FACILITY FORM 602

N65-35210 (ACCESSION NUMBER) | (THRU)

23 (PAGES) | 1 (CODE)

TMX-54625 (NASA CR OR TMX OR AD NUMBER) | 01 (CATEGORY)

(NASA TMX-54625)

SELF-INDUCED BALLOON MOTIONS AND THEIR EFFECTS ON WIND DATA

By Harold N. Murrow and Robert M. Henry [1964] 23p refs

NASA Langley Research Center
Langley Station, Hampton, Va.

Presented at the
AMS Fifth Conference on Applied Meteorology; Atmospheric Problems of Aerospace Vehicles

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

Atlantic City, New Jersey
March 2-6, 1964

[redacted] Only.

SELF-INDUCED BALLOON MOTIONS AND THEIR EFFECTS ON WIND DATA

By Harold N. Murrow* and Robert M. Henry*
NASA Langley Research Center

ABSTRACT

Examples of self-induced motions of spherical balloons ascending in still air inside a large hanger are shown and discussed. Analogies with self-induced motions of other types of spheres such as bullets and balls are considered. The effect of these self-induced motions on wind measurements derived from balloon tracking is described. Finally, some approaches to the reduction or elimination of the self-induced motions are indicated, and results of some preliminary tests of modified balloons are discussed.

INTRODUCTION

The importance of horizontal winds on vertically rising vehicles has long been recognized. Several techniques have been investigated for sampling in detail the fluctuations in horizontal wind velocities encountered by missiles in near vertical flight through the atmosphere. Two promising techniques for measuring small-scale fluctuations are the smoke-trail technique (ref. 1) and the tracking of lightweight spherical balloons with precision radar (ref. 2). Data have been published giving detailed wind profiles derived from samplings by using both smoke trails and lightweight spherical balloons as wind sensors. On a few occasions comparisons have been made in data obtained from these two techniques (ref. 3). An example is shown in figure 1. From such comparisons it is evident that data obtained from precision radar tracking of the spherical balloons show much greater high-frequency wind fluctuations than do data from the smoke-trail technique.

It was of concern to Langley Research Center personnel that these high-frequency fluctuations on the balloon-measured profile were inconsistent with any previous samplings of atmospheric wind structure and that apparently the spherical balloon data were contaminated. Wake interactions and vortex shedding by blunt bodies are well-known phenomena in fluid flow, and a review of the literature divulged much interesting information, including observations that spheres moving through fluids experienced noticeable deviations from the path they would be expected to follow if only the known external disturbances were affecting motion (refs. 4 and 5). Baseball fans are familiar with knuckle-ball effects; it is probably not so commonly known that early golfers who used smooth golf balls noticed that their drives went further and straighter if the balls were old and battered, with a roughened surface. Other interesting data have shown that the standard, flexible neoprene balloons that are used routinely to

*Aerospace Engineer, Atmospheric Inputs Section, Dynamic Loads Division.

[redacted]

carry radiosonde instruments aloft experienced significant deviations from the vertical when released in still air (ref. 6). The reason for these erratic motions has not been completely explained, but it is possible that they are associated with some type of vortex shedding. They have also been attributed to distortions of the balloon shape.

The latter results for balloons were determined from release in the large dirigible hangar at Lakehurst, New Jersey, in 1958. It seemed desirable to conduct a similar series of tests in the Lakehurst hangar with standard operational Mylar spherical balloons to determine the magnitude of deviations that would occur in the absence of wind and to what extent these deviations would affect the wind measurements obtained by radar tracking of the balloons. Arrangements were made with the U.S. Army Electronics Command at Belmar, New Jersey, for assistance and the tests were conducted jointly by NASA Langley Research Center and the U.S. Army Electronics Command during the week of April 22, 1963. Representatives from NASA Marshall Space Flight Center and Air Force Cambridge Research Laboratories were present as observers. It is the purpose of this paper to present the principal results of the 1963 tests in the Lakehurst hangar.

DESCRIPTION OF THE EXPERIMENT

Observing the ascent of balloons with essentially no external excitation requires access to a volume of undisturbed air of (1) sufficient height that the rising balloons will possess their terminal velocity for a sufficient length of time for observation and (2) of sufficient horizontal dimensions to avoid interaction of the balloon and the walls.

The Lakehurst Hangar

For the tests discussed herein, arrangements were made with the U.S. Navy to use Hangar Number One at the Lakehurst, New Jersey, Naval Air Station. This large hangar, shown in figure 2, is 220 feet high, 800 feet long, and 265 feet wide, allowing about 180 feet of ascent at terminal velocity with negligible disturbance by wall effects. It also provides ample space for tracking apparatus.

Detection and Measurement of Winds

Merely being "indoors" does not assure negligible air motions. Not only is there movement of air through cracks around doors and windows, but also appreciable thermally induced circulations develop within the hangar itself, especially near sunrise and sunset. (There have been reports of "rain" inside the hangar.) In order to be certain that no appreciable air currents were present at any level, nylon cords with 1/4-mil Mylar streamers attached every 8 feet were suspended from floor to ceiling near the test area. Since these streamers fluttered violently at wind speed well below 1 fps, one streamer at each location was weighted with a small strip of masking tape to reduce its sensitivity. In addition to these detection devices, measurements of wind velocity were made near the floor with a Thornthwaite anemometer, and at higher levels by noting the drift of small constant level balloons. During all of the test runs wind speeds were less than 3 feet per second at all levels, and, except for a thin layer near the floor, less than 1 foot per second below the height where the balloons reached terminal velocity. During most runs the unweighted tassels hung limp at all levels, indicating wind speeds well below 1 foot per second.

Tracking Equipment

Phototheodolites and plate cameras 8 inches by 10 inches were located as indicated in figure 3. In addition, when lighting permitted, time exposures were made with a Polaroid Camera for the immediate guidance of the experimenters.

The phototheodolites were the same instruments used in the previous Lakehurst tests (ref. 6) but were modified by installation of a wider-angle lens, to help keep the balloon in the field of view at the close range involved, and by attaching a spotlight to the theodolite lens barrel to produce a small bright spot in the center of the metalized spherical balloons to facilitate precise measurements.

A single timing circuit provided pulses at 1/4-second intervals to operate a solenoid balloon release and the shutters of both the phototheodolites and the plate cameras. A stepping relay was incorporated into the plate camera circuit so that the shutters were open for the first 1/4 second of each 1/2 second, and closed the latter 1/4 second. This exposure sequence produces a series of streaks whose length is proportional to the average speed of the balloon during the 1/4-second interval.

Temperature and Pressure Measurements

Temperatures near the floor were measured with a mercury thermometer, and six thermocouples were spaced along a wire from the floor to the catwalk to provide a measure of the temperature lapse rate.

Hourly pressure measurements are available from the Weather Station at the Lakehurst Naval Air Station. However, because of the small variation of pressure and temperature in percent, these variations were not considered in the computation of Reynolds numbers.

Types of Balloons Tested

A variety of balloon types were included in the tests. A description of the balloons is given in table 1 and some of the balloons are shown in figure 4. On the left of figure 4 is a standard 2-meter Mylar sphere which was taken from a lot procured for routine releases at Cape Kennedy. The next balloon shown is a standard balloon modified by the addition of strips of 1/8-inch by 3/8-inch polyurethane tape to form 80 equal triangles. These triangles were formed by subdividing each of the 20 equilateral triangles of a regular icosahedron pattern into 4 smaller triangles.

