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Recent Developments in High-Altitude Meteorological Balloons

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I. Recent Developments in High-Altitude Meteorological Balloons

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Two years ago I was accorded the privilege of speaking to you here about two new types of special-purpose balloons which had recently been developed. It is gratifying to be asked to talk to you again for two reasons. First, because I must conclude that the previous address was of interest to at least a few of you. Second, because it is good to know that the humble, rather shabby looking, dusty meteorological balloon still finds its place among its glamorous polyolefin sisters and its noisy boisterous brothers, the rockets.

During this two-year interval we have been concentrating on providing balloons capable of reaching ever higher altitudes with greater reliability. It is my purpose to acquaint you with the vehicles which are now available for high-altitude soundings and research. At the same time, I want to describe a technique which resulted from the development of the ML-566 fast-rise balloon that simplifies the launching of large balloons and further improves their reliability and performance.

The largest balloons which are supplied in high volume quantities are the ML-537 balloons, which are purchased by the Armed Forces, and its counterpart purchased by the U.S. Weather Bureau and identified as the 1200-g balloon. The ML-537 is required to reach an altitude of 110,000 ft by day and by night at an

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ascensional rate of at least 1,000 ft/min. The altitude requirement for the Weather Bureau is slightly lower, being 31,500 m or 103,500 ft. Considerable data is, of course, available for this type of balloon, and in order to demonstrate the reliability of this vehicle we are using the test data obtained by the U.S. Weather Bureau during the course of the last production contract. These balloons were manufactured by the Kaysam Corporation of America and the flight data presented as Table 1 were obtained with balloons selected at random from production lots by Weather Bureau inspectors and flown by Weather Bureau personnel.

Table 1. Flight Performance of 1200-g Balloons

		Percentage of Flights Reaching			
		105,000 ft	110,000 ft	115,000 ft	120,000 ft
Total of 140 flights		89	81	56	30
October 1965	Day	86	57	50	21
	Night	93	93	71	43
November	Day	72	57	29	0
	Night	100	100	80	40
January	Day	100	100	75	50
	Night	40	40	20	0
February	Day	67	50	17	0
	Night	67	50	17	0
March	Day	100	100	63	25
	Night	73	64	18	9
April	Day	100	94	67	19
	Night	89	89	67	45
July	Day	93	93	62	54
	Night	92	92	67	42

In all cases a nozzle lift of 2,800 g was employed and the flights were conducted over a period of about eight months, including midwinter. Rather than list the individual flights, we have grouped them in altitude ranges, showing the number of flights which exceed a given altitude as a percentage of the total number of flights conducted.

The reliability of this balloon is clearly demonstrated by these results; almost 90 percent of the flights reach the minimum altitude required by the specification and 30 percent flew to altitudes of more than 120,000 ft. It is interesting to observe that although the balloons perform almost equally well by day and by night, there is a noticeable improvement in the altitudes reached during the summer months. We will make further reference to this phenomenon.

The next largest balloon which carries an Armed Forces nomenclature is the ML-564. This balloon has a day and nighttime altitude requirement of 120,000 ft and a weight specification of 1,800 ± 100 g. This balloon is purchased in relatively small quantities and the data available are, therefore, much more limited than that for the ML-537 balloon. However, it is possible to present sufficient data to illustrate this balloon's capabilities and the results of a series of carefully monitored flights is shown in Table 2.

Table 2. Flight Performance of 120G and 120GH Balloons
120 GH Ballons

Type	Altitudes Reached	
	Day Flights	Night Flights
120GH	140,597	136,808
	126,896	131,620
	135,076	143,205
	129,902	131,903
	129,665	131,502
120G	125,933	42,146
	140,092	135,860
	132,917	127,953
	133,789	65,282
	135,984	123,432
	131,542	124,292
	137,005	127,618
	134,938	123,050
	124,016	133,927
	131,220	118,438
	139,879	133,730
	127,195	130,850
	133,234	134,003
	140,308	
	127,759	

These flights were conducted under the supervision of Air Force Cambridge Research Laboratories and we would point out that the data presented are for this entire group of balloons and not a collection of carefully screened flights. Only if a flight were terminated because of the inability of the tracking equipment to follow the balloon were the results omitted from this tabulation.

It is again clear from the data that a vehicle which is very reliable to the 120,000-ft level is now available with equal performance and capabilities at night and during the day. It should be noted that the first five balloons in each group were substantially heavier than the remaining balloons and that these balloons appear to be somewhat more consistent in performance. Although they were no larger than the other balloons, it appears that the somewhat greater wall thickness does result in a more reliable balloon. By increasing the length somewhat further, however, a balloon capable of reaching an altitude of at least 130,000 ft can be obtained. Less data are available for this balloon, but Table 3 gives an indication of the performance obtainable from this type of balloon which weighs about 2,500 g and has a length of approximately 160 in.

