California State University at Northridge

OPTIMIZATION OF PARACHUTES

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in Engineering

by

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January, 1973
The thesis of Donald Thomas Reynolds is approved:

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Committee Chairman

California State University at Northridge
January, 1973
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ABSTRACT

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An analytical method for the prediction of internal loads in a parachute has been modified to determine the optimum weight design of a parachute of known geometry under the influence of known riser and aerodynamic forces. The internal load prediction method, as described in Reference 2, treats the parachute as a deformable membrane, using finite elements with nonlinear elastic properties to represent the structure. This method has been modified to design an optimum weight structure by an iterative procedure which minimizes the strength of each finite element subject to the applied loads. The method searches the entire inflation process for the maximum loads on each member and makes the member just strong enough to carry that load. Efficiency factors for typical fabric joints are included in the analysis to determine required member strength. A table of available materials has also been included to
determine the weight of a "buildable" parachute. Non-optimum factors which indicate the weight increase from the optimum to the "buildable" designs are calculated. A discussion of the optimization of parachute geometry is also given and results of a study in which the number of gores was treated as a variable are presented.
INTRODUCTION

Until recently, the method of designing a parachute began by roughly sizing all of the structural members by previous design experience. The preliminary design had to satisfy the required inflation characteristics as well as the strength requirements. A stress analysis of the design was then performed for a few instants in the inflation process after gross assumptions as to inflated canopy shape were made. With the advent of recovery systems for space vehicles, limitations on weight and volume have forced improvements in the prediction of parachute stresses. The finite element method described in Reference 2 solves for the inflated canopy shape at any time in the deployment sequence. Since the inflated shape is dependent upon the stress distribution, the solutions of shape and stresses are obtained simultaneously.

The internal load prediction method of Reference 2 idealizes the parachute by a structural model made up of simple members capable of carrying uniaxial tension only and subjected to large non-linear deformations during deployment. Each of the structural members in the canopy (horizontals, radials, and verticals) deform in response to the applied aerodynamic pressure. This pressure is resolved into meridional and circumferential component loads on the structural members. Each member is then displaced according to its own characteristic load-strain
relationship. The method iterates on the canopy radius at the skirt and the magnitude of the applied pressure until the correct radius of the vent and vertical load equilibrium have been achieved. When these conditions have been satisfied, an equilibrium canopy shape has been attained and the correct internal loading found.

By modifying this method, it is possible to design the optimum parachute for an entire deployment sequence, providing the required inflation characteristics such as inflation speed and descent rate have been defined. These inflation characteristics define the required canopy type (ring-sail, conical ribbon, flat-circular, etc.) porosity, and geometry. The method given in this paper will not include the variables of canopy type or porosity in the optimization routine but will solve for the minimum weight design once these variables have been fixed. An investigation of the effect of a variable number of gores on the stress distribution and canopy weight has been included and suggestions for future work are given.
DESCRIPTION OF OPTIMIZATION METHOD

The optimization method consists of an iterative routine which has been added to the internal load prediction program of Reference 2. The routine uses the same structural model, shown in Figure 1, as the load prediction program and is limited by the same simplifying assumptions. Three additional assumptions have been made to simplify the optimization routine and reduce the computation time. They are:

1) All materials of a particular type can be expressed by a single load-strain relationship.

2) Fabric joint efficiency factors are defined by joint type and not affected by material strength.

3) The weight of a particular material type can be parametrically expressed as a function of its breaking strength.

The first of these assumptions allows a typical load-strain relationship to define the deformation characteristics of a structural member by previously knowing only its type; tape, web, cloth or cord. Thus, a change in member strength does not require the definition of a new load-strain relation. The second assumption allows a single joint efficiency factor to define the percent strength retention of a particular joint independent of the material strength. The third assumption allows for the estimation of parachute weight with the structural member type and
strength known. These assumptions introduce some inaccuracies into the analysis. However, the optimization program has been written to provide a method for the definition of a more efficient preliminary design than is presently available. A final check of the strength of the design must be made after the actual materials and joints have been selected. Actual member weights can then be calculated.

The load-strain relations selected for this study are shown in Figure 2. They are typical of the material types used on the recovery system for the Apollo Spacecraft. Extensive data are available as to the breaking strengths, load-strain relationships, and joint efficiencies of these materials. Typical joint strength efficiency factors have been summarized and are shown in Table I. The parametric relations between strength and weight for tapes, webs, cloths, and cords are shown in Figure 3. These curves were established from data on material characteristics given in Reference 1. With these assumptions and material characteristics defined, the optimization process can now be performed. The method described herein minimizes the weight of the parachute for all applied loading conditions by optimizing the strength of each structural member.

As a parachute is deployed, it is subjected to various dynamic pressures at various stages of inflation. In order to completely optimize the parachute, each member must be
FIG. 1 STRUCTURAL MODEL OF TYPICAL GORE

FIG. 2 LOAD-STRAIN RELATIONSHIPS FOR CORD, CLOTH, TAPE, AND WEB
## TABLE I

### Typical Fabric Joint Efficiency Factors

<table>
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<tr>
<th>Joint Type</th>
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<tr>
<td>Radial at skirt band</td>
<td>88%</td>
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<tr>
<td>Radial with attached doubler</td>
<td>91%</td>
</tr>
<tr>
<td>Radial without attached doubler</td>
<td>92%</td>
</tr>
<tr>
<td>Radial at vent band</td>
<td>67%</td>
</tr>
<tr>
<td>Skirt band overlap</td>
<td>95%</td>
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<tr>
<td>Horizontal overlap</td>
<td>63%</td>
</tr>
<tr>
<td>Vent band overlap</td>
<td>95%</td>
</tr>
</tbody>
</table>
Fig. 3 Weight-Strength Relationships for Web, Tape, Cord, and Cloth
sized for the critical combination of pressure and inflation configuration. Three instantaneous configurations in a typical deployment sequence are depicted in Figure 4. In configuration (a), the upper members are subjected to high pressures while the lower members have no applied differential pressure. In configuration (b), more of the members are inflated and the total riser force, \( W \), may be greatest for the entire inflation process. Finally, in configuration (c), all members are inflated but even though the drag area is greatest, the dynamic pressure may be sufficiently low so that the total riser force, \( W \), may not be maximum. Thus, the total inflation process must be searched to find the critical loading on each member. A revision to the internal load prediction program has been written to minimize the breaking strengths of fabric members in the parachute for all loads and inflation configurations in the inflation process.

