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Status of Meteorological Sounding Balloons

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Abstract

The current status of the various types of balloons used in meteorological sounding operations is discussed. Balloons include the expansible neoprene kind used for standard radiosonde flights, as well as the rocket-ejected ROBIN falling sphere and the ROSE rising rigid sphere. Recent advances in the design and performance of these balloons are described along with problem areas for future consideration.

1. INTRODUCTION

In assessing the status of meteorological sounding balloons this paper will be concerned with balloons quite a bit different in nature than most of those that will be under discussion at this Symposium. Meteorological balloons include, of course, the expansible neoprene type normally used by Air Force, Weather Bureau and other agencies in routine sounding operations, and in addition some special purpose plastic types also used for meteorological observations. In the latter category are the rocket-ejected ROBIN falling sphere and the ROSE rising rigid sphere.

1.1 Radiosonde

Almost everyone is familiar with the standard balloon-borne radiosonde technique of sounding the atmosphere. The radiosonde carried aloft by a balloon from which it is separated by about 100 ft. of cord telemeters to a ground receiving station information on various thermodynamic parameters of the atmosphere. Its space position as determined by the ground tracking equipment permits calculation of wind data. Although improvements are continually being made in both the ground and airborne equipments the major problem as far as consistency of performance and adequacy of the data-gathering is the balloon carrier. Thus a comprehensive balloon

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research and development program is being carried on to improve balloon performance. Practically all of this type of balloon work in the United States is funded by Air Force Cambridge Research Laboratories and the Army's Meteorological Division at Ft. Monmouth, N. J.

The seemingly simple weather balloon is in fact a rather complex fabrication. In addition to the basic neoprene latex, a balloon film contains such materials as plasticizers, accelerators, anti-ozonants, anti-oxidants and reinforcing agents, to name some of them. The film must have elongation, modulus and tensile strength characteristics to achieve the desired height and rate of rise requirements and to permit inflation and launching handling and wind buffeting without damage. Since there is usually a long time lapse between the fabrication of a balloon and its actual flight, the film must have an adequate aging capability. It must perform in weather extremes of temperature, precipitation and winds. And with all this it must be low-cost.

A film study contract during the past few years with the Kaysam Corporation of America by the Army has endeavored to investigate many of the areas mentioned previously. Without doubt this program has been very productive. As an example one of its results has been the currently standard ML-537 balloon, a relatively small 800 gm balloon capable of reaching 100, 000 ft. in height at a minimum rate of rise of 1000 ft. /min. both at night and during the day. The ML-537 represents a 10-20, 000 ft. height improvement over the separate day and night balloons it replaced. It also has a specified 80% reliability, as compared to the previously required 60%. The cost of this balloon in procurement is in the order of $7-$8.

Recent advances in the balloon study program indicate that an operational balloon capable of rising consistently to about 125, 000 ft. is not too far off. This should be only a little larger and slightly more costly than the ML-537. We believe that considerable progress will continue to be made beyond that. Meteorological balloons have already been flown to 150, 000 ft. on several occasions, although admittedly they have been of a fairly large size and consistent performance has not been possible.

As has been pointed out, progress in meteorological balloons is in general very satisfactory. However there are also some definite problem areas with which we are concerned. The foremost of these is the cold temperature effect on a balloon film. This problem exists in the tropics, where the extremely cold tropopause temperatures, as low as -90°C, often cause freezing of the film during nighttime flights. Solar heating of course, prevents this freezing occurrence in the daytime. Special purpose tropical balloons are now being used to penetrate the cold tropopause layer. However these balloons, because of the extra plasticizer required for freeze resistance, are fairly soft and easily damaged. Another cold temperature problem is found in wintertime arctic flights. Here the temperatures are not as extreme as the tropical minima, but the consistent cold throughout the duration of the flight tends to deteriorate balloon performance. One of the major goals in our current R&D program is to try to overcome these cold temperature effects.

1.2 Fast-Rise Balloon

Another balloon effort which continues to be somewhat of a problem is the development of a satisfactory 100,000 ft. fast-rise balloon. The requirement for a fast-rise balloon is two-fold: (1) It will cut down the time needed to make a flight (it takes about an hour and a half at the present time with the standard balloon), and (2) It will permit more accurate and complete data to be received from radiosondes launched when strong jet stream wind conditions exist, resulting in very low tracking angles. Low elevation angles could mean distorted transmitting signals because of ground reflections and also data deterioration because of the trigonometric nature of the data reduction technique used.

Several configurations have been investigated for a possible optimum fast-rising balloon. These included a thick walled spherical balloon and a two-piece streamlined or tear-drop type. The current design being investigated utilizes the principle of one balloon inside another, with an attached tail for streamlining purposes. The inner balloon is a 2000 gm size, with the outer one somewhat smaller and designed to break and drop off at 50,000 ft. The inner balloon then continues on essentially as a sphere. Preliminary results with this balloon look encouraging. Design criteria are day and night performance to at least 100,000 ft. with a minimum ascension rate of 1700 ft./min.

Before leaving the expansible balloon discussion it might be of interest to mention that at least three efforts have been made in recent years to design plastic balloons as radiosonde carriers. Unfortunately, none of these programs came even close to success with respect to height or rate of rise performance. In any case it does appear that cost-wise the use of a plastic operational balloon at this time is prohibitive. Perhaps in the not too distant future, materials and techniques will be available to produce a reliable and low cost plastic sounding balloon.

