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# WIND-TUNNEL INVESTIGATION OF INFLATION OF DISK-GAP-BAND AND MODIFIED RINGSAIL PARACHUTES AT DYNAMIC PRESSURES BETWEEN 0.24 AND 7.07 POUNDS PER SQUARE FOOT

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# WIND-TUNNEL INVESTIGATION OF INFLATION OF DISK-GAP-BAND AND MODIFIED RINGSAIL PARACHUTES AT DYNAMIC PRESSURES BETWEEN 0.24 AND 7.07 POUNDS PER SQUARE FOOT

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## SUMMARY

Exploratory wind-tunnel tests of the disk-gap-band and modified ringsail parachute configurations have been conducted at dynamic pressures between 0.24 and 7.07 lb/ft$^2$ (11 and 339 N/m$^2$). Both parachutes exhibited positive inflation characteristics over the range of the tests within technique limitations. The disk-gap-band configuration required less time and distance to inflate than the modified ringsail configuration did.

## INTRODUCTION

Parachutes are among the oldest deceleration devices known to man. Recently increased emphasis has been placed on the use of these devices because of possible application to future interplanetary missions. (See ref. 1.) Such applications may require parachute operations at low dynamic pressures. Use as recovery devices on high-altitude balloon experiments on earth is another application in which knowledge of low-dynamic-pressure inflation characteristics is required. Presently, there is a general lack of inflation data on geometrically porous parachute configurations at low dynamic pressures. The conditions at which inflation aids are required are unknown. In an effort to study this problem, exploratory tests have been conducted in the Langley full-scale tunnel. Disk-gap-band and modified ringsail parachute configurations, without inflation aids, were tested at dynamic pressures between 0.24 and 7.07 lb/ft$^2$ (11 and 339 N/m$^2$). The purpose of this paper is to describe the results of these tests. Specifically, the inflation times, distances, and diameter growth histories which were obtained from camera data are presented.

## SYMBOLS

$D$ diameter of canopy mouth, feet (meters)

$D_{max}$ maximum diameter of canopy mouth, feet (meters)

| | |
|---|---|
| $D_o$ | nominal diameter of parachute canopy, $\left(\frac{4}{\pi}S_o\right)^{1/2}$, 15 feet (4.6 meters) |
| $q_\infty$ | free-stream dynamic pressure, pounds per foot$^2$ (newtons per meter$^2$) |
| $S_o$ | nominal surface area of canopy including gaps and vent, 176.8 feet$^2$ (16.4 meters$^2$) |
| $t_f$ | filling time, seconds |
| V | free-stream velocity, feet per second (meters per second) |
| $\lambda_g$ | canopy geometric porosity based on $S_o$, percent |

## PARACHUTE DESCRIPTION

Both the disk-gap-band and modified ringsail parachutes had nominal diameters of 15 feet (4.6 meters) and nominal areas of 176.8 feet$^2$ (16.4 meters$^2$). Sketches of the two parachutes showing typical gore dimensions are shown in figures 1 and 2. The ringsail configuration for these tests was modified by the removal of one row of sails to provide a gap near the canopy mouth and to obtain the desired geometric porosity. As modified, the canopy contained two rings in the crown and two sails, a gap, and another sail in the skirt. (See fig. 1.) The modified ringsail configuration had a geometric porosity of approximately 15 percent, and the disk-gap-band configuration had a geometric porosity of approximately 12.5 percent. Both parachutes were constructed of 2.0 oz/yd$^2$ (68 g/m$^2$) dacron for the canopy cloth and 0.75-inch-wide (1.9 cm) tape (400-lb (1779-N) rating) for radials and panel reinforcements. The suspension lines were 550-lb (2450-N) rated-strength coreless braided dacron 15 feet (4.6 meters) in length. The masses of the disk-gap-band and modified ringsail parachutes (including canopy and suspension lines) were 5.52 lb (2.50 kg) and 5.78 lb (2.63 kg), respectively.

## TEST DESCRIPTION

The tests were conducted in the Langley full-scale tunnel. Arrangement of the apparatus within the tunnel is shown in the sketch in figure 3. The test parachute was tied to a pylon which was mounted in the test section of the tunnel. The parachute canopy was packed in a "strung-out" position inside a long cylindrical deployment bag which looked like a sleeve. A nylon line was tied to the pylon, the mouth and aft end of the deployment bag, and an eyebolt in the tunnel floor. Inserted in the line was an electrical heater disconnect and a length of rubber tension cord. The nylon line and tension cord were pulled to a tension of 40 pounds (178 N) prior to connection to the eyebolt. To deploy the parachute, current was applied to the heater which burned through the line between the pylon and the mouth of the bag. Tension in the system then stripped the bag rearward off the canopy and exposed the entire parachute to the airstream in a "strung-out" position. The velocity of the stripping action was high enough to ensure that little preinflation occurred during the stripping process. When free from the deployment bag, the canopy would begin to drop (from the force of gravity) until significant resultant force was produced to hold the system off the floor within the tunnel. At dynamic pressures above 1 lb/sq ft $\left(48\ \mathrm{N/m^2}\right)$, the inflation was rapid enough to permit little falling motion to be observed. For lower dynamic pressures, the filling times became so long that the canopy hit the floor before it had a chance to inflate. The falling of the canopy onto the floor was a limitation caused by the test technique and is believed not to have significantly affected test results when either no or minimum contact with the floor was observed. The velocities and dynamic pressures for each test run are given in table I. Tests were not conducted in the 14 ft/sec (4.2 m/sec) velocity range for the modified ringsail configuration because the canopy hit the floor prior to inflation under this low velocity condition.

## RESULTS AND DISCUSSION

Photographs showing typical inflation sequences of the disk-gap-band parachute at dynamic pressures of 2.97 and 0.24 $\mathrm{lb/ft^2}$ $\left(142 \text{ and } 11\ \mathrm{N/m^2}\right)$ are presented in figure 4. Time histories showing canopy mouth inflation for the modified ringsail and disk-gap-band configurations are given in figures 5 and 6, respectively. Data are shown for each dynamic pressure range at which tests were conducted. The instant when the deployment bag completes stripping from the crown of the canopy is counted as zero time. The interval (approximately 0.25 second) required for the stripping process is not included in the inflation histories shown. Correlation of the filling time parameter data $t_f/D_o$ with the mean empirical curve given in references 2 and 3 is shown in figure 7. Comparison of the filling distances, in terms of the number of nominal diameters traveled along the flight path, with empirical values is presented in figure 8.