The method first solves for the internal loads in an arbitrary parachute with riser load and inflation configuration specified. The arbitrary parachute need only have a geometry consistent with the required inflation characteristics discussed previously. Structural member strengths can be completely arbitrary. It is convenient to begin with a configuration at one end of the inflation process and proceed through the optimization routine to the other end of the inflation process. Either the least
FIG. 4 TYPICAL PARACHUTE INFLATION SEQUENCE
inflated configuration or the fully inflated configuration can be used as a starting point. The internal loads are then compared to the arbitrary breaking strengths of the members and the strengths are revised to match the applied loadings. The parachute is then reanalyzed for the new construction and the internal loads are again determined. After a new solution is found, the load on each member is again compared to its previously defined breaking strength. The strengths are then revised as required and another equilibrium shape is determined for the parachute. This process is continued until all members have breaking strengths within a range of zero to five percent more than the applied load. A five percent range was selected to reduce the computer time required for a solution. After the member strengths have been minimized for the first load-configuration condition, the parametric weight curves are used to calculate the current weight of the horizontals, radials, suspension lines, and total parachute. These weights are for a parachute which is built from an infinite variety of available materials. In fact, only a relatively few materials are available for each area of the parachute. To account for this, a table of available materials for the horizontals and radials has been included in the input data. After the weight of the optimized parachute has been calculated, the program selects the closest available material strength for each member without
selecting a material which is weaker than that required. A "buildable" weight is then computed for each of the members and the total parachute. Non-optimum factors based upon the ratio of "buildable" weight to optimum weight are then calculated for the horizontals, radials, suspension lines, and the total parachute. This completes the optimization routine for a single load-configuration condition but the remaining load configuration conditions must also be investigated to find the single optimum design for the entire inflation process.

The solution to the first load-configuration condition is used as the initial structural model for the second load-configuration condition to be analyzed. The internal loads on each member caused by the second condition are compared to the breaking strengths required for the previous conditions. If a member is found to be understrength, it is increased in strength to match the applied load. If a member is found to be overstrength, however, it is not revised since that strength is required for the previous condition. The parachute is then reanalyzed for the new construction. This process is continued until all members either have breaking strengths within a range of zero to five percent more than the applied load or have breaking strengths defined by the previous load-configuration condition. When these conditions have been met, the parametric weight curves are again used to compute member
weights. As for the first condition, the weight of a "buildable" design is also computed and non-optimum factors calculated. This routine is continued until all of the load-configuration conditions have been analyzed. The solution to the final condition will be the single optimum parachute for the entire inflation process. A solution algorithm for this routine is shown in Figure 5. The parachute analysis program including the optimization routine, is listed in the Appendix.
INITIAL GEOMETRY, CONSTRUCTION, AND APPLIED LOADS

INTERNAL LOADS ANALYSIS

SOLUTION FOR CURRENT LOAD-CONFIGURATION CONDITION

NOPT=0

READ NEXT LOAD-CONFIGURATION CONDITION

NOPT=1

COMPARE HORIZONTAL AND RADIAL LOADS AGAINST STRENGTH OF HORIZONTALS AND RADIALS MULTIPLIED BY EFFICIENCY FACTORS

LOAD<STRENGTH \( \text{LOAD}>1.05 \times \text{STRENGTH} \)

NOCONFIG = 1

STRENGTH<LOAD<1.05(\text{STRENGTH})

LOAD=STRENGTH

CALCULATE WEIGHT OF OPTIMUM CONSTRUCTION

SELECT AVAILABLE MATERIALS

CALCULATE WEIGHT OF "BUILDABLE" PARACHUTE

COMPUTE NON-OPTIMUM FACTORS

FIG. 5 SOLUTION ALGORITHM FOR PARACHUTE OPTIMIZATION ROUTINE
RESULTS

Analysis of the Apollo Spacecraft drogue parachute has been performed with the internal load prediction program as modified with the optimization routine. The method has been programed in Fortran H language and runs have been made on an IBM 370/165 Computer.

Extensive flight test and strength data have been recorded for this parachute in References 3 and 4. Construction of the actual parachute is shown in Figure 6. The canopy is a conical ribbon type with 20 gores. This construction has been used as the initial structural model for the optimization program. The model has constant strength horizontal members of 110 pounds per inch. The radials step from 1950 pound strength to 1300 pound strength material at a point two-thirds of the distance from the skirt to the vent. The vertical members cannot be included in the internal load prediction program but they have been accounted for by increasing the strength of the meridional members by the strength of the attached vertical members. Typical radial member joint efficiencies for this type of construction is approximately 91 percent with the exception of the skirt and vent areas where heavier members are attached. For this model, these efficiencies are 86 percent at the skirt and 67 percent at the vent. Typical horizontal member joint efficiencies used were 63 percent away from the skirt and vent and 95 percent at the skirt.
FIG. 6 CONSTRUCTION OF APOLLO DROGUE PARACHUTE
and vent. The input geometry and material characteristics are shown in Figure 7.

A listing of available materials that was used as input for the program is shown in Table II. The table includes a variety of materials which can either be used as horizontal or meridional members. Both the strength and type of material must be entered. The strength of horizontal members is entered in pounds per inch of meridional length and the strength of the meridional members is entered in pounds. Material type is indicated by a code number; 1.0 for cloth, 2.0 for tape, 3.0 for web, and 4.0 for cord. The code number associates the material with the appropriate strength-weight relationship shown in Figure 3. By selectively choosing the available materials, the table can be limited to a maximum of 20 potential materials for horizontals and 20 potential materials for radials. Normally, cords are not included as potential horizontal member materials and are infrequently used for radial members. A light-weight design will require the use of an extensive variety of cloth material for the horizontal members. Strength requirements of meridional members will generally require the use of a variety of tape and web materials.

The drogue parachute has been analyzed for both a reefed and a fully inflated condition. The reefed configuration was selected as the initial condition and the
### PARACHUTE GEOMETRY

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**FIG. 7** INPUT GEOMETRY AND MATERIAL CHARACTERISTICS FOR APOLLO DROGUE PARACHUTE
### TABLE II

**AVAILABLE MATERIALS FOR CONSTRUCTION OF A "BUILDABLE" PARACHUTE DESIGN**

<table>
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<tr>
<th>FOR HORIZONTALS (LB/IN)</th>
<th>FOR RADIALS (LB)</th>
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pressure distribution shown in Figure 8 for a reefed canopy was used as the applied loading. This distribution has been found to give the appropriate canopy shape for this condition (Reference 3). As can be seen, the canopy has no differential pressure acting below station 12 in the reefed condition. Above this station the canopy has uniform pressure applied. After seven complete iterations through the optimization routine, the parachute was optimized for the reefed condition.