1.3 ROBIN System

With Air Force requirements now existing for obtaining meteorological information far above the capability of the balloon-radiosonde system, in particular for support of the missile program, AFCRL has become deeply involved in the development of meteorological rocket systems. One of the payloads developed which has proved to be highly successful is the ROBIN sphere. The ROBIN is carried aloft in a deflated form by the rocket (the ARCAS and LOKI-DART are the two types of meteorological rockets currently being used). Ejected at apogee - somewhat above

200, 000 ft. - the sphere is inflated to a superpressure of 10 to 12 mbs by the vaporization of 35 cc of isopentane liquid contained in a capsule within. As it falls the one meter diameter, half-mil mylar ROBIN, weighing about 100 gms, is tracked by ground radar. Accurate space-time data permit the calculation of wind, density, temperature and pressure as a function of height through use of the basic equations of motion, gas laws and hydrostatic relationship. The sphere has a built-in metallized mylar corner reflector for radar tracking although a simpler metallized skin has also been successfully flown.

This rather radical technique for atmospheric sensing is currently being standardized for Air Force operational use. It is also being used to obtain high altitude meteorological data by the Navy and NASA. When tracked by an extremely high precision radar such as the C-band AN/FPS-16 wind accuracies of the order of a few knots and density accuracies of about 2 to 3% are obtainable. Temperature and pressure data, also computed from the ROBIN flight, are somewhat less accurate than the density. An error analysis of the ROBIN system shows that these accuracies are essentially dependent on three factors: the sphere drag coefficient, the measurement of fall velocity and acceleration, and the tolerance to which the sphere is fabricated. The first of these, that of drag, has been the subject of a very comprehensive program in the high-speed variable-density wind tunnel of the University of Minnesota where tests of small spheres ranging from 3/4 to 2 in. in diameter were performed over a wide range of Mach and Reynolds Numbers that the falling ROBIN experiences. In this region (M = 0. 9 and below and R = 1000 to 40, 000), a good part of the data represents spherical drag information never before obtained, a sizable contribution to aerodynamic state-of-the-art. Velocity and acceleration measurements are a function of the tracking accuracy. In the case of the FPS-16 its angular accuracy is about 0. 1 mil and range about 3 yards. As for fabrication the required ROBIN dimensional tolerance and weight measurement is 1/2% - no problem has been experienced in attaining this.

The advantages of the passive ROBIN technique are its simplicity (no mechanical parts, no electronics) and its cost, currently about $100. On the debit side are its need for a high precision radar and a fairly good-sized computer. As for the latter problem, it appears that an IBM 1620 might be satisfactory. In any case the operational use of the ROBIN system is restricted mainly to the various missile ranges where the required facilities exist. For general weather service rocket applications AFCRL is developing a rocketsonde telemetering payload similar to the balloon-borne radiosonde - in fact, both systems will use the same basic ground equipment.

One of the more serious problems that has been encountered in the ROBIN development has been that of premature balloon deflation. This problem is gradually being overcome by redesign of the inflation capsule, improved fabricating and packing techniques and elimination of powder burn holes on the film from the rocket separation charge. A technique has been built into the computer program to analyze the fall rate curve to detect the occurrence of the deflation. Print-out of the thermodynamic data then automatically stops. Wind data, however, are still valid - although the accuracy in tracking a deflated sphere is only slightly less than a fully inflated one.

In addition to the deflation investigation current efforts are arrived at getting ROBIN data to higher altitudes. Using a vehicle such as sidewinder - ARCAS, we believe it is feasible to eject the ROBIN at 450, 000 ft. and make useful measurements from about 330, 000 ft. down. The program encompasses a study of the sphere configuration for optimum performance in that rarefied atmosphere as well as a continuation of the Minnesota drag work to cover the added height.

1.4 ROSE System

The other plastic balloon application, that of the ROSE rising rigid sphere, evolved from an Air Force requirement for more detailed information on the structure of the wind field in the region from the surface to at least 65, 000 ft. for the design and test of missile and rocket systems. While generally good wind data can be obtained from the standard rawinsonde flights, these are actually winds averaged over a two minute time interval (approximately 2000 ft.). Much more detailed information was needed for certain uses in missile design and testing. Various wind shear probes under investigation, including a rocket-smoke trail technique, appeared to be too complex and costly for operational use.

The ROSE balloon is similar to the ROBIN in that it is a superpressured sphere and is tracked by a high precision radar to get accurate space-time data. It is solely a wind sensor, however, whose accuracy is a function of the radar accuracy and its response to extreme wind shears such as are encountered in gusts. Preliminary analyses of the ROSE performance indicate that it is capable of measuring wind data through a layer of 100 ft. to an accuracy of about 1 m/sec.

In its current configuration the ROSE balloon has a diameter of 2 meters and is fabricated of 1/2 mil metallized mylar. It has two exhaust valves and an inflation valve made of teflon, positioned such that the sphere is statically balanced. In operation it is inflated with helium or hydrogen to an overpressure of 8 mbs. Upon release from the ground it exhausts enough gas to maintain approximately this overpressure, as it rises at an average ascension rate of 1000 ft./min. to a maximum height of 75, 000 ft. The weight of the balloon is 280 gms. It costs about $55 in relatively small procurement quantities.

ROSE is presently being used at the Atlantic Missile Range and other sites to support both Air Force and NASA missile programs. In addition, the Climatological Branch of the Aerospace Instrumentation Laboratory is conducting a program at Eglin AFB whereby a ROSE flight will be made daily for a year to determine day to day variability of the wind. In addition, on some days multiple flights will be made to investigate the diurnal variability.

The ROSE program has its problem area also. Recent flights in the Lakehurst, N. J. Hangar under calm conditions indicate a somewhat oscillatory pattern to the flight path in several tests. We are investigating this phenomenon at the present time to try to determine its cause and magnitude. While future events could conceivably force us to modify the ROSE system, we believe it will still continue to be a valuable tool for meteorological sounding.