$$

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

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

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

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



10.2.7 Moment of Inertia - Intermediate Riser

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

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

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

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

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

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

10.2.8 Moment of Inertia - Bridle

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

$$= 82^\circ$$

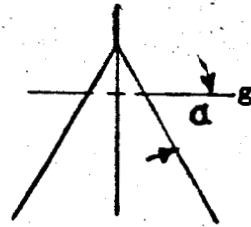
$$\sin = .990$$

$$I_g = 1.50/12 (4.50)^2 (0.990)^2$$

$$I_g = 2.48 \text{ lb-ft}^2$$

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

$$I_{\text{c.g. system}} = 2404.48 \text{ lb-ft}^2$$



10.2.9 Moment of Inertia - Included Air Mass

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

$$I_g = .26 mr^2$$

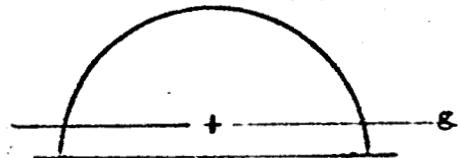
$$I_g = .26 \times 1.3 \times 177.69$$

$$I_g = 60 \text{ lb-ft}^2$$

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

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

$$I_{\text{c.g. system}} = 173.6 \text{ lb-ft}^2$$



10.2.10 Total Pitch and Yaw Moment of Inertia

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

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

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 $(C_D S)$.

$$(C_D S)_{\text{Reefed}} = \frac{W}{\rho/2 v^2}$$

where: $v = 40$ ft/sec

$\rho =$ density at 4000 ft

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

$$(C_D S)_o = 628.32 \text{ ft}^2$$

where: $(C_D S)_o =$ unreefed drag area

then:

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

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) 437-6382

Specialists in Mid-Air Recovery Systems

15 September 1967

WEIGHTS ON 40' D₀ DGB PARACHUTE SYSTEMS

	<u>S/N 671</u>		<u>S/N 672</u>	
	<u>lb</u>	<u>oz</u>	<u>lb</u>	<u>oz</u>
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 $0.62(C_D S)_0$ during the reefing process.

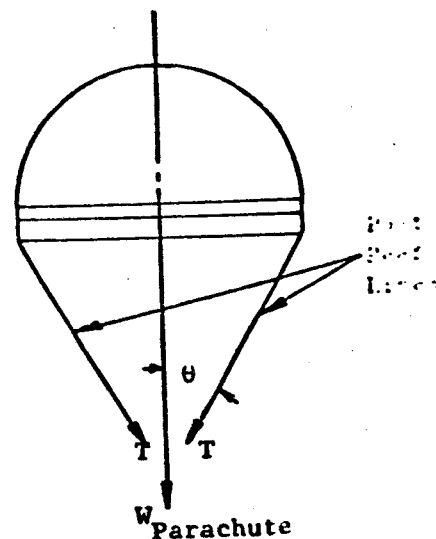
Then:
$$V^2 = \frac{2W}{\rho C_D S}$$

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

$$C_D S = 0.62 \times 0.52 \times 1256.64$$

$$C_D S = 413 \text{ ft}^2$$

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



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

TABLE I

<u>T (lb)</u>	<u>2T cos θ</u>	<u>W (lb)</u>	<u>V_{par} (ft/sec)</u>
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)

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

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

$$\frac{v^2}{2} = \left(\frac{W_{P.L.} - 2T \cos \theta}{M} \right) l_s + \frac{v_o^2}{2}$$

where

l_s = length of secondary riser = 16.5 ft

v_o = payload velocity at time of disconnect

$v_o = 81 \text{ ft/sec}, v_o^2 = 656$

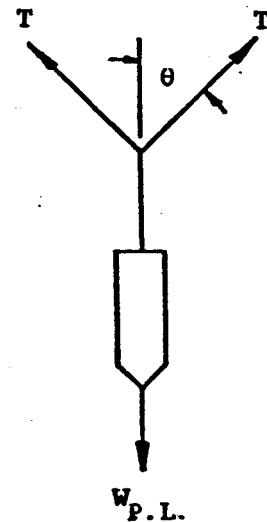


TABLE II
Payload Velocity vs T

(1) T (lb)	(2) $W_{P.L.} - 2T \cos \theta$	(3) $2 \left(\frac{WP - 2T \cos \theta}{M} \right) \text{ ft/s}$	(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	$P = \Delta V \sqrt{\frac{P_{max} W}{e_{max} g}}$
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 found. 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