The hoop loadings on the inflated horizontal members for the initial and optimized solutions are shown in Figure 9. The load distributions are similar with peak loadings of approximately 51 pounds per inch occurring at station 27 for both solutions. The load distributions and, therefore, the equilibrium shapes are similar even though the strength of the optimized canopy has been extensively modified. The variations of load ratio for the horizontals in the initial and optimized solutions are shown in Figure 10. The load ratio is the ratio of applied loading to breaking strength. As shown in Figure 10, the optimized solution resulted in a load ratio of approximately 0.6 everywhere except at the vent where the ratio was 0.91. Since the efficiency factor was 0.63 for the horizontals away from the vent and 0.95 for the horizontal at the vent, all horizontal members are essentially fully loaded. In other words, the minimum strength and weight member has
FIG. 8 DIFFERENTIAL PRESSURE COEFFICIENTS FOR REEFED AND FULLY INFLATED DROGUE CANOPIES

FIG. 9 INTERNAL LOAD DISTRIBUTIONS FOR INITIAL AND OPTIMIZED SOLUTIONS OF A REEFED DROGUE CANOPY
FIG. 10 VARIATION OF LOAD RATIO FOR INITIAL AND OPTIMIZED SOLUTIONS OF THE REEFED DROGUE PARACHUTE
been placed at each location on the canopy. The initial construction, which is also the actual construction, has a load ratio distribution everywhere below the strength capability of the horizontal members. This indicates an overweight design, especially in areas away from the peak load. However, safety factors have been applied to the actual parachute to obtain a conservative design.

The actual weight of the drogue parachute is 25.04 pounds. The weight of the parachute with only the reefed condition optimized is 24.49 pounds. This weight is very close to the actual weight since only the upper members in the canopy have been optimized while the lower, larger members have been maintained from the actual construction. Table III shows the required strengths at each station along the canopy resulting from the computation of a "buildable" design. It can be seen that below station 12, no optimization has been performed and the program has selected the closest available material above the input values of 110 pounds per inch. The weight of the "buildable" parachute with only the reefed condition analyzed is 27.62 pounds. This represents a non-optimum factor of 1.128 for the total parachute. The majority of this non-optimum factor is due to the horizontal members which weigh 12.56 pounds for the "buildable" design and have a non-optimum factor of 1.250 when compared to the optimized design. After the first load-configuration condition has
TABLE III
CONSTRUCTION OF A "BUILDABLE" CANOPY
WITH ONLY THE REEFED CONDITION OPTIMIZED

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<td>36</td>
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</tbody>
</table>

Total Weight of Horizontals = 12.56
Total Weight of Radials = 3.00
Total Weight of Suspension Lines = 12.06
Total Canopy Weight = 27.62

Non-optimum factor for horizontals = 1.259
For radials = 1.093
For suspension lines = 1.026
For the canopy = 1.128
been analyzed, the load-configuration data for the second condition is read by the program. The second condition for the drogue parachute is a fully inflated configuration with a pressure distribution defined by Figure 8. This pressure distribution has been found to produce an equilibrium canopy shape consistent with shapes observed during aerial tests.

The final canopy construction for the reefed condition is used as the initial trial construction for the fully inflated condition. As was done for the reefed condition, the strength of each of the loaded members is compared against the applied load. When a member is found to be too weak to carry the applied load, it is increased in strength to match the applied load. However, if a member is stronger than the applied load the program checks to determine if the member had been analyzed for a previous condition. If the member has been analyzed previously and a required strength determined, its strength will not be reduced for the current condition. If, however, the member has not been analyzed previously, as for members below station 12 of the reefed condition, they are reduced to match the applied load. The new construction is then re-analyzed to determine the equilibrium shape. This process is performed until no changes in strength are made to any of the structural members. Seven iterations through the optimization routine were required to solve the fully
inflated condition of the drogue parachute. The final solution has load ratios within 5 percent of the member efficiency factors as discussed for the reefed condition. This solution represents the overall optimum construction for the entire inflation process since the required construction for all load-configuration conditions have been considered. By considering additional load-configuration conditions, a more accurate solution may be obtained but the two conditions that have been analyzed have included all possible complexities in the analysis.

The weight of the optimized parachute is 20.05 pounds. A breakdown of this weight gives 7.36 pounds for horizontals, 2.63 pounds for radials, and 10.05 pounds for the suspension lines. Table IV shows the required strengths at each station for a "buildable" design. The horizontal members have minimum strength material (42 pounds per inch) at the skirt and vent and a maximum of 135 pounds per inch material from stations 22 to 27. The radials vary from 1000 pound material near the vent to 1800 pound material near the skirt. The 1200 pound material required at the vent is due to the relatively low efficiency factor for this area. The total parachute weight for the "buildable" design is 22.28 pounds. The weight of horizontals, radials, and suspension lines are: 8.60 pounds, 2.63 pounds, and 10.85 pounds, respectively. The non-optimum factor for the parachute is 1.112.
TABLE IV

CONSTRUCTION OF A "BUILDABLE" CANOPY FOR AN OPTIMIZED DROGUE PARACHUTE

These are the optimum strengths for a buildable chute:

<table>
<thead>
<tr>
<th>STATION</th>
<th>HORIZONTAL STRENGTH</th>
<th>RADIAL STRENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42.00</td>
<td>1800.00</td>
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<tr>
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Total weight of horizontals = 8.60
Total weight of radials = 2.83
Total weight of suspension lines = 10.85
Total canopy weight = 22.28

Non-optimum factor for horizontals = 1.112
For radials = 1.079
For suspension lines = 1.169
For the canopy = 1.075
The horizontal members are seen to have the greatest potential for weight reduction. If a greater variety of materials for horizontal members were available, the weight of the "buildable" design could be substantially reduced. However, there is only a slight benefit to be obtained by increasing the variety of radial member materials. The weight of the "buildable" parachute is 89 percent of the weight of the actual drogue parachute design. This high percentage is an indication that the actual parachute has been well designed for minimum weight. The total computer time required for solution of the optimized parachute was 1.30 minutes.

A study to determine the effect of varying the canopy geometry on the optimum weight of the parachute has been performed. The spacing and dimensions of horizontal members are largely dependent upon aerodynamic characteristics rather than structural requirements. The number of gores has, therefore, been selected as the variable geometric parameter.

