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LOW-SPEED DEPLOYMENT, INFLATION, AND STEADY-DESCENT CHARACTERISTICS OF RAM-AIR-INFLATED BALLOON RECOVERY SYSTEMS WITH PERIPHERAL AIRSCOOPS

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LOW-SPEED DEPLOYMENT, INFLATION, AND STEADY-DESCENT CHARACTERISTICS OF RAM-AIR-INFLATED BALLOON RECOVERY SYSTEMS WITH PERIPHERAL AIRSCOOPS

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SUMMARY

A free-flight investigation at low subsonic speeds has been conducted in a 20-foot (6.1-meter) vertical tunnel on several 6.0-foot-diameter (1.83 meter) ram-air-inflated balloons with various numbers and locations of peripheral airscoops to determine the deployment, inflation, and steady-descent characteristics of this type of recovery system. The configurations consisted of balloons constructed with 6, 12, and 24 gores with airscoops in each gore; the number of open airscoops for a given balloon could be reduced by closing some of the airscoops. Some of the balloons also were equipped with an open throat to provide additional inlet area.

The results of the investigation indicated that the altitude loss during deployment and inflation, and the inflation time of the balloon decreased as the total airscoop area of the balloons increased. The balloons however reached their final drag coefficient and rate of descent considerably before they became completely inflated; and in some instances, balloons with a smaller airscoop area achieved their final drag coefficient and final steady-state rate of descent with less altitude loss than balloons with a greater airscoop area. Location of the airscoops higher on the balloon, up to a point somewhat above the maximum diameter, produced a more rapid inflation and less altitude loss. Also, the use of an open throat together with peripheral airscoops increased the balloon inflation rate somewhat and reduced the altitude loss. The balloons in the fully inflated condition were stable when equipped with a burble fence and unstable when not so equipped.

INTRODUCTION

The National Aeronautics and Space Administration is conducting research programs to evaluate different types of terminal recovery systems for boosters, spacecraft, and instrument and cargo packages. As a part of this program, an investigation at low subsonic speeds has been conducted to compare the deployment, inflation, and steady-descent characteristics of several hot-air balloon recovery systems with peripheral airscoops which are used for inflation with ram air. The primary objective of this investigation was to determine the altitude loss during deployment and inflation of balloons with various inlet scoop configurations since altitude loss is a critical factor in the deployment of balloon recovery systems. Hot-air balloon recovery systems are used as drag and flotation devices to accomplish terminal deceleration and controlled rate of descent. After aerial deployment and ram-air inflation of the balloon, buoyancy for flotation is provided by heating the air in the balloon. By regulating the temperature of the air, ascent, hover, or descent can be accomplished. The present investigation, however, did not include tests of the air heating phase of the operation. Further information on this type of recovery system can be found in reference 1.

Seven balloon configurations of similar shape and 6 feet (1.83 meters) in diameter were tested in the present investigation to determine the deployment, inflation, altitude loss, stability, and drag characteristics of the various configurations. Included in these configurations were 6-gore, 12-gore, and 24-gore balloons (with airscoops constructed in each gore). Two of the balloons had open throats as well as the peripheral airscoops, and one balloon was built of heavier fabric than the others. The balloons were also tested with and without a burble fence.

SYMBOLS

Measurements used in this investigation were taken in the U.S. Customary System of Units. Equivalent values are indicated herein in the International System of Units (SI). Details of the system together with conversion factors can be obtained in reference 2. When measuring distances relative to the balloon gore length, the balloon gore is considered to be laid out flat.

C_D drag coefficient of balloon recovery system based on maximum cross-sectional area and steady rate of vertical descent, D/qS_b

D drag of balloon recovery system at steady rate of descent (drag is equal to total weight of balloon plus payload), lbf (N)

d maximum diameter of balloon, ft (m)

ΔH average altitude lost during deployment and inflation of balloon, ft (m)

l length of balloon gore, 9.45 ft (2.88 m)

q dynamic pressure, $\rho V^2/2$, lbf/ft^2 (N/m^2)

S_a total area of open airscoops (area of individual airscoop obtained by determining area of theoretical circle which has a circumference equal to twice the distance measured between cusps of airscoop; see fig. 1), ft^2 (m^2)

S_b maximum cross-sectional area of fully inflated balloon excluding burble fence, ft^2 (m^2)

S_t cross-sectional area of open throat of balloon, ft^2 (m^2)

V average vertical rate of descent, ft/sec (m/sec)

z_c distance between bottom of gore and cusp of airscoop, ft (m)

z_e distance between bottom of gore and upper end of lower portion of balloon envelope (see fig. 1), ft (m)

z_f distance between bottom of gore and burble fence, ft (m)

ρ air density, $lbf\text{-}sec^2/ft^4$ (kg/m^3)

MODELS

A sketch showing a typical configuration of the balloons tested and the payload is shown in figure 1; photographs of the two configurations being tested are shown in figure 2. The physical characteristics of the balloon configurations are presented in table I, and sketches of the balloons are presented in figure 3. Balloons 6 feet (1.83 meters) in diameter were selected as the largest feasible on the basis of freedom of movement in the tunnel and tunnel blockage effects. The payload was 3 inches (7.62 cm) in diameter and 10.5 inches (26.67 cm) in length; its size, although somewhat arbitrarily selected, was considered to be a reasonable size relative to the size of the balloon and to represent a fairly dense research payload.

Weight Considerations

The total mass of the system was chosen to represent (under the sea-level conditions of the tests and constant Froude number scaling) deployment at an altitude of 15 000 feet (4575 meters) of a 6-foot-diameter (1.83 meters) balloon system which could become buoyant at an altitude of 5000 feet (1525 meters) with an internal air temperature of about 350° F (449° K). The total weight of the system, that is, the balloon and payload, was kept constant at 4.94 pounds (21.97 N). In order to maintain a constant system weight, the payload weight was varied slightly for each balloon configuration to compensate for the slight differences in balloon envelope weights. The average weight of the balloon envelope, suspension lines, and burble fence was 1.98 pounds (8.81 N), and the average weight of the payload was 2.96 pounds (13.16 N). Thus, the weight of the balloon envelope is about 40 percent of the total system weight. This percentage indicates that the balloon envelope constituted much too large a part of the total weight since for this type of recovery system the balloon envelope weight should be no more than approximately 10 percent of the total weight. The lighter balloons, however, were made of the lightest fabric available, and they could not be made lighter. The fact that the relative weights of the balloon and payload were not correct would be expected to influence the stability motions of the system, but would not be expected to have any significant effect on the inflation time or altitude lost during inflation.

Balloon Envelopes

All the balloon envelopes were designed and fabricated to have a "natural" shape in which, theoretically, the envelope material experiences only meridional stresses when the balloon is floating in the static buoyant mode. Although the shape is assumed to be the optimum shape for the buoyant flight mode, it may not necessarily be the optimum shape for the deployment, inflation, or cold descent modes.

Balloons 1, 2, and 7 form a series in which the number of gores, and consequently, the number and size of the airscoops, was varied; balloons 2, 3, and 4 form a series in which the vertical location of the airscoops was varied; balloons 2 and 5 form a series with and without an open-throat air inlet in addition to the peripheral airscoops (diameter of open throat was 30 percent of maximum diameter of balloon); and balloons 5 and 6 form a series in which the weight of the fabric was varied. The balloon envelopes were made of a very low porosity calendered nylon about 2 mils thick; the weight of the material used for six of the balloons was about 1.2 oz/yd^2 (0.40 N/m^2) and the weight of the material for the other (balloon 6) was about 1.8 oz/yd^2 (0.60 N/m^2).

A burble fence made of the same material as the balloons and 4.5 inches (11.43 cm) wide was attached to the balloons just above their equators. The fence was made readily detachable so that tests could be conducted without it.