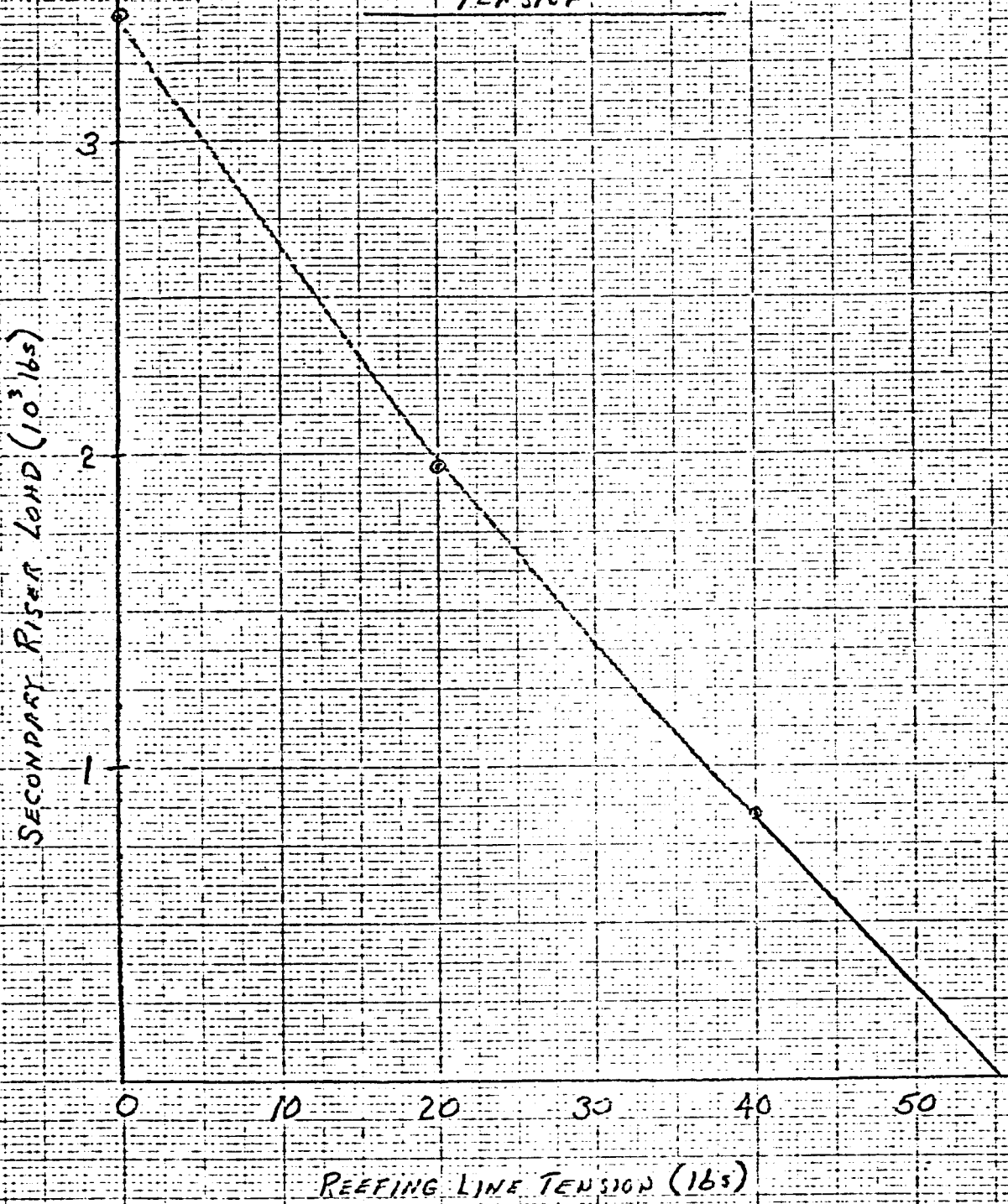


FIGURE 1.0

APPENDIX C

COMPONENT STRUCTURAL TEST REPORTS

TEST REPORT

<u>TEST ITEM</u>		<u>PROJECT</u>	
MAIN RISER WEB JOINT		15092	
<u>PURPOSE</u>	X ULTIMATE STRENGTH	X POINT OF FAILURE	
	X EFFICIENCY	OTHER	
<u>TEST METHOD</u>			
INSTRON TENSILE TESTER, 5 in/min JAW SEPARATION RATE, 18 INCH JAW SPEED			
<u>REQUESTED BY</u>	<u>DATE</u>	<u>APPROVED BY</u>	
R. LEMKE	6-14-67	R. LEMKE	
<u>TABLE</u>		<u>COMMENTS</u>	
<u>SAMPLE</u>	<u>TENSILE STRENGTH (lbs)</u>	ALL SAMPLES FAILED IN WEB STITCHING. RATED STRENGTH OF MIL-W-25361, TYPE III DACRON WEBBING IS 7000 lb.	
1	7000		
2	7050		
3	7200		
AVG.	7083		
<u>RESULTS</u>			
MINIMUM JOINT STRENGTH/RATED WEB STRENGTH x 100 = JOINT EFFICIENCY = 7000/7000 x 100 = 100%			
<u>CONCLUSIONS</u>			
JOINT ACCEPTABLE FOR USE, AND MEETS DESIGN REQUIREMENTS			
<u>TESTED BY:</u> <i>E. Schuyler</i>		<u>DATE TESTED:</u> 6-14-67	