The third balloon shown is a 2-meter sphere fabricated from Mylar film laminated with a 1/4-inch by 3/8-inch mesh of Dacron scrim. This balloon also differs from standard production items in that no relief valves were installed.

The next balloon in the photograph is a standard ROBIN and is one of several specially prepared 1-meter Mylar spheres and the last balloon shown in the figure is a streamlined Mylar balloon.

Several other modified balloons were prepared for the tests, including 6-inch and 12-inch square mesh patterns of 1/16- and 1/8-inch-diameter string applied to 1-meter and 2-meter Mylar spheres. Also, several balloons were modified during the tests by the addition of balsa wood and cardboard vanes having widths of 3 inches to 20 inches and projecting 5 inches from the equator.

In addition to the rigid plastic balloons several elastic neoprene balloons were tested. The ML-391 radiosonde balloon was included for replication of the earlier tests, and the currently used ML-518A radiosonde balloons and large- and small-size chaff-coated pilot balloons were also tested.

Balloon Release and Recovery

Because balloons released in free flight were severely damaged by impact with the girders supporting the roof, and because recovery of loose ballons was difficult, it was necessary to attach a recovery line to balloons which were to be used again. For this purpose a lightweight 20-pound test nylon fishing line with a 2-foot length of 1/2-inch surgical rubber tubing was used at the lower end to act as a shock absorber. The line was carefully laid out in a zigzag pattern on a clear area of the floor to avoid tangling during balloon ascent.

During the course of the tests several unrestrained releases were made - some planned and some unplanned - including at least one free flight of each balloon type tested. There was no apparent difference in the behavior of the completely unrestrained balloons and those with the light recovery line attached.

In several cases, balloons were dropped from the catwalk. No restraining cord was attached to the dropped balloons. An attempt was made to catch the balloons before impact with the floor, but because of the unpredictable motion of the balloons the attempt was often unsuccessful.

Test Procedure

The nearly inflated balloon to be tested was fastened to the solenoid release device, and an additional safety cord was attached. The balloon was then "topped off" with the inflation gas. Various mixtures of air, helium, and freon were used to provide a range of Reynolds number from about 4×10^5 to 10^6.

The free lift (positive or negative) was measured, then the safety cord was released and the timer started. The first timing pulse operated the solenoid release and the camera and phototheodolite shutters.

TEST RESULTS

Rubber Balloons

For the purpose of replication of previous experiments (refs. 4 and 6) several rubber balloons were tested. This replication was considered to be particularly desirable in order that, if differences were found between behavior of the rigid plastic spheres and the elastic rubber balloons, the differences could be attributed to the effects of the rigid spherical shape, rather than to possible differences in experimental techniques.

Balloon A (table 1) was identical to the radiosonde balloons in the tests of reference 6, balloons B and C were currently used radiosonde balloons, and balloon D was a chaff-coated neoprene pilot balloon, such as is used with radar tracking for "wind-weighting" of unguided rockets launched at Wallops Island. The behavior of these balloons was similar to that observed in the earlier tests.

Rigid Plastic Spheres

One of the recent developments in fine-scale wind measurements is a spherical plastic balloon whose spherical shape is maintained by a small pressure differential between the contained lift gas and the ambient atmosphere. This pressure differential is controlled by a pair of spring-loaded relief valves. This type of balloon has been given the name ROSE by its developers at the Air Force Cambridge Research Laboratories.

The primary purpose of this experiment was to determine to what degree rigid spherical balloons would exhibit self-induced motions similar to those shown by the deformable rubber balloons previously tested in the absence of air currents.

Balloons E, F, and G were unmodified spherical plastic balloons, and balloon H was modified by the addition of an empirically determined counterweight opposite the filler valve. The behavior of all of these balloons was similar, and is typified by balloon G, which was released with varying mixtures of air and helium to provide a range of free lift values as indicated in table 2. Figure 5 shows a "chopped" photograph of one ascent of this balloon. As has been noted previously, the shutter was opened for the first 1/4 second of each 1/2-second interval, so the length of each segment corresponds to the average speed over a 1/4-second interval.

Figure 6 illustrates the motion of the balloon during another ascent. During this ascent, the balloon experienced a maximum displacement in the arbitrarily designated X-direction of 26 feet at a height of 95 feet. Over the portion of the ascent between 15 and 95 feet the displacement in the X-direction is 27 feet, yielding an average velocity component of about 8.3 ft/sec. The root-mean-square velocity components computed from 1/4-second averaged winds are 10.19 feet per second in the X-direction and 4.49 feet per second in the Y-direction.

Since the trajectory of the balloon does not necessarily lie in any specific plane, it is of interest to examine X-Y plots. Figure 7 shows the X-Y plots of the six flights of this particular balloon. These plots show, first of all, that while the trajectories of some flights lie approximately in a plane, others very definitely do not, and second, there is no apparent tendency for repetition of the pattern, although great care was taken to make the release conditions as nearly identical as possible.

A reduction in the displacement of the balloon with smaller values of free lift might have been expected. However, no reduction is observed in figure 7. The effect of varying the free lift can be seen more clearly in figure 8. Here the root-mean-square velocity is plotted as a function of the terminal velocity of the balloon. It is apparent that the rms horizontal velocity is an approximately linear function of the (vertical) terminal velocity over the range covered by this experiment.