The Apollo drogue parachute is again used as the structural model to be analyzed but the overinflation line at the skirt has been eliminated so that the canopy can freely inflate. The canopy structure is varied from 10 to 20 to 40 gores. Loading consistent with the fully inflated condition is applied to the canopy. Equilibrium canopy profiles at the midpoint of the gores for the optimized
canopies are shown in Figure 11. The 10 gore canopy results in a shape which is larger than the 20 or 40 gore designs. Internal load distributions for the three canopy constructions are shown in Figure 12. Higher loading near the skirt of the 10 gore design causes the larger diameter. The maximum loading, however, occurs for the 40 gore design near station 23. Although the peak loading for the 10 gore design is less than the maximum loadings for either the 20 or 40 gore designs, the total parachute is heavier. The optimized weights of the 10, 20, and 40 gore designs are; 20.39, 17.33, and 15.12 pounds respectively. The 10 gore design is heavier due to the relatively high loading near the skirt where the horizontal members are longest. It can be concluded from this study that a maximum number of gores be used to design the parachute. The number of gores will still be subject to the required aerodynamic characteristics and manufacturing considerations, however.
FIG. 11 DROGUE PARACHUTE PROFILES FOR 10, 20, AND 40 GORE CONSTRUCTIONS
FIG. 12  INTERNAL LOAD DISTRIBUTIONS FOR 10, 20, AND 40 GORE CONSTRUCTIONS
SUGGESTIONS FOR FUTURE WORK

Further extensions and revisions to the load prediction program and the optimization routine can be made to increase the accuracy and utility of the method. Four areas for improvement in the method are seen as: 1) Elimination of one or more of the simplifying assumptions currently invoked, 2) Inclusion of manufacturing considerations, 3) Inclusion of aerodynamic requirements, and 4) Optimization of geometry.

The elimination of the simplifying assumptions used in the optimization routine would appear to greatly increase the amount of input data required for the program while not significantly increasing the accuracy of the method. Work is underway, however, in eliminating a basic assumption in the internal load program. The program is being modified to include vertical members in the analysis and eliminate the assumption that all meridional load is carried by the radial members.

Inclusion of manufacturing considerations such as available cloth and tape sizes and parachute cost as a function of number of joints may increase the generality of the program. Inclusion of cost would add a realistic constraint but may require the input of a large amount of additional data.

Inclusion of aerodynamic requirements such as porosity, speed of inflation, descent rate, etc. would allow a
completely arbitrary construction to be used as an initial model. This increase in generality will not improve the accuracy of the solutions obtained by the current method, however.

The major benefit to be obtained by including manufacturing considerations and aerodynamic requirements in the program is that the parachute geometry can then be optimized in addition to the strength and weight of individual structural members. Inclusion of geometric optimization is seen as a significant improvement of the method and worth further investigation.
BIBLIOGRAPHY


APPENDIX

Listing of Parachute Analysis Program

PROGRAM CAND

1 REVOLMS, ORG: 2005, FXT 14/96. THIS PROGRAM DETERMINES THE SHAPE AND STRESS DISTRIBUTION IN A PARACHUTE FOR A GIVEN BLOD LOAD AND CANDY DIFFERENTIAL PRESSURE DISTRIBUTION, USING FINITE ELEMENTS TO REPRESENT THE STRUCTURE.

DEF, NVP 4422 AND AIAA PAPER 77-1105, USERS MANUAL NVP 4429.

DIMENSION NS(21), PST(21), FS(21), NSP(21), RPT(21), NCFG(21), DT(21), Q(21), DA(21), NCA(21), 2RPR(21), NSPG(1,100), RSP(1,100), SM(1,100), RP(100), PS(100), FS(1,100), RS(100), NCS(1,100), RL(100), RP(100), DE(100), DLPR(100), R(100), J(100), P(100), OL(7)

WRITE (6,1001) NS, PST, CF, CFSP, DS, NPST, RPS, RPT, NCFG, DT, Q, DA, NCA, 2RPR, NSPG, RSP, SM, RP, PS, FS, RS, NCS, RL, RP, DE, DLPR, R, J, P, OL

DIMENSION TITLE(61), ENSP(100), EFFR(100), EFFH(100), ENSR(100), KSt(100), ASPT(100), ASQ(100), ABSR(100), WP(100), AWP(100), WPS(100), WPST(100), WPST(100), WTSM(100), WTSM(100), XRST(100), XRST(100)

WRITE (6,100)

READ (6,120) T, E, R, S, N, NCF(10), T, T

WRITE (6,110)

RETURN 0

3 WRITE (6,115)

CONTINUE

3 WRITE (6,116)

CONTINUE

4 WRITE (6,114)

CONTINUE

5 WRITE (6,117)

CONTINUE

6 WRITE (6,119)

CONTINUE

7 WRITE (6,122)

CONTINUE

APPENDIX

Listing of Parachute Analysis Program

PROGRAM CAND

1 REVOLMS, ORG: 2005, FXT 14/96. THIS PROGRAM DETERMINES THE SHAPE AND STRESS DISTRIBUTION IN A PARACHUTE FOR A GIVEN BLOD LOAD AND CANDY DIFFERENTIAL PRESSURE DISTRIBUTION, USING FINITE ELEMENTS TO REPRESENT THE STRUCTURE.

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WRITE (6,1001) NS, PST, CF, CFSP, DS, NPST, RPS, RPT, NCFG, DT, Q, DA, NCA, 2RPR, NSPG, RSP, SM, RP, PS, FS, RS, NCS, RL, RP, DE, DLPR, R, J, P, OL

DIMENSION TITLE(61), ENSP(100), EFFR(100), EFFH(100), ENSR(100), KSt(100), ASPT(100), ASQ(100), ABSR(100), WP(100), AWP(100), WPS(100), WPST(100), WPST(100), WTSM(100), WTSM(100), XRST(100), XRST(100)

WRITE (6,100)

READ (6,120) T, E, R, S, N, NCF(10), T, T

WRITE (6,110)