TEST REPORT

<u>TEST ITEM</u> INTERMEDIATE RISER	<u>PROJECT</u> 15092													
<table style="width:100%; border:none;"> <tr> <td style="width:33%;"><u>PURPOSE</u></td> <td style="width:33%;">X ULTIMATE STRENGTH</td> <td style="width:33%;">X POINT OF FAILURE</td> </tr> <tr> <td></td> <td>X EFFICIENCY</td> <td>OTHER</td> </tr> </table>		<u>PURPOSE</u>	X ULTIMATE STRENGTH	X POINT OF FAILURE		X EFFICIENCY	OTHER							
<u>PURPOSE</u>	X ULTIMATE STRENGTH	X POINT OF FAILURE												
	X EFFICIENCY	OTHER												
<u>TEST METHOD</u> TINIUS OLSON TENSILE TESTER, 14 INCH JAW SPREAD 4½ in/min JAW SPEED														
<u>REQUESTED BY</u> R. LEMKE	<u>DATE</u> 7-12-67	<u>APPROVED BY</u> R. LEMKE												
<table style="width:100%; border:none;"> <tr> <td style="width:30%;"><u>TABLE</u></td> <td style="width:30%;"><u>TENSILE STRENGTH (lbs)</u></td> <td style="width:40%;"><u>COMMENTS</u></td> </tr> <tr> <td><u>SAMPLE</u></td> <td></td> <td rowspan="4" style="vertical-align: top; padding: 5px;">SAMPLES FAILED AT LOOP END OF RISER, JOINTS SHOWED NO SIGN OF DAMAGE.</td> </tr> <tr> <td>1</td> <td>26,250</td> </tr> <tr> <td>2</td> <td>25,650</td> </tr> <tr> <td>AVG.</td> <td>25,950</td> </tr> </table>	<u>TABLE</u>	<u>TENSILE STRENGTH (lbs)</u>	<u>COMMENTS</u>	<u>SAMPLE</u>		SAMPLES FAILED AT LOOP END OF RISER, JOINTS SHOWED NO SIGN OF DAMAGE.	1	26,250	2	25,650	AVG.	25,950		
<u>TABLE</u>	<u>TENSILE STRENGTH (lbs)</u>	<u>COMMENTS</u>												
<u>SAMPLE</u>		SAMPLES FAILED AT LOOP END OF RISER, JOINTS SHOWED NO SIGN OF DAMAGE.												
1	26,250													
2	25,650													
AVG.	25,950													
<u>RESULTS</u> JOINT EFFICIENCY IS 100% SINCE NO FAILURES OCCURRED IN JOINT														
<u>CONCLUSIONS</u> RISER CONSTRUCTION ACCEPTABLE FOR INTENDED USE, AND MEETS DESIGN REQUIREMENTS.														
<u>TESTED BY:</u> <i>R. Lemke</i>	<u>DATE TESTED:</u> 7-12-67													

TEST REPORT

<u>TEST ITEM</u> BRIDLE LEG	<u>PROJECT</u> 15092															
<table style="width:100%; border:none;"> <tr> <td style="width:33%;"><u>PURPOSE</u></td> <td style="width:33%;">X ULTIMATE STRENGTH</td> <td style="width:33%;">X POINT OF FAILURE</td> </tr> <tr> <td></td> <td>X EFFICIENCY</td> <td>OTHER</td> </tr> </table>		<u>PURPOSE</u>	X ULTIMATE STRENGTH	X POINT OF FAILURE		X EFFICIENCY	OTHER									
<u>PURPOSE</u>	X ULTIMATE STRENGTH	X POINT OF FAILURE														
	X EFFICIENCY	OTHER														
<u>TEST METHOD</u> TINIUS OLSON TENSILE TESTER, JAW SEPARATION 18 INCHES, JAW SPEED 4½ in/min.																
<u>REQUESTED BY</u> R. LEMKE	<u>DATE</u> 7-12-67															
<u>APPROVED BY</u> R. LEMKE																
<table style="width:100%; border:none;"> <tr> <td style="width:30%;"><u>TABLE</u></td> <td style="width:20%;"></td> <td style="width:50%;"><u>COMMENTS</u></td> </tr> <tr> <td><u>SAMPLE</u></td> <td><u>TENSILE STRENGTH (lbs)</u></td> <td></td> </tr> <tr> <td>1</td> <td>9150</td> <td rowspan="5" style="vertical-align: top; padding: 5px;">ALL SAMPLES FAILED AT END OF JOINT STITCHING</td> </tr> <tr> <td>2</td> <td>9750</td> </tr> <tr> <td>3</td> <td>9550</td> </tr> <tr> <td>AVG.</td> <td>9483</td> </tr> </table>	<u>TABLE</u>		<u>COMMENTS</u>	<u>SAMPLE</u>	<u>TENSILE STRENGTH (lbs)</u>		1	9150	ALL SAMPLES FAILED AT END OF JOINT STITCHING	2	9750	3	9550	AVG.	9483	
<u>TABLE</u>		<u>COMMENTS</u>														
<u>SAMPLE</u>	<u>TENSILE STRENGTH (lbs)</u>															
1	9150	ALL SAMPLES FAILED AT END OF JOINT STITCHING														
2	9750															
3	9550															
AVG.	9483															
<u>RESULTS</u> JOINT EFFICIENCY = $\frac{9150}{10000} \times 100 = 91.5\%$																
<u>CONCLUSIONS</u> JOINT EFFICIENCY ACCEPTABLE AND MEETS DESIGN REQUIREMENT.																
<u>TESTED BY:</u> <i>R. Lemke</i>	<u>DATE TESTED:</u> 7/12/67															