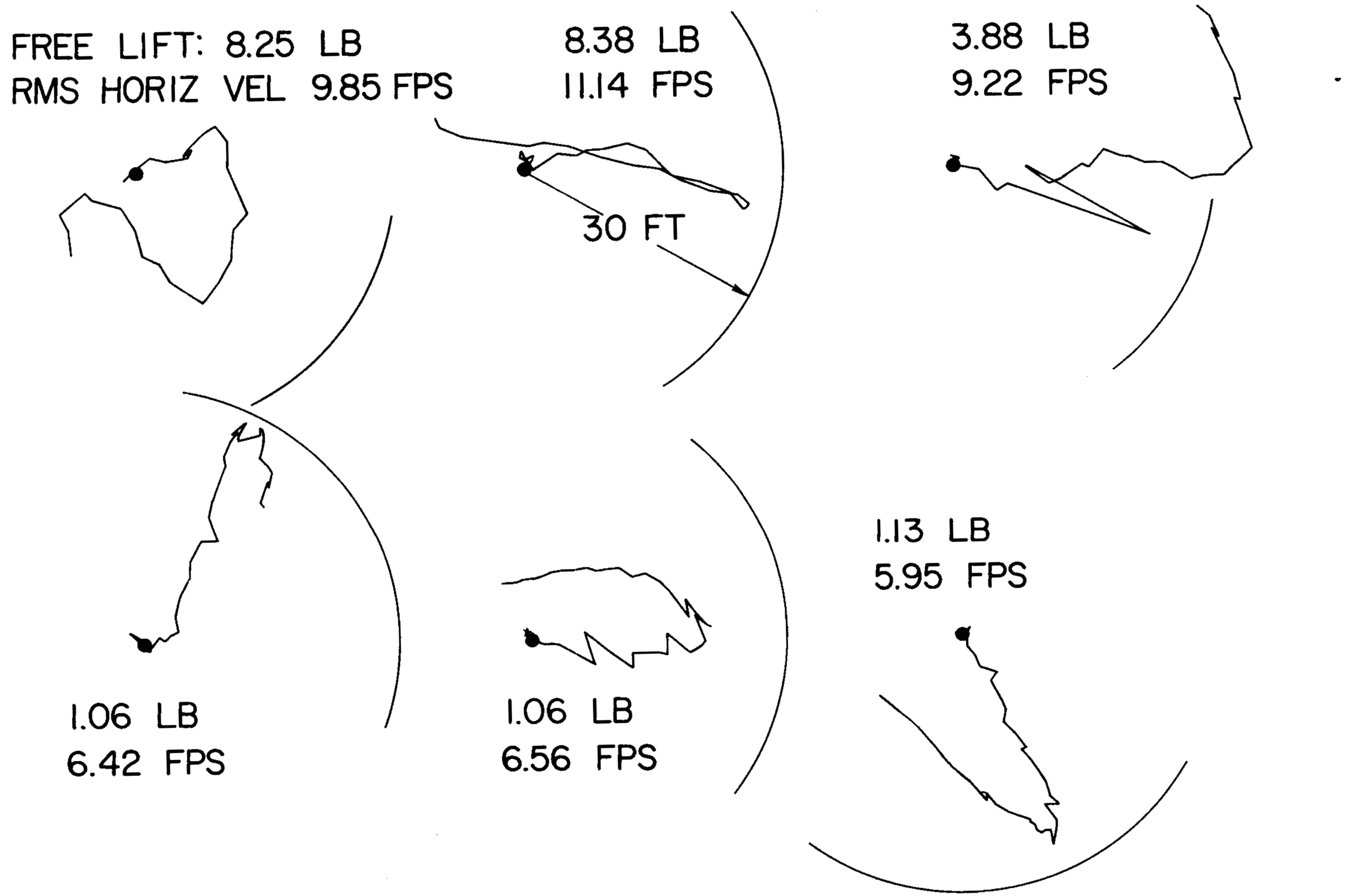
The other smooth balloons, including the balloon with the added balance weight (H) and the smooth ROBIN (I and J) behaved in the same fashion as the balloon just discussed.

Experimental Balloons

Since it was not entirely unexpected that spherical balloons might exhibit self-induced motions, some modifications which might alleviate the unwanted fluctuations were included in the test plans. The modifications included aerodynamic roughening of the surface of some spheres, and use of a streamlined shape.

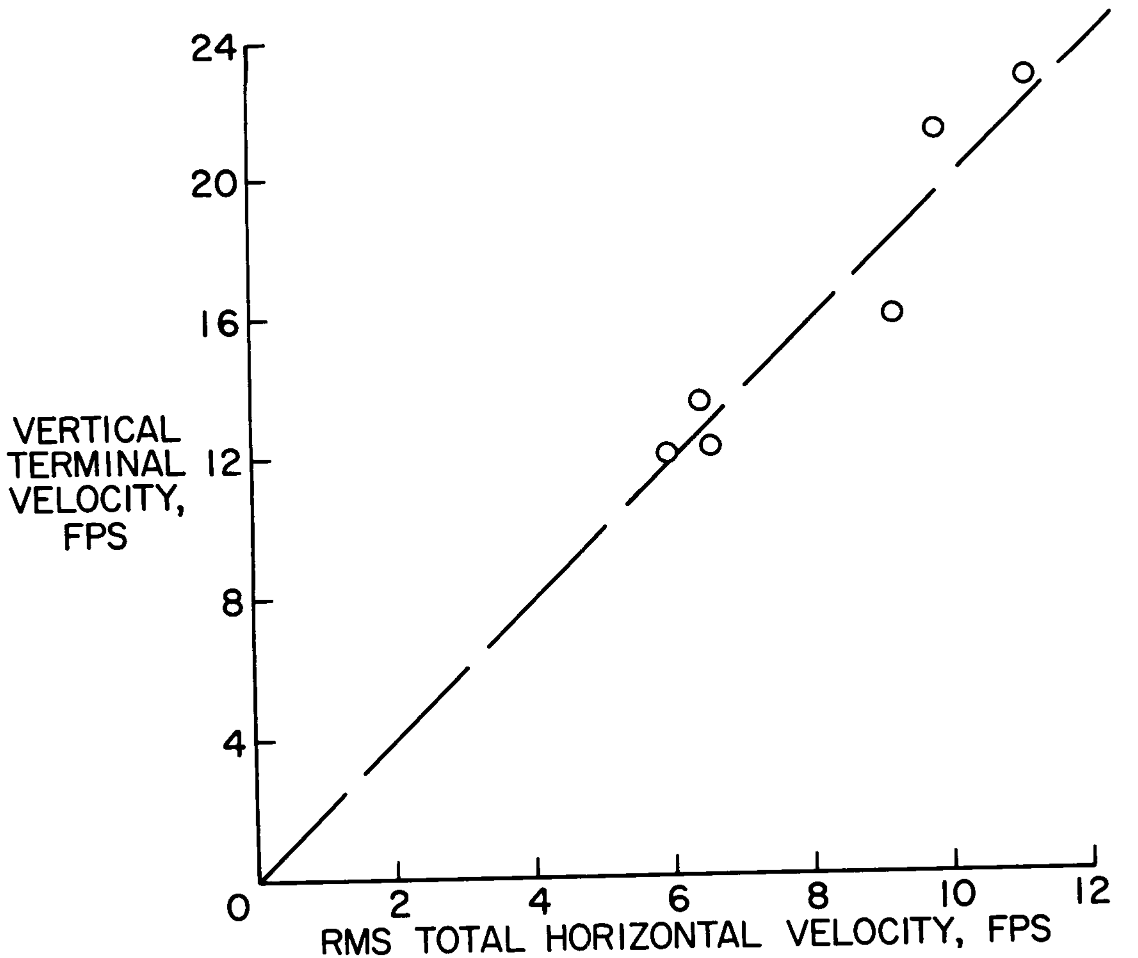
Slightly roughened balloons.- The roughening of the prepared balloons was designed only to trigger transition from laminar to turbulent flow in the boundary layer. For this reason only small projections were used, varying from about one-hundredth of an inch on balloon K to one-eighth of an inch on balloons L, M, N, and O. On balloon M a counterweight was placed opposite the filler valve, and on balloon N a 1,000-gram weight was attached below the balloon for static stability. All of these slightly roughened balloons behaved in the same general manner as the smooth balloons.