The suspension lines of the balloons were made of 0.018-inch-diameter (0.046 cm) braided copper cable and were 12 inches (30.45 cm) long. The upper ends of the lines were attached near the bottom of the balloons on each gore seam.

TESTING FACILITY AND TECHNIQUE

The tests were conducted in the Langley spin tunnel (ref. 3), which is an atmospheric wind tunnel with a vertically rising airstream. The maximum airspeed of the tunnel is approximately 90 ft/sec (27.4 m/s) and the maximum acceleration and deceleration of the airstream are 15 ft/sec^2 (4.6 m/s^2) and 25 ft/sec^2 (7.6 m/s^2), respectively.

Visual observations and motion pictures at a camera speed of 24 frames per second were made of the behavior of the balloon recovery system. Time for inflation of the balloon was obtained from a timer superimposed on the motion-picture film. Airstream velocity (rate of descent) was measured by a pitot tube and recorded on an oscillograph. The air lines from the pitot tube to an electrical transducer were very short (about 2 feet (0.61 meter)) to minimize the time lag in the velocity measurement.

Because of the excessive bulk of the balloon material, it was not possible to pack it in the end of the payload for the deployment tests. Therefore, a container to hold the balloon and payload was used. It was approximately 9 inches (22.86 cm) square, 7 inches (17.78 cm) deep, and had a door on the bottom. The balloon material was packed accordion fashion into the container, the payload being laid on the balloon envelope. The container was inverted, and was then hoisted to the top of the tunnel and held in position by a line. When the tunnel airstream velocity reached the desired value, the balloon and payload were released from the container in a psuedo-deployment fashion.

During deployment and inflation tests of the balloon, an attempt was made to maintain the system at a constant height in the tunnel by continuously adjusting the airstream velocity. With the balloon in the fully inflated condition, there was relatively little vertical movement. During the deployment of the balloon, however, and in the initial stages of inflation, a fair amount of vertical movement resulted from the rapidly changing drag characteristics of the balloon envelope. This movement was corrected by the use of trigonometric relationships which utilized distances and angles obtained from reference lines painted on the walls of the tunnel. (These lines may be seen in fig. 2.) The time was obtained from a timing device in view of the camera.

The deployment period of the balloon was considered to begin when the payload (which was in the packing container) was exposed to the airstream and to end when the balloon envelope was fully extended. The inflation period was considered to begin when the balloon envelope was fully extended, and to end when the balloon was fully inflated. The altitude loss period was considered to begin when the payload was exposed to the airstream during deployment and to end when the balloon envelope was fully inflated.

The stability and drag characteristics of the balloons were determined with the balloons maintained at a nearly constant height in the tunnel. The motions of the balloons were observed to determine their stability characteristics. The drag characteristics of the balloons were obtained by measuring the tunnel velocity which is a direct indication of the system drag.

TESTS

The Reynolds number of the tests based on the fully inflated balloon diameter ranged from about 460 000 to 613 000 with the burble fence on and off, respectively.

The various conditions tested on the balloons are presented in table II. The balloons were deployed at an approximate velocity of 24.0 ft/sec (7.3 m/sec). Higher deployment velocities were not possible because of tunnel-testing-technique limitations. The number of open airscoops on each balloon was systematically varied by closing different airscoops with tape in a symmetrical manner. The two balloons with open throats were tested with the throats opened and closed. In addition, the balloons were tested in a streamed condition with the throats and airscoops closed. The balloons also were tested with and without a burble fence. To determine the repeatability of the data, approximately five tests were made for each test condition. The individual results obtained did not vary more than approximately 10 percent from their average values.

RESULTS AND DISCUSSION

A motion-picture film supplement showing some typical results of the balloon tests has been prepared and is available on loan. A request card form and description of the film will be found at the back of this paper.

The following discussion is for the case in which the burble fence is attached, unless otherwise noted.

Deployment and Inflation Conditions

Deployment.- During the deployment tests the balloon envelopes streamed freely from the container and commenced ingesting air as soon as the airscoops or open throats were exposed to the airstream. Typical time histories of the average rate of descent of the 6-, 12-, and 24-gore balloon configurations during the deployment and inflation phases are presented in figure 4. The data indicate that the payload accelerated quickly during the deployment phase and then decelerated rapidly because of the increase in drag of the balloon envelope as it started to inflate. For all test conditions the balloons required approximately 0.8 second for deployment and the average increase in velocity of the payload was about 20 feet per second (6.1 m/sec). These values of time and increase in velocity correspond approximately to those for free-fall of the payload in a vacuum for the 9.5-foot (2.9-meter) distance required to extend fully the length of the collapsed balloon during deployment (0.77 sec and 25 ft/sec (7.6 m/sec), respectively). Therefore, it appears that even though the balloon may ingest a small amount of air during the deployment phase prior to significant inflation, the amount of air is not enough to affect the drag characteristics and rate of descent of the balloon.

Inflation time and altitude loss.- Observation of the film records and analysis of the time histories indicated that all the balloons during inflation had the following characteristics in common:

(1) The envelopes had a positive tendency to inflate in spite of random opening and closing of airscoops and/or balloon throat

(2) The system drag increased rapidly to almost the fully inflated envelope value after only a small percentage of the envelope inflation was completed

(3) The systems were stable during the period of inflation.

Tabulated data on the inflation times and altitude losses of the various balloon configurations are presented in table II. The variation of the inflation time with the number of open airscoops on the balloons is shown in figure 5; and in figure 6 the inflation time is plotted against the nondimensional ratio of open airscoop area S_a to maximum cross-sectional area S_b of the balloons. In figures 7 and 8 the altitude loss is plotted against the number of open airscoops and the ratio S_a/S_b, respectively.

In figure 9 the altitude loss is plotted against open airscoop area, these quantities being nondimensionalized by using balloon diameter and maximum cross-sectional area, respectively. This figure shows that for comparable balloons (that is, excluding open-throat balloons), reasonable correlation between altitude loss and open airscoop area is indicated. There is some scatter in the data which is due primarily to the difficulty in exactly determining when the balloons with closed throats are fully inflated (which in turn determines the altitude loss) since there is a considerable amount of slack fabric at the bottom of the balloon; this fabric whips to and fro even when inflation is complete. Also some of the scatter in data may be attributed to slight inaccuracies in measuring the airscoop openings which, of course, are made of fabric which stretches slightly.

By examining the results in more detail (figs. 5 to 8), it can be seen that for any given balloon configuration as the number of open airscoops or the ratio S_a/S_b was increased, the time for inflation and the altitude loss generally decreased. Comparison of the time for inflation and altitude loss for the 6-, 12-, and 24-gore balloons for the condition where all the airscoops are open and the throats closed shows that the 6-gore balloon had the shortest inflation time and the least altitude loss; the reason for this effect is that the total area of all the airscoops was considerably greater for the 6-gore balloon than that of the 12- or 24-gore balloons. (See table I.)

Conversely, the 24-gore balloon required the longest inflation time and experienced the greatest altitude loss because, although it had the greatest number of airscoops, the total area of the airscoops was the smallest of any tested. It is interesting to note, however, that the 24-gore balloon reaches a steady rate of descent in approximately the same time as the other balloon configurations (fig. 4). These facts regarding the achievement of the final steady-state rate of descent bring up the question of whether one is concerned with the altitude lost by the balloon in achieving complete inflation or in achieving its final rate of descent, or drag coefficient. The factor of most concern might depend on the application for which the balloon is being used. For example, if the air in the balloon is to be heated to make the balloon buoyant, the complete inflation might be the important consideration; whereas, if the balloon is to be used simply as a decelerator, the achievement of its final drag coefficient might be the important consideration. From an analysis of film records of the tests of the 24-gore balloon, it appears that the balloon inflates quickly to about three-quarters of its diameter and increases its drag considerably; thus its rate of descent is reduced quickly. The airscoops, however, appear to remain relatively more closed than those of the other configurations during the latter part of the inflation so that full inflation of the configuration takes longer.