RETURN 0

3 WRITE (6,115)

CONTINUE

3 WRITE (6,116)

CONTINUE

4 WRITE (6,114)

CONTINUE

5 WRITE (6,117)

CONTINUE

6 WRITE (6,119)

CONTINUE

7 WRITE (6,122)
Computing number of points in strain and pressure curves

1. DO 17 K=1,K1
2. DO 9 II=1,A
3. IF (PAS([II]+1,K)-PAS([II],K)) 10,10,9
4. CONTINUE
5. N(K)=II
6. DO 12 K=1,K2
7. IF (II=1,A) 12,12,11
8. CONTINUE
9. NN(K)=II
10. PRI=3.14159/M
11. CPIM=SI(N(PIM))
12. CPIM=COS(PIM)
13. SPIM2=SI(N(2.0*PIM))
14. GO TO 261
15. JVT=9
16. IF (NOPT(1)=1) 261,261,200
17. NPTIME=PARACHUTE
18. DO 206 Jr=1,NS
19. ARS(J)=ARS(1)*EFFH(I)
20. IF (ARSX(J)-PASX(I)) 206,206,203
21. ARS(J)=ARSX(I)*EFFH(I)
22. IF (ARSX(I)-ENPSP(1)) 203,203,204
23. ARS(J)=ENPSP(I)*EFFH(I)
24. IF (ARSX(I)-CPU) 204,204,205
25. ARS(J)=ENPSP(I)*EFFH(I)
26. GO TO 210
27. JYV=JYV+1
28. ARS(J)=PASX(I)*EFFH(I)
29. IF (ARSX(I)-CPU) 206,206,207
30. ARS(J)=PASX(I)*EFFH(I)
31. IF (ARSX(I)-CPU) 207,207,208
32. CONTINUE
33. IF (JYV(1)=1) 207,207,209
34. DO 297 Jr=1,NS
35. IF (ARS(J)-153) 297,297,275
36. JVT=1
37. GO TO 277
38. JVT=1
39. IF (ARS(J)-1000) 277,277,279
40. JVT=1
41. GO TO 277
42. JVT=1
43. GO TO 240,291,242,1,1,1
44. WTASR(1)=1.3256-06*ARS(1)*DLS(I)*SM(1)*M*DLS(I)
45. GO TO 283
46. WTASR(1)=9.22E-07*ARS(1)*M*SM(1)*DLS(I)
47. GO TO 283
48. WTASR(1)=1.75E-04+6.95E-07*ARS(1)*M*SM(1)*DLS(I)
49. CONTINUE
50. Nr=2,NS
51. IF (ARS(J-1)-1000) 274,284,285
52. JVT=1
53. GO TO 274
54. JVT=1
55. GO TO 274
56. JVT=1
57. GO TO 280
58. WTASR(1)=9.25E-07*ARS(1)*M*DLS(I)
59. GO TO 280
60. WTASR(1)=3.75E-04+6.95E-07*ARS(1)*M*DLS(I)
61. CONTINUE
62. WTSUM(1)=ARS(1)*7.5E-07*EL
63. WTSUM(I)=WTASR(1)
64. DO 220 Jr=1,NS
65. WTSUM(1)=WTPSO(I)+WTSUM(I-1)
66. WTSUM2(I)=WTASR(1)
67. DO 231 Jr=1,NS
68. 35
291 WTSUM1(I)=WTASR(I)+WTSUM2(I-1)
   WTSUM3=WTSUM1(NS)+WTSUM2(NS)+WTSL
   WTAS=WTSUM1(NS)
   WTORSP=WTSUM2(NS)
   WTSCAN=WTSUM3
   WRITE6.274WTSUM1(NS),WTSUM2(NS),WTSL,WTSUM3
   WRITE6.141
C CALCULATE & BUILDABLE PARACHUTE
   DO 248 I=1,NS
      J=1
   249 IF(ASR(I)-ASACT(J))252,252,253
   250 J=J+1
   GO TO 254
   252 XASR(I)=ASACT(J)
   C DETERMINE WEIGHT OF HORIZONTAL MEMBER
   IWT=AWTASR(J)
   GO TO (262,263,264,265),IWT
   262 WTSASR(I)=1.525E-06*XASR(I)*DLS(I)*SM(I)*DLS(II)
   GO TO 264
   264 WTSASR(I)=0.25E-07*XASR(I)*DLS(I)
   GO TO 266
   266 WTSASR(I)=7.5E-07*DLS(I)*XASR(I)*DLS(II)
   268 CONTINUE
   DO 271 I=1,NS
      J=1
   255 IF(ASR(I)-ASR(J))256,256,257
   256 J=J+1
   GO TO 258
   258 XASR(I)=ASACT(J)
   C DETERMINE WEIGHT OF RADIAL MEMBER
   IWT=AWTASR(J)
   GO TO (267,268,269,270),IWT
   267 WTSR(J)=0.0
   GO TO 271
   268 WTSR(J)=9.25E-07*XASR(J)*DLS(I)
   GO TO 271
   269 WTSR(J)=1.75E-04+6.95E-07*XASR(J)*DLS(I)
   GO TO 271
   270 WTSR(J)=7.4E-07*DLS(I)*XASR(I)*DLS(II)
   271 CONTINUE
C DETERMINE WEIGHT OF SUSPENSION LINES
   WTS=7.5E-07*XASR(I)*EL
   WRITE4.143
   DO 280 I=1,NS
   280 WRITE6,1421,XASR(I),XASR(I)
C DETERMINE TOTAL CANOPY WEIGHT
   WTSUM1(I)=WTASR(J)
   DO 272 I=2,NS
   277 WTSUM1(I)=WTSR(J)+WTSUM1(I-1)
   WTSUM2(I)=WTASR(J)
   DO 272 I=3,NS
   273 WTSUM2(I)=WTASR(I)+WTSUM2(I-1)
   WTSUM3=WTSUM1(NS)+WTSUM2(NS)+WTSL
   WRITE6,274WTSUM1(NS),WTSUM2(NS)+WTSL
C DETERMINE PNP-OPTIMUM FACTOR
   ANSAS=WTSUM1(NS)/WTSL
   ANSASR=WTSUM1(NS)/WTASR(J)
   ANSSL=WTSL/WTSL
   ANSCAN=WTSUM3/WTSCAN
   WRITE6,1441ANSSA,ANSSA,ANSSL,ANSCAN
   280 NEX=11
C NEW LOAD CONDITIONS START HERE
   261 RPAAN5-127NCOND,FA,NCF,NPC,TKP
   WRITE6,121
   WRITE6,1271NCOND,FA,NCF,NPC,TKP
   NCON=NCON+1
   MPK=TKP
   RP=TAQR(NCF)
219 KFND=0
LC=6
JR=NS
S=0.0
PF=0.02
NII=NII(NCF)
NIT=NIT+1
DN 14 I=NIT, NS
DS=DLS(I-I/12, 0*DLS(I) /2.0)
14 S=S+75
C2=0.0
IF (NII(NCF)=11 17, 17, 15
C CALCULATE DIMENSION C2
15 DN 16 I=2, NII
C1=(DLS(I-1)*DLS(I))/2.0
16 C2=C2+C1
17 EL=EL+C2
C ITERATIONS START HERE
ITRY=0
18 NY=0