Both the disk-gap-band and modified ringsail parachutes exhibited positive inflation characteristics whenever the filling times were short enough to ensure that the canopy did not hit the floor prior to partial inflation. Under similar velocity conditions, the disk-gap-band configuration required less time and distance to inflate than the modified ringsail configuration did. The shorter filling times and distances allowed disk-gap-band tests to be conducted at dynamic pressures as low as 0.24 $\mathrm{lb/ft^2}$ $\left(11\ \mathrm{N/m^2}\right)$, whereas modified ringsail data were limited to dynamic pressures greater than 0.51 $\mathrm{lb/ft^2}$ $\left(24\ \mathrm{N/m^2}\right)$.

Inflation was characterized by first, a partial inflation of the canopy mouth; next, a large collection of air mass in the canopy crown; and finally, positive inflation growing from the air mass in the crown. (See fig. 4.) After reaching the fully inflated condition, both parachutes exhibited continuous panel flutter around the canopy mouth and angle-of-attack oscillations about the pylon in the wind tunnel. These instabilities may be the result of the wind-tunnel test arrangement. Neither canopy instability nor large angle-of-attack oscillations have been observed during drop tests of similar parachutes.

Both the disk-gap-band and modified ringsail configurations required significantly less time and distance to inflate than would be predicted by the mean empirical curve given in references 2 and 3. Comparison with the empirical values is presented to provide a basis from which the inflation characteristics may be compared with other configurations. Precise agreement should not be expected because the empirical curve was derived from data of many types of parachutes. (See ref. 3.) Such factors as configuration type, porosity distribution, deployment altitude, trajectory gradients, and so forth certainly affect the inflation characteristics of parachutes. The empirical values do provide order-of-magnitude estimates of inflation times for use in preflight design studies and are a measure for comparison of actual test data. In the final analysis, however, test data should be used to derive more valid relationships for each type of parachute configuration.

## CONCLUDING REMARKS

Exploratory tests have been conducted in the Langley full-scale tunnel to determine the inflation characteristics of geometrically porous parachutes at low dynamic pressures. Disk-gap-band and modified ringsail configurations were tested without the use of inflation aids at dynamic pressures between 0.24 and 7.07 lb/ft$^2$ $\left(11 \text{ to } 339 \text{ N/m}^2\right)$. Both parachutes exhibited positive inflation characteristics whenever filling times were short enough to ensure that the canopy did not hit the tunnel floor prior to partial inflation. The disk-gap-band configuration required less time and distance to inflate than the modified ringsail configuration did. Both parachutes required significantly less inflation time and distance than is usually predicted by empirical methods.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., February 27, 1969,
124-07-03-05-23.

## REFERENCES


1. Murrow, Harold N., and McFall, John C., Jr.: Summary of Experimental Results Obtained From the NASA Planetary Entry Parachute Program. Paper presented at AIAA Second Aerodynamic Deceleration Systems Conference (El Centro, Calif.), Sept. 1968.

2. Anon.: Performance of and Design Criteria for Deployable Aerodynamic Decelerators. ASD-TR-61-579, U.S. Air Force, Dec. 1963.

3. Fredette, R. O.: Parachute Research Above Critical Aerodynamic Velocities. P-1031C (Contracts AF 33(616)-3346, AF 33(038)-10653, AF 33(616)-5507, and AF 33(616)-5991), Cook Res. Labs., Cook Elec. Co., c.1961.

TABLE I.- PARACHUTE TEST CONDITIONS

| Run | Velocity | | Dynamic pressure | |
|---|---|---|---|---|
| | ft/sec | m/sec | $lb/ft^2$ | $N/m^2$ |
| Modified ringsail configuration | | | | |
| 1 | 49.21 | 15.00 | 2.88 | 138 |
| 2 | 49.21 | 15.00 | 2.88 | 138 |
| 3 | 48.96 | 14.92 | 2.85 | 136 |
| 4 | 36.80 | 11.22 | 1.61 | 77 |
| 5 | 36.69 | 11.18 | 1.60 | 77 |
| 6 | 36.69 | 11.18 | 1.60 | 77 |
| 7 | 29.43 | 8.97 | 1.03 | 49 |
| 8 | 29.43 | 8.97 | 1.03 | 49 |
| 9 | 29.72 | 9.06 | 1.05 | 50 |
| 10 | 20.71 | 6.31 | .51 | 24 |
| 11 | 20.71 | 6.31 | .51 | 24 |
| 12 | 21.11 | 6.43 | .53 | 25 |
| 13 | 71.80 | 21.58 | 6.13 | 294 |
| Disk-gap-band configuration | | | | |
| 1 | 49.98 | 15.23 | 2.97 | 142 |
| 2 | 48.79 | 14.87 | 2.83 | 136 |
| 3 | 49.21 | 15.00 | 2.88 | 138 |
| 4 | 36.80 | 11.22 | 1.61 | 77 |
| 5 | 36.69 | 11.18 | 1.60 | 77 |
| 6 | 29.43 | 8.97 | 1.03 | 49 |
| 7 | 28.71 | 8.75 | .98 | 47 |
| 8 | 28.71 | 8.75 | .98 | 47 |
| 9 | 19.02 | 5.80 | .43 | 21 |
| 10 | 21.11 | 6.43 | .53 | 25 |
| 11 | 21.11 | 6.43 | .53 | 25 |
| 12 | 14.21 | 4.33 | .24 | 11 |
| 13 | 14.21 | 4.33 | .24 | 11 |
| 14 | 14.21 | 4.33 | .24 | 11 |
| 15 | 77.11 | 23.50 | 7.07 | 339 |