Opening the throat of one of the balloons in addition to the airscoops reduced somewhat the time for inflation and altitude loss. (Compare runs 27 and 30 in table II.) With only the balloon throat open, the time for inflation and altitude loss increased considerably. (See run 31, table II.)

The effects of vertical location of the airscoops on the inflation time and altitude loss for the 12-gore balloons are shown in figures 5 and 7. The results indicate that, for the range tested, as the airscoops were located higher on the balloon, the time for inflation and altitude loss decreased. The primary reason for these decreases was the increased area of the airscoops resulting from the increase in the width of the gore shape.

The data of table II show that removal of the burble fence from the balloons decreased the time for inflation significantly but generally reduced the altitude loss only slightly. This decrease in inflation time was caused by the increase in balloon rate of descent or a decrease in the time required to cover approximately the same inflation distance.

There was no significant difference in the time for inflation and altitude loss between the balloon constructed with the heavy fabric and the one constructed of a lighter fabric. (See runs 27 and 36 in table II.) It is realized, however, that the difference in weights of fabrics used in the present investigation was not large.

Fully Inflated Condition

Stability.- The number of airscoops that were open did not appear to affect the stability of the balloons. In general, all balloon configurations when equipped with the burble fence were stable during the steady rate of descent phase after they became fully inflated. The balloons with open throats translated and oscillated slightly more than the ones with closed throats; oscillations of up to $\pm 10^{\circ}$ were encountered with the open-throat balloons. The balloons with closed throats had a fair amount of slack fabric below the equator of the balloon even in the fully inflated condition, and this fabric would whip to and fro somewhat during descent. These motions are illustrated in the film supplement.

Balloon 1 with six gores was the only balloon that tended to be deformed or "out-of-round" when fully inflated. This deformation was a result of the balloon having too few gores. Because of the poor shape, the airscoops tended to remain slightly open as it oscillated and thus heating of the air in the balloon may present a problem. Consequently, this balloon configuration may require more fuel than the other configurations.

Removal of the burble fence made all the balloons unstable in that they would tilt about 45° and rotate about a vertical axis. (See table II.) An indentation or dimple which extended from the bottom of the balloon to the airscoops would form on the windward side of the balloons and force the airscoops on this side to remain partially open. These effects are illustrated in the film supplement. In some instances, balloons 3 and 7 which had open throats rotated intermittently. This effect may be due to the tendency of these configurations to oscillate occasionally; this oscillation stops the rotation temporarily. The motions of the balloons with the burble fence removed are believed to be due primarily to the unsteady, asymmetric separation of the flow from the tops of the balloons.

Drag.- There was no appreciable difference in the drag coefficients of the various balloons for a given condition. (See table II.) The average drag coefficients for all the balloons when fully inflated with all the airscoops open and with and without the burble fence were 1.01 and 0.56, respectively. There was no appreciable change in the drag coefficient with the balloon throat open or closed.

With the balloons in a streamed condition, that is, with the airscoops and throats closed, the drag coefficient ranged from 0.14 to 0.18 with the burble fence on and from 0.051 to 0.078 with it off. (See table II.) This variation in drag coefficient was due to the rapidly changing shapes of the balloons as they were streaming. It was difficult to keep the streamed balloons at a constant height in the tunnel and the airstream velocity in the tunnel was continually being varied in an attempt to keep the balloons from moving up or down appreciably. This change in airspeed causes a variation of the indicated drag coefficient of the balloons.

SUMMARY OF RESULTS

The results of a free-flight investigation in a vertical tunnel of several 6.0-foot-diameter (1.83 meter) ram-air-inflated balloons with various numbers and locations of peripheral airscoops may be summarized as follows:

1. As might be expected, the altitude loss during deployment and inflation, and the inflation time of the balloons decreased as the total airscoop area of the balloons increased; also, altitude loss correlated reasonably well with airscoop area for the various balloons.

2. The balloons however reached their final drag coefficient and rate of descent considerably before they became completely inflated; and in some instances, balloons with a smaller airscoop area achieved their final drag coefficient and final steady-state rate of descent with less altitude loss than balloons with a greater airscoop area.

3. Locating the airscoops higher on the balloon, up to a point somewhat above the maximum diameter, produced a more rapid inflation and less altitude loss.

4. The use of an open throat in conjunction with peripheral airscoops increased the balloon inflation rate and reduced the altitude loss.

5. The balloons with closed throats were slightly more stable than the ones with open throats.

6. The balloons in the fully inflated condition were stable when equipped with a burble fence and unstable when not so equipped.

7. The average drag coefficient for all of the balloons when fully inflated, with and without the burble fence, was 1.01 and 0.56, respectively.

Langley Research Center,
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124-07-03-06-23.

REFERENCES

1. Hunter, George S.: Hot-Air Balloons Studied for Pilot Rescue. Aviat. Week Space Technol., vol. 89, no. 7, Aug. 12, 1968, pp. 56-61.

2. Mechtly, E. A.: The International System of Units – Physical Constants and Conversion Factors. NASA SP-7012, 1964.

3. Neihouse, Anshal I.; Klinar, Walter J.; and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NASA TR R-57, 1960. (Supersedes NACA RM L57F12.)

TABLE I.- DIMENSIONAL AND MASS CHARACTERISTICS OF BALLOON

Balloon	Balloon diameter		Type		Airscoop location, z_c/l	Area of individual airscoop		Total area of all airscoops		Area of open throat, S_t		Upper end of lower portion of balloon envelope location, z_e/l	Balloon envelope weight (including suspension lines)		Balloon envelope weight per unit area		Burble fence					Number of suspension lines
																	Location, z_f/l	Width		Weight		
	ft	m	Gores	Airscoops		ft^2	m^2	ft^2	m^2	ft^2	m^2		lbf	N	oz/yd^2	kg/m^2		ft	m	lbf	N	
1	6.0	1.83	6	6	0.425	2.55	0.237	15.30	1.421	0	0	0.66	1.59	7.08	1.2	0.0406	0.591	0.37	0.11	0.37	0.144	6
2	6.0	1.83	12	12	.350	.43	.040	5.16	.479	0	0	.45	1.55	6.90	1.2	.0406	.591	.37	.11	.37	.144	12
3	6.0	1.83	12	12	.425	.55	.051	6.60	.613	0	0	.54	1.61	7.16	1.2	.0406	.591	.37	.11	.37	.144	12
4	6.0	1.83	12	12	.500	.70	.065	8.40	.780	0	0	.61	1.55	6.90	1.2	.0406	.591	.37	.11	.37	.144	12
5	6.0	1.83	12	12	.425	.55	.052	6.60	.613	2.54	.24	.54	1.51	6.72	1.2	.0406	.591	.37	.11	.37	.144	12
6	6.0	1.83	12	12	.425	.55	.051	6.60	.613	2.54	.24	.54	1.74	7.74	1.8	.0608	.591	.37	.11	.37	.144	12
7	6.0	1.83	24	24	.425	.14	.013	3.36	.312	0	0	.47	1.70	7.56	1.2	.0406	.591	.37	.11	.37	.144	24