TEST REPORT

<u>TEST ITEM</u>		<u>PROJECT</u>	
SUSPENSION LINE TO MAIN RISER		15092	
<u>PURPOSE</u>	X ULTIMATE STRENGTH	X POINT OF FAILURE	
	X EFFICIENCY	OTHER	
<u>TEST METHOD</u>			
INSTON TENSILE TESTER, 12 INCH JAW SPREAD, 12 in/min SEPARATION RATE			
<u>REQUESTED BY</u>	<u>DATE</u>	<u>APPROVED BY</u>	
R. LEMKE	6-6-67	R. LEMKE	

<u>TABLE</u>		<u>COMMENTS</u>
<u>SAMPLE</u>	<u>TENSILE STRENGTH (lbs)</u>	
1	4400	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.
2	4290	
3	4200	
AVG.	4296	

RESULTS

JOINT IS 100% EFFICIENT SINCE NO JOINT FAILURES OCCURRED.

CONCLUSIONS

JOINT ACCEPTABLE FOR INTENDED PURPOSE, AND MEETS DESIGN REQUIREMENT

TESTED BY: <i>[Signature]</i>	DATE TESTED: 7/11/67
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TEST REPORT

<u>TEST ITEM</u> Radial Tape To Vent Reinforcement Tape - Load Applied To Radial Tape		<u>PROJECT</u> 15092
<u>PURPOSE</u> <input checked="" type="checkbox"/> ULTIMATE STRENGTH <input checked="" type="checkbox"/> EFFICIENCY		<input checked="" type="checkbox"/> POINT OF FAILURE <input type="checkbox"/> OTHER
<u>TEST METHOD</u> Instron Tensile Tester, Jaw Spread, 5 inches, Jaw Speed 6 in/min.		
<u>REQUESTED BY</u> R. Lemke	<u>DATE</u> 6-5-67	<u>APPROVED BY</u> R. Lemke
<u>TABLE</u>		<u>COMMENTS</u>
Sample	Tensile	Avg Ultimate Strength of Dacron Tape is 611.6 based on control sample tests.
1	570	
2	620	
3	630	
4	660	
Avg	620 lb.	
<u>RESULTS</u> Min. joint strength/ min. tape strength $\times 100 = \frac{570}{575} \times 100 = 99\%$.		
<u>CONCLUSIONS</u> Joint Strength Is Acceptable For Intended Application and Meets Requirements.		
TESTED BY: <i>R. Lemke</i>	DATE TESTED: 6-5-67	

TEST REPORT

TEST ITEM 550 lb. Dacron Line — Pioneer Parachute Co. Specification E-0C67-2	PROJECT 15092
PURPOSE	<input checked="" type="checkbox"/> ULTIMATE STRENGTH <input type="checkbox"/> EFFICIENCY
POINT OF FAILURE <input type="checkbox"/> OTHER	
TEST METHOD Instron Tensile Tester, 10" Jaw Spread, 12-inch/min. Jaw Speed	
REQUESTED BY R. Lemke	DATE 6-6-67
APPROVED BY R. Lemke	

<u>TABLE</u>			<u>COMMENTS</u>
Sample No.	Tensile (lb.)	Elong %	
1	650	44	Samples Broke at Jaw
2	650	44	
3	660	44	
4	610	49	
5	630	60	
Avg.	640 lb	48 %	

RESULTS

Average Strength Well Over Rated Strength of 550 #

CONCLUSIONS

Line Acceptable For Intended Use. Exceeds Design Requirements.