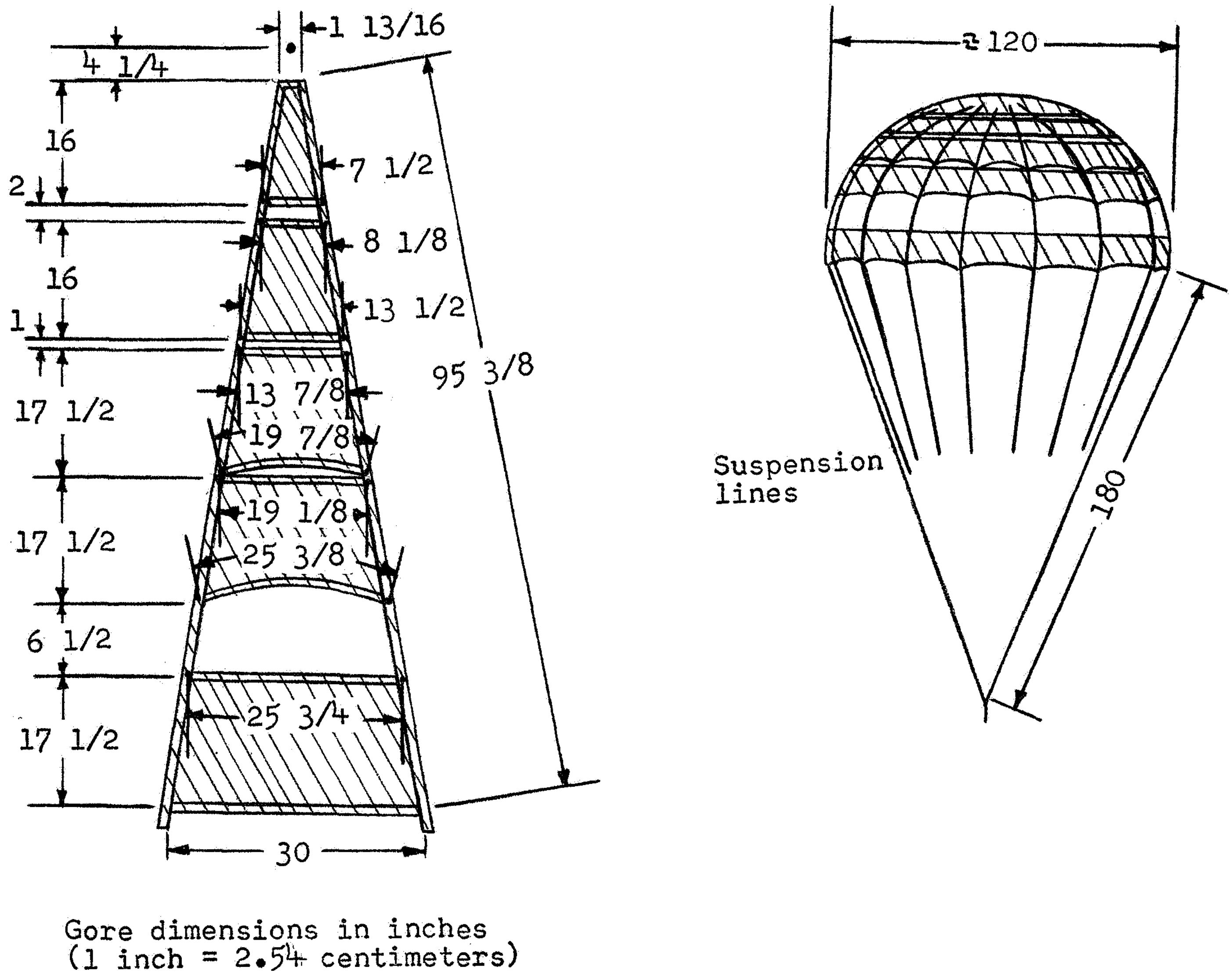



Figure 1.- Modified ringsail parachute configuration.