TABLE II.- SUMMARY OF TEST RESULTS

Run	Balloon	Type		Airscoop location, z_c/l	Number of airscoops open	Throat	Burble fence	Average inflation time, sec	Average altitude loss		Average rate of descent		Average rate of rotation, rev/sec	C_D
		Gores	Airscoops						ft	m	ft/sec	m/sec		
1	1	6	6	0.425	2	Closed	On	9.2	184	56	---	---	---	0.078
2	1	6	6	.425	4	Closed	On	5.6	120	37	---	---	---	.14
3	1	6	6	.425	6	Closed	On	5.4	116	35	11.7	3.6	---	1.07
4	1	6	6	.425	6	Closed	Off	4.6	112	34	16.0	4.9	0.49	.57
5	1	6	6	.425	Closed	Closed	Off	---	---	---	43.5	13.3	---	.078
6	1	6	6	.425	Closed	Closed	On	---	---	---	30.0	9.1	---	.16
7	2	12	12	.350	3	Closed	On	33.1	516	157	---	---	---	----
8	2	12	12	.350	12	Closed	On	8.8	165	50	12.5	3.8	---	.94
9	2	12	12	.350	12	Closed	Off	7.2	150	46	16.8	5.1	.44	.52
10	2	12	12	.350	Closed	Closed	Off	---	---	---	47.7	14.5	---	.065
11	2	12	12	.350	Closed	Closed	On	---	---	---	31.4	9.6	---	.15
12	3	12	12	.425	3	Closed	On	20.8	352	107	---	---	---	----
13	3	12	12	.425	6	Closed	On	14.6	228	69	---	---	---	----
14	3	12	12	.425	9	Closed	On	8.7	150	46	---	---	---	----
15	3	12	12	.425	12	Closed	On	7.4	128	39	12.5	3.8	---	.94
16	3	12	12	.425	12	Closed	Off	5.8	125	38	16.0	4.9	.38	.57
17	3	12	12	.425	Closed	Closed	Off	---	---	---	47.7	14.5	---	.065
18	3	12	12	.425	Closed	Closed	On	---	---	---	28.5	8.7	---	.18
19	4	12	12	.500	3	Closed	On	14.6	260	79	---	---	---	----
20	4	12	12	.500	12	Closed	On	6.5	126	38	11.7	3.6	---	1.07
21	4	12	12	.500	12	Closed	Off	5.2	115	35	15.4	4.7	.52	.62
22	4	12	12	.500	Closed	Closed	Off	---	---	---	47.1	14.4	---	.066
23	4	12	12	.500	Closed	Closed	On	---	---	---	28.5	8.7	---	.18
24	5	12	12	.425	3	Open	On	10.8	201	61	---	---	---	----
25	5	12	12	.425	6	Open	On	8.1	162	49	---	---	---	----
26	5	12	12	.425	9	Open	On	6.7	137	42	---	---	---	----
27	5	12	12	.425	12	Open	On	4.8	110	34	11.7	3.6	---	1.07
28	5	12	12	.425	12	Open	Off	4.4	103	31	16.0	4.9	0.42	.57
29	5	12	12	.425	12	Closed	Off	6.0	148	45	15.4	4.7	.53	----
30	5	12	12	.425	12	Closed	On	6.4	150	46	16.8	5.1	---	----
31	5	12	12	.425	Closed	Open	On	21.7	366	112	12.0	3.7	---	----
32	5	12	12	.425	Closed	Open	Off	20.9	400	122	16.0	4.9	---	.57
33	5	12	12	.425	Closed	Closed	Off	---	---	---	53.8	16.4	---	.051
34	5	12	12	.425	Closed	Closed	On	---	---	---	32.1	9.8	---	.14
35	6	12	12	.425	3	Open	On	11.8	203	62	11.7	3.6	---	1.07
36	6	12	12	.425	12	Open	On	5.3	117	36	11.7	3.6	---	1.07
37	6	12	12	.425	12	Open	Off	4.8	113	34	15.9	4.8	.35	.58
38	6	12	12	.425	Closed	Open	On	23.5	360	110	11.7	3.6	---	1.07
39	6	12	12	.425	Closed	Closed	Off	---	---	---	49.1	15.0	---	.061
40	6	12	12	.425	Closed	Closed	On	---	---	---	29.2	8.9	---	.17
41	7	24	24	.425	6	Closed	On	45.0	670	204	---	---	---	----
42	7	24	24	.425	12	Closed	On	31.4	450	137	---	---	---	----
43	7	24	24	.425	18	Closed	On	26.9	383	117	---	---	---	----
44	7	24	24	.425	24	Closed	On	20.9	306	93	12.5	3.8	---	.94
45	7	24	24	.425	24	Closed	Off	12.6	236	72	16.0	4.9	.47	.57
46	7	24	24	.425	Closed	Closed	Off	---	---	---	43.5	13.3	---	.078
47	7	24	24	.425	Closed	Closed	On	---	---	---	28.5	8.7	---	.18