TESTED BY: <i>R. Lemke</i>	DATE TESTED: <i>6-6-67</i>
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TEST REPORT

<u>TEST ITEM</u> Tape Splice - 550 lbs. Dacron Tape	<u>PROJECT</u> 15092
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<u>PURPOSE</u> X ULTIMATE STRENGTH X EFFICIENCY	X POINT OF FAILURE OTHER
---	-----------------------------

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

<u>REQUESTED BY</u> R. Lemke	<u>DATE</u> 6-5-67	<u>APPROVED BY</u> R. Lemke
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<u>TABLE</u>	<u>COMMENTS</u>														
<table border="1"> <thead> <tr> <th>Sample</th> <th>Tensile Strength</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>510</td> </tr> <tr> <td>2</td> <td>560</td> </tr> <tr> <td>3</td> <td>510</td> </tr> <tr> <td>4</td> <td>560</td> </tr> <tr> <td colspan="2"><hr/></td> </tr> <tr> <td>Avg</td> <td>535</td> </tr> </tbody> </table>	Sample	Tensile Strength	1	510	2	560	3	510	4	560	<hr/>		Avg	535	<p>Avg tensile Strength of Dacron tape, lot no. 2344 was 611.6 lb. joints failed at end of stitching.</p>
Sample	Tensile Strength														
1	510														
2	560														
3	510														
4	560														
<hr/>															
Avg	535														

RESULTS
 Joint Efficiency = Min. Joint Strength / Min. Tensile Strength of Tape X 100 =
 $\frac{510}{610} \times 100 = 84\%$

CONCLUSIONS

TESTED BY: <i>R. Lemke</i>	DATE TESTED: 6-5-67
----------------------------	---------------------

TEST REPORT

<u>TEST ITEM</u> Dacron Tape, 3/4 Wide, Balley Ribbon Lot No. 2344.		<u>PROJECT</u> 15092	
<u>PURPOSE</u>		X ULTIMATE STRENGTH EFFICIENCY	X POINT OF FAILURE OTHER
<u>TEST METHOD</u> Instron Tensile Tests, 4" Jaw Spread, 12 inch/min. Crosshead Speed			
<u>REQUESTED BY</u> R. Lemke		<u>DATE</u> 5-16-67	<u>APPROVED BY</u> R. Lemke
<u>TABLE</u>			<u>COMMENTS</u>
Sample Number	Tensile (lb)	Elong %	
1.	670	33	
2.	590	31	
3.	575	31	
Avg.	611.6	31.6%	
<u>RESULTS</u> All Samples Failed At Edge of Jaws			
<u>CONCLUSIONS</u> Material Suitable For Use In Fabrication Of 40-foot D. G. B.'s			
<u>TESTED BY:</u> <i>R. Lemke</i>		<u>DATE TESTED:</u> 5-16-67	

TEST REPORT

TEST ITEM 2.0 oz/yd ² Dacron fabric, 15586, lot no. 2344	PROJECT 15092
---	-------------------------

PURPOSE	X ULTIMATE STRENGTH	X POINT OF FAILURE	
	EFFICIENCY	OTHER	

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

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

<u>TABLE</u>				<u>COMMENTS</u>
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%	

RESULTS All Samples Failed at Edge of Jaws.

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

TESTED BY: <i>R. Lemke</i>	DATE TESTED: 5-16-67
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TEST REPORT

<u>TEST ITEM</u> Main Seam	<u>PROJECT</u> 15092
-------------------------------	-------------------------

<u>PURPOSE</u>	<input checked="" type="checkbox"/> ULTIMATE STRENGTH	<input type="checkbox"/> POINT OF FAILURE
	<input checked="" type="checkbox"/> EFFICIENCY	<input type="checkbox"/> OTHER

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

<u>REQUESTED BY</u> R. Lemke	<u>DATE</u> 5-15-67	<u>APPROVED BY</u> R. Lemke
---------------------------------	------------------------	--------------------------------

<u>TABLE</u>		<u>COMMENTS</u>
Sample No.	Tensile Strength (lbs/in.)	Avg. material strength is 109 lb/in.
1	104	
2	84	
3	115	
4	90	
Avg	98.25	

RESULTS

Min. seam strength/minimum material strength X 100 =
 $84 / 84 \times 100 = 100 \% \text{ joint efficiency}$

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.

<u>TESTED BY:</u> <i>R. Lemke</i>	<u>DATE TESTED:</u> 5-16-67
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APPENDIX D

PARACHUTE PACKING PROCEDURE



Schjoldahl 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: *Renald A. Lemke*
 Approved By: *Bernard K. Valinski*
 Approved By: *D. Schapper*
 Released By: *J. Schult*

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.