Streamline shape.- The behavior of the streamline shape balloon P appeared to be qualitatively similar to that of the spheres. However, the motions of this asymmetric shape, with its apparently random translation and rotation, proved to be impossible to follow with the phototheodolites. When modified by the addition of a 500-gram weight held below the "tail" by an 18-inch strut, balloon Q, it rose quite steadily for about 100 feet but then oscillated



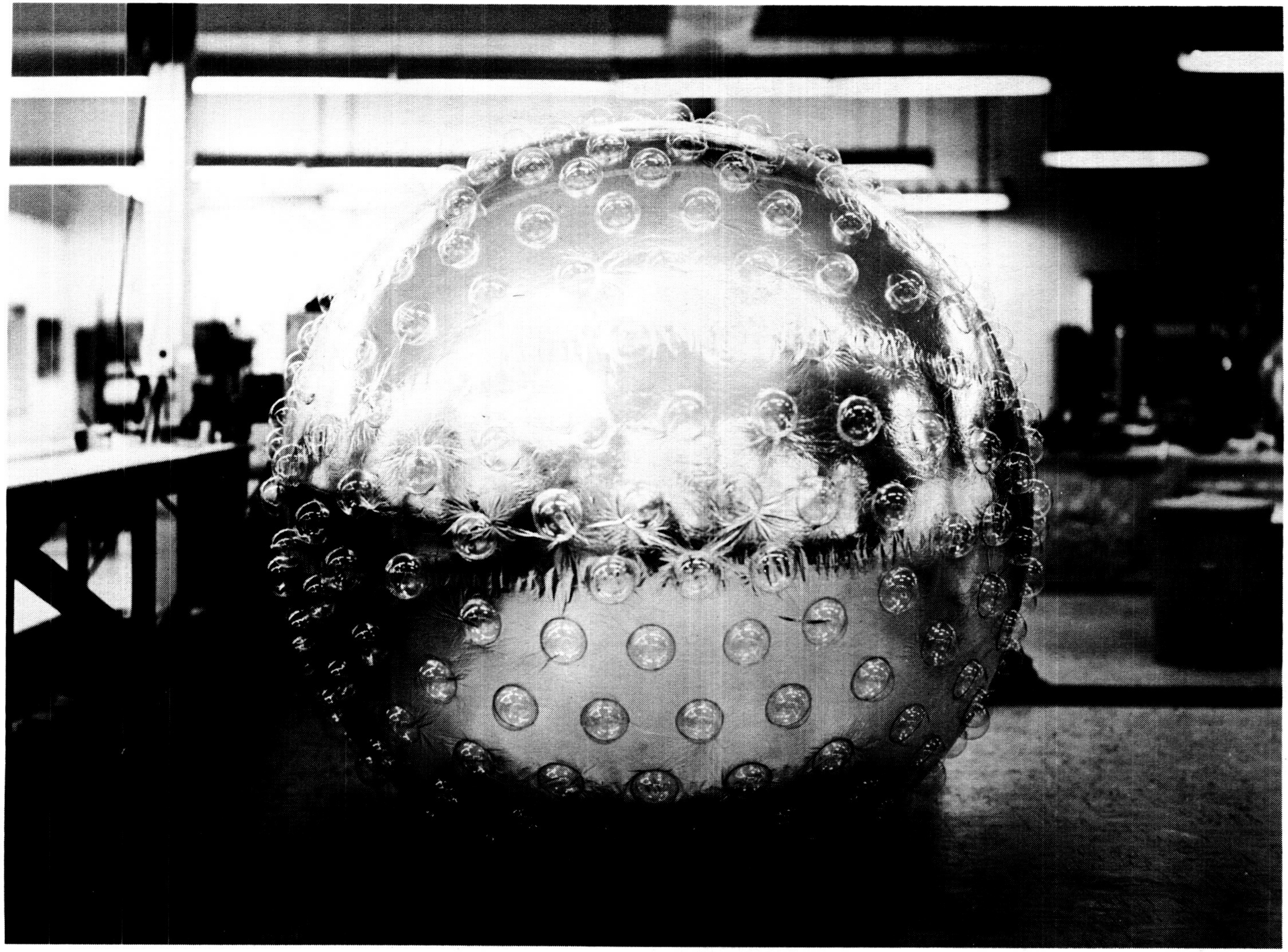
NASA

Figure 7.- Plan view of six balloon ascents. In runs 1 and 2, free lift was approximately 8.5 pounds, in run 3 free lift was approximately 3.5 pounds, in runs 4, 5, and 6 free lift was approximately 1 pound.



NASA

Figure 8.- Variation of rms horizontal velocity with ascent velocity.



NASA

Figure 9.- Photograph of "golfoon."

NASA-Langley, 1964

wildly. The free lift of the weighted streamlined balloon was very small (too small to measure accurately with equipment on hand) and the long initially smooth path may be related to the low acceleration.

Spheres with large roughness elements.- Since the prepared roughened spheres with roughness elements of up to 1/8-inch projection did not exhibit any significant reduction of the self-induced motions, a few balloons with 5-inch projections were prepared on site and tested. Observation of the ascents of balloons R and S with balsa vanes of 3-inch width suggested a reduction of fluctuations, and balloon T, with 20-inch-wide projections around the equator seemed to show a definite reduction (about 50 percent) in the amplitude and wavelength of fluctuations, although the fluctuations were certainly not eliminated.

IMPLICATIONS TO WIND DATA

Several implications of the test results as they concern the accuracy of wind data may be mentioned. It is evident that the self-induced balloon motions may produce a significant error in wind velocities derived from balloon tracking. This error is a function of the averaging interval used. Thus, the error produced by these self-induced motions in standard radiosonde wind data, averaged over a 2-minute, or approximately 2,000-foot, interval may be expected to be small compared to the other types of errors in these data. On the other hand, they will not be negligible in wind increments, or shear measurements, over a few hundred feet of altitude. From the experiment reported here, one can conclude only that the errors are significant for increments up to 200 feet. Later experiments conducted in open air at the NASA Marshall Space Flight Center suggest that the effects may continue up to increments of about 700 to 800 feet. Errors over the 200-foot increments will be of concern for many missile and space vehicle applications, for turbulence and diffusion studies, and for studies of small-scale wind variability.

POSSIBLE METHODS OF ALLEVIATION

Where the fine-scale variations of the wind are not important, the effects of self-induced motions can be removed by simple filtering, for example, the 2-minute time average filter used in radiosonde reduction. For reduction of errors in wind data where fine-scale fluctuations of the wind are important two approaches become obvious. One is simply to reduce the ascent rate of the balloon, by increasing either its weight or its drag. Of course this approach results in certain disadvantages, such as a longer time requirement for a given sounding, and the occurrence of low elevation angles, which in turn can produce large tracking errors. If the ascent rate is decreased by increasing the balloon mass, the error due to inertial lag of the balloon will also be increased (ref. 7).

Another approach is the attempted reduction of the instability of the balloon. The theory of these self-induced motions is still not well understood, but experience gained in other fields may be applicable. As examples, the spherical projectile has disappeared as ammunition for rifles, pistols, and cannon over the past hundred years, while the knuckle ball has come into prominence on the baseball diamond. An example of greater use in the present problem is the evaluation of the golf ball. In 1848, the smooth, solid gutta-percha ball was introduced to replace the feather-stuffed leather ball previously in use. Golfers soon discovered that old, scarred balls flew further and straighter than new, smooth balls, which tended to "bob" erratically in flight. By 1850 hand-hammered roughening patterns had appeared, and by 1907 both bumpy and dimpled balls were commercially available. At present the dimpled ball is virtually standard; however, wind-tunnel tests show that bumps and dimples are equally effective aerodynamically. The adaptation of the golf ball pattern to the balloon is shown in figure 6. This pattern, using 336 hemispheres in place of dimples, is the same as is used by the major golf ball manufacturers, and the diameter of the hemispheres has the same proportion to the sphere diameter as the dimple of the golf ball has to the ball diameter. The outward projection of the bumps is somewhat greater in proportion to the sphere diameter than the depth of the golf ball dimple.