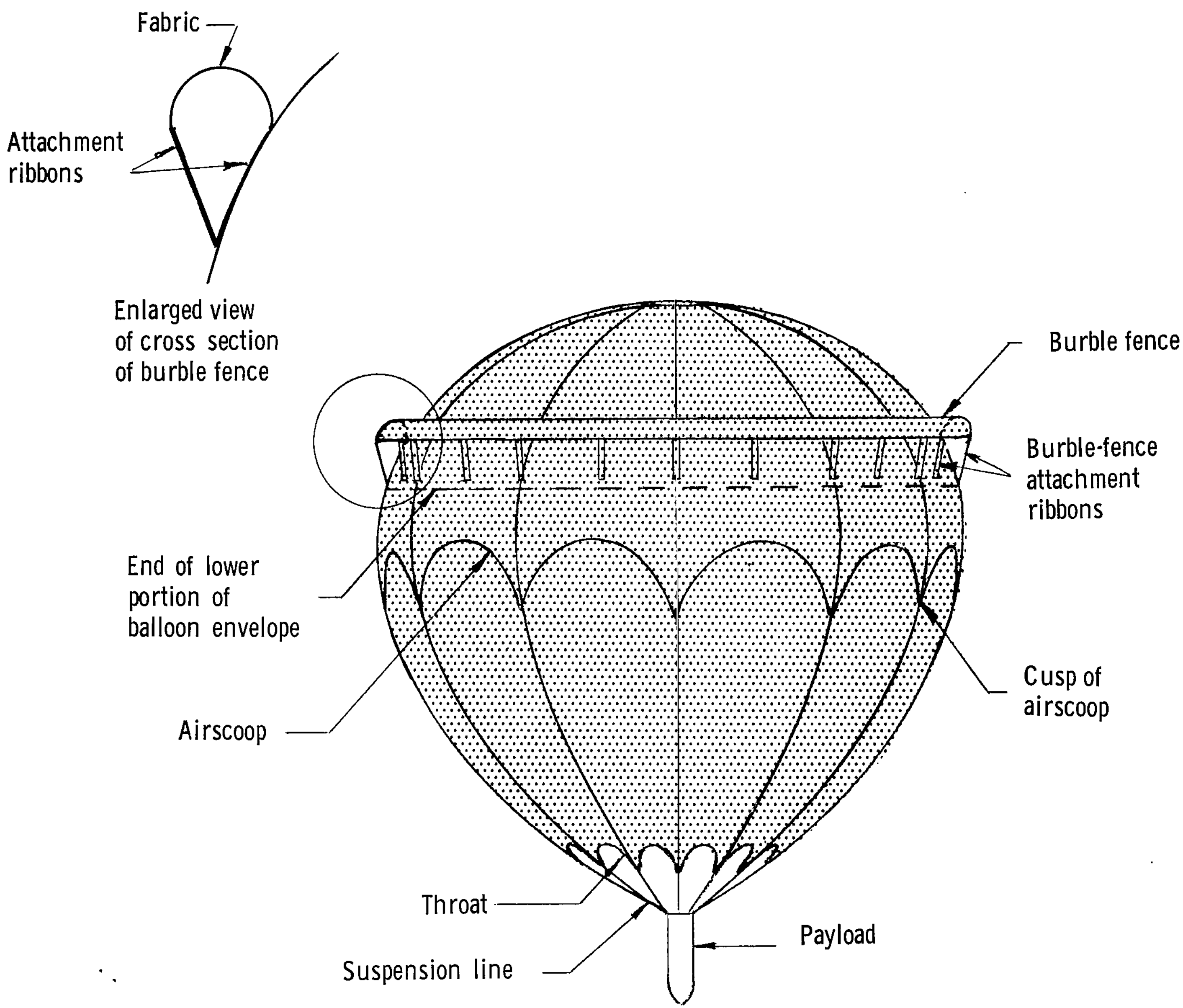
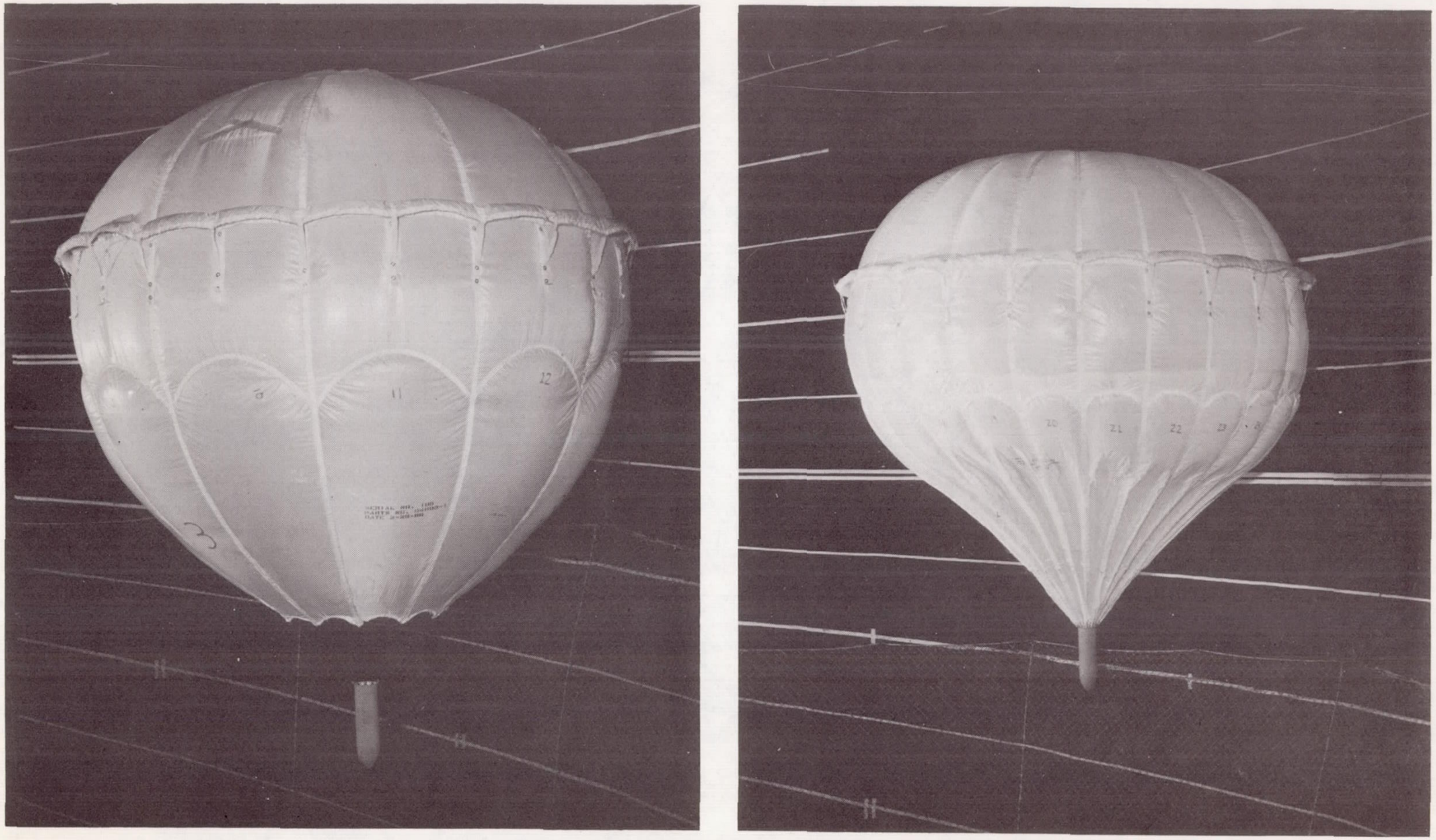


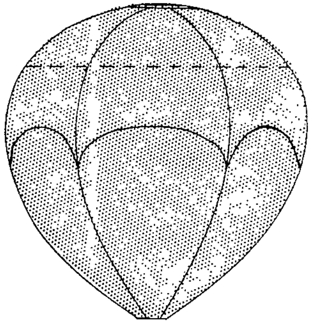
Figure 1.- Typical balloon configuration.



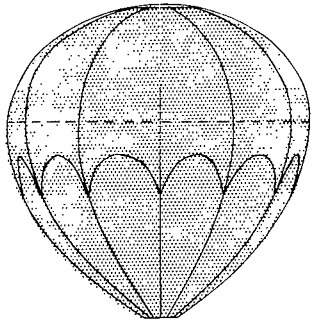
(a) 12 gore, open throat.

(b) 24 gore, closed throat.

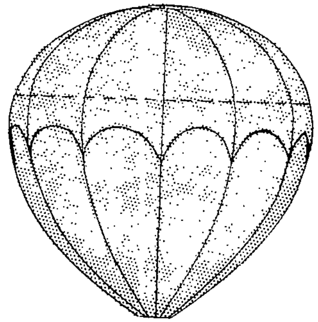
Figure 2.- Typical fully inflated balloon configurations being tested in spin tunnel. L-69-1317



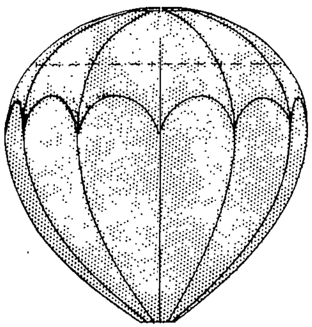
Balloon 1
6 gores
Airscoop location, $z_c/l = 0.425$



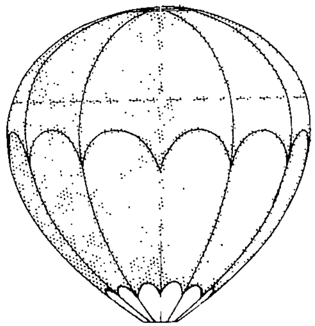
Balloon 2
12 gores
Airscoop location, $z_c/l = 0.350$



Balloon 3
12 gores
Airscoop location, $z_c/l = 0.425$

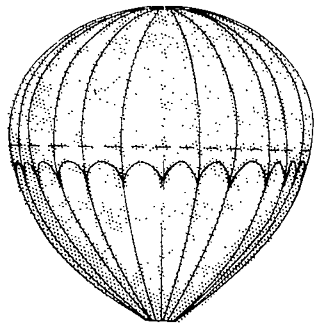


Balloon 4
12 gores
Airscoop location, $z_c/l = 0.500$



Balloon 5 and 6
(6 has heavy fabric)
12 gores
Airscoop location, $z_c/l = 0.425$

Open throat



Balloon 7
24 gores
Airscoop location, $z_c/l = 0.425$

Figure 3.- Balloon configurations used in investigation.