Schjoldahl Company

G.T. SCHJELDAHL COMPANY • NORTHFIELD, MINNESOTA 55057

SPECIFICATION

CLASSIFICATION

Page 2 of 4
 Specification NO. P-450
 Date Issued 5-22-67
 Revision A

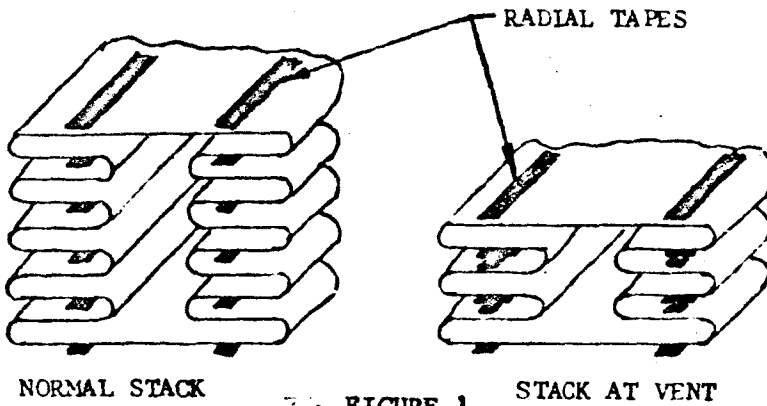


FIGURE 1

REV.	ECO	CHANGED

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)

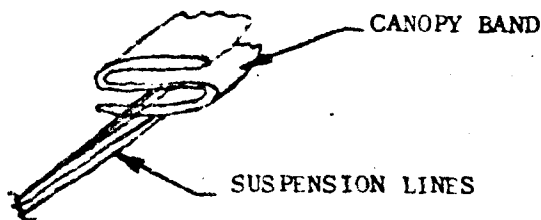


FIGURE 2



SPECIFICATION

CLASSIFICATION

Page 3 of 4

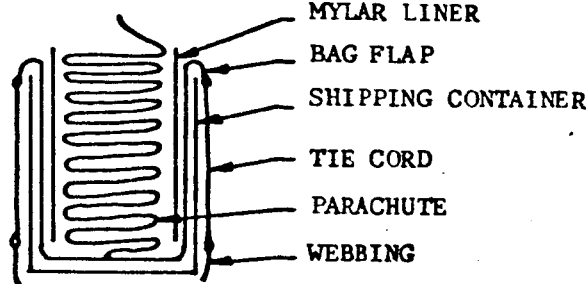
Specification NO. P-450

Date Issued 5-22-67

Revision A

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.
14. Fold the bag flaps over the top rim of the can and tie them at 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 accordion 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.

REV.	ECO	CHANGED



Schjeldahl Company

G. T. SCHJELDAHL COMPANY • NORTHFIELD, MINNESOTA 55057

SPECIFICATION

CLASSIFICATION

Page 4 of 4

Specification NO. P-450

Date Issued 5-22-67

Revision A

- | REV. | E C O | 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 "P" thread making sure the two post reefing lines are on the correct side of the main riser. | | |
| 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. | | |