Several of these "golfoon" or "raspberry" balloons were fabricated for Langley Research Center by the G. T. Scheldahl Co., and so far two of these have been flown at Wallops Island in conjunction with smoke-trail and smooth balloons. Unfortunately, technical difficulties prevented acquisition of high-resolution radar data for these flights. Further flights are scheduled, but all that can be said at present is that the visual observations of the golfoon ascents were encouraging, and that variations of ascent rate averaged over 10-second intervals were much smaller for the golfoon than for the smooth balloons.

CONCLUDING REMARKS

Tests under conditions of essentially zero wind velocity showed that rigid spherical balloons, as well as deformable rubber balloons exhibit random self-induced motions over the Reynolds number range encountered in atmospheric soundings.

The magnitude of these self-induced motions is directly proportional to the terminal velocity of the balloon.

These motions are of such magnitude and wave length as to produce significant errors in wind measurement of an altitude interval of a few hundred feet, but not over an increment of a thousand or more feet, such as is used in standard radiosonde data.

Addition of roughness elements of up to 1/8-inch projection had no apparent effect on the self-induced motions, but projections of 4 or 5 inches produced encouraging results.

Further research is needed in both the immediate practical problem of reducing the effects of these motions on fine-scale wind data, and in understanding the physical mechanisms producing the motions.

ACKNOWLEDGMENT

We wish to express our gratitude to Mr. William Barr and his associates, in particular Mr. George Day and Mr. Layton Clark, at the U.S. Army Electronics Command, Belmar, New Jersey, for making arrangements with the Navy at Lakehurst for conducting the tests; for providing and operating phototheodolite tracking equipment; and for reading the phototheodolite film data and tabulating elevation and azimuth angles. In addition, much helpful advice and assistance was provided by Mr. Wilmer H. Reed III of the NASA Langley Rsearch Center.

REFERENCES

1. Henry, Robert M., Brandon, George W., Tolefson, Harold B., and Lanford, Wade E.: The Smoke-Trail Method for Obtaining Detailed Measurements of the Vertical Wind Profile for Application to Missile Dynamic Response Problems. NASA TN D-976, 1961.

2. Leviton, R.: A Detailed Wind Profile Sounding Technique. Air Force Surveys in Geophysics, No. 140, Volume I, pp. 187-196, Geophysics Research Directorate, Bedford, Massachusetts, March 1952.

3. Scoggins, James R.: High Resolution Wind Measurement: A Launch Design Problem. Astronautics and Aerospace Engineering, April 1963, pp. 106-107.

4. Hirsch, P.: Motion of Spheres in Still Fluids. NACA Technical Memorandum No. 257, April 1924.

5. Shapiro, Ascher H.: Shape and Flow, the Fluid Dynamics of Drag, Figure 13. Doubleday and Company, Inc., 1961.

6. Killen, Gwendolyn L.: Balloon Behavior Experiments. USASRDL Technical Report 2093, January 15, 1960.

7. Reed, Wilmer H. III: Dynamic Response of Rising and Falling Balloon Wind Sensors With Application to Estimates of Wind Loads on Launch Vehicles. NASA TN D-1821, 1963.

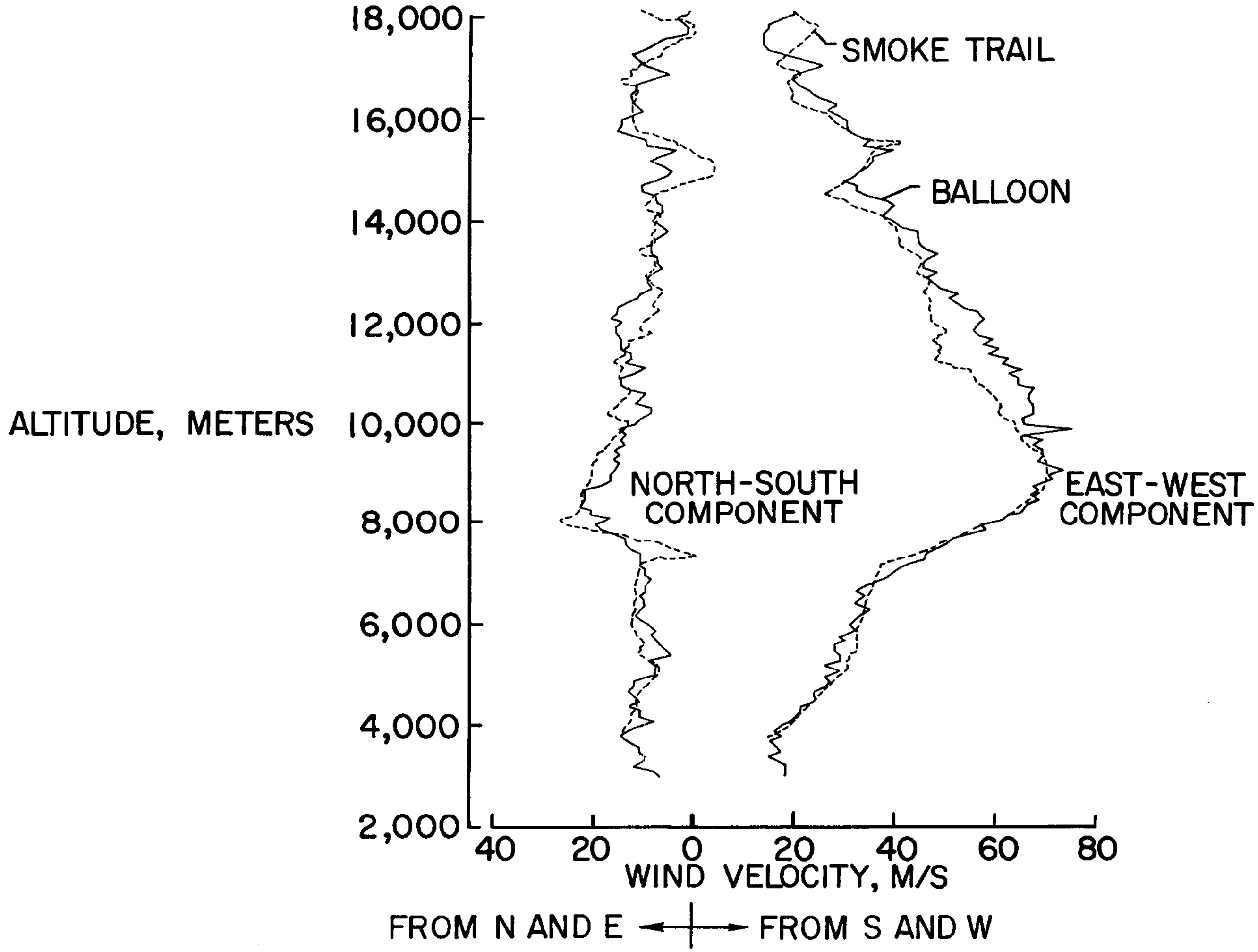
TABLE 1.- DESCRIPTION OF BALLOONS TESTED