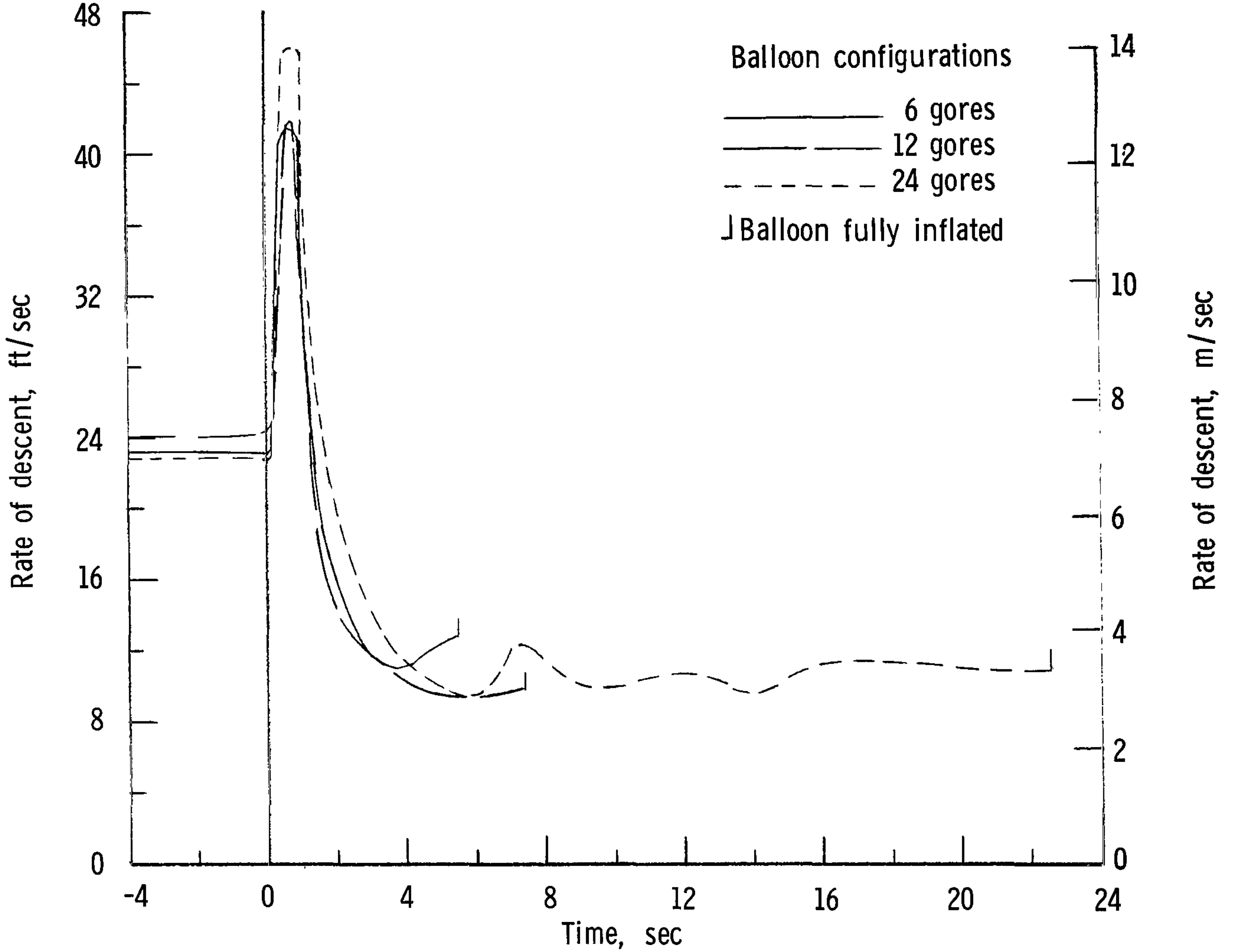


Figure 4.- Typical time histories of rate of descent of balloons during deployment (pseudo) and inflation phases for balloons having various numbers of gores. All airscoops are open and throats closed; burble fences are on. $z_c/l = 0.425$.

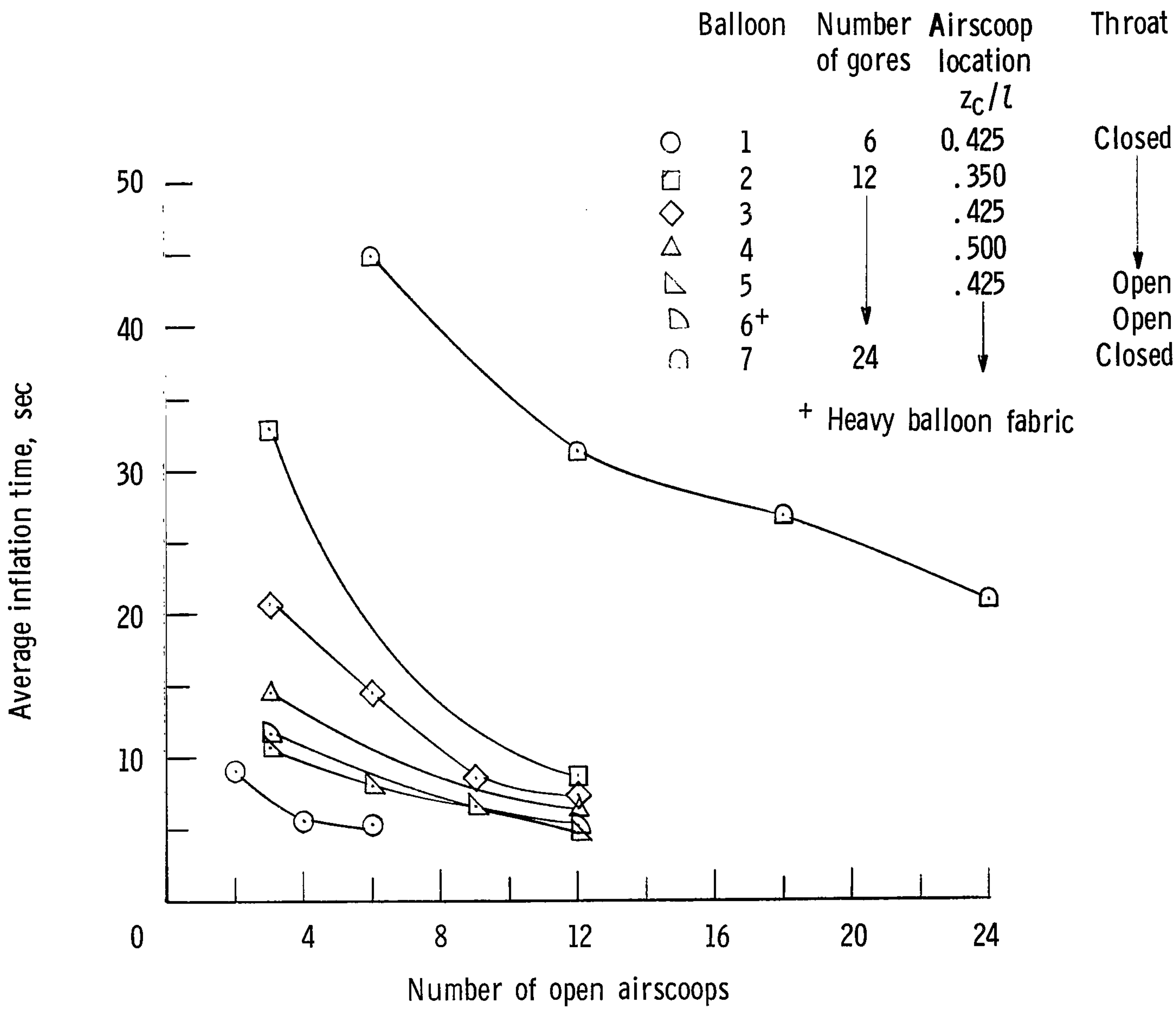


Figure 5.- Variation of balloon average inflation time with number of open airscoops.