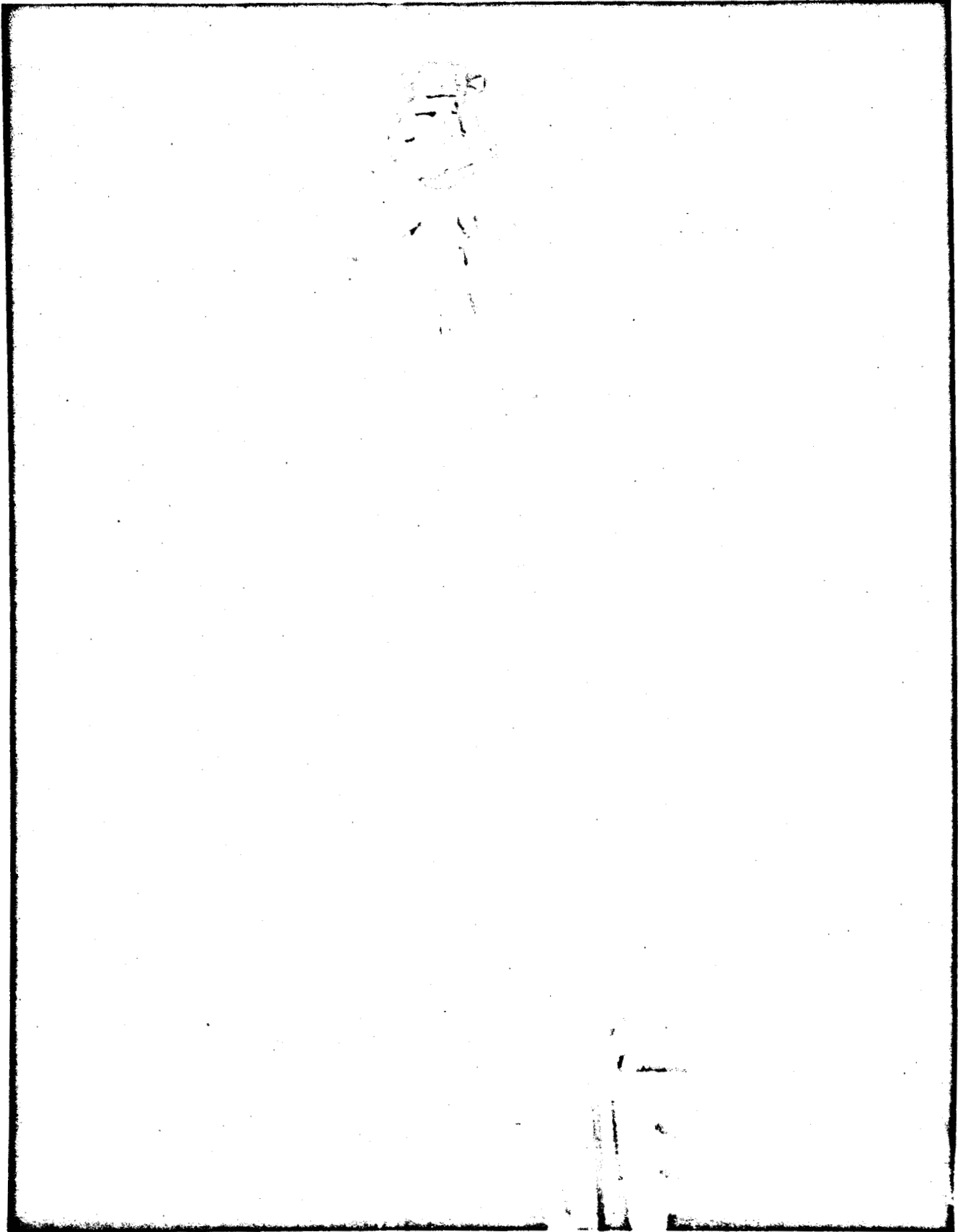


Figure 3 Parachute Folded Longitudinally

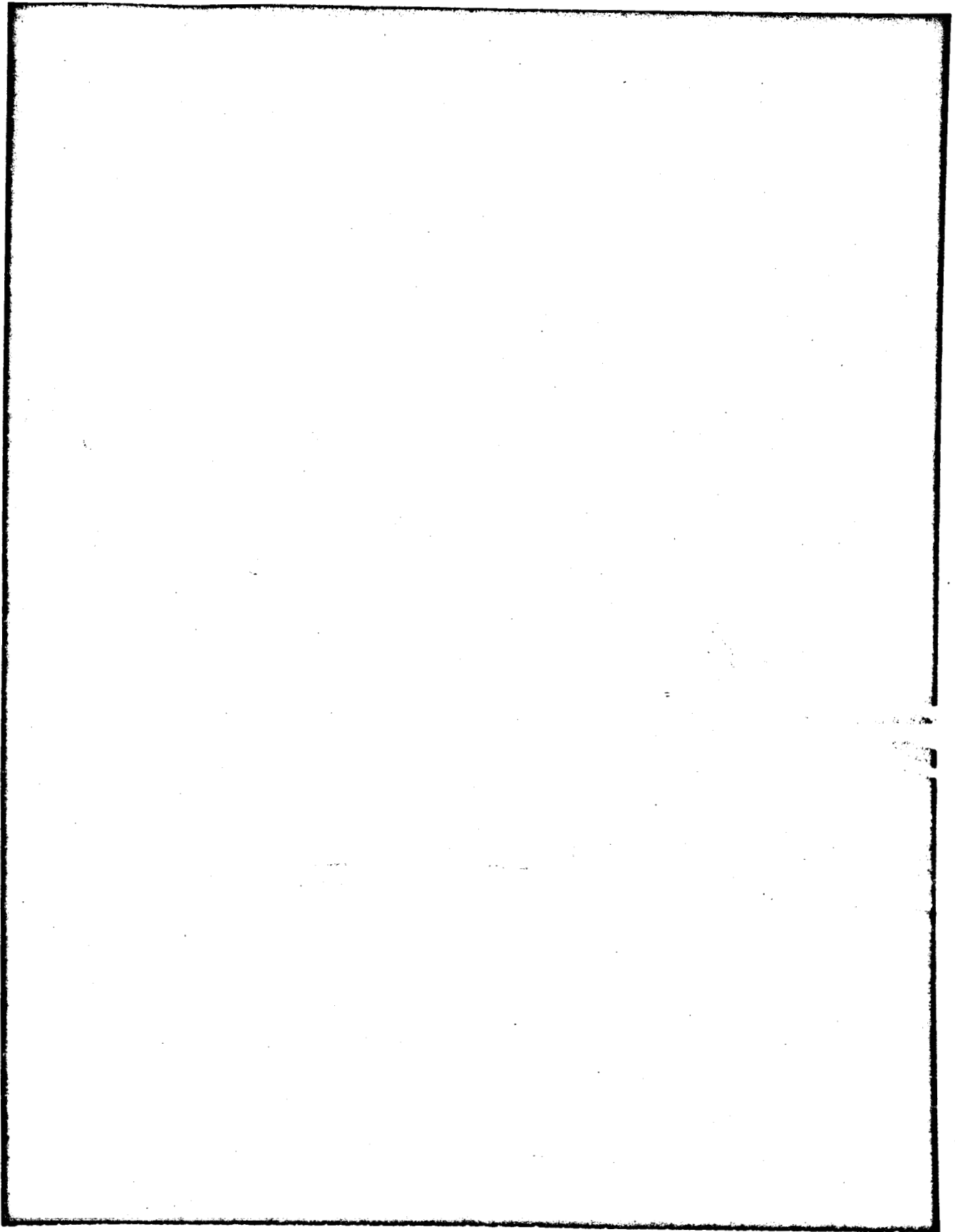