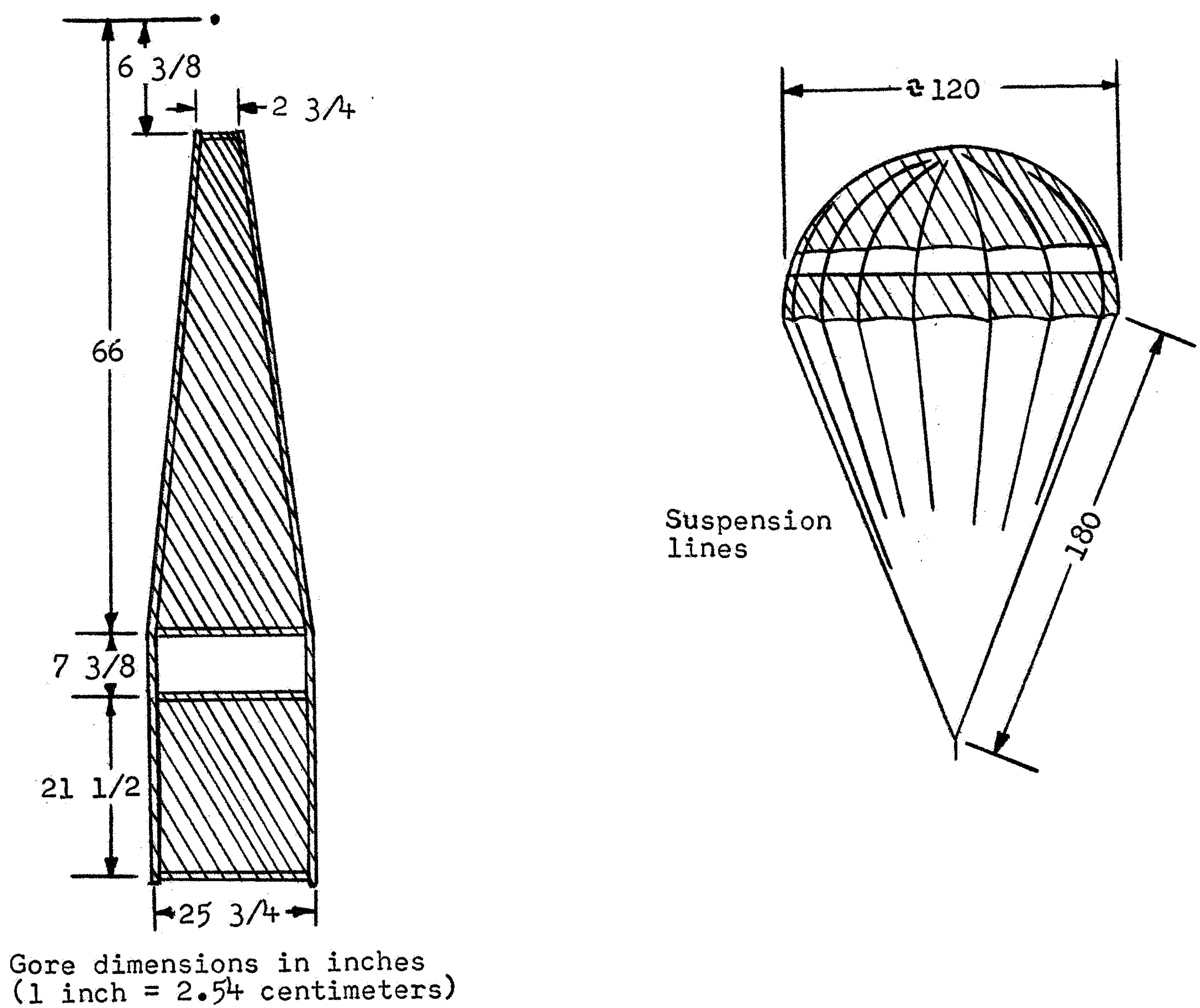
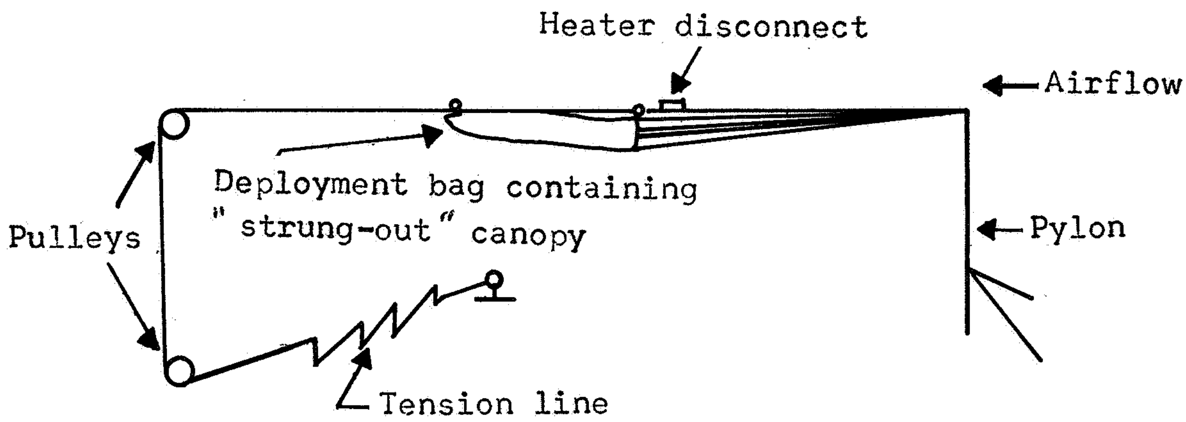
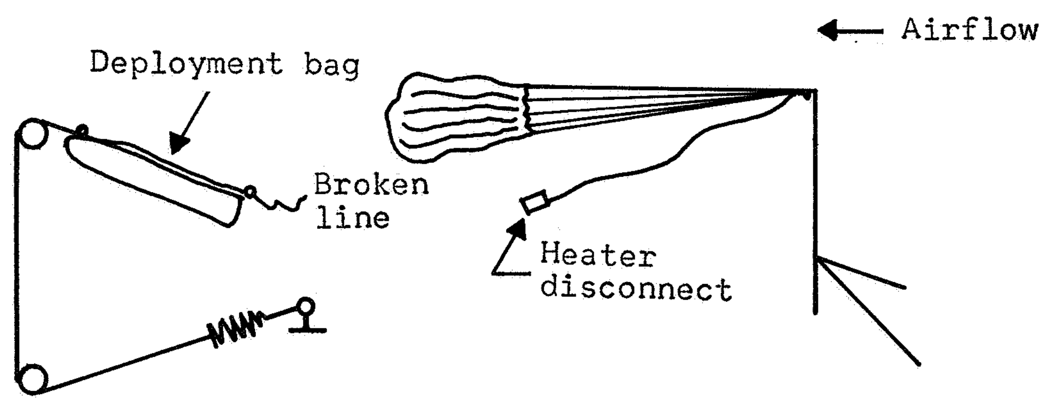



Figure 2.- Disk-gap-band parachute configuration.

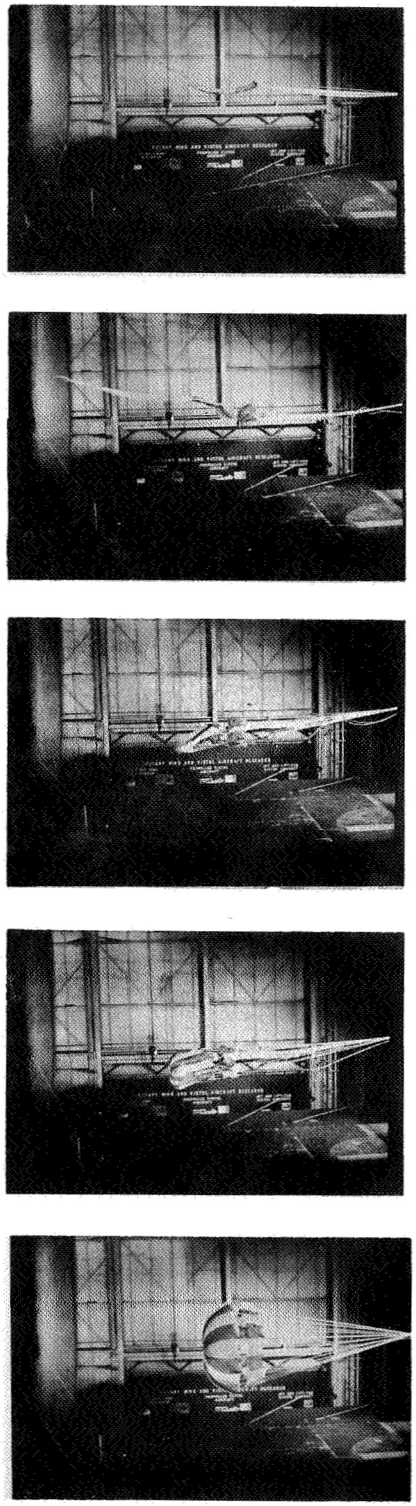



(a) Suspended position prior to deployment.