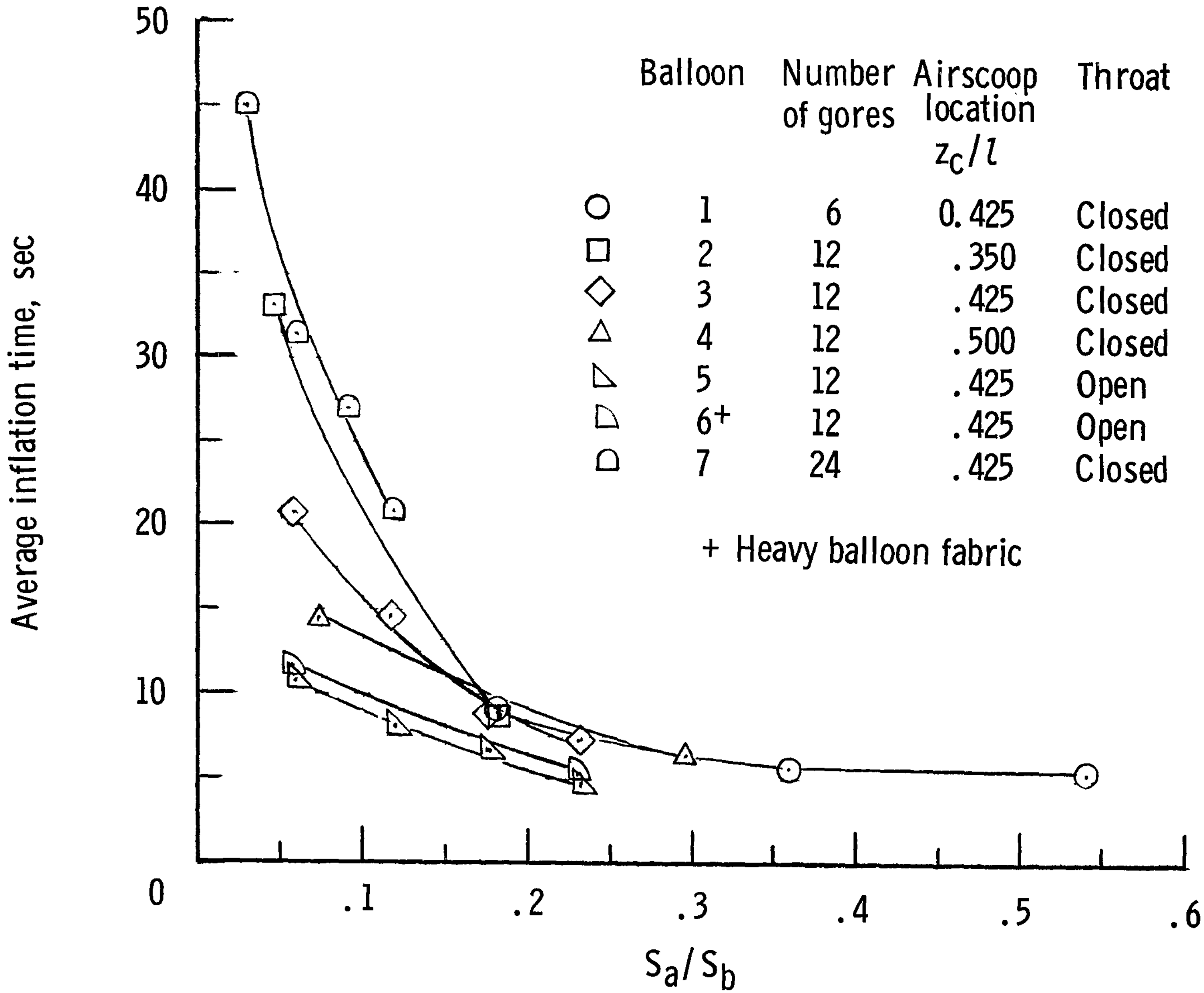


Figure 6.- Variation of balloon average inflation time with ratio of open airscoop area to maximum cross-sectional area of balloon.

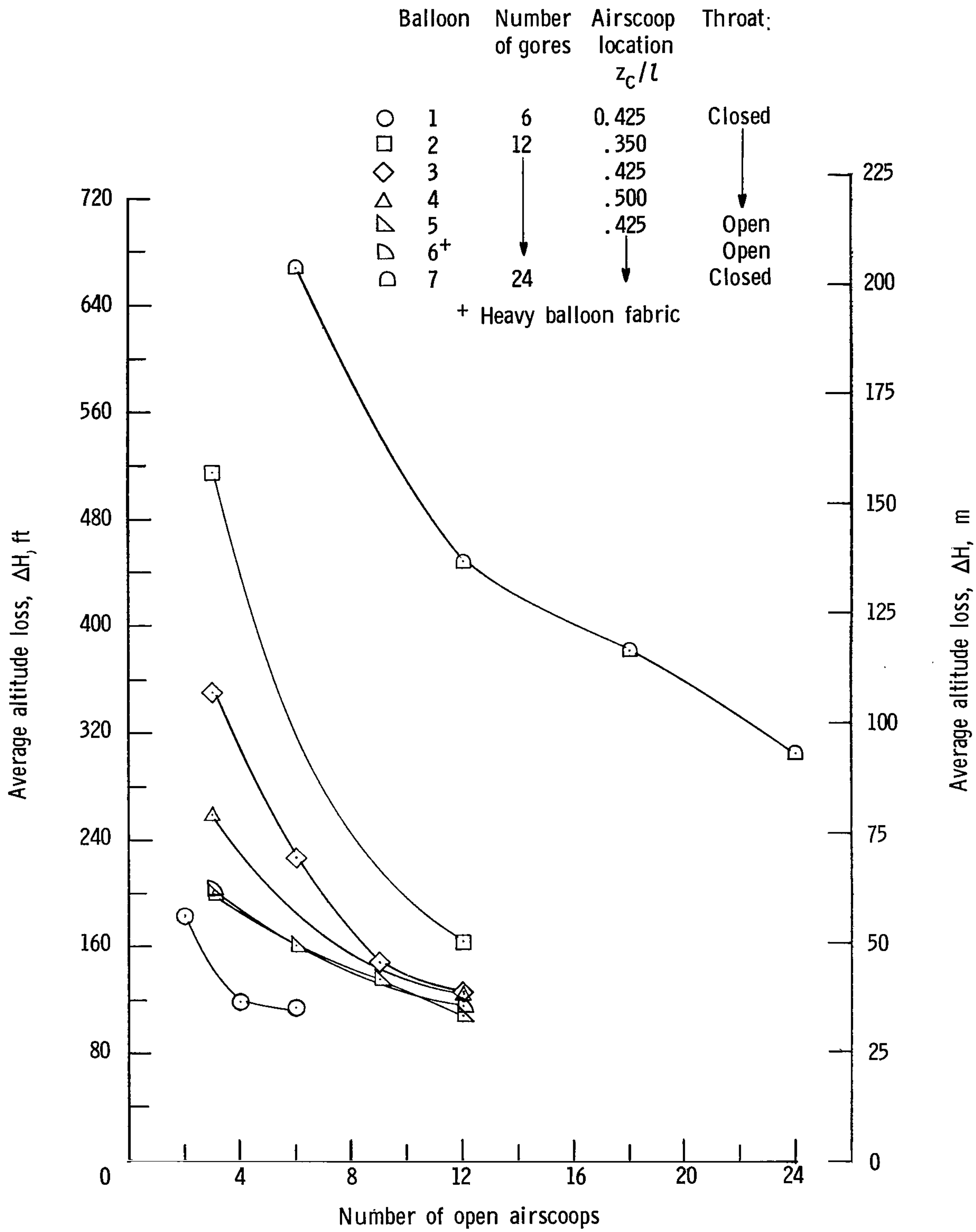


Figure 7.- Variation of balloon average altitude loss with number of open airscoops.