A	Standard radiosonde balloon, type ML-391, with simulated radiosonde attached
B,C	Standard radiosonde balloon, type ML-518A, with simulated radiosonde attached
D	Standard 300-gram chaff-coated pilot balloon
E	Standard 2-meter Mylar spherical balloon taken from lot procured for routine release at Cape Kennedy, serial no. 203
F	Same, serial no. 378
G	Same, serial no. 379
H	Balloon F, with counterweight added opposite filler valve
I	Standard ROBIN 1-meter Mylar sphere
J	Standard ROBIN 1-meter Mylar sphere with inflation capsule removed
K	Specially fabricated 2-meter Mylar sphere with 1/4-inch × 3/8-inch mesh Dacron scrim laminated to Mylar
L	2-meter Mylar sphere, serial no. 377, with 80 triangle pattern (quadrisected icosahedron) of 1/8-inch × 3/8-inch polyurethane foam strips
M	Balloon L with counterweight opposite filler valve
N	Balloon L with 1,000-gram weight attached below balloon
O	1-meter Mylar sphere (ROBIN) without inflation capsule or corner reflector, and with 6-inch square mesh of 1/8-inch-diameter string
P	Streamlined Mylar balloon
Q	Balloon P with 500-gram weight attached to tail by 18-inch strut
R	Standard 2-meter sphere, serial no. 215, with six 3-inch × 5-inch projection balsa vanes incline at 45° angle spaced around equator
S	Same as R but with horizontal vanes
T	Same as R but with 20-inch × 5-inch projection horizontal vanes

TABLE 2.- DATA FROM SEVERAL BALLOON RUNS

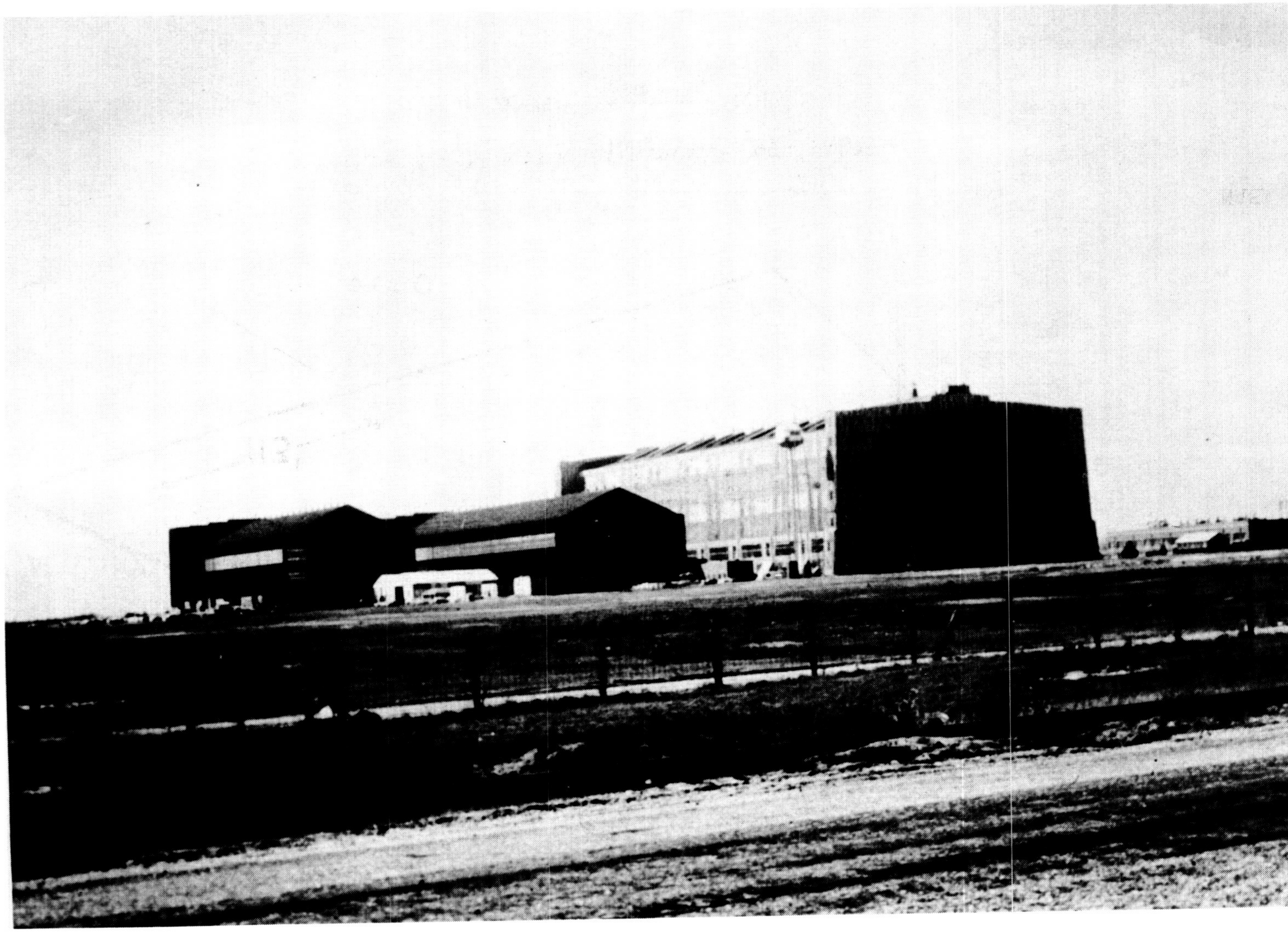
Balloon	Run number	Ascent or drop	Recovered or free	Balloon weight, lb	Free lift, lb	Terminal velocity, ft/sec	Rms X velocity, ft/sec	Rms Y velocity, ft/sec	Rms resultant velocity, ft/sec
A	1	A	R	5.65*	4.00	20.0	6.61	8.23	10.56
A	2	A	F	5.65*	4.00	18.0	8.58	6.22	10.60
C	2	A	F	6.3*	6.13	18.5	5.37	3.75	6.55
G	1	A	R	.66	8.25	22.0	5.86	7.92	9.85
G	2	A	R	.66	8.38	25.0	10.19	4.49	11.14
G	3	A	R	.66	3.88	20.0	5.81	7.16	9.22
G	4	A	R	.66	1.06	12.5	3.59	5.32	6.42
G	5	A	R	.66	1.06	12.5	4.76	4.51	6.56
G	6	A	F	.66	1.13	12.5	4.11	4.30	5.95
K	1	A	R	1.63	7.31	20.0	11.92	9.32	15.13
L	1	A	R	.85	7.94	20.0	6.07	7.15	9.38
L	2	D	F	.85	-2.13	-11.0	3.36	3.32	4.72
L	3	D	F	.85	-2.25	-10.0	3.21	4.01	5.14

*Includes weight of train suspended beneath balloon.