(b) Parachute inflation after deployment.

Figure 3.- Sketch of wind-tunnel test arrangement.



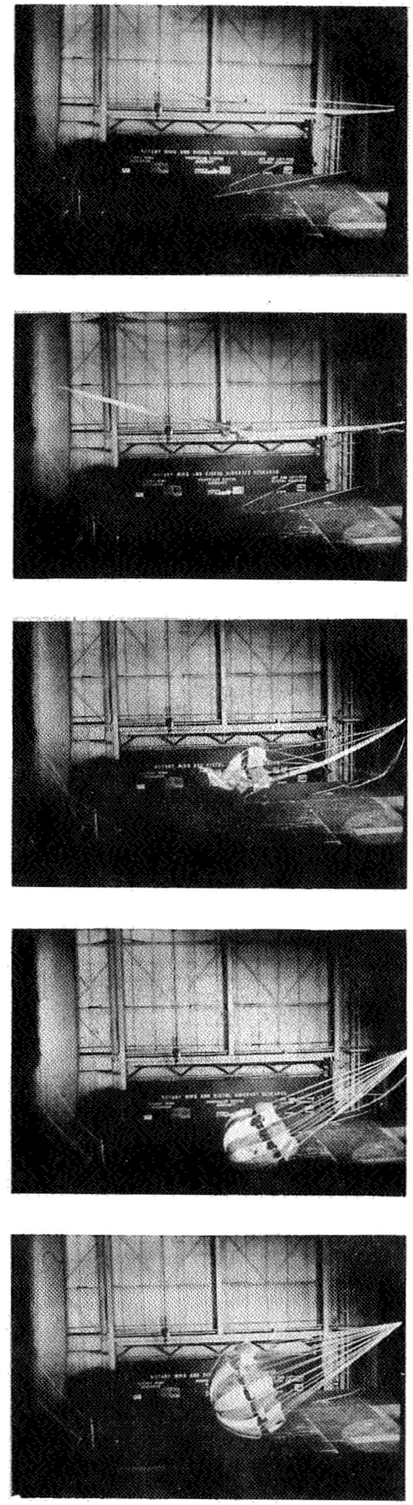
Strung-out position prior to deployment

Bag-strip condition after deployment

Partial inflation condition

Partial inflation condition

Maximum diameter condition



$q_\infty$ = 2.97 lb /ft$^2$

$q_\infty$ = 0.24 lb/ft$^2$

Figure 4.- Photographs showing typical inflation sequences.

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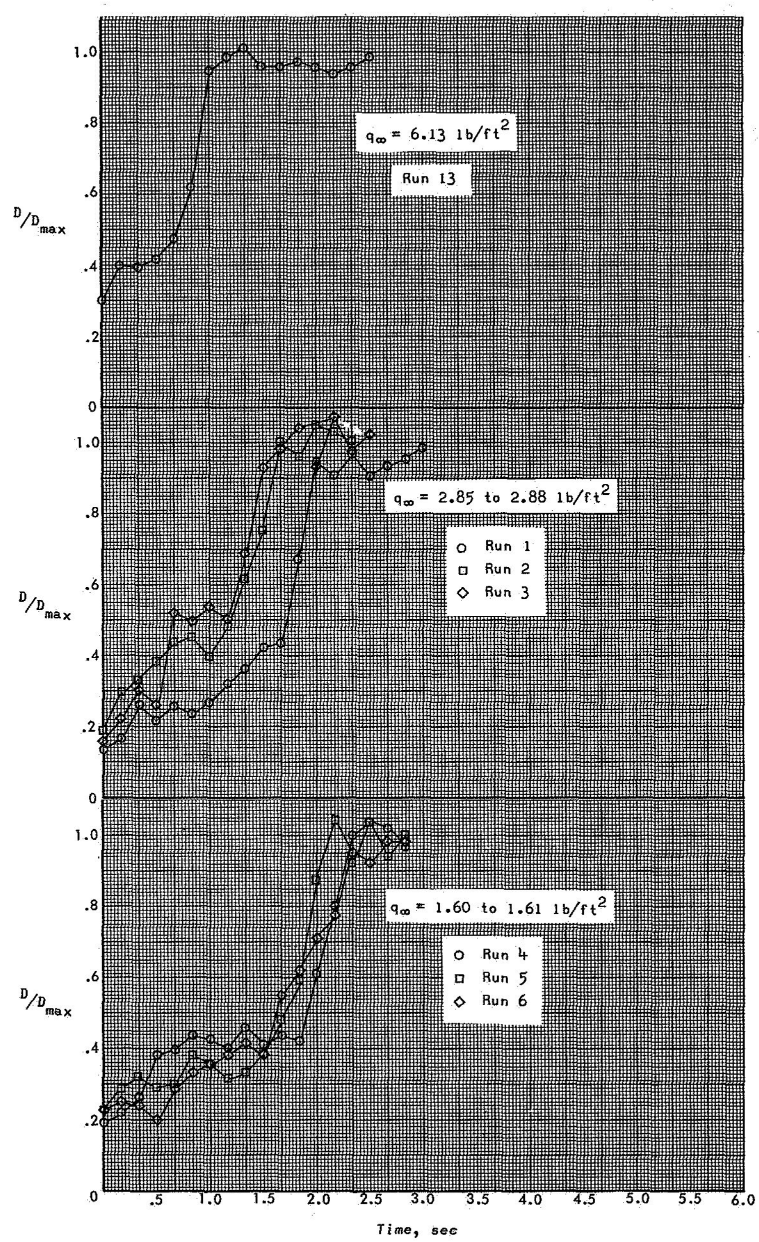



Figure 5.- Time history of modified ringsail canopy inflation.