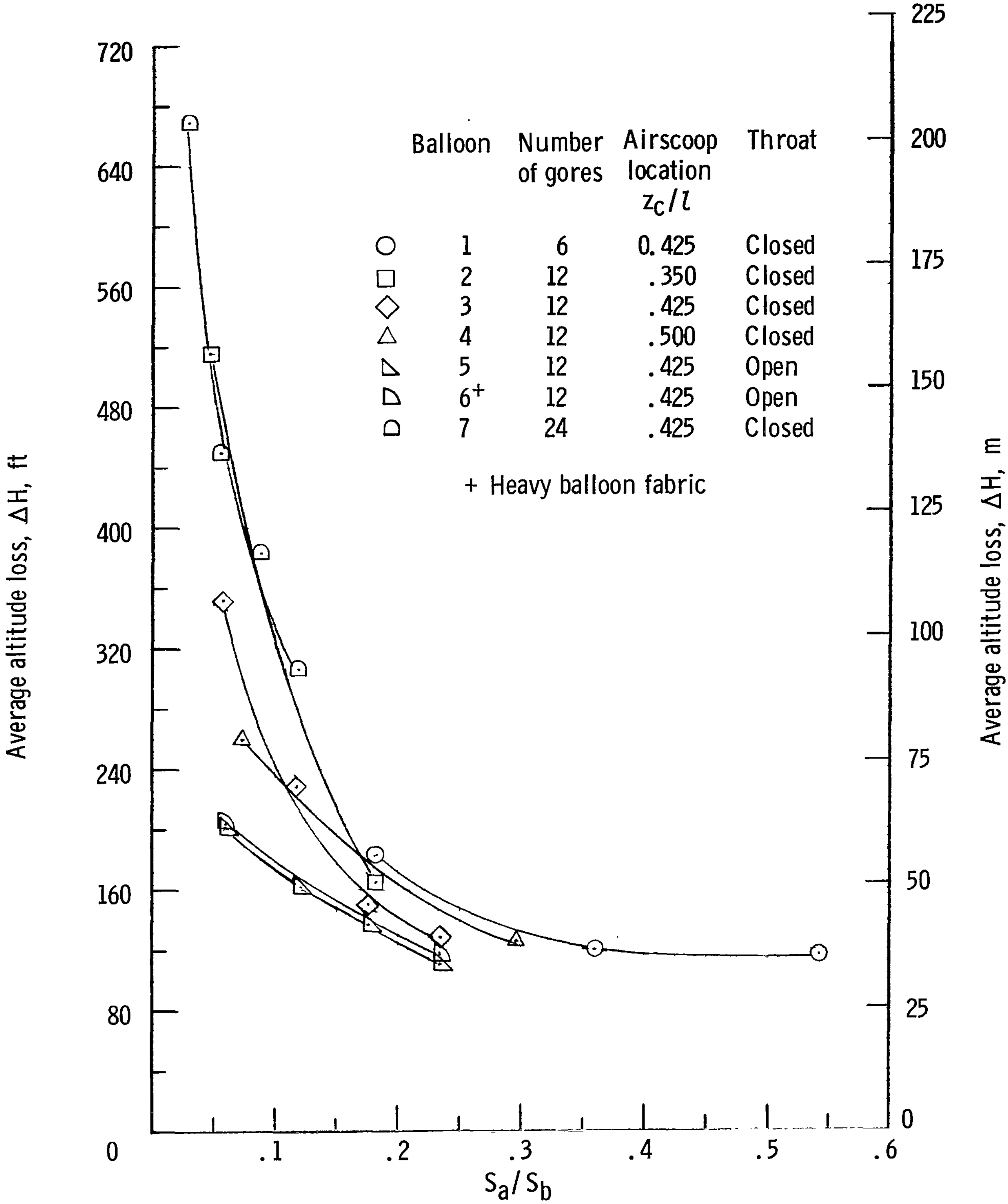


Figure 8.- Variation of balloon average altitude loss with ratio of open airscoop area to maximum cross-sectional area of balloon.

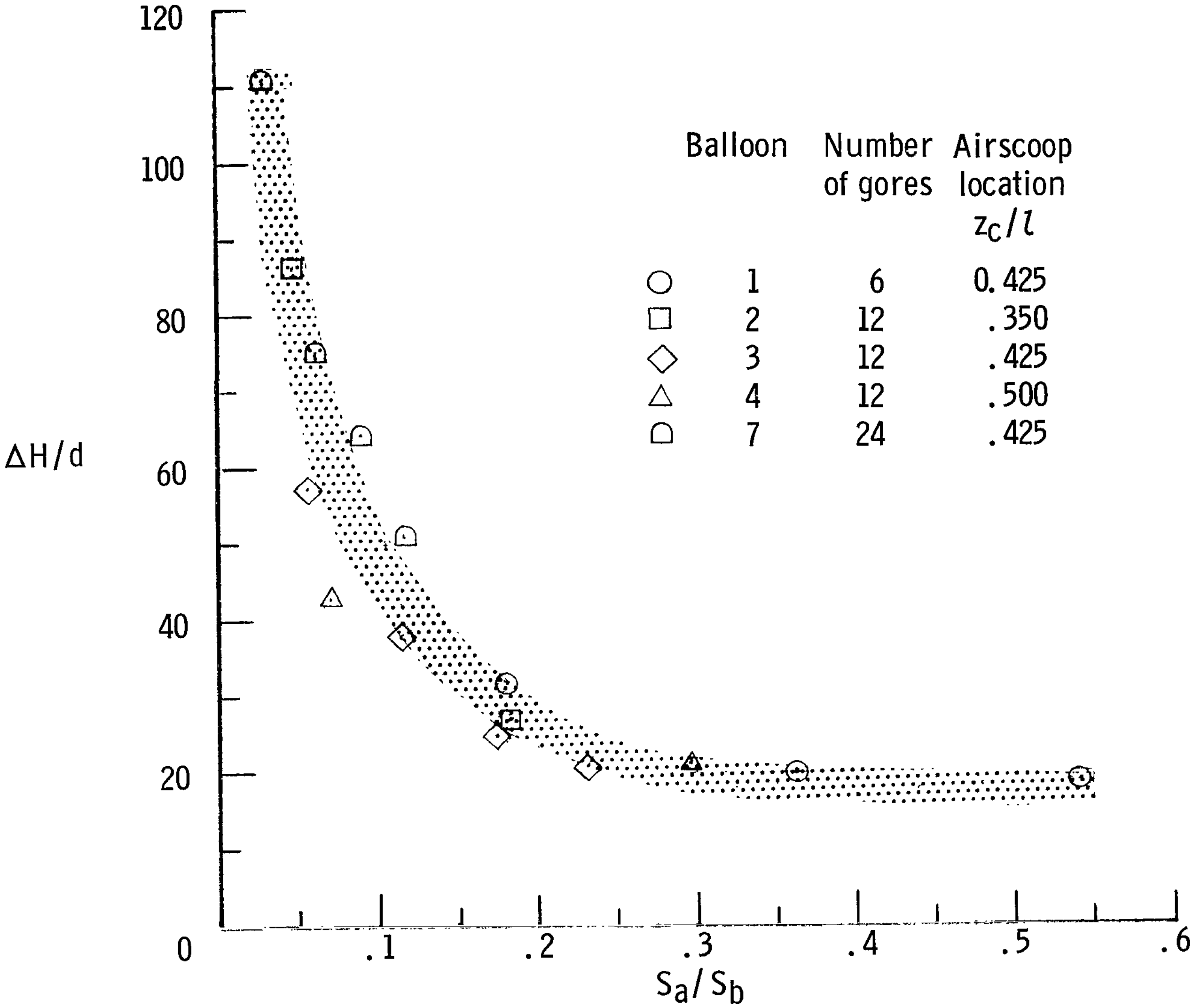


Figure 9.- Variation of balloon average altitude loss (hatched area) with open airscoop area. These quantities have been nondimensionalized by using the balloon diameter and the maximum cross-sectional area of balloon. Closed-throat balloons.

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