The same compound was used for the manufacture of all the balloons described so far. As in many other fields, however, making a balloon which will reach still greater altitudes is not simply a question of increasing the size. Numerous other factors, including the ability of the heavier balloon to carry its own greater weight and the duration of the flight itself, necessitate building certain characteristics into the balloon compound. In order to reach altitudes of 140,000 ft and higher, a specially designed compound for use at such altitudes was developed in the laboratories of the Kaysam Corporation of America. Calculations showed that a balloon made from this compound, weighing in the order of 4,000 g, and having a flaccid length of about 240 in., should be capable of reaching an altitude of at least 150,000 ft. At the time of the original manufacture of these balloons the altitude reached for an expanding meteorological balloon was 146,000 ft, which had been attained by a balloon weighing about 6,000 g. Other balloons of this weight had also exceeded altitudes of 140,000 ft, but their performance was generally very erratic.

Table 3. Flight Performance of 130G Balloons

Day Flights	Night Flights
146,283	136,778
123,812	134,360
130,659	139,180
135,636	113,707
147,844	139,340
137,470	136,253
139,314	138,500
147,000	114,300
127,953	135,500
114,000	124,500

The size of these balloons is a basic cause of their erratic performance. A balloon having a flaccid length of 240 in. has a surface area of over 500 sq ft. In order to reach an altitude of 150,000 ft the balloon has to be capable of expanding uniformly until its surface area has increased to almost 8,000 sq ft. One small defect, such as a minute pinhole or small thin spot which prevents that particular area from expanding the required amount, can lead to premature rupture and more or less considerable reduction in bursting altitude. Hence, not only the manufacturing process itself must be conducted with meticulous care, but the inspection of the finished balloon must be carried out to the same exacting standards.

This balloon is for use in the daytime only and a limited number of flights were conducted by U.S. Army Electronics Research and Development Laboratories at Fort Monmouth, New Jersey. Five of six balloons were successfully tracked to burs and the altitudes ranged from 127,000 ft to 147,800 ft. Two of these five balloons reached altitudes in excess of 140,000 ft; the remaining three reached altitudes of 127,000, 135,000 and 139,000 ft. However, a much larger series of flights has just been completed in West Germany with this type of balloon.

The flights covered a period of about eight months and the results obtained are shown in Tables 4 and 5. The flights are given in chronological order with the date of the flight as well as the bursting altitude. Table 4 shows the performance of balloons from September, 1965, through April, 1966. The performance during the month of September was generally extremely good, and the balloon appears to be almost as reliable as the 1200-g balloon flown by the U.S. Weather Bureau, the performance of which was shown originally in Table 1.

During the winter months, however, there was a sharp deterioration in performance and as a result the number of flights was sharply curtailed, being restricted to a few evaluation flights. This situation persisted until April when there was a marked improvement in performance. Table 5 shows the results obtained during the months of May and June. It is immediately obvious that at this time of the year, and presumably from April through September, this balloon provides an extremely useful and reliable vehicle for high-altitude meteorological observations and research. Actually, during the month of June 67 percent of the balloons reached altitudes of over 150,000 ft, which surpasses the original performance in September of last year when 64 percent reached altitudes of more than 140,000 ft but only 27 percent reached the 150,000 ft level.

It has been noted that many of the problems associated with the manufacture of this balloon are due to its physical size. In a similar manner the size of the balloon also produces difficulties in inflation and launching. Furthermore, the duration of the flight can be a problem in itself. With a rate of ascent in the order of 1,000 ft/min, a flight to 150,000 ft takes 2-1/2 hr. This is uncomfortably close to the life of the battery in a standard radiosonde and there is a danger that the flight may

Table 4. Flight Performance of 140D Balloons Flown in West Germany from September 1965 to April 1966

Date Flown	Altitude	Date Flown	Altitude
9/1/65	152,000	1/20/66	26,000
9/3/65	155,500	2/21/66	46,000
9/6/65	148,500	3/29/66	23,000
9/8/65	152,000	4/1/66	26,000
9/11/65	148,500	4/5/66	144,000
9/13/66	111,500	4/7/66	125,000
9/15/65	148,500	4/19/66	111,000
9/16/65	121,500	4/22/66	147,000
9/17/65	135,000	4/25/66	157,000
9/20/65	148,500	4/26/66	95,000
9/22/65	42,000	4/26/66	131,000
11/5/65	137,500	4/27/66	141,000
12/22/65	135,000	4/28/66	75,500
12/28/65	142,000	4/28/66	137,500
1/6/66	30,000	4/30/66	154,000
1/7/66	132,000		
1/17/66	23,000		