NJ=0
19 ITRY=ITRY+1
IF (ITRY-100) 20, 21, 21
20 IF (KFND) 22, 22, 25
21 WRITE (6, 124) ITRY
GO TO 13
22 IF (LC=45) 24, 23, 23
23 WRITE (6, 130)
LC=0
24 WRITE (6, 125) ITRY, PDB, PKP
LC=LC+1
25 MLI=MLI(NCF)
SUMAI=0.0
SUMAS=0.0
SUMAS=0.0
GO TO (26, 30), MLI
26 RC=PRA
C START EQUILIBRIUM FOR OPEN CHUTE
27 FV=5*RT(ABS(EL1*EL1-RO*RO))
ANGA=ATAN(RO/FV)
ANGA0=ANGA*.57, 296
CANGA=COS(ANGA)
PL=FA/CANGA/M
PCRS=PL/RL
K=NCF
CALL DEM (N(K), PCRS, EPL, PBS(I, K), EPS(I, K))
EL2=(EL+M)*1.0/G+EPL
IF (ABS(FL2-FL1)/EL1 < 0.001) 29, 29, 28
28 EL1=EL2
GO TO 27
29 I=NII(NCF)
PH1(1)=1.5708*ANGA
PHM=PH1(1)*57.296
PH(1)=PL
P(11)=RO
GO TO 38
C SKIRT EQUILIBRIUM FOR REFFED CHUTE
C SUSPENSION LINE LENGTH CALCULATION
30 PL=FA/M
C2=0.0
PA=0.04*FA
31 PCRS=PL/RL
K=NCF
47
SAL = SPIM * SIN(PI(I))
CAL = SQRT(1.0 - SAL * SAL)
SISC = SIN(PS) * SAL / CAL
FNTH(I) = ENPS * CPIM * (COS(PS) * SISC)
FN2 = 2.0 * ENPS * (SIN(PS) / CAL) - SAL * (COS(PS) * SISC)
R1 = PR(I) / ENR2
R2 = R
N(I) = DLS(I)(1, O + EPR)
DLPH(I) = DLT(I) / R1
DLPH2(I) = 2.0 * ENPS * SPIM * COS(PI(I)) * (COS(PS) * SISC)
E = R1 * COS(PI(I)) * SIN(DLPH(I) / 2.0)
H = R1 * SIN(PI(I)) * (1.0 - COS(DLPH(I) / 2.0))
MLR(I) = E + F
N = R1 * SIN(PI(I)) * SIN(DLPH(I) / 2.0)
G = R1 * COS(PI(I)) * (1.0 - COS(DLPH(I) / 2.0))
0(I) = 0
G(I) = G
NL(I) = N - G
T(I) = 0.0
Z(I) = (1.0 - COS(PS)) * COS(PI(I)) * Z(I)
R2 = R2
ADLS(I) = 0.0
V = F
PH2 = NPH(I) * 57.296
PSO = PS * 57.296
R2 = R2 / SIN(PI(I))
C END OF CALCULATIONS AT FIRST STATION
IF (IAR - 1) 48
48
WRITE (6, 126) I, V, P(I), RC, PHO, E, FNPS, R1, ENPH, EPS, ASR(I), AS(I), P(I)
C START CALCULATIONS FOR SECOND SEGMENT
C PARTIAL TAPE GEOMETRY
49
I = N(I - NCF)
50
I = I + 1
C SLOTS DETECTOR
IF (SMT(I)) 74, 75, 76
C NOT SLOTS
51
PP = DP(I - 1)
C START P1 AND P2 LOOP
NCOUNT = 0
52
PCAS = PPP / ASR(I)
K = NCF(I)
CALL NEW (N(K), PCAS, EPR, PPS(1, K), EP(1, K))
N(I) = DLS(I)(1, 0 + EPR)
DLPH(I) = DLT(I) / R1
DLPH2(I) = 2.0
PH2 = NPH(I) / 2.0
PH2 = NPH(I) / 2.0
E = R1 * COS(PI(I)) * SIN(DP2)
H = R1 * SIN(PI(I)) * (1.0 - COS(DP2))
MLR(I) = E + F
R(I) = R(I - 1) - DLT(I - 1) - EH
H = R1 * SIN(PI(I)) * SIN(DP2)
N(I) = 0
G = R1 * COS(PI(I)) * (1.0 - COS(DP2))
G(I) = G
0(I) = 0 - G
Z(I) = -Z(I - 1) - DLT(I - 1) + D*G
ADLS(I) = ADLS(I - 1) + DLS(I - 1) / 2.0 + DLS(I) / 2.0
PS = ADLS(I) / S
K = NPS
CALL NEW (N(NK), PCS, PP, PAT(1, K), PPS(1, K))
P(I) = PP * PK
C START PSI OPERATIONS
PS = 0.0
NPS = 0.745
ENPS=0(I)*STP/STP(S)
ENPSD=ENPS*(1.+EP)
PCAS=ENPS/S(I)*EPS
K=NEP(S)
CALL NEW(N(I),PCAS,EPS,PS(I),I,EP(I),I)
X1=5*M(I)*EPS
Y2=PS/SINP(S)*1.*EPS
IF ((X1-X2) .LT .59) GO TO 65
IF (111-X111)/(I-I.0) .GE 59,55
PS=PS+LPS
GO TO 53
C END OF PSI LOOP
58 WRITE (6,127) I
LC=LC+1
GO TO 50
SAL=SINP(S)*SINP(PH(I))
CAL=50P(T(I),SAL)*SAL
SISC=SINP(S)*SAL/CAL
FNI=W,0*EPS*SINP(S)/CAL=SAL*COS(PH(I))
DEPH=I2.0*EPS*SINP(S)*SISC
DP(I)=DP(I)-DLPR2(I)-1D(I)-11/2.0=DLPR2(I)*DL(I)/2.0
PI=PI/1/FNR
IF ((ABS(PI-R(I))/R(I)-1.0001) .LE 62,62,60
RIP=RI
PRP=PR(I)
COUNT=COUNT+1
IF (COUNT .GE 201) 57,61,A1
54 WRITE (6,128) I
LC=LC+1
GO TO 50
C END OF RI LOOP
62 IF ((ARS(PI-I)-PRP)/PRI(I)-C.001) .LE 65,65,63
63 COUNT=COUNT+1
IF (COUNT .LE 201) 64,61,61
64 RIP=RI
GO TO 62
C END OF PR LOOP
66 IF (PS-A.01) 77,66,66
67 WRITE (6,129) I
LC=LC+1
GO TO 92
C MISCELLANEOUS CALCULATIONS
68 V=M0*P(I)*STP(S)
FHTH(I)=ENPSCOS(PH(I))
PS=SM(I)*EPS/2.0/PS
AR=4.0*EPS*EPS*EPS*EPS*EPS
A=R=A+4.0*EPS*EPS*EPS*EPS*EPS
A=A*A/A/2.0*A*</I>1.0157*P2
T(I)=T(I)+DL(I)*11111+G
R=R*PS*(1.0-COS(PH(I)))*COS(PH(I))
R=R+R*EPS/SIN(PH(I))
PS=PS*PS*PS*PS
FNP=PI(1-1)*P(I-1)*PI(1-1)+G(I-1)*G(I-1)+PI(1)*G(I)*G(I)*P(I)
SUMA=SUMA+P
A2=FHTH(I)*DL(I)/2.0+FHTH(I)*DL(I)/2.0
A1=FHTH(I)*DL(I)/2.0+FHTH(I)*DL(I)/2.0
SUMA=SUMA+A
SUMA=SUMA+A
ENDH=ENDH*PR(1)/(5.28318*R(I))
A1=A1=A1
IF (1111) 6R,6R,71
CONTINUE
IF (11-I-3) 77,69,69
41