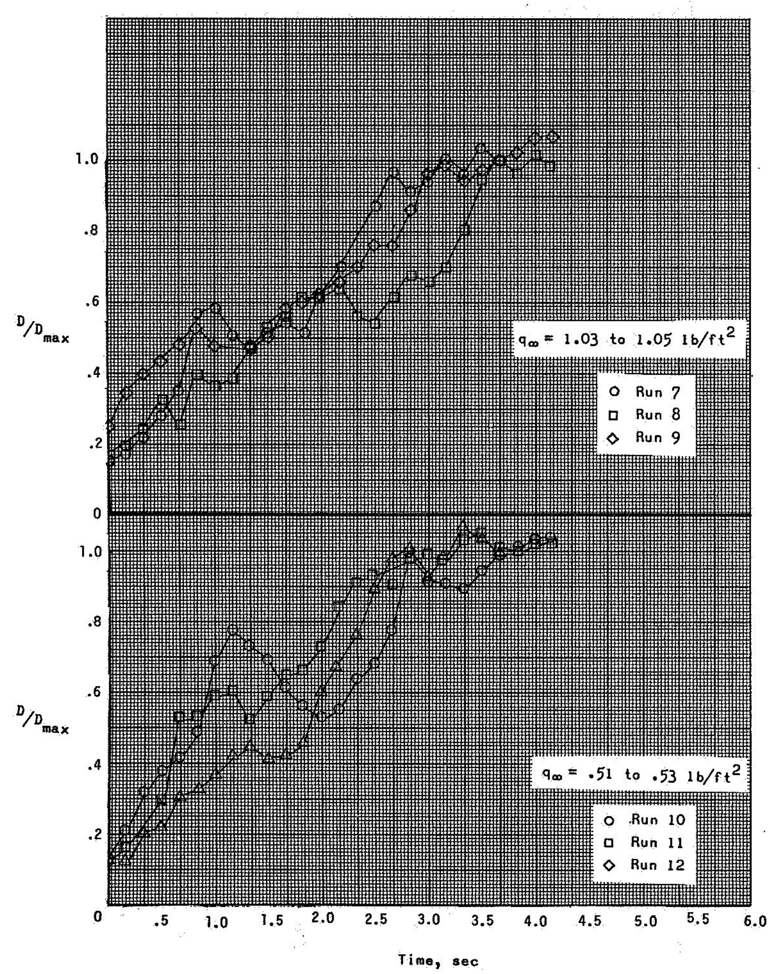



Figure 5.- Concluded.

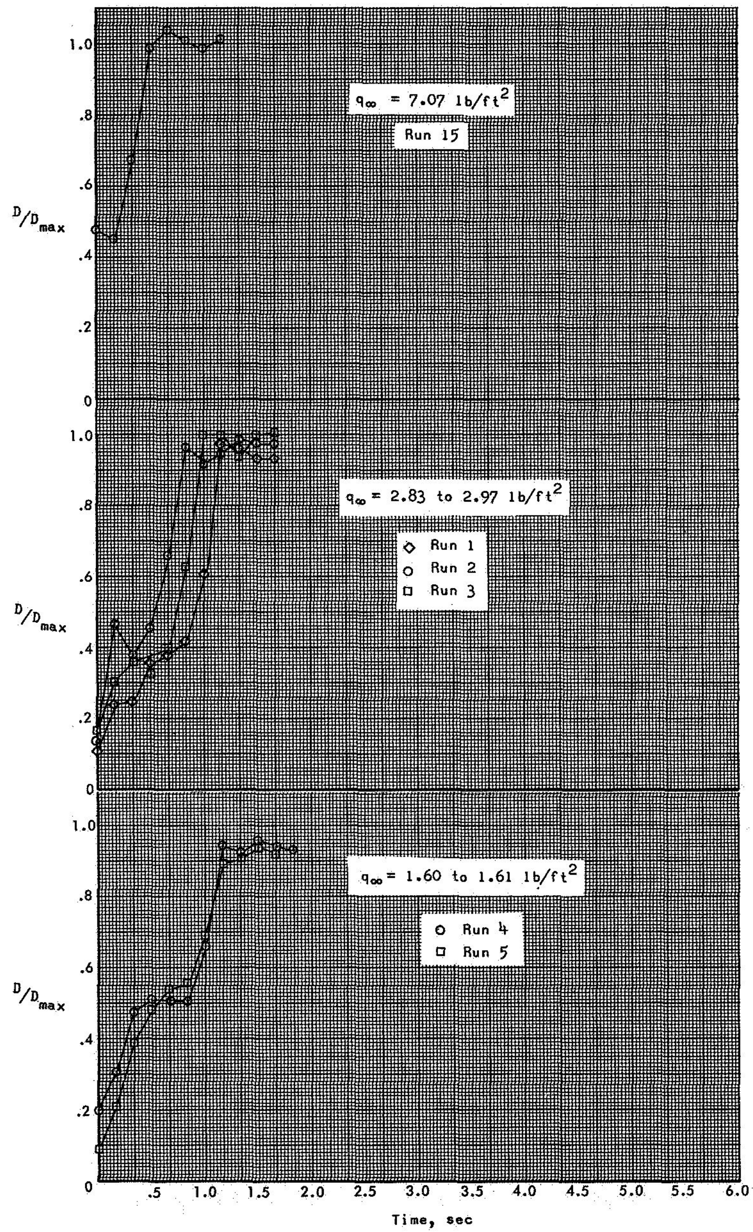



Figure 6.- Time history of disk-gap-band canopy inflation.