Table 5. Flight Performance of 140D Balloons Flown in West Germany from May to June 1966

Date Flown	Altitude	Date Flown	Altitude
5/1/66	43,000	5/30/66	147,000
5/2/66	134,000	5/31/66	164,000
5/3/66	151,000	6/1/66	138,000
5/4/66	151,000	6/3/66	151,000
5/7/66	29,500	6/6/66	161,000
5/11/66	66,000	6/7/66	158,000
5/12/66	128,000	6/8/66	33,000
5/13/66	141,000	6/9/66	168,000
5/14/66	138,000	6/10/66	72,000
5/16/66	128,000	6/12/66	151,000
5/17/66	147,000	6/13/66	158,000
5/18/66	62,000	6/14/66	158,000
5/24/66	56,000	6/15/66	161,000
5/25/66	147,000	6/21/66	79,000
5/28/66	111,500		

terminate because of battery failure rather than balloon burst. Furthermore, if high winds are encountered aloft then the angle may become low enough to result in the signal being lost through ground interference.

It was felt that the carrier balloon technique which resulted from the development of the ML-566 balloon could be adapted to the high-altitude balloon with advantage. The ML-566 balloon is designed to reach an altitude of 100,000 ft at over 1,700 ft/min. This balloon consists of a high-altitude balloon enclosed inside a two-piece streamlined balloon, as illustrated in Figure 1. The inner balloon, which is approximately twice the length of the outer balloon, is initially folded as indicated. In the case of the ML-566 the folds in the inner balloon have virtually disappeared when the assembly has been inflated and is ready for launch (see Figure 2). As the assembly rises the streamlined outer balloon provides for rapid ascent during the early stages of the flight, and this balloon is designed to burst at about 50,000 ft.

Figure 3 illustrates the appearance of the assembly after the outer balloon has ruptured and fallen away. The inner ballon, which during the early part of the flight flies in a horizontal position, as it were, now turns through 90° and assumes the normal position for a meteorological balloon with the neck at the lowest point.