60  WRITF (6,130)
   IF (KENDI 71,71,70
70  WRITE (6,135)
71  LC=3
72  CONTINUE
73   LC=LC+3
74  WRITE (6,111) I,V,P(1),PG,RH,E,FNPS,R1,ENDH,FPIS,AR1(1),BS1(1),P(1)
75  WRITE (6,111) I,V,P(1),PG,RH,E,FNPS,R1,ENDH,FPIS,AR1(1),BS1(1),P(1)
76   IF (JAN1=40,90,74
77   GO TO 79
78   IF (LC=42) 78,77,77
79  WRITF (6,130)
80  WRITF (6,135)
81  LC=3
82  CONTINUE
83   LC=LC+3
84  WRITF (6,132) 1
85  GO TO 80
86  IF (KENDI=42) 83,81,81
87  IF (KENDI=42,82,95
88  WRITE (6,113)
89  GO TO 95
90  IF (V-P(1)*A4/0-V) A4,85,85
91  PER=PER/2.0+0.5
92  GO TO 14
93  IF (V-P(1)*A4/0) A4,85,85
94  PKP=PKP/(1.0+0.5*PKK)
95  PER=PER/2.0+0.002
96  GO TO 14
97  IF (V-P(1)*A4/0) A4,85,85
98  PKP=PKP/(1.0+0.5*PKK)
99  PER=PER/2.0+0.002
100  GO TO 14
101  KP CHECK AT VENT
102  IF (ITRY=50) A3,91,81
103  IF (KENDI=42,82,95
104  WRITE (6,113)
105  GO TO 95
106  IF (V-P(1)*A4/0-V) A4,85,85
107  PER=PER/2.0+0.5
108  GO TO 14
109  IF (V-P(1)*A4/0) A4,85,85
110  PKP=PKP/(1.0+0.5*PKK)
111  PER=PER/2.0+0.002
112  GO TO 14
113  VENT PNTRIS CHECK
114  K=NCV
115  PKP=PKP/(1.0+0.5)
116  CALL FNEW (N1K),PCAS,FPV,PS1(+1),EP(1,+1)
117  RNTP=RNTP+1.0+0.5
118  WRITE (4,140) RNTP
119  IF (I=.EQ.1)
120  IF (IAN(1)=97) 95,95,95
121  IF (IAN(1)=97) 95,95,95
122  C TIGHT
123  N=1
124  IF (N=1) 96,91,90
125  SOL=xR
126  POL2=ROM
127  ROM=ROM*PER*F08
128  POL3=ROM
129  GO TO 14
01 \texttt{RL2=RLA}
\texttt{RLA=RAL1*(RLA-RLA1)/24}
\texttt{GO TO 19}

02 \texttt{CONTINUE}
\texttt{IF (VL-0.1) 93,94,93}
\texttt{RLA=RLA1}
\texttt{RLA1=RAL2*(RLA1-RLA11)/24}
\texttt{GO TO 19}

03 \texttt{KIND=KIND1}
\texttt{IF (KIND1) 94,95,94}

04 \texttt{JA=1}
\texttt{PA=SUMA/SUMA2}
\texttt{PVENT=PAAR/SUMA2/11}
\texttt{PSKIRT=SUMA2-PVENT}
\texttt{WRITE (6,114) NCIND,PA,NEG,NDC}
\texttt{LC=17}
\texttt{WRITE (6,115) GO TO 19}

05 \texttt{CONTINUE}
\texttt{GO TO (98,99), ML}

06 \texttt{WRITE (6,116) FLI,PL,FLI,ANGAD}
\texttt{WRITE (6,117) ZBAR,PVENT,PSKIRT}
\texttt{GO TO 192}

07 \texttt{IF (LC=12) 101,102,100}
\texttt{100 WRITE (6,118) FLI,PL,FLI,ANGAD,PC,RDA,RSA,PAI,ERL}
\texttt{102 WRITE (6,119) SUMA,SUMA1,SUMA2}
\texttt{GO TO 13}