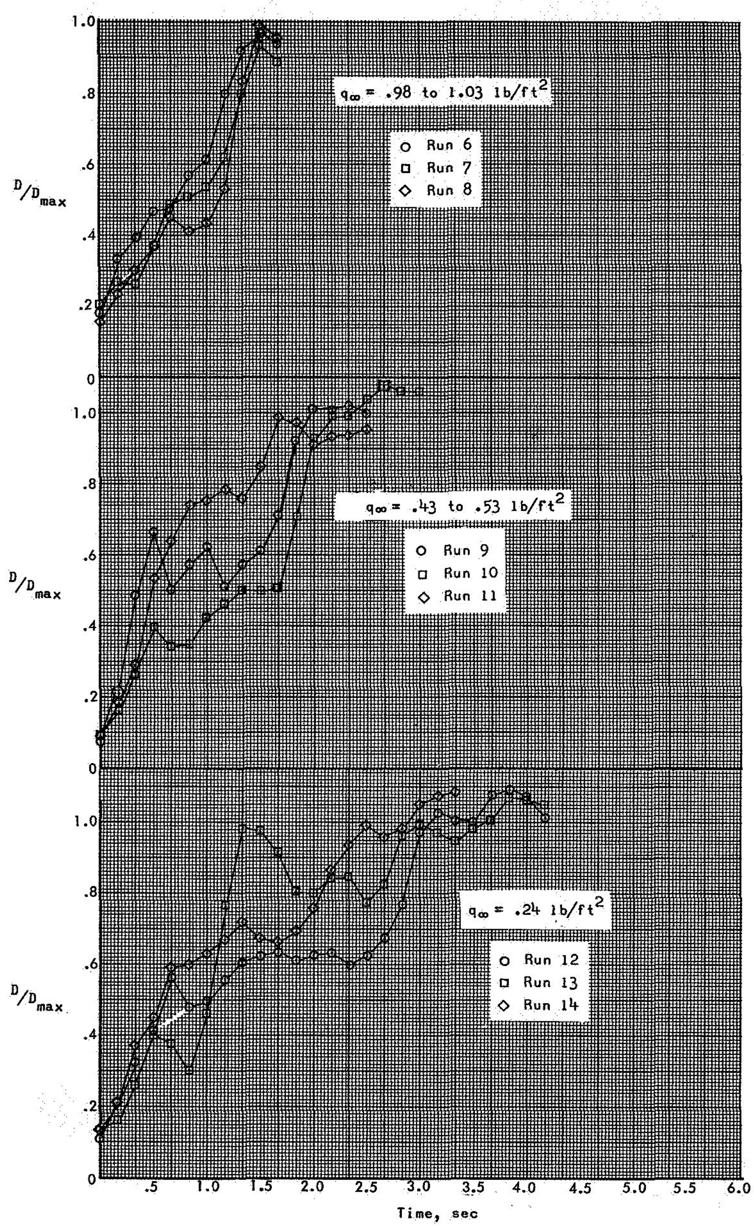
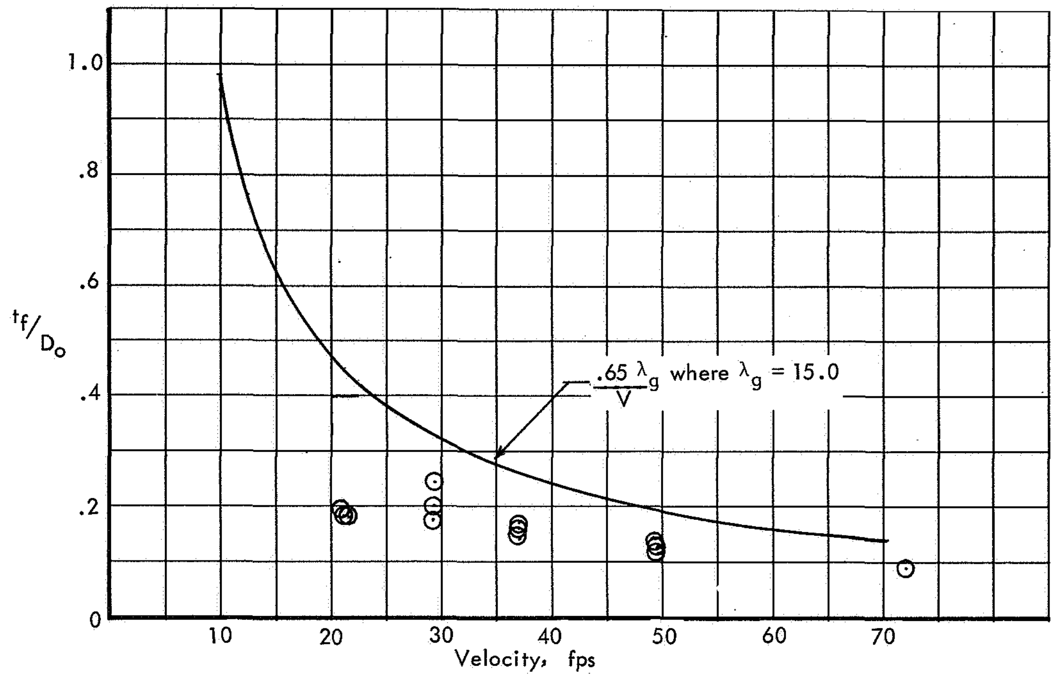
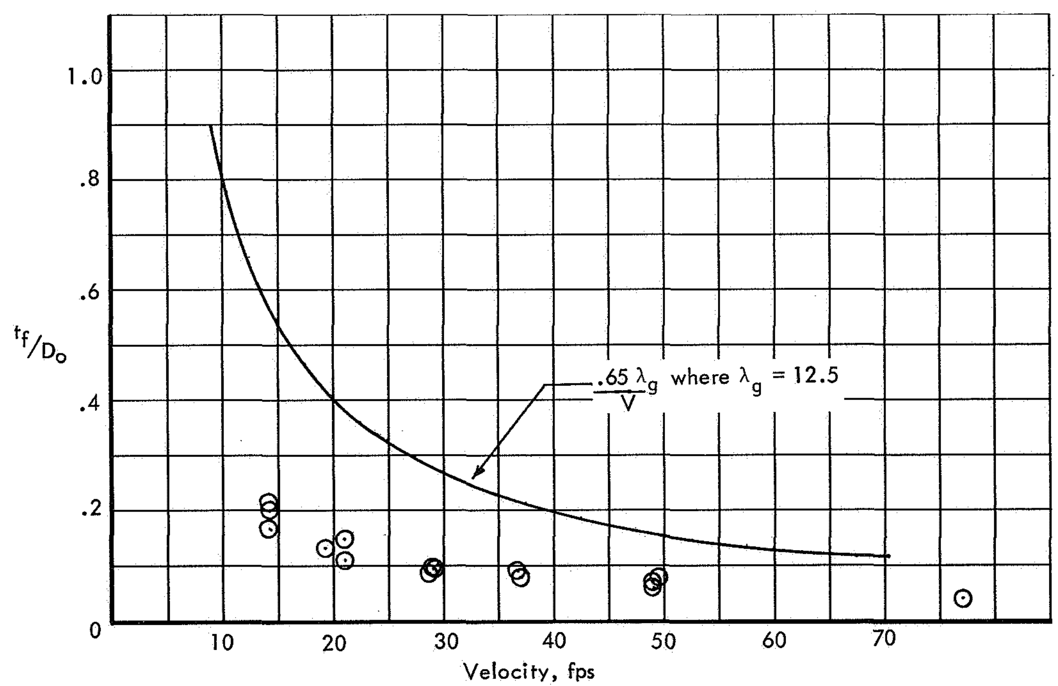