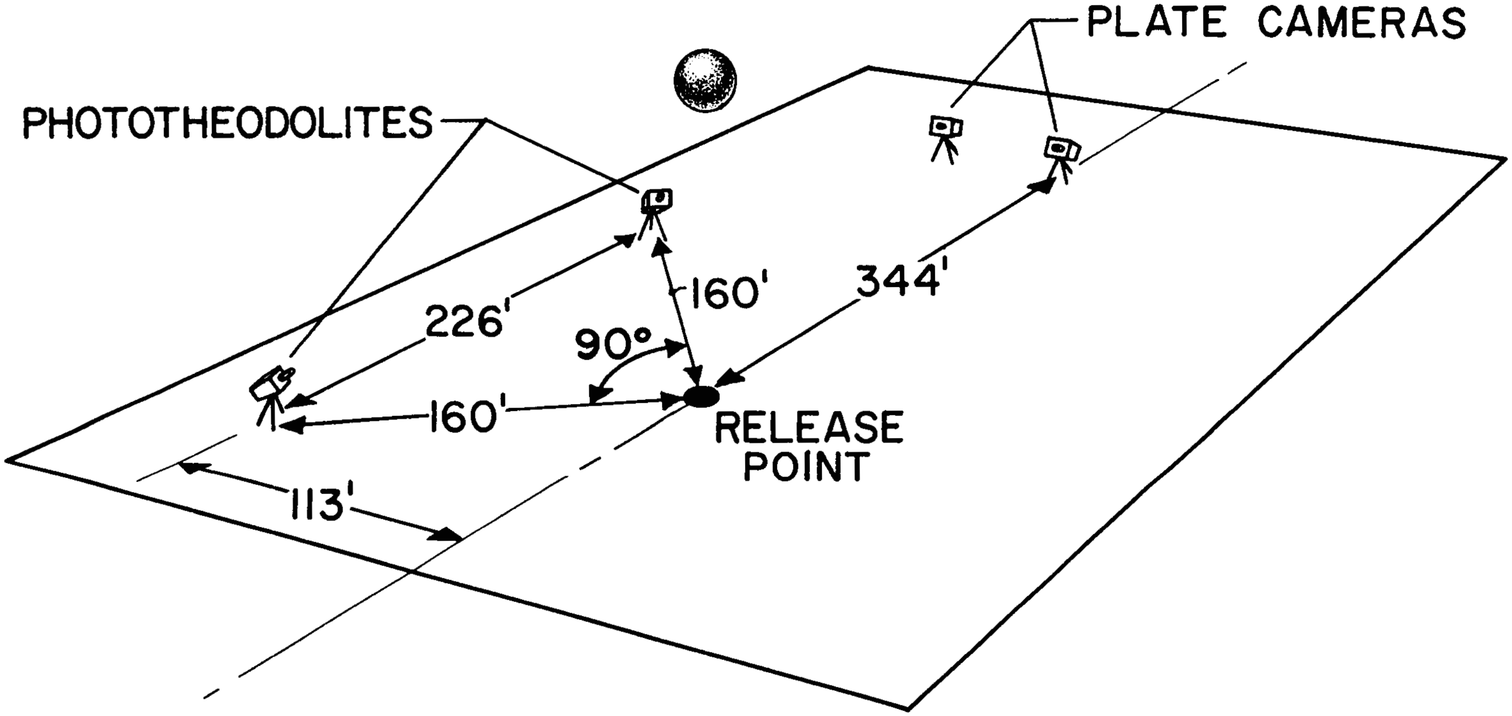
NASA

Figure 1.- Comparison of winds derived from 6-foot spherical balloon and smoke trail.



NASA

Figure 2.- Photograph of Lakehurst Hangar No. 1.



NASA

Figure 3.- Location of tracking equipment.

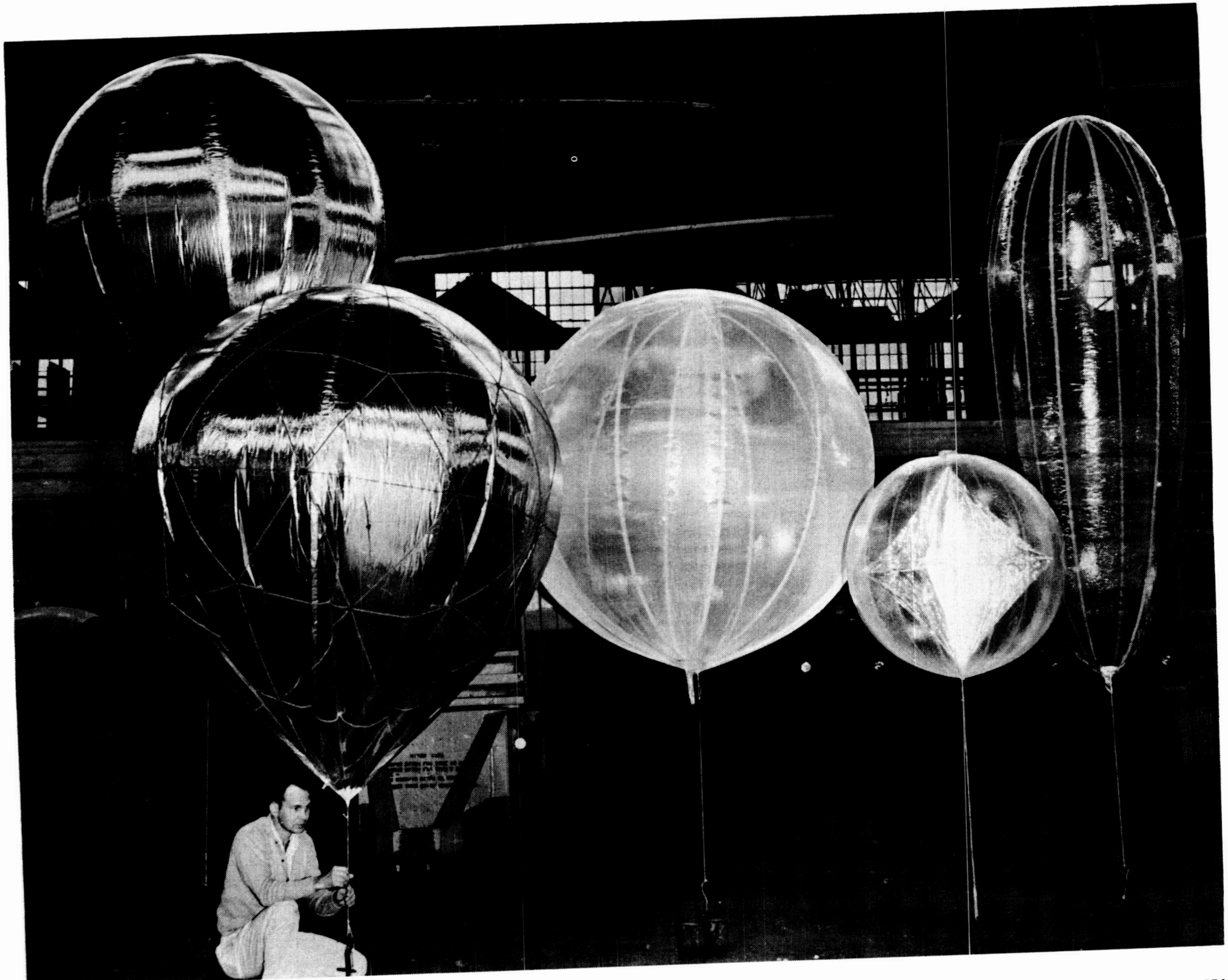
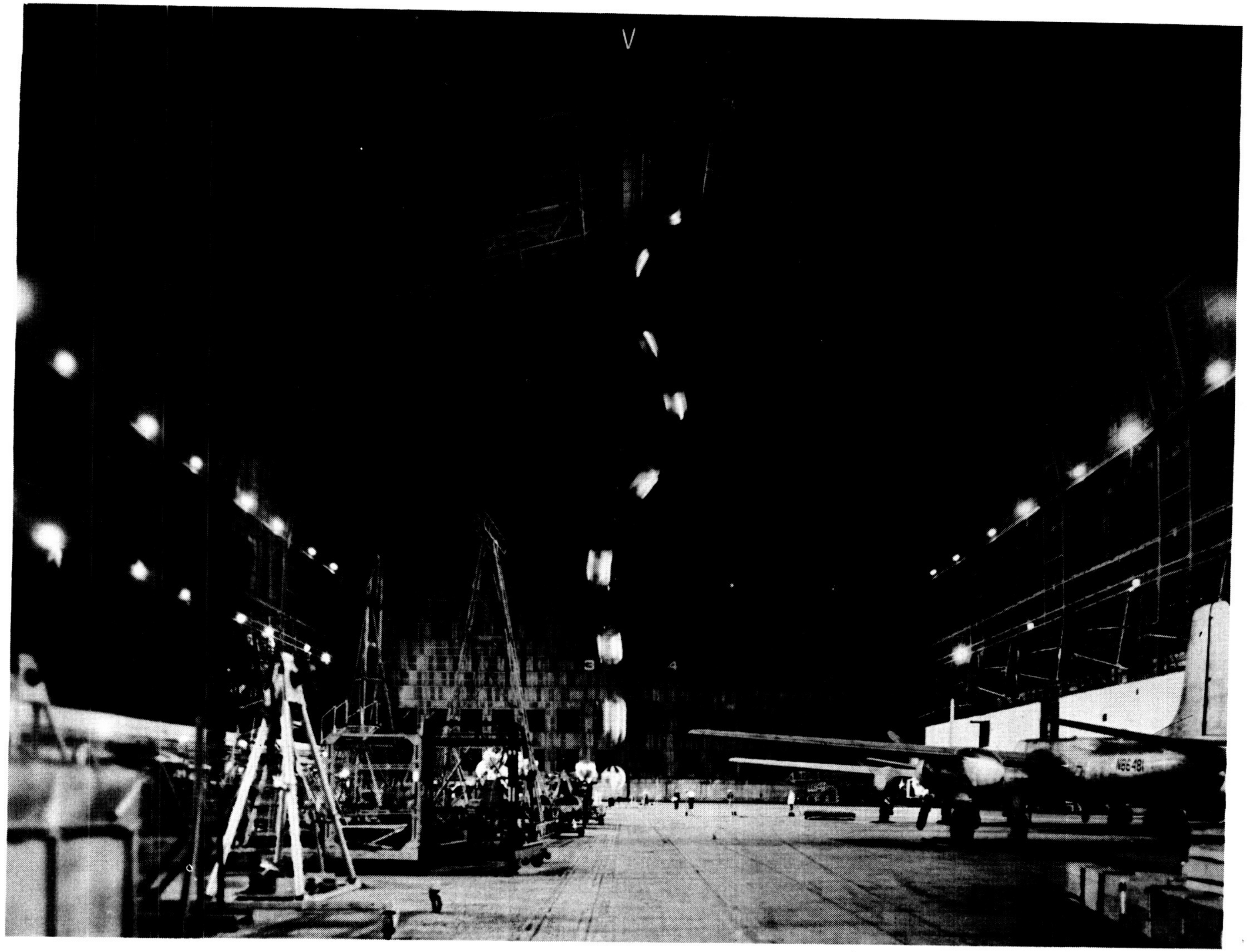