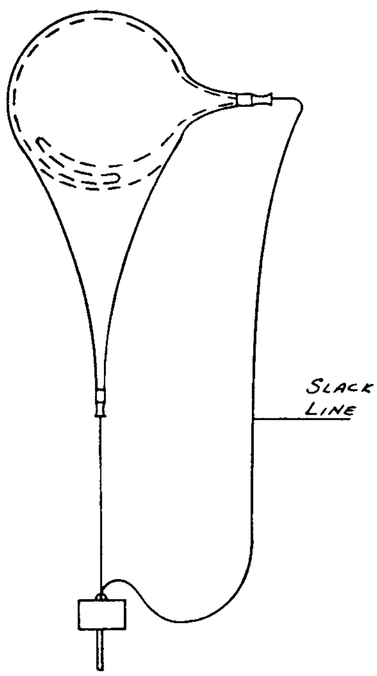

Figure 1. Carrier Balloon Assembly

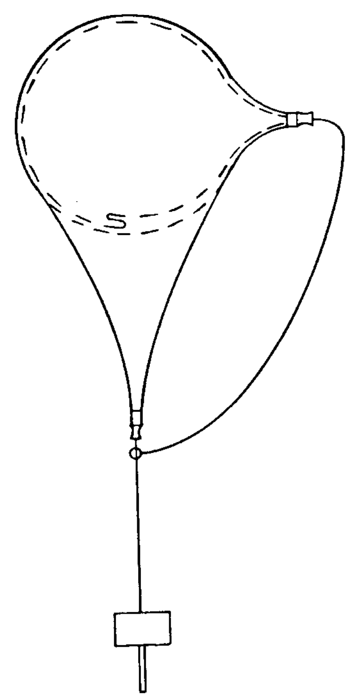

Figure 2. Carrier Balloon Assembly at Release

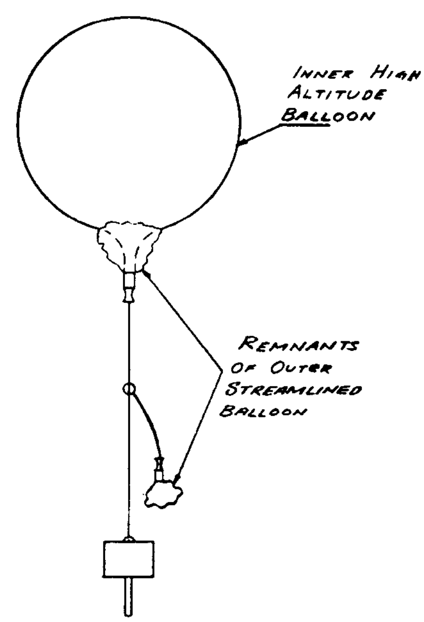

Figure 3. Carrier Balloon Assembly — Second Stage

Although the assembly was originally developed to provide faster rates of ascent, there are other advantages when it is used in conjunction with very high-altitude balloons. As already mentioned, the Kaysam 140D balloon has a flaccid length of about 20 ft. If inflated in the normal manner to a free lift of 2,000 g, which is recommended for this balloon, the balloon has a vertical height of a little more than 20 ft. This is too great for most inflation shelters which usually have doors not more than 12 ft high. Therefore it becomes necessary to tie off the balloon near its equator during inflation and to take the balloon out of the shelter in this condition. The tie is then removed and the gas allowed to rise into the upper part of the balloon which is then released. The possibilities of damaging the balloon film by this procedure are substantial, particularly if winds exceed 10 knots.

By enclosing the high-altitude balloon inside a carrier balloon, however, the danger of damage to the inner balloon is eliminated. Furthermore, since the carrier balloon is much smaller than the inner balloon, the problem of its excessive length is also overcome and inflation and launching can be carried out in conventional shelters or from an automatic launching device.

In addition to the increased ease of handling and launching which the carrier technique provides, the outer balloon provides protection against atmospheric attack during the early part of the flight. This is admittedly a somewhat tenuous advantage in that there is little evidence that balloon flights do terminate as the result of atmospheric attack. However, it had been observed in the past that there appeared to be an upper limit of about 145,000 ft beyond which a meteorological sounding balloon was incapable of flying. One thought is that this limit was set by the duration of the flight or time of exposure of the balloon to the atmosphere. Should this be the case, then the protection afforded by the outer balloon during the early stages of the flight would permit the inner balloon to reach higher altitudes by reducing the length of time during which it was subject to atmospheric attack.

The fact that the carrier technique also increases the ascensional rate, thereby still further reducing the total flight time, also minimizes the possibility of failure by atmospheric deterioration of the balloon film. The reduction in overall flight time also decreases the possibilities of the flight being lost due to battery failure, and because the more rapid rate of rise provides higher angles from the ground tracking equipment the chances of a flight being lost due to interference from the ground are also substantially reduced.

The use of a carrier balloon system has, therefore, numerous practical advantages and flights are now being conducted with this type of assembly. At the present time the number of such flights is quite limited, and it is by no means clear that this technique is enabling the balloons to reach higher altitudes. Table 6 shows the performance obtained with these balloons so far. Although the highest altitude obtained in the United States by a meteorological balloon of the expanding type was with this type of assembly, there have been higher altitudes reported from West Germany with single balloons. However, the advantages in ease of handling and more rapid rate of ascent still render the carrier balloon system worthy of consideration, particularly where the inflation and launching

Table 6. Flight Performance of High-Altitude Carrier Balloon Assemblies

Altitude	Rate of Ascent
151,634	1309
145,000 F/A	1368
140,662	1240
133,244 F/A	1196
136,194 F/A	1345
143,842	1262
156,390	1511
139,215 F/A	1290

area is restricted. They could, for instance, be used successfully on ships where such conditions prevail. Furthermore, the reliability of the balloon appears to have been greatly improved; the lowest altitude recorded is 133,244 ft and not because of a balloon burst.

In conclusion, we may say that meteorological balloons of the expandable type are now available which are capable of reaching altitudes of as high as 120,000 and 130,000 ft with a high degree of reliability. By enclosing these types of balloons in carriers, the rate of ascent can be raised from as little as 1,000 ft/min to at least 1,300 ft/min with virtually no loss in altitude. In addition, there is also a balloon capable of reaching altitudes of over 140,000 ft and frequently over 150,000 ft with good consistency. Use of this balloon is limited at present to the hours of daylight. Research aimed at providing a similar vehicle for use at night is being conducted.

Acknowledgments

I should like to express my thanks to Mr. M. Sharenow of U.S. Army Electronics Research and Development Laboratories for his valuable advice during the course of this research that has led to the development of the balloons described. I also want to acknowledge Mr. R. Leviton of AFCRL and Mr. Sharenow for conducting the flights in the United States, and the U.S. Weather Bureau for making available the flight data on the 1200-g balloons, and Professor Scherhag of the University of West Berlin for the results of the 4000-g balloon flights carried out in West Germany.