Figure 6.- Concluded.

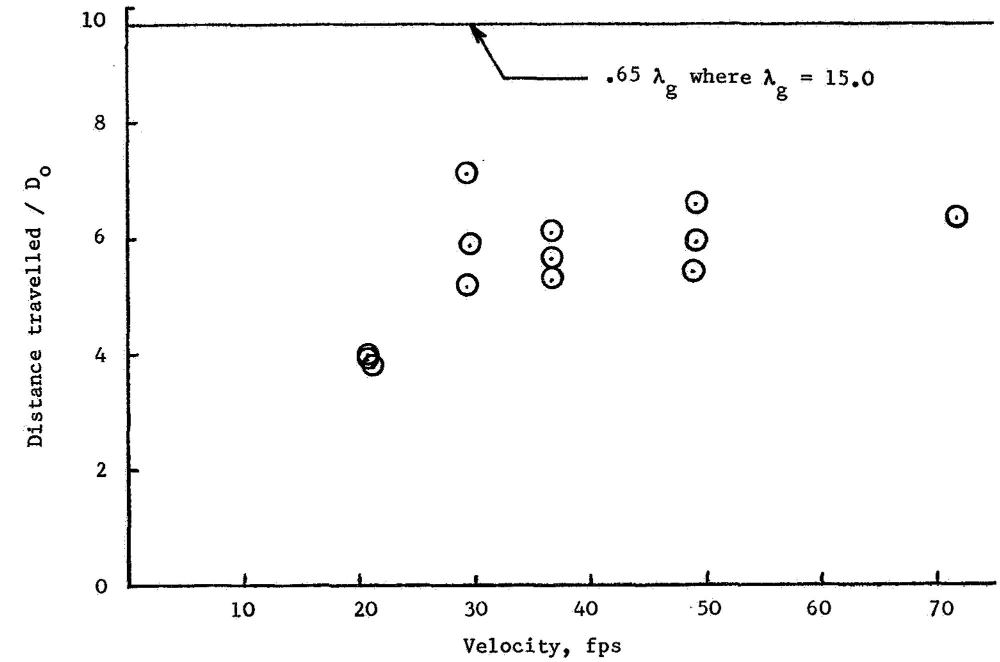



(a) Modified ringsail configuration.

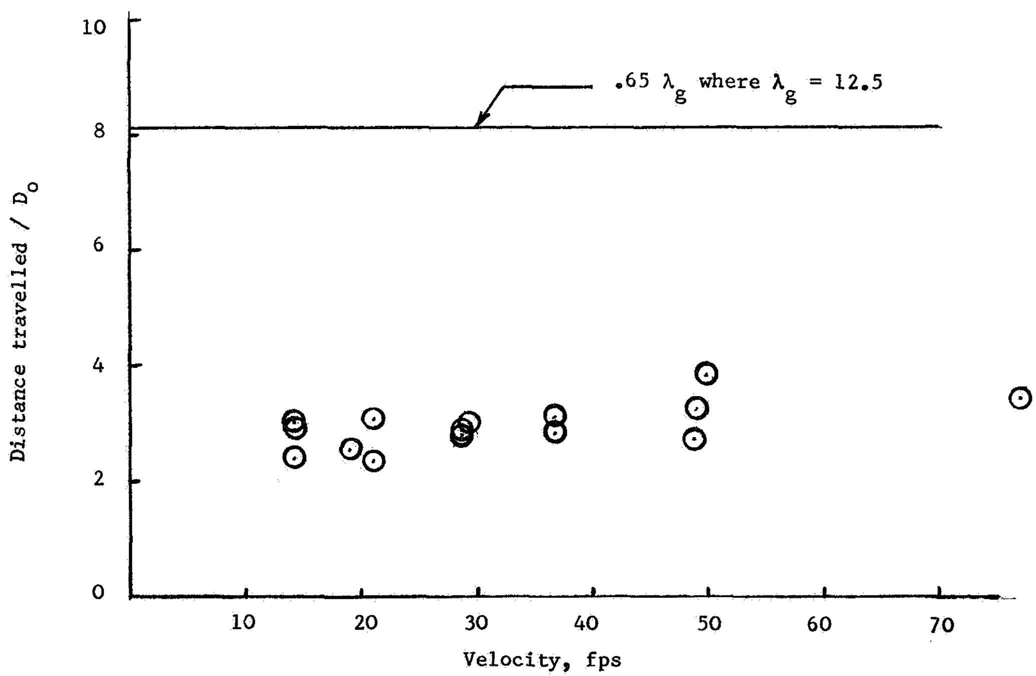



(b) Disk-gap-band configuration.

Figure 7.- Correlation of filling time.




(a) Modified ringsail configuration.




(b) Disk-gap-band configuration.

Figure 8.- Correlation of filling distance.



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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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