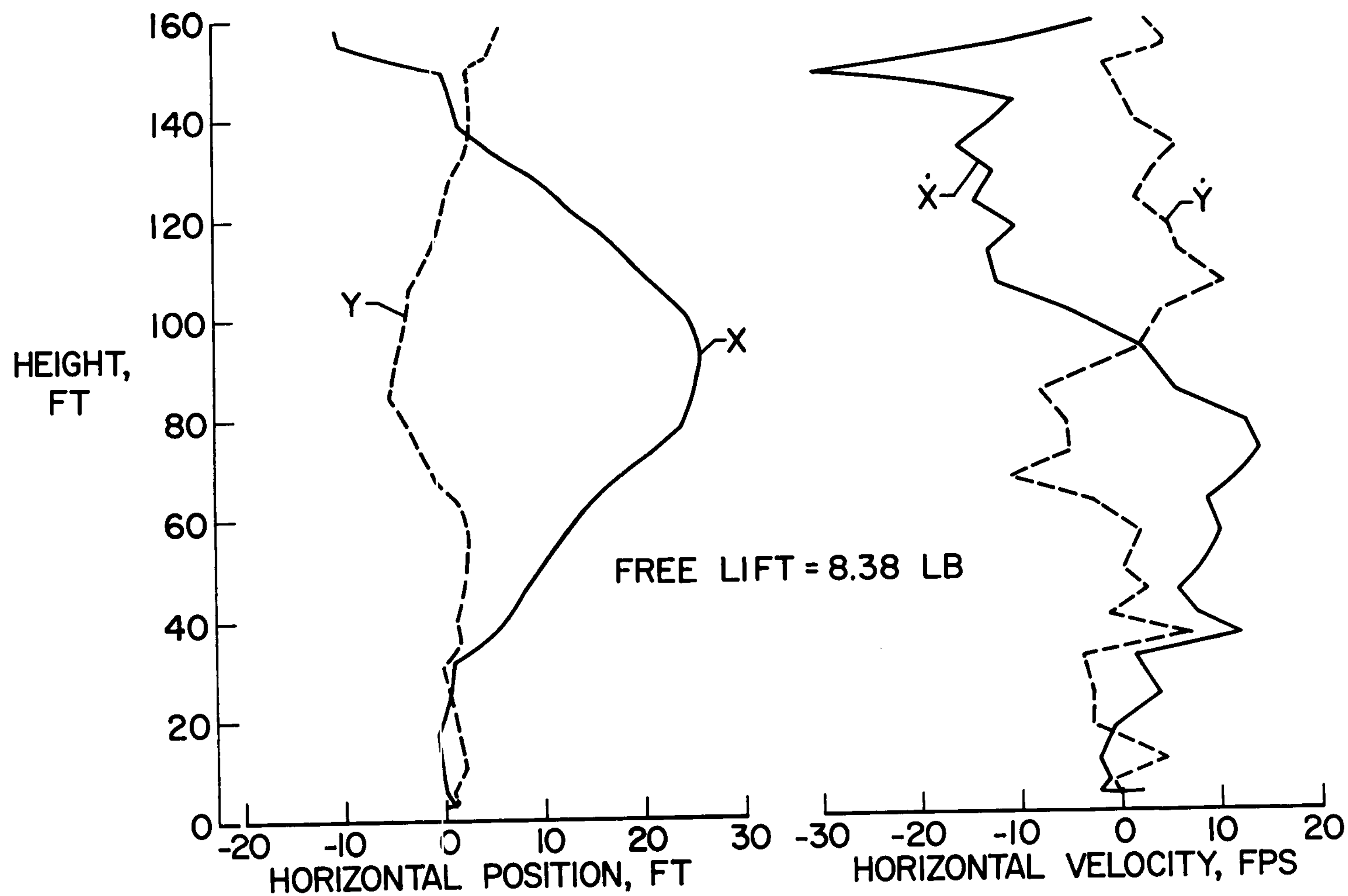
Figure 4.- Balloons being prepared for release.

NASA



NASA

Figure 5.- Intermittent 1/4-second exposure photograph of spherical balloon during ascent.



NASA

Figure 6.- Orthogonal components of balloon position and velocity.