Figure 4 Folded Suspension Lines

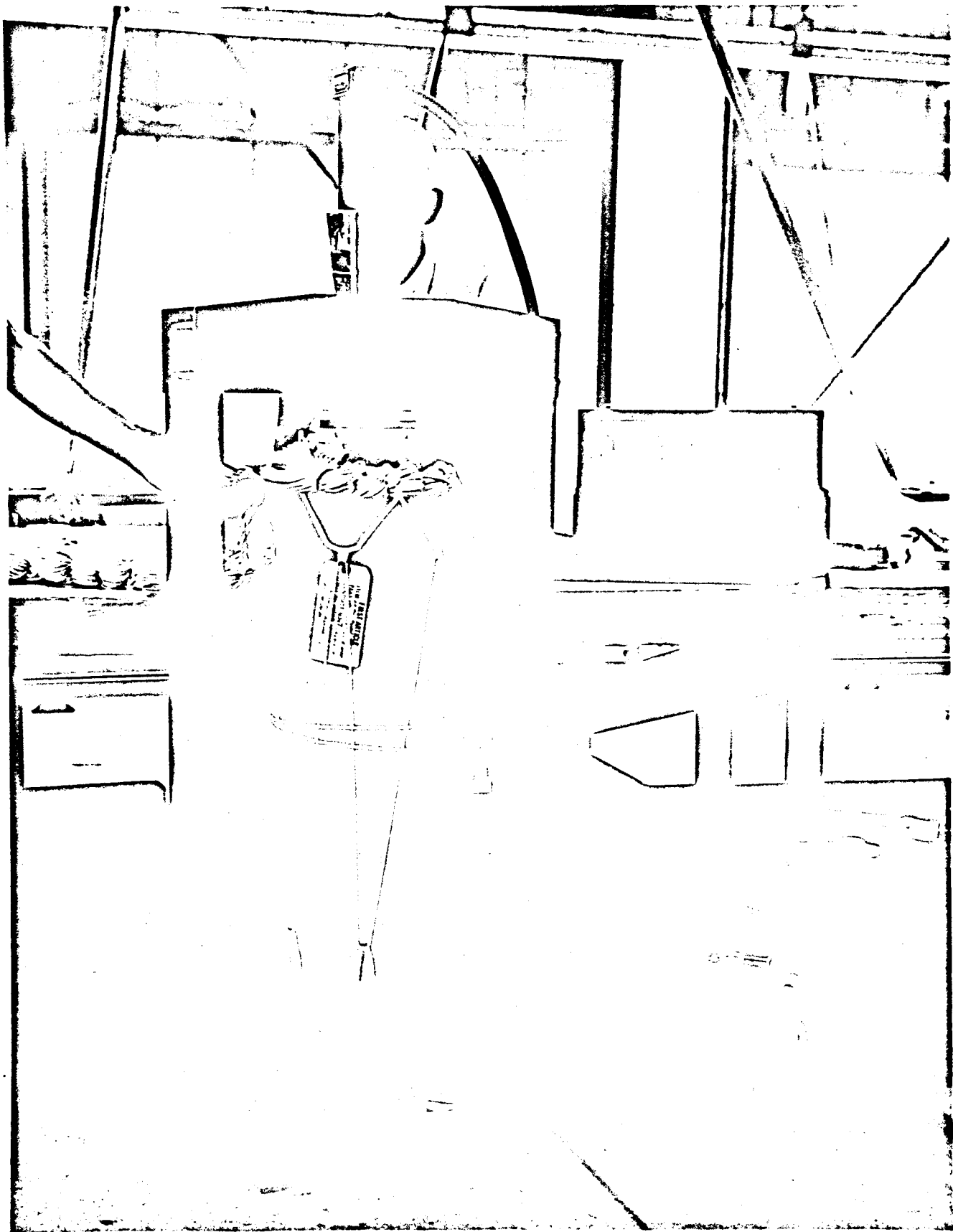


Figure 5 Typical Pressure Packing