08 \texttt{FORMAT (14),T40,LOADINPUT DATA}
\texttt{FORMAT (//X,19HPARAMETRIC SEGMENT//10X,70H--SUSPENSION LINES--,RX}
\texttt{1.14H--VENT LINES--9X,6HLENGTH STRENGTH CURF RADIUS STRENGTH}
\texttt{2 CURVE CODE SEGMENTS/) 105}
\texttt{FORMAT (AX,2F9.2,1A,2F9.2,31A//)}
\texttt{106 FORMAT (AQ,4,IP,2F9.2,21P)}
\texttt{107 FORMAT (AQ,FR3,F9.1,F9.1,FL1,II,IX,FR4,5X,FR4)}
\texttt{108 FORMAT (AX,9HGROUP DATA//7X,STATION,T11,STRENGTH,T11,SEGMENT,T19,RADIUS,T19,}
\texttt{RC8,1CHORD,T19,9HORI,T33,POORM,T3,T3,LENGTH,T19,STRENGTH,T19,NO.,T19,STRENGTH,T19,}
\texttt{NO.,T19,EFFICIENCY,T19,EFFICIENCY/) 109}
\texttt{FORMAT (19,9F9.4)}
\texttt{110 FORMAT (1H1),AXHN STAIN CURVES/) 111}
\texttt{112 FORMAT (1A,16A4)}
\texttt{113 FORMAT (AX,17,1A4)}
\texttt{114 FORMAT (AX,4HSTAIN,13,9F9.4/)}
\texttt{115 FORMAT (AX,4HSTRAIN,13,9F9.4/)}
\texttt{116 FORMAT (AX,9HLOADING CONDITIONS//7X,3HLOADING AXIAL LOAD CURVE KG)}
\texttt{117 FORMAT (AX,3HLOADING AXIAL LOAD NUMBER CURVE KP)}
\texttt{118 FORMAT (AX,3F9.4,18,E14.4)}
\texttt{119 FORMAT (2X,1HCONFIGURATION DATA//10X,9HCONFIG.LX.21HINITIAL REFERENCE TRIAL/10X,35HNUMBER STATION/}
\texttt{2CODE CP RADIUS STRENGTH CURVE PO OR B)}
\texttt{120 FORMAT (AX,3F9.4,2F9.4,2F9.4,2F9.4)}
\texttt{121 FORMAT (AX,1A,19A4)}
\texttt{122 FORMAT (AX,1A,19A4)}
\texttt{123 FORMAT (AX,1A,19A4)}
\texttt{124 FORMAT (AX,1A,19A4)}
\texttt{125 FORMAT (AX.1A,19A4)}
\texttt{126 FORMAT (AX,1A,19A4)}
127 FORMAT (1X,2HTHRITAL TERMINATED AT STATION (3,1X,10H TOO TIGHT)
128 FORMAT (1X,3HTHRITAL TERMINATED AT STATION (3)
129 FORMAT (1X,2HTHRITAL TERMINATED AT STATION (3,1X,10H TOO LOOSE)
130 FORMAT (1X)
131 FORMAT (2X,12,2X,F7.0,2F7.2,F10.3,2F7.2,F7.4,2F8.0/
   1F6,3,F7.0,2F7.2,F10.3,F8.2,F7.2,F7.4,F8.2,1F8,1,F8.3/)
132 FORMAT (1X,13,1X,'SLIT',//)
133 FORMAT (1X,4HEXCESSIVE ITERATIONS, PRINT RESULTS AND GO TO NEXT C
   ONDITION//)
134 FORMAT (1H1,T40,'CONDITION',15//1X,T14,4HLOAD,FB.0,2HLB,T31,13HC0N
   FIGURATION,X,1X,T4,1H PRESSURE CURVE NO.15/)
135 FORMAT (3X,T5,'[T],1V',17,'R',T2,'RG',T3,'RH',T43,'E',T49,'N
   10K',T50,'O',T6,'AA',NUMH,T72,'PS',T81,'AS',T65/'F5,'P',T11,'A'
   X,17+'J',1T5,11'C',17,1P5,1T61,11'H',1P5,1T6,1NTH1,773
   3,1FPR,T11,1UPP,F93,1PNSP,104,1ILP//)
136 FORMAT (1X,16HSUSPENSION LINES,3X,THLENGTH=F6.1,3X,5HLLOAD=F6.1/
   3X,7HSTRAIN=F5.3,3X,6HANGL=,F5.2//)
137 FORMAT (1X,5H7RAD=F7.2,2X,5HPVENT=F8.2,2X,7HPSKIRT=F8.2//)
138 FORMAT (1X,16HSUSPENSION LINES,3X,THLENGTH=F6.1,3X,5HLLOAD=F6.1/
   3X,7HSTRAIN=F5.3,3X,6HANGL=,F5.2//)
139 FORMAT (1X,3SUMMATION NTHETA X DELTA S =,F6.0/1X,3SUMMATION P XR X DELTA Z
   2 =,F16.2/)
140 FORMAT (1H4,1VENT LINE LENGTH=,12X,F6.3/)
141 FORMAT (1H4,1THE ABOVE SOLUTION IS A THEORETICALLY OPTIMUM CHUTE
   1F/)
142 FORMAT(1X,10STATION =,13,A22HORIZONTAL STRENGTH = ,FB.2/
   16X,1HORIZONTAL STRENGTH = ,FB.2)
143 FORMAT (1X,5H3THSE ARE THE OPT. STRENGTHS FOR A BUILDABLE CHUTE)
144 FORMAT (//=1X,3THEOR-OPTIMUM FACTOR FOR HORIZON
   TALS = ,FB.3,11X,3FOR RADIALS = ,FB.3,2X,23FOR SUSPENSION LINES = ,FB.3,6X,17
   24FOR THE CANOPY = ,FB.3)
145 FORMAT (10F9.2)
146 FORMAT(1H11,1X,2HTRALLE OF AVAILABLE MATERIALS,1//,1X,3HFOR HORIZONT
   1ALS (LB/N) FOR RADIALS (LB/)//,1X,4HSTRENGTH TYPE ST
   2NZENHT TYPE PF)
147 FORMAT(1X,F9.1,5X,F5.2,9X,F7.1,3X,F5.2)
148 FORMAT (1X,30HTOTAL WEIGHT OF HORIZONTALS=F5.2,1//,1X,20HTOTAL WE
   IGH OF RADIALS=F5.2,1//,1X,3HTOTAL WEIGHT OF SUSPENSION LINES=F5
   2,2,1//,1X,20HTOTAL CANOPY WEIGHT=F5.2)
END

<FUNCTION OF N,XR,YR,X,Y>
C
N=NUMBER OF POINTS, XR=INDEPENENT ENTRY, YR=DEPENDENT ANSWER
C
XI AND YI ARE INDEPENDENT AND DEPENDENT COORDINATES
DIMENSION XI(3,Y(1)
IF (YP-(Y(1)) 1,1,2
1 YR=Y(1)
GO TO 7
2 IF (XR-X(1)) 5,5,4
3 IF (YR-Y(1)) 1,3,6
5 YR=Y(1)-(Y(1)-Y(1))*(X(1)-XR)/(X(1)-X(1))
GO TO 7
4 YR=Y(1)
7 RETURN
END